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Look to Europe? Examining the Relevance and Applicability of the European Experience with the Waste to Energy as a Residual Waste Treatment Method for the Province of Ontario

Bronwen Smith

Supervisors

Andrius Plepys & Thomas Lindhqvist

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Published in 2006 by IIIEE, Lund University, P.O. Box 196, S-221 00 LUND, Sweden,
Tel: +46 – 46 222 02 00, Fax: +46 – 46 222 02 10, e-mail: iiiee@iiiee.lu.se.

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Abstract

This research explores the development and use of waste to energy (WTE) technologies in Europe and in the Province of Ontario, Canada. As the quantity of waste generated has continued to increase in industrialized countries, the need for alternative waste management methods to reduce the dependency on landfill and to recover the resource in the waste has also increased. Many European countries, including Sweden, the Netherlands and Germany, have developed WTE facilities to achieve these goals, whereas the use of WTE in Ontario has been extremely limited. However, the current shortage of residual waste management capacity in Ontario has sparked debate over the potential for the use of WTE. This thesis examines the driving forces that have promoted the use of WTE in Europe and the barriers that have prevented its use in Ontario. From this investigation the main lessons learned from Europe's use of WTE were identified as well as the areas of knowledge that are required in Ontario to foster the discussions over the potential for WTE technologies. This research analyses the European lessons learned to determine if they are applicable and relevant for satisfying the knowledge gaps in Ontario. As well recommendations are made for ensuring that the discussions over residual waste management and the potential use of WTE in Ontario move forward successfully resulting in crucial actions being taken.

Executive Summary

Over the past 50 years the generation of waste in Western industrialized countries has increased significantly. This increase in waste generation led to the need for additional waste disposal capacity, which has traditionally been landfill. In efforts to try to reduce the dependence on landfills, alternatives such as material recycling, biological treatment and incineration have emerged as options.

Much effort and attention has been given to the source separation of waste for material recycling and more recently the separation of organic waste for biological treatment. Despite the success of increasing diversion of municipal solid waste from landfill through material recycling and biological treatment, in most Western countries there is still a significant amount of residual waste that remains to be managed. While North American cities have primarily relied on landfill to manage their residual waste; many parts of Europe and Japan have developed waste to energy (WTE) facilities to manage a significant portion of their residual waste.

Currently, in the Province of Ontario there is a lack of waste management capacity for residual waste. So many municipalities are investigating in potential alternative technologies that could increase their diversion of municipal solid waste (MSW) from landfill and manage their residual waste. It is inevitable that WTE will be one of the technologies suggested in these investigations. Therefore it is essential to understand why WTE is used so extensively in Europe as well the lessons that have been learned from its use in order to determine if any of Europe's experiences are relevant and applicable in the context of Ontario.

The three objectives of this research are to: (1) determine what has been the main driving forces promoting the use of WTE to manage residual waste in Europe and what lessons have been learned from its use; (2) identify what barriers have prevented the implementation of WTE in Ontario and what are seen as the potential opportunities for these technologies; and (3) conclude if any of the European experiences applicable and relevant to the situation in Ontario and if not what knowledge and experiences are needed to further foster the discussion about the potential use of WTE.

Multiple case studies are employed for the investigations into the use of WTE in Europe and Ontario. Sweden is used as the primary case study for Europe with the Netherlands, Germany, Italy and the UK used as secondary examples. In Ontario, the Golden Horseshoe region is used as the main case study for Ontario with additional experiences from municipalities across Ontario and Canada.

The investigation into the historical development and current use of WTE in Sweden, the Netherlands, Germany, Italy and the UK identified driving forces as well as the lessons learned. Six main driving forces that have influenced the development of WTE in Europe to manage residual municipal solid waste are:

- Since many countries in Europe are very densely populated with limited space available for landfill the ability of WTE to significantly reduce the volume of waste has and continues to be a driving forces for the development of WTE.

- The development of district energy infrastructure led to the need for fuel to produce energy for space heating. The excess heat generated from waste incineration was and still remains a technically and economically viable source of fuel to provide space heating for these systems.

- The oil crises during the 1970s had a major effect on Europe since the majority of European countries were dependent on foreign fossil fuels. So when the price of oil spiked waste was increasingly seen as a feasible low cost non-fossil alternative fuel. Waste was a readily available and secure fuel source, which made it a very appealing alternative.

- The development of WTE slowed down significantly as a result of the public opposition caused by the dioxin scare. However the implementation of stringent air emission requirements and the ability for the technology to improve to meet and exceed the new standards restarted the development of the technology.

- A European wide driver has been the EU decisions to adopt the waste hierarchy as its central waste management strategy, which promotes the use of WTE ahead of landfill.

- Some European countries have implemented incentive based electricity policies to encourage the generation of energy from non-fossil fuel sources, including WTE. The economic incentives that these programs provide have made WTE more cost competitive and therefore driven its development

The analysis of the historical driving forces affecting the use of WTE technology identified several lessons learned from the European experience. These experiences pertain to both addressing concerns surrounding the technology as well as strategies for advancing its use. From the European case studies examined the following five main lessons should be highlighted:

- The dioxin scare caused an erosion of the public's trust in their local and federal regulators and in industry. However, the government and industry was able to regain the public's trust by working together to address the problem through developing strict new air emission standards and improving the technology to be able to meet and exceed these new requirements.

- One of the main concerns surrounding the use of WTE is its perceived negative effect on recycling and other diversion programs. However, the experiences from Europe have been the opposite; the countries with the highest waste diversion rates are also countries that are very dependent on WTE as seen in Figure 5.

- The steering effect of different waste management policies is another lesson that has been learned. From the case studies examined it has been learned that implementing a landfill tax prior to a landfill ban increases its effectiveness.

- Another experience gained from Europe is that mass burn incineration is the most reliable and proven WTE technology and as such there is little willingness to develop alternate WTE technologies.

- The majority of European countries have developed national waste management strategies based on the waste hierarchy. These overarching waste management strategies have provided leadership and guidance for municipalities and acts as the foundation for all waste management policies in these countries.

An investigation was conducted in Ontario into the barriers that have historically and currently prevented the growth of WTE. The Golden Horseshoe region is used as the main case study and is supplement with information from other Canadian jurisdictions. From the research conducted two barriers can be highlighted as the main contributing factors that have prevented the development of WTE in Ontario.

- **Public and political mistrust of the technology**. Public mistrust was caused by the legacy of poor performing WTE facilities in Ontario. The public's concerns about the technology were not immediately addressed and remedied so as a result the public's mistrust has yet to dissipate. The public opposition towards the technology has put pressure on politicians to also oppose it resulting in a major barrier to the development of WTE in Ontario.

- **Access to cheap alternative waste disposal options**. The majority of municipalities in Ontario have access to landfills, either within Ontario or in Michigan, with costs that are significantly less than WTE. As long as there is the availability of cheap landfills, the development of WTE in Ontario will be limited.

As part of the investigation into the situation in Ontario the perceived opportunities for the potential use of WTE technology are identified. Two of these opportunities can be highlighted as the main two factors that are currently driving the interest in WTE technology in Ontario.

- **The lack of secure residual waste management capacity in Ontario**. There is limited developed capacity for residual waste in Ontario as a result a significant portion of the residual waste is exported to a landfill in Michigan, which is not a secure option due to fears of the boarder being closed to the waste. As a result municipalities are considering developing WTE facilities as a secure, local residual waste management option.

- **Energy generation opportunities**. Currently, there is a shortage of local decentralized energy sources in Ontario, which is contributing partially to the increasing electricity prices. These factors are providing an opportunity for new energy sources to be developed that might have before been economically unviable. This has created significant interest in the use of advanced thermal technologies and RDF with the primary objective of energy generation not waste management.

Beyond the identification of the barriers and opportunities regarding the use of WTE in Ontario, it was recognized that there are several areas of contention and conflict within the topic. These areas of contention need to be resolved before the discussions over the appropriateness of the use of WTE in Ontario can move forward. As a result there are several areas of knowledge and experience needed to address these contentious issues. Seven of these knowledge gaps were identified through the investigations.

- **Political Approach.** There is significant disagreement over which actor should be responsible for developing residual waste management strategies. This uncertainty over responsibility has resulted in limited action by the municipalities and the Province. A better understanding of how the responsibility should be divide between these two groups in order to relieve the uncertainty and provide a clearer and more efficient framework is need to mitigate the current stagnation.

- **Regaining Public Trust.** A loss of the public's trust resulted from experiences in which their political leaders and the industry did not safeguard them adequately against the risks from polluting landfills and incinerators. Since this failure of protection has not been addressed and resolved adequately, the scepticism of the public has increased over time. Experience is needed on how to regain the public's trust so that they can become an engaged and proactive partner in the decision making process.

- **Technology Evaluation.** Since there is limited experience with WTE in Ontario there is little first hand knowledge about the technology and its capabilities. In order to evaluate the potential of different WTE technologies, experiences from other jurisdictions are need on the performance of all WTE technologies.

- **Economic Evaluation.** Similar to the technology evaluation an analysis of the economics of WTE is needed. Experiences and knowledge are needed to understand the investment and operating costs associated with a WTE facility in order to determine if it is an economically feasible solution for residual waste management in Ontario.

- **Effect of WTE on Recycling.** The effect of WTE on recycling and other diversion programs is one of the most contentious issues. Therefore, experiences from other jurisdictions are needed to determine how WTE affects recycling in practice and how these affects can be minimized.

- **Optimisation of the EA Process.** The majority of waste management actors agree that the Environmental assessment process in Ontario needs improvement. However there is debate over what form that improvement should take. Experience is needed to determine how to optimise the EA process and allow for it to be more efficient for the applicants while enhancing its evaluation of the proposed waste management installations.

- **Combining Waste Management and Energy Generation Strategies.** The investigation into the situation in Ontario revealed that WTE is viewed separately from a waste management perspective and from an energy generation viewpoint. Experience is needed to understand how an integrated approach could improve the potential for WTE as both a waste management solution and as an energy source.

Relevance and applicability were selected as the two conditions that were used to determine if the European experiences with the use of WTE could be used within the Ontario context. Relevance and applicability were chosen as the two criteria because for a transfer of knowledge from Europe to Ontario to be successful the European experiences must be pertinent and needed in Ontario; as well it must be appropriate to the conditions present in Ontario. A summary of the evaluation of the applicability and relevance of the European experience is shown in Table ES-1.

Table ES-1: Applicability and Relevance of European Experience

Experience	Relevant?	Applicable?	Explanation
The process of regaining the public's trust	Yes	Yes	• The European experience in regaining the public's trust is relevant and appropriate to be transferred to the situation in Ontario
The effects of WTE on material recycling and other diversion initiatives	Yes	Yes (Partially)	• The European knowledge on the effects of the ***recent*** development of WTE on waste recycling and reduction efforts is appropriate and required knowledge in Ontario
The steering effects of waste management policies	Potentially	Potentially	• Since Ontario is currently not considering using steering waste management tools such as landfill bans or taxes, the European experience is not relevant or applicable to the current situation in Ontario • However this experience has the potential of being applicable and relevant in the future if interest develops for using policy tools to steer waste away from landfill
The performance of WTE technology	Yes	Yes	• The knowledge gained in Europe on the performance of WTE technologies is required and appropriate knowledge for Ontario
The effect of an overarching waste management strategy	Yes	Yes	• Europe's experience using the waste hierarchy as a national and EU waste management strategy is relevant and appropriate to address the uncertainty in Ontario over who should be responsible for developing a waste management framework

After the relevance and applicability of the European experiences was determined the final step of the thesis was to conclude if these European experiences could fulfil all of the knowledge and experience requirements in Ontario. Each of the seven identified areas of required knowledge and experience in Ontario was analysed to determine if they could be fulfilled by the relevant and applicable knowledge from Europe. The conclusions of this analysis are summarized in Table ES-2.

Table ES-2: The Fulfilment of Knowledge Gaps in Ontario

Experience	Fulfilment?	Explanation
Political Approach	Yes	• The European political approach to setting an overarching waste management strategy fulfils Ontario's need to gain a better understanding of the best political approach to develop waste management strategies
Regaining the Public Trust	Yes	• The European experience of regaining the public trust after the dioxin scare can fulfil the requirement for this knowledge in Ontario
Technology Evaluation	Yes (Partially)	• Ontario's need for an evaluation of WTE technology can be fulfilled by the European knowledge and experience with the technology recognizing the strong legacy of incineration technology in Europe and the need for additional experience on the technical performance of other (non-incineration) WTE technologies
Economic Evaluation	Partially	• An extensive evaluation of the economics of WTE was not preformed for the European case studies due to the differences in the energy markets • However some of the European economic trends and relative costs on WTE could be used to partially fulfil the required knowledge in Ontario if it was complemented with economic evaluations of WTE technologies from other jurisdictions
Effect of WTE on Recycling	Yes	• The knowledge required in Ontario on the effect of WTE on recycling can be fulfilled by the European experiences with the effects of the recent development of WTE in Europe on their recycling programs
Optimisation of the EA Process	Potentially	• The European environmental assessment and approvals process for waste management facilities was not investigated in detail for this study and therefore the knowledge required for Ontario on this subject can not be fulfilled from the experience gathered in this report • However there is the potential that this knowledge could be gained from European experiences not examined in this study
Combining Waste Management and Energy Generation Strategies	Potentially	• The European case studies investigated showed some examples of the combination of waste management and energy generation strategies however it was not identified as a main lesson learned • Further research is required to determine if the knowledge that is needed in Ontario on this topic exists in Europe

Through the course of this research the author has been able to identify several key factors that are essential for fostering that debate in Ontario surrounding residual waste management and the appropriateness of WTE technology. The following recommendations for Ontario are aimed at ensuring these discussions and debates move forward successfully resulting in crucial actions being taken:

- Strong political leadership to develop a waste management framework that will provide clear guidance and direction for managing the entire municipal solid waste stream;

- Discussions that are based on facts, not on historical experiences, promises, hearsay or emotion especially within the public forum; and

- The engagement and participation of the public in the decision making process to help develop solutions rather than only offering an opposing voice.

If these three recommendations are achieved, the discussions surrounding waste management options should be successful and result in action that is accepted by all parties. Throughout this research a theme has emerged that highlights the importance of immediate action. It has been seen that once a problem is identified the faster it is remedied the more successful the response is. Conversely, problems that are not addressed immediately continue to develop into larger, more complex situations that are more difficult to solve in the future.

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1. Introduction

1.1 Background Information

Economic growth has historically led to increases in the quantity of waste generated. This trend has been seen in Western industrialized countries where the amount of waste generated has increased dramatically aligned with the expansion of these countries' economies since the end of the World War II. This increase in waste generation led to the need for additional waste disposal capacity, which has traditionally been landfill. At the same time as the expansion in waste generation, the environmental impacts caused by landfilling, especially groundwater pollution from the leachate, were beginning to be documented. Additionally, in some countries there was limited space to build new landfills to handle the increasing waste generation, particularly in dense highly urbanized areas.

Alternatives to landfills, such as material recycling, biological treatment and incineration, emerged as options to reduce the dependence on landfills. In Europe a waste hierarchy was developed by Ad Linsank, a Member of Parliament in the Netherlands, as a tool to encourage diversion of waste from landfill and it set an order of preference for alternative treatment methods. The order of preference outlined in the waste hierarchy was: reduce, reuse, recycle, and landfill as the last option. Similar waste management approaches were adopted in other regions of the global at this time as well.

Over the past 25 years much effort and attention has been given to the source separation of waste for material recycling and more recently the separation of organic waste for biological treatment. Despite the success of increasing diversion of municipal solid waste from landfill through material recycling and biological treatment, in most Western countries there is still a significant amount of residual waste that remains to be managed. The top performing urban regions in these countries are currently achieving approximately 45% diversion of MSW, excluding energy recovery. Therefore, about 55% of the municipal waste stream remains to be treated (RRF, 2004).

While North American cities have primarily relied on landfill to manage their residual waste; many parts of Europe and Japan have developed waste to energy (WTE) facilities to manage a significant portion of their residual waste. Waste to energy treatment substantially reduces the volume of material that requires final disposal as well as generating energy that can be used as heat and/or to produce electricity. However, WTE has historically been a very polluting technology releasing high levels of toxic air emissions.

Many cities and regions, including the City of Toronto, have adopted zero waste targets with the intent of eliminating all waste going to landfill. However, it appears that 100% diversion is not feasible through material recycling and biological treatment alone and that alternative treatment technologies are required to approach the zero waste target. Currently, many municipalities in the Province of Ontario, Canada are in the midst of discussions surrounding potential alternative technologies that could increase the diversion of municipal solid waste (MSW) from landfill. It is inevitable that WTE will be one of the technologies suggested. Therefore it is essential to understand why WTE is used so extensively in Europe as well the lessons that have been learned from its use in order to determine if any of Europe's experiences are relevant and applicable in the context of Ontario.

1.2 Purpose

This thesis investigates why WTE is used extensively in Europe for the treatment of residual MSW whereas its use is extremely limited in the Province of Ontario, Canada. The drivers that have led to the growth of WTE in Europe, focussing on Sweden, are identified along with the experiences and lessons learned from its use. Contrasting this, the situation in the Golden Horseshoe region, which is used as an example for Ontario, is examined and the barriers that have prevented the growth of WTE are discussed.

As discussions and debate over the potential use of WTE in Ontario continue to amplify, undoubtedly there will be calls to "look to Europe" and learn from their experiences. Therefore, it is necessary that the European situation be examined to determine if their experiences are appropriate to be used and applied in the context of Ontario. The purpose of this thesis is to ascertain if any or all of the European experiences with WTE are applicable and relevant to the current situation in Ontario and if they are not, to determine what knowledge is needed to support the discussion over the potential use of WTE for specific conditions of Ontario.

1.3 Research Questions

1. What has been the main driving forces promoting the use of WTE to manage residual waste in Europe, using Sweden as the primary example, and what lessons have been learned from its use?

2. What barriers have prevented the implementation of WTE in Ontario, using the Golden Horseshoe region as the primary example, and what are seen as the potential opportunities for these technologies in Ontario?

3. Are the European experiences applicable and relevant to the situation in Ontario and if not what knowledge and experiences are needed to further foster the discussion about the potential use of WTE?

1.4 Scope and Limitations

The scope of the thesis is limited to investigating the situation surrounding WTE in Europe and Ontario and the potential for the transfer of experience. The aim of this research is not to promote WTE as the "solution" for residual waste management in Ontario but instead to simply acknowledge that it is one option that warrants consideration. As such it is necessary to understand more about WTE and to determine the relevance of knowledge from jurisdictions that have more experience with WTE technologies.

This research only examines thermal WTE technologies and does not investigate other alternative treatment methods for the residual waste, including alternatives that also have the potential to generate energy such as anaerobic digestion. Only thermal WTE technologies are considered because the market for these technologies, including the drivers and barriers, are unique compared to other waste management methods that also generate energy. From herein in the report the terms waste to energy and WTE will refer exclusively to thermal technologies unless otherwise noted.

All of the main waste management treatment methods are presented and discussed in Section 2.3.2. However, there is no comparison or evaluation of the alternatives to try to determine which method is preferred either generally or in the specific situation of Ontario. The objective of the thesis is not to evaluate the benefits and concerns or landfill versus WTE.

The scope of this research is also limited to examining only municipal solid waste. The use of WTE to treat industrial, commercial and institutional wastes is not considered as part of this investigation. Since the composition of MSW is relatively similar across industrialized countries, MSW provides a better basis for comparison across jurisdictions. Also the management of MSW is generally the responsibility of municipalities, which makes the capacity to manage the waste similar in different jurisdictions.

The PESTEL research framework will be used to structure the data collected. Therefore only the political, economic, social, technical, environmental and legal aspects of WTE are considered. As a result other factors including international relationships and diplomatic and transboundary issues are not included in the delimitations of this research. While political and social factors are considered, institutional theory and the relationship and structure of a government with its citizens is beyond the scope of this research and therefore will not be examined as part of this investigation.

One limitation of the research is the dependence on personal communications as the main source of data. Since there is limited published material available on this topic it is necessary to gather the majority of information from actors involved or affected by the development and use of WTE. However the reliability and nature of information collected through personal communications is uncertain. This barrier was addressed by interviewing as many actors as possible to reaffirm or counter data collected from other interviewees.

Sweden has been selected as the primary example of the situation surrounding the use of WTE in Europe. It is recognized that the situation in Sweden is not representative of Europe, as a whole. One reason that Sweden has been chosen is its physical similarities to the Province of Ontario, in terms area, population, density, and geography. Wherever possible, the Swedish situation is complemented with examples from other European countries in attempts to provide a more representative overview.

The Golden Horseshoe, as seen in Figure 1, is a densely populated area in Southern Ontario anchored around the City of Toronto. The Golden Horseshoe region has been selected to be representative of the situation in Ontario. The region is comprised of 7 municipalities: the City of Toronto, the City of Hamilton, the Regional Municipality of Durham, the Regional Municipality of York, the Regional Municipality of Peel, the Regional Municipality of Halton, and the Regional Municipality of Niagara. The population of the Golden Horseshoe region is approximately 7 million, which represents more than half of the Province of Ontario's population. Municipalities in the Golden Horseshoe region are engaged in discussions over the potential use of WTE. These discussions are similar to ones occurring in many other municipalities across the Province. The situation in the Golden Horseshoe region is complemented with examples from other municipalities in Ontario and across Canada, wherever possible.

Figure 1: Canada and the Golden Horseshoe Region

1.5 Methodology

1.5.1 Research Approach

The case study research approach was used for this thesis. A case study is defined as "an empirical inquiry that attempts to examine a contemporary phenomenon in its real-life context, especially when the boundaries between phenomenon and context are not clearly evident and in which multiple sources of evidence are used" (Yin, 1994). Since the essence of this research is to determine the reasons behind the development of WTE in Europe and its stagnation in Ontario the case study approach provides an appropriate vehicle to examine these phenomenon.

There are three main types of case studies, which can all be either single or multiple-case studies: exploratory, descriptive and explanatory (Yin, 1994). The research in this thesis is best categorized as explanatory, which is suitable for the study of causal relationships, since the aim of this investigation is to understand and describe the contrasting use of WTE in Europe and Ontario.

A case study research approach has several advantages including but not limited to:

- It provides a holistic view of a situation and an understanding of the context as well as the details;
- It generates an analysis and thereby a more complete understanding of the situation that is rich in detail;
- It gathers a broad spectrum of information and perspectives from multiple actors;
- It allows a situation or a phenomenon to be described, understood and explained (Yin, 1994).

Multiple case studies are used for this research since the situation surrounding the use of WTE is examined in both Europe and Ontario. Sweden is used as the primary case study for Europe with the Netherlands, Germany, Italy and the UK used as secondary examples. In Ontario, the Golden Horseshoe region is used as the main case study for Ontario with additional experiences from municipalities across Ontario and Canada.

1.5.2 Data Collection

The first phase of the data collection was to obtain information about the historical development and current use of incineration in Europe focussing primarily on Sweden. The second phase was to collect data on the historical barriers that have limited the use of WTE for the treatment of residual MSW in the Province of Ontario as well as future opportunities for the technology. The PESTEL framework was used as a tool to collect and structure the information gathered from both Europe and Ontario.

The PESTEL framework helps to organize and identify the barriers and drivers surrounding a specific issue by categorizing data according to the following criteria: political, economic, social-cultural, technical, environmental and legal. The framework can also aid in structuring the analysis of the influence of each factor as well as their cumulative effect on a business or within an industry. The results of a PESTEL analysis can be used to determine opportunities and barriers within an industry and to develop strategic plans according to the findings (Byars, 1991; Cooper, 2000). The PESTEL framework can also be used as a strategic tool for understanding the development and decline of a market (Kotler, 1998). As a result a PESTEL analysis is an effective tool for strategic planning, market analysis, industry and business development and also for research.

The PESTEL analysis was a valuable framework to use for this research because it provided a standard approach to understand the WTE market within both Europe and Ontario. The framework was used to organize and identify the political, economic, social-cultural, technical, environmental and legal factors, which made it possible for their impact and influence to be determined. The results of this analysis answered Research Questions 1 and 2 by identifying the barriers and drivers influencing the use of WTE both in Europe and in Ontario. The PESTEL framework was also useful for highlighting and classifying the market conditions for WTE and the main perceived opportunities and concerns for the technology.

As discussed above one limitation of collecting data from personal communications is the uncertainty of the reliability and nature of the data. To address this condition multiple actors were interviewed and asked the same questions in order to verify the information given by other interviewees. Additionally opposing viewpoints from different actors were sought in order to achieve an objective overview of the historical development and current use of WTE. This technique was used in data collection for both Europe and Ontario.

The entire methodology used to collect the data within the PESTEL framework for both Europe and Ontario is described in the following two sections.

Experience from Europe

A literature review was preformed first to obtain a theoretical background to the topic of WTE and its development in Europe, focussing primarily on Sweden. The literature review investigated the current status of WTE in Europe as well as its historical development. Literature sources also provided information about the technical, economic, regulatory, social and environmental framework surrounding WTE and its development.

Interviews with key actors in the Swedish and European waste management field followed the literature review. These interviews were used to complement and expand on the information gathered from the literary sources. Structured, open-ended interview questions were posed to obtain information on the historical development of WTE and the technical, economic, regulatory, social and environmental factors surrounding its use. As well the interviewees were asked for their opinions about what have been the main driving forces that led to the expansion of the use of WTE. Interviews were held with actors from municipalities, industry, governmental agencies and environmental non-governmental agencies in Sweden, The Netherlands, Italy, Belgium and Germany. The information collected from both the literature review and the interviews was compiled and used to establish the factors that appeared to have influenced the development of WTE.

Situation in Ontario

The second phase of the data collection process was to obtain information surrounding the situation in the Province of Ontario, specifically the Golden Horseshoe region, regarding WTE. Interviews were the primary source of information that was used to complete this phase. Structured, open-ended interviews were conducted with various actors involved in the discussion concerning the potential for the use of WTE in Ontario. The groups that were interviewed are: municipalities, provincial and federal government agencies, the WTE industry, the energy industry, environmental non-governmental organizations, local citizens groups, the media, and environmental consultants.

The interviews had three main purposes. The first was to determine the barriers that have prevented the development of incineration in the Province. The second purpose was to obtain an understanding of the current situation including the influence of political, economic, social, technical, environmental and regulatory factors on the potential for WTE in Ontario. The third purpose was to determine what the areas of contention and disagreement are between the different actors and highlight them as areas where further knowledge is needed to foster the debate over WTE in Ontario. The information gathered from the interviews was supported by data from literary sources.

From this analysis the barriers that appear to have prevented the development of incineration were identified and their current significance discussed. Also the main political, economic, social, technical, environmental and regulatory concerns and opportunities regarding the use of WTE were presented.

1.5.3 Data Evaluation

After the data were collected for the situations in Ontario and Europe surrounding WTE the findings were analysed to determine the experiences and lessons learned from Europe and the knowledge required in Ontario. The European experiences gained were then evaluated against **the criteria of relevance and applicability** in order to determine which (if any) of the European experiences are relevant and applicable to the situation in Ontario. Relevance is an important criterion for this investigation because even if a European experience is valuable and informative if that knowledge is not needed in Ontario then it is not a suitable piece of experience to transfer between the two jurisdictions. The second criterion, applicability, was chosen because even if knowledge is needed in Ontario, the experiences must also be appropriate and suitable to the specific conditions in Ontario.

The European experiences that were applicable and relevant were then compared against the knowledge needed in Ontario to determine if they could fulfil the knowledge requirements of Ontario. From this analysis the portions of Ontario's needs that could and could not be fulfilled by the European experiences were identified. This resulted in the determination of remaining knowledge gaps in Ontario, which require experience and knowledge from jurisdictions other than Europe. Through the data evaluation process Research Question 3 was answered.

1.6 Why Sweden?

Sweden is used as the main example of a European country that has chosen to treat a significant portion of its residual waste with WTE technology. The extensive use of WTE in Sweden was driven by both country specific factors as well as European wide influences. All of these drivers were investigated and discussed as examples of how the local and regional conditions influenced the expansion of WTE technology in Sweden.

Another reason that Sweden was selected as the primary example is that it combines the use of WTE with high rates of diversion of waste by material recycling and biological treatment. Since high diversion from material recycling and biological treatment are essential components of Ontario's waste management strategy, it is important to study a country where WTE is used for only the residual waste that remains after significant primary diversion efforts have occurred.

1.7 Why the Golden Horseshoe?

In 2002, the one of the last major landfills in the Golden Horseshoe region, Keele Valley landfill, was closed. This left the region with very little available disposal capacity, significantly less than required to service the region. Prior to the closure of the Keele Valley landfill there was an extensive search to identify and find consensus for a new landfill site to handle the residual waste from the region. However, this process was unsuccessful due to limited available undeveloped land close to the region as well as due to strong public opposition to a new landfill. As a result of the inability to develop a new landfill in Ontario, a contract was awarded to a landfill in Michigan, USA for the management of several Golden Horseshoe municipalities' residual waste. Therefore, since 2002, when the Keele Valley landfill closed, the majority of the Golden Horseshoe's residual waste has been exported to Michigan, a distance of almost 500 km. The export of waste to Michigan poses numerous problems including increased costs, the environmental impacts associated with the long haul transportation and the lack of security due to fears that Michigan could close its border to Ontario's waste with limited notice. Due to these concerns this solution is seen to be unsustainable for the management of the region's residual for the long term.

Due to this situation six of the seven municipalities within the Golden Horseshoe are now investigating alternative treatment methods for the residual waste. Waste to energy is one technology that has been presented as a potential solution for the region's lack of treatment capacity for residual waste. Therefore the Golden Horseshoe is a good example of the situation in Ontario where there are increasing discussions and debate over the potential for WTE. The Golden Horseshoe will serve as a model to determine what knowledge and experience is needed to evaluate the potential of WTE in Ontario. From the results of this it can be determined what lessons and experiences can be learned from Europe that is relevant to the local situation.

1.8 Outline

Chapter 1 presents the subject of the thesis including a definition of the problem being addressed, the research objective, the research questions and the methodology. Chapter 2 introduces the reader to the municipal solid waste stream and the various waste management options available for its treatment. Chapter 3 provides a general background of waste to energy technologies. Chapter 4 presents the data collected from the investigation of the European experiences with WTE; this includes a general European overview as well as specific information from Sweden, the Netherlands, Germany, Italy and the UK. The information collected from Ontario surrounding WTE is presented in Chapter 5 including a general review of the situation in Ontario followed by specific information on the situation in the Golden Horseshoe and from selected regions across Ontario and Canada. Chapter 6 analyses and discusses the data presented in Chapter 4 and 5 to determine what knowledge and experiences are required in Ontario and which of the European experiences are both relevant and applicable for the context of the discussions in Ontario. Chapter 7 presents the results to the three research questions as well as making recommendations for Ontario and suggesting areas of further research. Please note that all costs are in Canadian dollars unless otherwise specified.

2. Municipal Solid Waste Management

2.1 Municipal Solid Waste (MSW)

2.1.1 Definition of MSW

Municipal solid waste is defined by the OECD as waste collected and treated by or for municipalities including waste from households, bulky waste, waste from commerce and trade, office buildings, institutions and small businesses, yard and garden waste, street sweepings, the contents of litter containers, and market cleansing waste (OECD, 2006). Municipal solid waste does not include municipal sewage waste or municipal construction and demolition waste.

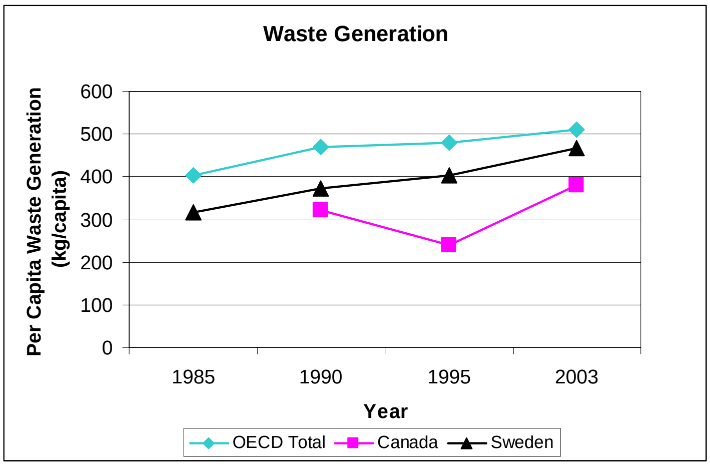
However, many countries have a slightly different definition of what is considered and measured as municipal solid waste. For example, in some countries municipalities are not responsible for the collection and treatment of waste from commercial enterprises and therefore, that waste is not included in those country's MSW totals.

In Ontario MSW is defined as: (a) any waste, whether or not it is owned, controlled or managed by a municipality, except, hazardous waste, liquid industrial waste, or gaseous waste, and (b) solid fuel, whether or not it is waste, that is derived in whole or in part from the waste included in clause (a) (Toronto, 2003). Conversely, in Sweden MSW is generally categorized as household waste and is defined as "waste coming from households and waste from other activity with a type or composition resembling waste from households" (RVF, 2005).

2.1.2 MSW Generation

Figure 2 below shows the increase in MSW generation in Sweden and Canada as well as the average of OECD countries over the past 15 years. The generation of MSW has continued to increase in most industrialized nations despite significant waste reduction efforts. For example in the European Union the ultimate objective of the EU Waste Management Policy is to prevent the generation of waste, however, despite this policy waste quantities are continuing to increase. It is assumed that this continued increase can be explained by the correlation between economic growth and waste generation (EEA, 2001).

Figure 2: MSW Generation Rates, 1985-2003



Source: OECD, 2006

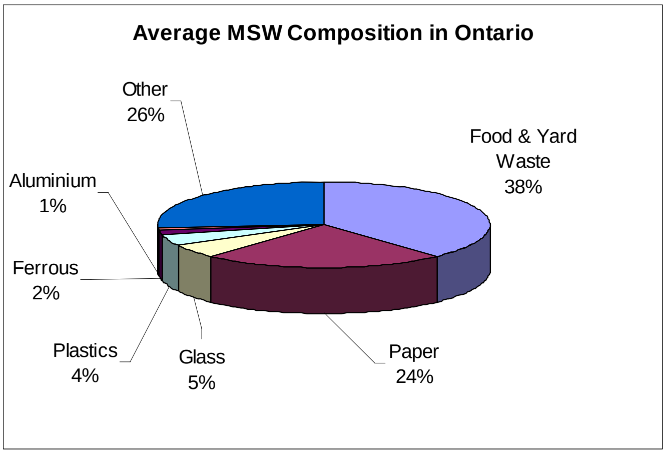
Throughout the world there appears to be a strong link between GDP and waste generation. There has been an OECD-wide increase in waste generation directly proportional to its economic growth. Between 1980 and 1999 there was a 40% increase in the OECD's GDP during this same timeframe there was a 40% increase in MSW generated (OECD, 1999).

This link between economic growth and waste generation has been documented in both Canada and Europe. In Canada, between 1998 and 2000, the per capita generation of municipal solid waste increased by approximately 10%. During this same period Canada's economy also experienced a rapid expansion with an 11% increase in per capita GDP (CIA, 1999-2001). Although this is a short time period to conclude a definite correlation it follows the reoccurring trend. Similarly the European Environmental Agency reported that total waste generation in the European OECD countries increased by almost 10 % between 1990 and 1995 while during the same timeframe the GDP in these countries increased by approximately 6.5 % (EEA, 2001). The increase in waste generation can also be partially attributed to the low durability of goods, unsustainable consumption patterns (Environment Canada, 2003) and the influx of low cost products from abroad.

2.1.3 MSW Composition

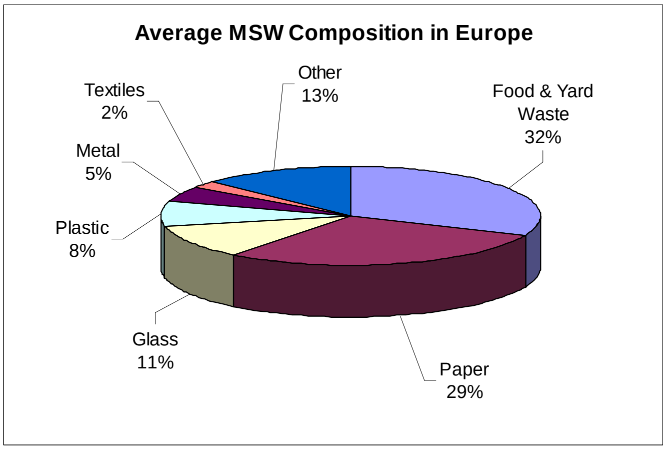
The composition of MSW can vary significantly between countries especially between developing and industrialized regions. Generally the main components of MSW are food waste and paper waste. This is the case both in Europe and in the Province of Ontario as shown in Figure 3 and Figure 4 below. Additionally, industrialized countries tend to have a greater percentage of packaging and 'other' wastes due to the higher consumption of processed, packaged and complex goods.

Figure 3: Average MSW Composition in Ontario



Source: MOE, 2004

Figure 4: Average MSW Composition in Europe



Source: AEA, 2001

2.2 Diversion of MSW

2.2.1 Waste Reduction

The first priority of any waste management system is to reduce the quantity of waste being generated. This is the most effective type of waste management since waste that is not created does not need to be managed. The generation of waste is seen as "a lost raw material, lost product, lost resource, lost profit" (US EPA, 2006). The current rate of the consumption of goods in industrialized countries is seen as unsustainable due to the large quantity of waste that results from it.

Reductions in the quantity of waste generated can be achieved by various techniques. Programs such as Extended Producer Responsibility (EPR) aim to encourage producers to reduce the quantity of waste generated from their product. This reduction in waste can be realized through design for the environment, product dematerialization, improved product durability and packaging reductions (OECD, 2006). Extended producer responsibility can also help to decouple waste generation from economic growth (OECD, 1999).

As well at-source waste reduction programs such as grasscycling, backyard composting, two-sided copying of paper, and reduction in consumer and transport packaging has yielded significant decreases in waste generation (US EPA, 2006).

Although waste reduction is the most effective type of waste management it is also the most difficult to quantify. It is therefore very hard to determine how successful waste reduction programs are because of the difficultly in determining the quantity of waste avoided. This is one of the reasons why little effort and resources are typically allocated towards waste reduction programs.

2.2.2 Waste Reuse

The second preferred option in most waste management plans is reuse of waste material. The most classic example of reuse is refillable beverage containers. Typically, refillable beverage containers are collected at a central depot after the beverage is consumed; the bottles are then cleaned, refilled with the beverage and sold. This results in a closed material loop for the bottle material. Although there are still environmental impacts associated with the initial production, refilling and eventually disposal of the container; these impacts are distributed over the multiple uses of the bottle resulting in a lower environmental impact per use. Other examples of product reuse are durable coffee mugs, cloth napkins, cloth shopping bags, and used clothing and furniture donations. Similarly to waste reduction it is very hard to try to quantify the success of waste reuse programs because of the difficultly to determine the quantity of waste avoided.

2.2.3 Material Recycling

Material recycling is the process of recovering dry waste material to be reprocessed into new products. There are four main categories of the municipal solid waste stream that can be recycled: glass, metal, plastic and paper. The range of materials accepted within each of these categories varies depending on jurisdiction. For example, many recycling programs only accept rigid plastic, such as polyethylene terephthalate (PET) and high density polyethylene (HDPE), while other programs also accept other grades of plastics including plastic film and polypropylene (PP). The main factors determining which materials are included within a recycling program are: costs, the presence and location of a market, legislation and public acceptance (FCM, 2004). The success of any recycling program is dependent on the effectiveness of the collection, sorting, reprocessing and reliable markets for the secondary materials.

Recycling programs can vary significantly based on the type of collection and processing. Recyclables can be either collected centrally or at the household; and materials can be required to be sorted at source or sorted at a central sorting facility.

After sorting, the separated streams of materials are reprocessed to produce new material. This reprocessing can either occur in a closed loop or an open loop. In closed loop recycling, the recycled material is used to produce the exact same material, i.e., a recovered aluminium can is reprocessed to produce a new can. Open loop recycling, or downcycling, occurs when the recycled material is used to produce a different material, usually of a lower quality and value. Since the recycling of metals and glass generally does not degrade them they can be used for closed loop recycling. Conversely, the quality of plastics and paper usually is degraded through the recycling process and therefore, they are generally used for open loop recycling.

No matter what type of recycling system is in place it is impossible to recover 100% of the waste paper, metals, plastics and glass. The Federation of Canadian Municipalities has estimated that material recycling is currently only applicable to 30-40% of the waste stream across Canada. The main barrier to increase this is the lack of developed markets in some areas for recycled materials (FCM, 2004).

2.2.4 Biological Treatment

Aerobic Composting

Aerobic composting is the process of the decomposition of organic material, by microbial activity, in the presence of oxygen to produce compost. It is possible to compost the organic component of the municipal waste stream. Typically, only kitchen scraps and yard waste are included in composting programs; it is, however, also possible to compost some grades of paper. There are two main types of composting: home composting and centralized composting, which differ primarily only by the scale of the operation. The quality of compost is dependent on the feedstock material; source separated organic waste generates higher quality compost than unsorted MSW. Significant revenues can be garnered from high quality compost whereas; there is no value for lower quality compost due to restrictions placed on its use (FCM, 2004).

The success of composting is dependent on providing proper conditions to encourage microbial activity, which includes ensuring an adequate supply of oxygen, water, and food (FCM, 2004). During the composting process the moisture in the waste is evaporated leading to a reduction in weight of material of approximately 40% (FCM, 2004). Aerobic composting is applicable to the kitchen and yard organic waste, which represents 30-40% of the municipal waste stream. This percentage can increase to 50% if low-value paper grades are accepted for composting (FCM, 2004).

Anaerobic Digestion

Similar to aerobic composting, anaerobic digestion (AD) is a treatment process for the organic fraction of the waste stream. AD is the process of the decomposition, by microbial activity, of organic material in the absence of oxygen to generate CH_4 in addition to CO_2. This process occurs in a controlled environment within a digester, an enclosed reactor. AD has the ability of managing all grades of paper in addition to kitchen and yard wastes. Therefore, anaerobic digestion is applicable to approximately 60% of the municipal waste stream, the kitchen and yard organic waste and paper waste. Another benefit of AD is that the methane created from this process can be used as an energy source for the generation of electricity, combined heating & power (CPH) or upgraded to a vehicle fuel. Additionally, through the AD process compost is generated that can be sold creating a product with a beneficial use and another revenue stream.

The vast majority of AD facilities managing source separated or mixed MSW are located in Europe. AD is more financially viable in Europe than North America since the costs of alternative waste management options are much higher in Europe. In Canada the main barrier, which currently prevents the development of AD, is that inexpensive landfill options are still available for most municipalities (FCM, 2004).

2.3 Residual MSW

2.3.1 Quantity and Composition

Despite the availability of the waste management options discussed above to prevent, reduce, reuse, and recycle municipal solid waste, there still remains residual wastes. Residual wastes consist of two main groups of materials. The first contains materials that that cannot be reused or recycled. The second are materials that could be reused or recycled but for various reasons are not. Additionally, residual wastes are generated from the sorting and processing in material recycling and biological treatment.

As stated in section 2.2.4 material recycling is applicable to 30-40% of the waste stream and biological treatment is appropriate for between 30-60% depending upon if paper is included. Therefore, approximately 70-80% of the municipal waste stream can be managed by the traditional waste diversion options of material recycling and biological treatment (FCM, 2004). However, this could only occur if all of the waste that could be diverted is disposed of appropriately, this might require the source separation of waste streams at the household or the participation in deposit return programs.

If it were assumed that 80% of the waste stream could be handled through recycling and biological treatment and that 80% of these materials were properly disposed, it would result in only 64% of the total waste generated being diverted while 36% of the waste stream would remain as residual waste. This compares to the top performing urban regions, which are currently achieving approximately 45% diversion of MSW, excluding energy recovery (RRF, 2004).

The composition of residual waste depends largely on the specific diversion programs in place and the materials that are included in these programs. However, one large component of the residual waste stream is 'other' materials. This includes large items such as furniture and household construction wastes as well as complex products that are made of multiple materials. These complex products are especially hard to manage since their unique composition makes them difficult to recycle.

2.3.2 Treatment Options

WTE

Waste to energy (WTE) is a high temperature thermal processes that substantially reduces the volume of waste as well as generating energy that can be used as heat and/or for the production of electricity. While WTE facilities are designed to manage waste with a specific calorific value they can handle virtually all combustible materials in the municipal waste stream. While not preferred, even small quantities of inert materials, such as glass and metals that have no calorific value, can go through the thermal process and the metals can be recovered from the bottom ash.

WTE encompasses several different technologies. For the purpose of this research, thermal WTE technologies are classified into three primary groups: established combustion technologies, advanced thermal technologies and solid recovered fuels. Combustion is a process of direct burning; the various types of combustion differ by their exact operating conditions and equipment alignment. Combustion technologies, like incineration, are the most established and the most widely used type of WTE. Advanced thermal technologies refer to processes that transform waste into a synthetic gas under extreme temperatures; this includes gasification, plasma technology, and pyrolysis. Solid recovered fuels are waste that has been processed into a fuel substitute that can be used to offset the use of a fossil fuel within an industrial process. The main application of this is within the cement industry.

Although the mechanisms behind these three categories of technology vary, they all involve the same main components: pre-processing, thermal treatment, heat and/or power recovery, air pollution control and an ash management system (FCM, 2004). The WTE technologies are described in more detail in Chapter 3.

Landfill

Landfill is the most traditional and widely used waste treatment method worldwide. While landfill is the lowest preference on most waste management hierarchies it is also an essential component of waste management due to the limited treatment options from some fractions of the waste streams. Some jurisdictions have implemented landfill bans for certain types of waste. These bans are aimed to manage the banned waste with an environmentally superior treatment option and prolong the life of landfills for wastes that do not have an alternative treatment. Some examples of wastes that have been banned from landfill in some jurisdictions are: recyclables, organic wastes, combustible wastes (with a specific calorific value), and construction/demolition wastes.

Landfills have evolved significantly from their original form as simply a hole in the ground. This evolution has been driven by public concerns of the environmental and human health risks associated with landfills. The result of this public opposition has led to more rigorous landfill standards as well as more stakeholder engagement in the planning and siting process of landfills. As a result, landfills have evolved from unlined attenuating facilities to the current engineered landfills that are heavily lined and unattenuating.

Landfills can manage all fractions of the waste stream. However there are significant concerns over the landfilling of organic wastes. This is because methane is generated when organic wastes decompose under the anaerobic conditions in a landfill. Due to the large emission of methane, landfills have begun to install landfill gas (LFG) recovery systems that are designed to capture the methane generated in the landfill. The methane collected can then either be flared or it can be collected and used as a fuel for the generation of heat and/or the production of electricity.

3. Waste to Energy Technologies

3.1 General Description

Waste to energy technologies are not new; waste incineration has existed since the end of the 19th Century when industrialization spurred the development of organized waste management systems. The first waste to energy facility was opened in 1874 in Nottingham, England and was named the 'Destructor' (INTUSER, 2006). The construction of the Destructor was followed by the development of waste incinerators across Europe and North America in the early 1900s (Knox, 2005).

Currently, there are many different thermal waste to energy technologies. All of these technologies process waste at a high temperatures reducing its volume to produce a stabilized ash material and energy that can be recovered as heat or steam. Although the specific operating conditions of the various technologies differ, there are several core processes that are pertinent to all of WTE technologies:

• pre-processing of the waste material;

• thermal treatment;

• heat and/or energy recovery;

• air pollution control; and

• ash management system (MWIN, 2006).

Incoming waste is processed to remove unacceptable materials such as hazardous waste and oversized materials. The waste is also processed, either mechanically or manually, to improve the homogeneity of its physical, chemical and heat value characteristics. The degree to which the waste is processed is dependent on the requirements of the specific WTE technology. Additionally, as part of the pre-processing waste can be sorted to recover recyclable materials from the waste stream.

The processed waste is then treated by the application of heat in a controlled environment, at a specific temperature either in the presence or absence of oxygen depending on the technology. Waste is either oxidized, combusted, into carbon dioxide and water, or is reduced into a synthetic gas or oil. The synthetic gas or oil is then combusted in a secondary process into carbon dioxide and water releasing heat (MWIN, 2006). In both of these scenarios the remaining waste material, the ash, is stabilized and substantially reduced in volume and weight.

MSW contains substantial heat energy, typically with a calorific value ranging between 10,500 and 12,800 KJ/kg (MWIN, 2006). The composition of the waste and the degree of pre-processing dictates the specific calorific value of the waste. Generally, boilers are used to recover the heat energy that is released from the waste and transforms it into steam (FCM, 2004). The energy efficiency of a WTE process is largely dependent on the end use of the energy recovered. For example, the generation of electricity from WTE has a low energy efficiency, but results in high priced energy, whereas the production of hot water for district heating garners a lower price but has a higher energy efficiency (World Bank, 2000). Overall energy efficiencies range from 35% for the production of only electricity to 85% for the generation of combined heat and power (World Bank, 2000).

WTE technologies release large volumes of flue gases, which contain residues from incomplete combustion as well toxic emissions. Therefore, air pollution control systems are necessary to treat the flue gas before it is released into the atmosphere. The composition of the waste, the thermal technology, and the emission limit regulations determine the specific requirements of the air pollution control system. The typical components of an air pollution control system are: a electrostatic precipitator, a bag house filter, a dry, semi-dry or wet acid gas removal system, activated carbon and catalytic reactor adsorption (World Bank, 2000). Air pollution control systems can also include equipment to continuously or periodically monitor emissions, for process control and regulatory compliance purposes (MWIN, 2006).

During the WTE process not all of the waste is combusted, either due to incomplete combustion or incombustible materials. This solid residue is referred to as bottom ash or slag. Ferrous and aluminium material can be recovered from the bottom ash, through magnetic and electrical screening, for recycling. The main disposal method for the remaining bottom ash material is landfill. However, it is also possible to utilize the bottom ash as an aggregate depending upon its composition, physical condition, and the local regulatory requirements (FCM, 2004). Bottom ash typically represents 10% by volume and 25% by weight of the incoming waste stream for a combustion WTE facility (MWIN, 2006). Some advance thermal technologies that employ extremely high temperatures vitrify the ash material, which further stabilizes it and reduces the quantity of ash generated to less than 5% by volume (MWIN, 2006). A solid residue, fly ash, is also collected in the air pollution control system. Fly ash is typically classified as a hazardous waste material, due to high levels or salts and heavy metals, and requires disposal in a hazardous waste landfill.

For the purpose of this research, thermal WTE technologies are classified into three primary groups: established combustion technologies, advanced thermal technologies and solid recovered fuels. **Established combustion technologies** include mass burn incineration (single stage combustion), fluidised bed combustion, starved air (or multiple stage) combustion, and rotary kiln combustion. These technologies have been widely used throughout Europe and North America for over 50 years to treat MSW. **Advanced thermal technologies** also referred to as new and emerging technologies, include gasification, plasma arc technology, and pyrolysis. Until recently these technologies have been utilized only for the management of specific waste streams (i.e., waste wood and oil) in Europe and North America. The production and use of **solid recovered fuel**, also known as refused derived fuel (RDF), is used as a fossil fuel substitute, especially for coal, within specific energy intensive industries.

The operations of these different technologies can vary significantly. The main variables that differentiate the technologies are: the process oxygen concentration, the process temperature, the positioning of air pollution control system within the operation and the location of the energy recovery (MWIN, 2006). The specific operating conditions of each WTE technologies are described in the sections below along with information about each technology's cost, capacity, energy and environmental implication.

3.2 Established Technologies

3.2.1 Mass Burn Incineration

Background

Mass burn incineration is a well established technology that has been used for over 100 years to generate energy from MSW. Mass burn incinerators are generally large scale facilities that are constructed to manage MSW from large urban centres with a population of over 1 million; operating on a large scale improves the economies of scale for the technology (MWIN, 2006).

Operating Conditions

Very little pre-processing of waste is required for mass burn incineration since it can accommodate large variations in the composition and calorific value of the waste (World Bank, 2000). Therefore the heterogeneous incoming waste is typically fed directly into the system 'as received'. Moving grates transport the waste into a single combustion chamber. Three main processes occur in the combustion chamber: drying, which reduces the water content of the waste; primary burning, which oxidizes the most combustible wastes; and finish burning, which oxidizes the fixed carbon (FCM, 2004).

Waste is oxidized in mass burn incineration either in a single function or in a two stage function, where the waste is initially partially oxidized on the grates and then the resultant gas is oxidized in the combustion chamber. The exact process is dependent on the operating temperature and oxygen content and the physical configuration of the combustion chamber (MWIN, 2006). Two stage mass burn incineration is more common since it results in a more controlled and complete combustion, and higher energy recovery. In both a single function or in a two stage function mass burn incinerator energy is recovered using a boiler (MWIN, 2006).

Cost and Capacity

As aforementioned mass burn incinerators are typically constructed on a large scale. The capacity of an average multiple grate mass burn incinerator ranges from 200 to 1000 tonnes per day, with the largest facilities having a capacity of over 3,000 tonnes per day (MWIN, 2006). The average total annualised capital and operating costs (including energy revenues) ranges from $65 to $85 CDN per tonne of waste processed (FCM, 2004).

Environmental and Energy

Mass burn incineration can recover heat and/or generate electricity with the use of a modern boiler. The technology generally exports its energy as steam or electricity and is capable of energy efficiency of up to 85% (World Bank, 2000). With the use of an appropriate air pollution control unit mass burn incineration has been successful in achieving the environmental regulatory requirements where the facilities are operating (MWIN, 2006).

3.2.2 Fluidised Bed Incineration

Background

Fluidised bed incineration has typically been used to manage specific homogeneous waste streams such as: sewage sludge, petroleum waste and paper industry waste. Fluidised bed incineration can also be used to treat municipal solid waste as long as the waste is pre-processed into a homogeneous state (MWIN, 2006).

Operating Conditions

A fluidised bed incineration is comprised of a large combustion chamber that has a bed of granular material such as silica sand, limestone or a ceramic material on the bottom. There is a burner at the bottom of the bed, which creates a temperature of about 850°C. Air is then injected at the bottom of the bed and is dispersed into the granular material, decreasing the density of the granular material making it easier for heat follow through it to the waste material (MWIN, 2006).

Waste that has been processed into a homogeneous state is fed onto the bed and is guided by a convection current movement of the air and granular particles. The waste is initially combusted to form carbon monoxide and other volatiles, which undergo further combustion above the surface of the bed, where additional combustion air is injected (MWIN, 2006). After combustion the flue gases are treated by the air pollution control system. Bottom ash that is deposited on the bed and removed on the opposite side of the bed from waste is injected (FCM, 2004).

Cost and Capacity

Fluidised bed systems typically operate on a smaller scale than mass burn incineration; the capacity of one unit ranges from 50 to 200 tonnes of waste per day. Larger systems can be constructed using multiple units (MWIN, 2006). The average total annualised capital and operating costs (including energy revenues) ranges from $80 to $110 CDN per tonne of waste processed (FCM, 2004). Fluidised bed incinerators have a simple design, resulting in long service life, and low maintenance costs (World Bank, 2000).

Environmental and Energy

Fluidised bed incineration produce less trace organic emissions, such as dioxins, furans, etc., due to the high residence time and turbulence in combustion chamber. The convection movement through the granular bed improves combustion resulting in less bottom ash. However, due to this movement more ash is carried into the flue gas, requiring a more extensive air pollution control system (MWIN, 2006). The technology is very versatile and is suitable for a wide range of fuel mixtures and waste materials (World Bank, 2000).

3.2.3 Starved Air Combustion

Background

Starved air incinerators, or controlled air incinerators, have been used widely for the treatment of MSW. A high level of oxygen control is required for this technology, which operates in two stages. The fist stage of the process operates very similarly to a gasifier. Starved air incineration technology has undergone continual improvements in order to improve its reliability. Currently, the technology is well established with a stable and reliable process (MWIN, 2006).

Operating Conditions

As mentioned above, starved air incinerators have a two stage combustion that occurs in a primary combustion chamber and a secondary combustion chamber. Limited processing of MSW is required before it is fed into the primary combustion chamber. In the primary chamber the waste is partially oxidized in a sub-stoichiometric environment, the oxygen level is below the required amount for complete combustion, producing a combustible gas, typically carbon monoxide (FCM, 2004). This combustible gas enters into the secondary combustion for complete oxidization, under temperatures of up to 1,200°C, for a residence time of 1 to 2 seconds (FCM, 2004).

There are two types of starved air incinerator that can be used to treat MSW: semi-continuous and batch process. Semi-continuous starved air systems are typically used in small municipalities. The most common type of this technology is a stepped hearth incinerator that has two to four stationary hearths in line (MWIN, 2006). Waste is fed into the first hearth at set intervals, about every 10 minutes, when the waste material reaches the end of the first hearth it drops onto the second hearth causing the waste to mix with the combustion air and exposing a new surface to the high temperature (MWIN, 2006).

A batch process starved air incinerator operates on a smaller scale than the semi-continuous process and is ideal for small communities of less than 2500 households. At the start of each batch operation waste has to be fed into the primary chamber of the unit. The air pollution control system of a batch process starved air incinerator can be much less extensive since these facilities are generally exempted from the strict air emission requirements due to their small size (MWIN, 2006).

Cost and Capacity

As mentioned above semi-continuous starved air systems are suitable for small municipalities. The capacity of an individual unit ranges from 10 to 100 tonne per day and the facilities typically have 3 to 5 units resulting in a total capacity of 30 to 500 tonnes per day (MWIN, 2005). The average total annualised capital and operating costs (including energy revenues) ranges from $100 to $150 per tonne of waste processed (FCM, 2004).

Batch starved air incinerators operate on a very scale with capacities ranging from 1 to 20 tonnes per day (MWIN, 2006). The average total annualised capital and operating costs (including energy revenues) ranges from $75 to $200 per tonne of waste processed depending on the size of the facility (FCM, 2004).

Environmental Issues and Energy Implications

With the use of an appropriate air pollution control unit a semi-continuous starved air incinerator is capable of meeting all environmental regulatory requirements (MWIN, 2006). The required air pollution control system is similar to those required for larger systems. Heat can be recovered and electricity can be generated from a semi-continuous starved air incinerator; however heat recovery is less feasible for smaller facilities (FCM, 2004).

Batch starved air incineration is a relatively simple operation with high quality and low quantity of ash generation as well as low levels of particulate emissions (MWIN, 2006). While batch starved air incinerators are generally exempt from the strict emission requirements due to their small size, the technology has the ability to meet most of these criteria even with modest air pollution control units (MWIN, 2006). Due to the small scale of this technology, the generation of electricity is generally not economical feasible; however heat recovery for nearby industrial applications may be viable (FCM, 2004).

3.2.4 Rotary Kiln Incineration

Background

Rotary kiln incineration has been used as a method of thermal treatment of MSW since the 1950s. This technology is also for the treatment of a variety of other waste streams including solid and liquid hazardous wastes.

Operating Conditions

Rotary kiln incinerators are also two stage combustion systems with a primary and a secondary combustion chamber. The primary chamber is a rotary kiln; a refractory lined rotating inclined cylinder. Waste is fed into the kiln and transported through it by the rotations of the inclined cylinder at a temperature of 850°C (World Bank, 2000). The rotations of the kiln ensure adequate mixing with combustion air; the residence time in the kiln is approximately 30 minutes (MWIN, 2006).

The retention time in the kiln is too short for complete combustion to occur, so the gases from the primary chamber flow into a secondary chamber. Complete combustion occurs in the secondary chamber, which has a temperature of between 1000°C and 1200°C and a residence time of at 1 to 2 seconds (MWIN).

Cost and Capacity

The typical capacity of a rotary kiln incinerator ranges from 10 to 50 tonnes per day (MWIN, 2006). The technology is relatively capital intensive, given the complexity of its rotating element design. The maintenance cost for rotary kiln incineration is also relatively high. The average total annualised capital and operating costs (including energy revenues) ranges from $125 to $150 per tonne of waste processed (FCM, 2004).

Environmental and Energy

With the use of an appropriate air pollution control unit a rotary kiln incinerator is capable of meeting all environmental regulatory requirements (MWIN, 2006). However, a relatively high quantity of bottom ash is generated due to incomplete combustion in the short residence time. The energy efficiency of this technology can be up to 80% from combined heat and power generation (World Bank, 2000).

3.3 Advanced Thermal Technologies

Advanced thermal technologies, also referred to, as 'new and emerging' technologies do not have the same commercial application record as the established combustion technologies for the treatment of MSW. Many of the details, including the costs and capacities, of these technologies are unknown since the proprietary technology vendors hold the information about their technical and environmental performance.

Many of these technologies have limited experience operating on a full scale and have only been proven only on a bench-scale or as pilot scale for the treatment of MSW. The operational process of these technologies is generally more complex and sophisticated; they can include the use of chemical reagents and more precise control over the oxygen concentrations and temperature profiles (MWIN, 2006). The main potential benefits of these technologies are lower contaminant emissions especially trace organic substances, as well as the ability to recover material resources including synthetic oils and gases. The main disadvantages of these technologies are the increased costs associated with the complexity of their operations and the requirement for MSW to be process into a homogeneous mixture (MWIN, 2006). The use of advanced thermal technologies have traditionally been limited to homogeneous waste streams such as: industrial sludge, wood waste and specific hazardous waste streams.

3.3.1 Gasification

Gasification is a process in which a fuel is partially combusted under stoichiometric conditions, with less oxygen present than required for complete combustion. A combustible synthetic gas (syngas) is generated from this process. The syngas is then cleaned so that it can be combusted in an internal combustion engine, a gas turbine, or a boiler under excess-air conditions (MWIN, 2006). The energy content of the syngas is dependent on the oxygen content of the oxidant; if air is used as the oxidant the syngas has an energy content of about one third of natural gas.

Gasification is not a new technology; it has been used to generated energy from coal and wood since the 19th Century. In the early 1900s the technology developed to be able to also manage specific industrial waste streams. During World War II there was a gasoline shortage, which acted as a driver for gasification (MWIN, 2006). However, at the end of the War gasoline become readily available at a relatively low cost, which virtually eliminated the use of gasification. Recently, gasification technology has been used to convert MSW into a syngas. Gasification requires a homogeneous feedstock; therefore MSW has to undergo signification pre-processing before it can be gasified. The environmental advantage of gasification is that it has the potential to generate fewer contaminant emissions and therefore requires a less extensive air pollution control system (MWIN, 2006).

3.3.2 Plasma Arc Technology

Plasma arc technology is well developed for use in electric arc furnaces and arc welding units within the steel and construction industries. It is also widely used for the treatment of hazardous waste (FCM, 2004). The operational process of plasma arc converts waste into simple molecules under extremely high temperatures in an oxygen-starved environment. An electric current is then directed though a stream low pressure gas to generate a thermal plasma field at a temperature of between 5,000 to 15,000°C. This process produces a combustible gas that can be combusted in an afterburner as well a vitrified inert ash is also produced from this process (FCM, 2004).

Due to the application of extremely high operating temperatures, this technology has the ability to destruct problematic hazardous materials such as PCBs and complex stable volatile organic compounds. There is a high capital and operating cost associated with plasma arc technology due the complexities of its process (FCM, 2004).

Depending on the feedstock and the scale of operation, plasma technology can either be a net energy user or producer. The synthetic gas can theoretically be used as an energy source; however this is dependent on its quality. Plasma technology is still considered to be on a demonstration/pilot scale; there are no commercial scale units treating MSW operating in North America (MWIN, 2006).

3.3.3 Pyrolysis

The pyrolysis process occurs in the complete absence of oxygen and requires an external source of heat to drive the reaction (MWIN, 2006). The process generates a synthetic gas (syngas), a liquid fuel (oil) and carbon char. The syngas is generally a combination of hydrogen, methane, carbon monoxide and carbon dioxide and is typically consumed internally to fuel the pyrolysis process. The liquid fuel generated is a combination of acetic acid, acetone, methanol and complex oxygenated hydrocarbons (tars), which can be process into a substitute for conventional fuel oil. The char produces is a mixture of pure carbon and inert materials (FCM, 2004).

Pyrolysis is used extensively within industrial operations; however the commercial application of MSW pyrolysis is extremely limited. There is only one facility in the world, a demonstration scale facility located in Germany, which has a pyrolysis system for MSW (MWIN, 2006). The technology has not developed on to a commercial scale due to high costs and the technical complexity of the system. However, increasing energy prices in the future might make this technology more economically feasible. Depending on the feedstock and the scale of operation, pyrolysis can either be a net energy user or producer (FCM, 2004).

3.4 Fuel Substitution

Background

In a solid recovered fuel system, municipal waste undergoes significant pre-processing to separate out the combustible materials with the highest calorific values. This material is then converted into either a palletised or loose homogeneous refuse derived fuel (RDF). As part of the pre-processing recyclable materials can also be recover. The processed RDF can be used to directly substitute conventional fossil fuels in industrial processes, utility power generation or institutional heating applications (MWIN, 2006). The most common application is in energy intensive industrial processes, such as cement kilns.

Operating Conditions

The pre-processing of municipal solid waste required in a solid recovered fuel system can either be performed manually or mechanically. The purpose of the pre-processing in this system is to improve the combustibility waste by increasing its calorific value. This is achieved by removing non-combustible material and materials with low heating values such as wet organics. Recyclable materials can be recovered during the pre-processing; as well organic material can be separated to be processed in a composting or anaerobic digestion system.

The pre-processing is also used to make the RDF a more homogeneous and uniform fuel. This can be achieved be shredding the waste into a uniform particle size. Reducing the particle size of the RDF increases the combustibility of the waste. The RDF can either be left as a loose fuel or it can be converted into pellets, which facilities its transportation and storage (MWIN, 2006).

Cost and Capacity

The capacity of fuel substitution systems is determined by the size of the energy customer markets for RDF. The most common use of RDF is within a cement kiln, which typically would require approximately 500 tonnes per day of RDF (MWIN, 2006). The average total annualised capital and operating costs (including energy revenues) to process waste into RDF ranges from $25 to $100 per tonne of waste processed. The costs of the process are dependent on the scale of the operation and the level of processing required (FCM, 2004).

Environmental and Energy

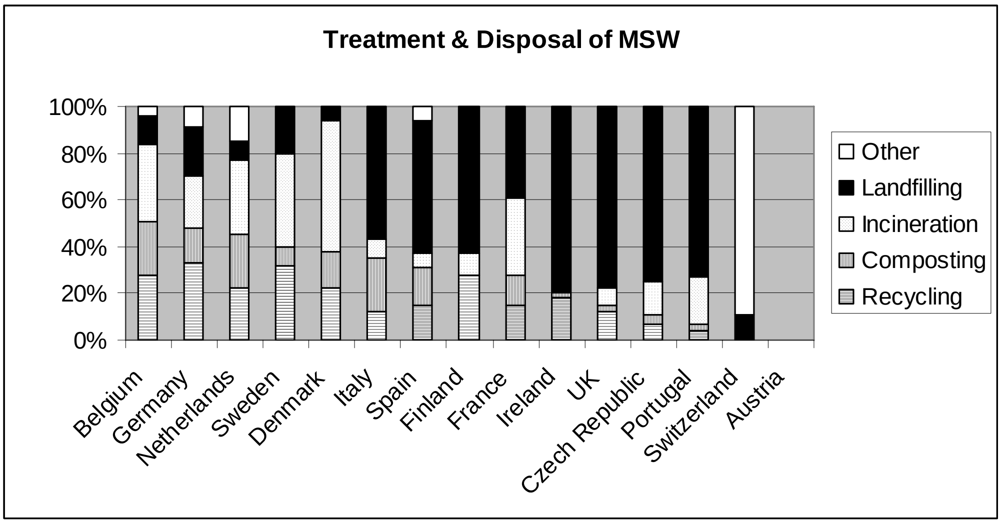
Solid recovered fuel systems yield improved air emissions, a reduced quantity of bottom ash, the potential to recover recyclable material and the access to higher level energy applications for the fuel (MWIN, 2006). Solid recovered fuel systems also offer the environmental benefit of directly displacing the non-renewable fossil fuels; especially coal, within energy intensive industrial applications. The energy efficiency of solid recovered fuel systems is dependent on the operational process that the RDF is used in.

4. Experience from Europe

4.1 European Overview

The treatment of municipal solid waste varies significantly by country across Europe as seen in Figure 5. Some countries, like the UK, Ireland and Czech Republic, are dependent on landfill for the treatment of almost 80% of their MSW. While other countries such as Belgium, Germany and the Netherlands have a more balanced waste management approach depending significantly on recycling, composting, incineration and landfill.

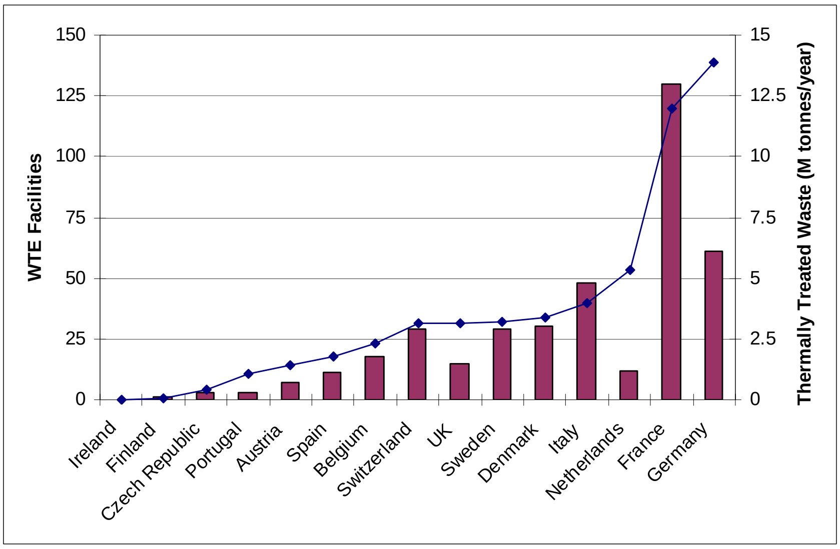
Figure 5: Treatment of MSW in Europe



Source: Eurostat, 2005

The dependence on WTE by countries in Europe for the treatment of their MSW also differs drastically. For example, Ireland does not have any WTE facilities whereas France has 130 WTE facilities treating 13 million tonnes of MSW per year. The number of WTE facilities in each country and the quantity of MSW treated by them are shown in Figure 6.

Figure 6: WTE Usage in Europe in 2004



Source: CEWEP, 2006

One aspect of WTE that also varies significantly across Europe is the efficiency of the technology. In Sweden and northern Europe there is a large demand for space heating so the excess heat generated from WTE can be captured and used in district heating applications. This is not representative of the whole continent since the need for space heating is not present in the Southern Europe resulting in a limited market for the excess heat produced from WTE.

The public acceptance of WTE across Europe seems to be highly dependent on historical experience with the technology. For example, in Denmark, which has a successful record of tightly enforcing high emission standards, there is a high level of tolerance for housing to be located very close to WTE facilities so that the excess heating can be utilised efficiently. Whereas, in Italy, where there has been a history of poor performing facilities, there is relatively low acceptance of facilities. This variance in acceptance is expect to change with the implementation of the Waste Incineration Directive that enforces higher emissions standards for both new and existing facilities across the EU placing facilities in all countries on an equal footing (Stengler, 19 June 2006).

Political support for WTE within the European Union varies according to historical experience and knowledge with WTE. According to Dr. Stengler of the Confederation of European Waste-to-Energy Plants, there is low political support for WTE from countries that have little or no knowledge or experience with the technology. Whereas in countries that have more experience with WTE and have been dependent on the technology for decades there seems to be more political support.

It is believed that the EU Landfill Directive and the ensuing landfill bans in member states have had the largest impact on the development of WTE in Europe (Stengler, 19 June 2006). If the current requirements of the landfill directive are to be achieved, it would be difficult to be accomplished without the increased use of WTE (Stengler, 19 June 2006). The EU Landfill Directive will be reviewed as part of the waste management strategy ten years after its implementation. It is predicted that the there will be stricter requirements imposed under the Landfill Directive in the future that will be more inline with those that many northern European countries have independently implemented, such as the landfill bans (Stengler, 19 June 2006).

Currently a new waste management framework for the EU is being developed. As part of this there has been a proposal by the Commission that WTE be classified as a renewable energy source (RES) if the facility is able to meet a specific energy efficiency threshold (Stengler, 19 June 2006). If this proposal is accepted it would provide an incentive to help to advance technology with an emphasis on improved energy efficiency in order to meet the threshold target.

There is also a trend towards the use of refuse derived fuels (RDF) especially within the cement industry. Currently RDF is still classified as a waste and therefore facilities that use RDF as a fuel substitute have to meet the same emission standards as WTE facilities. However there is currently strong lobbying to change the classification of RDF from a waste to a product/fuel so that facilities that use RDF are not subjected to the EU Waste Incineration Directive (Stengler, 19 June 2006).

Historically, the main argument against WTE has been the emissions release from the facilities. However, this is no longer the primary concern especially after the release of a report by the German minister of the environment that concluded that there are no significant human health or environmental impacts from WTE. The main concern with the increased use of WTE is the potential negative effect of WTE on material recycling (Stengler, 19 June 2006).

Landfill is still the cheapest waste management option is most European countries. This is changing with the introduction of landfill taxes in many countries, especially in Northern Europe. However, many countries, including Germany, have decided against the use of a landfill tax (Stengler, 19 June 2006). A summary of landfill taxes, landfill bans and incineration taxes across Europe is shown in Table 1.

Table 1: Landfill Taxes, Landfill Bans and Incineration Taxes across Europe in 2005

Country	Landfill Tax Implemented (€/t)	Landfill Tax Planned (€/t)	Landfill Ban Implemented	Landfill Ban Planned	Incineration Tax (€/t)
Austria	€ 44	€ 65 (Jan 2004)	Waste suitable for incineration (Jan 1 2004)		€ 7 (Jan 1 2006)
Belgium	Not for MSW	Not for MSW	Unsorted wastes, sorted and non-sorted wastes for recovery, combustible residual fraction from sorting (March 2004)		€ 3 (Proposed for 2006)
Czech Republic	€ 10 MSW (2005 – 2006)	€ 13(2007 – 2008) € 17 (after 2009)			
Denmark	€ 50.49 municipal and industrial waste		Waste suitable for incineration (Jan 1 1997)		€ 44.43
Finland	€ 30 MSW (Jan 1 2005) No tax for private industrial landfills for industrial waste		To be introduced 2005		
France	€ 7.32 – 9.15 MSW		Introduced in 2002		
Germany	No	No	Non pre-treated waste (June 1 2005)		No
Ireland	€ 15				
Italy	€ 10 - 25 MSW (varying by region)		Yes	Combustible waste (2007)	Tax on incineration without energy recovery – 20% of landfill tax
Netherlands	€ 86 (Jan 1 2006) for combustible waste	No	For 32 categories of waste	More categories of waste	
Portugal	No		No		
Spain	No national tax. In Madrid: € 7 domestic waste	In Cataluna: € 10 (Jan 1 2004)	No		
Sweden	€ 47 (Jan 1 2006)		Sorted combustible waste (Jan 1 2002)	Organic waste (Jan 1 2005)	€ 360 on fossil carbon in waste (Proposed for 2007)
Switzerland	€ 9.66 MSW		Effective since 2002		
UK	€ 19.94 (Apr 1 2003)	€ 21.37 (Apr 1 2004) Increasing € 4.27 each year until € 49.86	No		

Source: CEWEP, 2005

4.1.1 European Union Legislation

The European Union has developed numerous legislative requirements with regards to waste management that member states have been required to transpose into their national laws and statues. These legislations can be divided into three categories: horizontal/parent directives, treatment directives/waste management operations and waste stream specific directives. The goal of horizontal/ parent directives is to develop a general framework for waste management including definitions and principles. Treatment directives/waste management operations regulate the operations of specific waste management treatment methods such as technical standards of operation. Waste stream specific directives are concerned with the management of specific waste streams, including their collection, reuse, recycling and disposal (Waste Watch, 2004). Table 2 lists the main EU legislative requirements with regards to waste management.

Table 2: European Union Legislation

Horizontal/Parent Directives	Treatment Directives/ Waste Management Operations	Waste Stream Specific Directives
• Directive on Waste (Waste Framework Directive) - 1975 (amended '91 & '96) • Directive on Hazardous waste - 1991	• Directive on Integrated Pollution and Control (IPPC) – 1996 • Directive on Landfill of Waste (Landfill directive) – 1999 • Directive on the Incineration of Waste - 2000	• Directive on the Disposal of Waste Oils - 1975 • Directive on Batteries and Accumulators - 1991 • Directive on Packaging and Packaging Waste - 1994 • Directive on End of Life Vehicles - 2000 • Directive on WEEE - 2004 • Directive on the Biological Treatment of Biological Waste - working proposal

Source: Waste Watch, 2004

The legislative requirements are aimed to complement and supplement one another. The foundation of the majority of waste legislation is the EU Strategy for Waste Management that was introduced in the 7th May 1990 Council Resolution. The Strategy outlays the founding principles of waste management for the EU: 1) Waste Prevention, 2) Recycling and Reuse, 3) Promotion of recovery (inc. energy recovery), 4) Minimising and Improving final disposal and monitoring, and 5) regulation of waste transportation and remedial action (Europa, 2004).

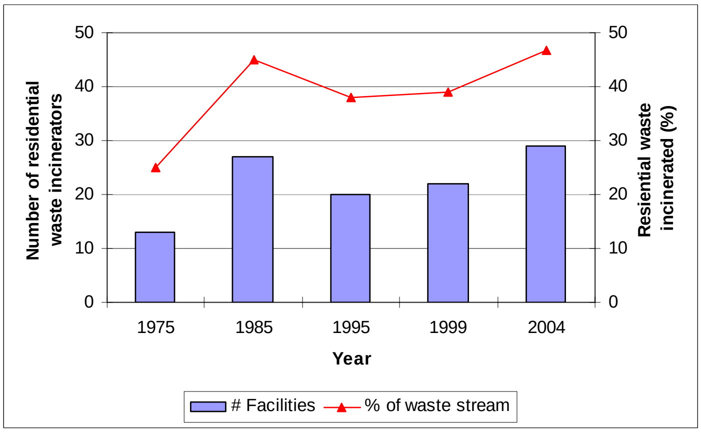
4.2 Sweden

4.2.1 Historical Development

This section details the historical development of WTE in Sweden from before 1970 through 2006. This includes descriptions of the situation surrounding WTE in each decade as well as a summary of the internal and external factors that have influenced the development of the technology in Sweden.

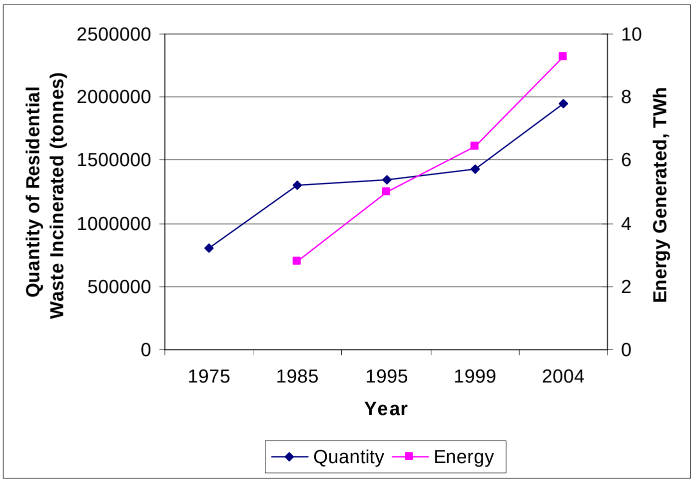
Figure 7 and Figure 8 graphically depict the development of WTE in Sweden. Since all the waste to energy technology in Sweden is incineration the terms WTE and incineration are used interchangeably in this section.

Figure 7: Development of Waste Incinerators in Sweden 1975-2004



Source: RVF, 2003; RVF, 2005

Figure 8: Waste Processed and Energy Generated from Waste Incineration in Sweden 1975-2004



Source: RVF, 2003; RVF, 2005

Pre 1970

The incineration of waste has occurred for over 100 years in Western Europe. In Sweden the first waste incineration facility began operations in 1901 outside of Stockholm in Lövsta (RVF, 2003). Waste incineration was initially a very crude operation occurring in simple furnaces, it took many years for the technology to develop into a more mature process that could operate on a large scale.

During the 1950s and 1960s the generation of household waste began to increase significantly. The introduction of packaged and "ready-made" products was a primary reason for this increase. As a result of the increasing quantity of waste, more disposal capacity was required. This prompted the construction of large scale incinerators in the 1960s (Wiqvist, 12 May 2006).

By the end of the 1960s, the main urban centres in Sweden had invested in the construction and operation of large waste incineration facility that could process waste from their entire region. Large scale incinerators, with the capacity of 150,000 – 200,000 tonne/year, were developed in Stockholm, Göteborg, Malmö and Uppsala during this period (RVF, 2003).

1970s

At the turn of the decade, two pieces of legislation were created that had a large impact on waste management activities. In 1969 the Environment Protection Act was enacted, which placed extensive environmental requirements on new waste management facilities (SEPA, 2005). This was followed by legislation in 1972 that made municipalities responsible for the collection and treatment of household waste (Wiqvist, 12 May 2006). These regulations forced municipalities to improve the environmental performance of their waste treatment operations, especially their landfills due to concerns over groundwater pollution. The new requirements acted as an incentive for municipalities to shift towards alternative waste management options, including incineration, for the treatment of household waste (Wiqvist, 12 May 2006).

The first oil crisis also occurred at the beginning of the 1970s, in 1973. Prior to 1970 none of the incinerators built in Sweden recovered energy. Due to the energy crisis significant attention was given to shifting towards alternative lower cost, non fossil fuel, forms of energy. This prompted many municipalities to shift their source of energy from oil to waste for space heating. This was done primarily in district heating networks, which had been developed in most large cities in Sweden during the 1960-1970s (Ohlander, May 24 2006; Wiqvist, 12 May 2006).

Along with the conversion of existing incinerators to recover energy, there was also the construction of new incinerators with energy recovery systems during the mid 1970s. This development was partially a result of the oil crisis and municipalities efforts to find alternative low cost alternatives to oil (Ohlander, May 24 2006). By the mid 1970s there were 13 waste incineration facilities in Sweden treating a total of 0.8 million tonnes of waste (RVF, 2003).

During the 1970s there were also increased efforts to shift waste away from landfill by material recycling and biological treatment of the organic fraction of household waste. The biological treatment consisted of the organic components of the mixed waste being mechanically separated and then composted. However, the separation proved very difficult and resulted in compost of very poor quality (Rylander, 11 May 2006). Material recycling had success for managing some fractions of the waste stream but there were inadequate secondary markets for all of the recovered material. Due to the limited success of the material recycling and composting programs to treat the entire waste stream, the opinion began to emerge that an integrated waste management approach was needed and that incineration was a required component (Rylander, 11 May 2006).

1980s

During the 1980s there was major public concern over the health and environmental impacts caused by waste incineration. These concerns primarily stemmed from high levels of dioxins, furans and heavy metals discovered in the ash and air emissions from incinerators at the end of the 1970s (RVF, 2003; Neideman, May 17 2006). The dioxins that were present in the air emissions from incinerators caused great concern among the public due to their link to cancer and other diseases.

Due to these increasing concerns, the Swedish government placed a moratorium on the construction of new waste incinerators in 1985. At that time, incineration was the most common waste treatment method. In 1985 there were 27 plants in operation treating 1.3 million tonnes of household waste, annually (RVF, 2003).

During the moratorium, there was an inquiry to investigate the impacts of waste incineration and evaluate its potential for continued use in the future. In 1986 the moratorium was lifted when the results of the inquiry were released. The findings from the inquiry concluded that waste incineration was not a health or environmental risks as long as certain requirements were met (Ejner, May 23 2006). The main recommendation of the investigation was that new, significantly stricter emission requirements for incineration be implemented (Rylander, 11 May 2006). As a result the Swedish

Franchise Board for Environmental Protection and the Swedish government enacted new environmental guidelines, for both existing and future waste incineration facilities, that focused on restricting emissions and other negative impacts of heavy metals and dioxins (RVF, 2003; Ejner, May 23 2006). It has been speculated that the Swedish government thought that the new stringent emissions requirements would be very difficult for the industry to achieve and that it could potentially result in the end of waste incineration (Rylander, 11 May 2006).

However, after these new guidelines were made various actors from the industry collaborated and decided to take the action required to meet the new standards. As a result 20 of the 27 existing facilities installed improved flue gas cleansing systems to achieve the new emission guidelines. The other seven incinerators were closed because it was not economically or environmentally feasible to fulfil the new guidelines (RVF, 2003). The motivation for the operators to make the necessary upgrades and improvements to continue incinerating waste was that the main alternative treatment, landfilling, was not seen as a sustainable option. Additionally, the economics of incineration were still feasible, even with the cost of the upgraded air pollution control systems, since all the heat generated could be sold in addition to the gate fees received for treatment of the waste (Rylander, 11 May 2006).

After the moratorium was lifted the majority of the industry's efforts were focused on improving the flue gas cleaning systems of existing facilities and as a result there was little interest in developing new incineration facilities (Wiqvist, 12 May 2006). This shift in focus combined with a negative public perception of incineration due to the dioxin scare caused a slowdown in the development of new waste incineration facilities in Sweden. An example of the negative public pressure against incineration at this time was seen in Kristianstad where strong public opposition cancelled the planned development of a waste incinerator in the city (Neideman, 17 May 2006). The strong public opposition stalled the development of waste incinerators in Sweden momentarily.

As a result of the oil crises in 1973 and 1979, Sweden continued its efforts to reduce its dependence on traditional fossil fuels, and municipalities continued to look for low cost alternatives to oil for their district heating systems. So, despite the dioxin scare and the negative public perception during the 1980s, waste incineration was still seen as a viable alternative energy source by municipalities. At this time the waste incineration industry shifted its efforts towards improving the efficiency of the energy recovery from incineration as well as the construction of cogeneration (combined heat and power) waste incineration facilities (Wiqvist, 12 May 2006).

There was no formal incentive or subsidy that encouraged this shift towards cogeneration facilities. One of the main drivers behind the shift was the belief that electricity prices would increase in the future. This was as the result of the referendum in 1980 to phase out nuclear power by 2010. It was thought that with the decreased use of nuclear power there would be an increase in electricity prices (Wiqvist, 12 May 2006). Another driver encouraging the shift towards cogeneration technology was that it allowed for more flexibility by increasing the number of products generated from incineration from one, heat, to two, heat and electricity (Rylander, 11 May 2006).

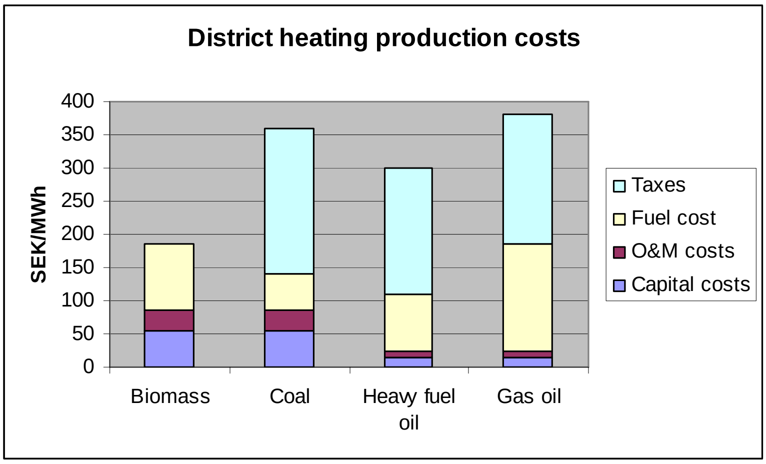
1990s

During the 1990s material recycling increased with introduction of Extended Producer Responsibility (EPR) regulations. This shifted some of the focus in waste management field away from incineration towards the development of material recycling programs. This resulted in some animosity between the two industries that were both vying for a larger percentage of the waste stream; however this did not last long as it soon became apparent that there was enough waste being generated to support both activities. At this same time the percentage of complex products, which are not easily recyclable, in the waste stream began to increase. Therefore, the percentage of waste treated by incineration did not change significantly since many of the materials (paper, glass, metal) were already being recycled before the introduction of EPR and due to the change in waste composition (Wiqvist, 12 May 2006).

In 1991 the energy tax system changed in Sweden, a carbon tax was introduced to complement the existing energy tax on fuels. The energy tax, which does not correlate to the carbon content of a fuel, was reduced by 50% with the introduction of the carbon tax (Johansson, 2004). Previous to this reform, the focus of the energy tax had been designed to discourage the use of oil and to promote oil substitution (Johansson, 2004). At this time, a sulphur tax and a nitrogen oxides tax were applied to electricity production, and a value added tax was introduced on energy consumption. As part of the reformed taxation system, industry was exempted from the energy tax and was required to only pay 50% of the carbon tax. Furthermore, there was no energy or carbon tax on electricity production however, electricity consumers had to pay a consumption tax on the electricity (Johansson, 2004).

One of the largest impacts of the reformed energy and carbon tax system was the development of biomass, including municipal solid waste, in the district heating system (Johansson, 2004). As seen in Figure 9 the expansion of biomass in district heating systems occurred because it become the lowest cost fuel for district heating after the implementation of the tax reform.

Figure 9: Heat Production Costs for New Plants



Source: Johansson, 2004

Sweden's accession to the EU occurred in 1995. As a result, Swedish waste management became subject to EU policy and regulatory frameworks. The main EU waste policy was the "waste hierarchy" which emphasized landfill as being the lowest, worst, treatment option (SEPA, 2005). This put increased pressure on Sweden to reduce the quantity of waste going to landfill in favour of other treatment alternatives especially incineration (Retzner, 19 May 2006). In the mid 1990s discussions began concerning the need for a steering instrument to provide incentives for waste to be handled according to the waste hierarchy and discourage waste from being landfilled (Wiqvist, 12 May 2006). This dialogue continued for the remainder of the decade and resulted in the landfill tax that was introduced in the year 2000.

In 2003 an extensive report was published by the Swedish Association of Waste Management (RVF) describing the state of incineration in Sweden in 1999. Some of the results, of the use of waste incineration in Sweden in 1999, highlighted in the report were:

- There were 22 waste incineration facilities managing a total of 1.9 million tonnes of waste, annually, of which 1.3 million tonnes were household waste;

- The five largest plants were in Göteborg, Stockholm, Uppsala, Linköping and Malmö, which treated a total of 1.3 million tonnes representing almost 70% of the total waste incinerated in Sweden;

- The size of the facilities ranged from 400,000 tonnes per year to 5,000 tonnes per year;
- The total energy production doubled from 2.8 TWh in 1985 to 5.6 TWh in 1999;
- The majority of energy, 5.3 TWh, was used in district heating and the remaining 0.3 TWh to generate electricity;
- Waste incineration accounted for 10% of the district heating requirement in Sweden;
- Sweden had the highest energy recovery by waste incinerated in Europe, 2.9 MWh per tonne of waste, which was comparable to the energy obtained from peat and damp wood fuel;
- Sixteen of the incinerators were grate fired facilities, accounting for 90% of waste incineration in Sweden; the other six facilities had fluidised bed boilers;
- Discharges to air of mercury, cadmium, lead, zinc and dioxins from waste incineration all decreased between 97-99% between 1985 and 1999;
- A total of 370,000 tonnes of slag and bottom ash were generated from the 22 facilities, annually, which was equivalent to 19% of the original weight of the waste incinerated.

2000s

In the year 2000 a tax on waste being disposed of in landfill was introduced. The purpose of this tax was to "discourage landfill as a waste disposal method and increase the economic incentives for treating and recycling waste in a more environmentally friendly and resource-efficient way" (SEPA, 2005). The tax was set at SEK 250/tonne in 2001 and was increased to SEK 288/tonne in 2002, SEK 370 in 2003 and SEK 435/tonne in 2005 (SEPA, 2005).

The landfill tax was followed by a landfill ban, as another measure to discourage waste from being disposed of in landfills and to promote alternative treatment methods 'higher up' the waste hierarchy. The ban prohibited combustible waste, exceeding a certain calorific value, from being landfilled as of 2002, and organic waste from being landfilled as of 2005 (SEPA, 2005).

The landfill tax and landfill ban seem to have spurred the latest wave of development of incineration in Sweden (Wiqvist, 12 May 2006). The quantity of waste being treated by incineration with energy recovery has doubled between 1994 and 2004 as a result of the landfill ban and landfill tax (SEPA, 2005). This increase in incineration is a result of both existing facilities expanding their capacity and the construction of ten new incinerators (SEPA, 2005). As seen in Figure 7, between 1999 and 2004 the percentage of household waste incinerated increased from 39% to 48%, which supports the correlation between the introduction of the landfill tax and ban and the increased use of incineration.

The landfill tax made the landfill ban more effective by providing an economic incentive for new incineration capacity to be constructed. Without the landfill tax, the landfill bans would not have provided the sufficient incentive to stimulate the construction of the new incineration capacity in preparation of the landfill ban (Wiqvist, 12 May 2006). This is what happened in Germany where a landfill ban was introduced without a tax on landfill, which caused numerous delays of the landfill ban because there was no economic incentive to build new treatment capacity needed to meet the requirements of the landfill ban (Wiqvist, 12 May 2006).

In 2001 new waste management targets were introduced in Sweden. One of the targets was that by 2005, less than 10% of household waste and less than 30% of industrial waste should be landfilled. In 2005 southern Sweden's waste management company Sysav AB achieved 91% diversion from landfill of the total waste they managed including both household and industrial waste. This was achieved through a combination of increases in material recycling, biological treatment and waste-to-energy (Rylander, 11 May 2006). This waste management target was followed with the goal to reduce the amount of waste landfilled, excluding mining waste, by at least 50 % compared with 1994 (RVF, 2005). This goal was achieved for household waste in 2003 (RVF, 2005). These waste management targets show that since 2000 the main focus of Sweden's waste management goals has been to reduce the quantity of waste to landfill.

In 2003 the EU entered into force the Waste Incineration Directive. This Directive sets more stringent standards for emissions to water and air and requirements on waste acceptable for incineration. The Swedish EPA has set additional technical and environmental standards for waste incineration and more rigorous criteria for the inspection of waste to be incinerated (SEPA, 2005). All incineration facilities had to meet these new EU and Swedish requirements by the end of 2005. This resulted in some incinerators having to be modified to meet the new standards while others were already in compliance (RVF, 2005).

In 2004 a new household waste incineration facility was constructed in the town of Finspång, increasing the total number of incinerators in Sweden to twenty nine. In 2004 almost 2 million tonnes or 48% of the total household waste was incinerated in Sweden (RVF, 2005). Over 95% of the heat generated from waste incineration was used in district heating, which supplied 15% of Sweden's total need (RVF, 2005).

Currently, there is a proposal by the Swedish government for a new tax on the incineration of the fossil component of the household waste stream for the purpose of encouraging material recovery (SEPA, 2005). The fossil portion of household waste is primarily the plastic waste, which represents about 10% of the waste stream. The tax is also expected to provide incentives for cogeneration incineration of waste. Hot water boiler facilities, which only produce heat, will be taxed at a higher rate than steam boiler facilities that can generate both heat and electricity (Rylander, 11 May 2006). The proposed incineration tax is only applicable to the incineration of household waste; however it is believed that this will be expanded to also cover industrial waste in the future (Retzner, 19 May 2006). The incineration tax was expected to come into force in July 1 2006 (Wiqvist, 12 May 2006) but has since been delayed until 2007.

It has been speculated that the tax will not have a large effect on the current mix of waste management treatment methods (Wiqvist, 2006; Retzner, 19 May 2006; Rylander, 2006). It will provide material recycling and biological treatment an increased economic incentive, which is expected to speed up the development of biological treatment to meet Sweden's food waste diversion goals (Rylander, 11 May 2006).

Although household waste is composed of 85% biomass, the generation of energy from its combustion is not considered as a renewable energy source in Sweden. Green certificates are used as a method of providing subsidies for the generation of electricity from renewable energy sources, with the goal of encouraging cogeneration production from biomass. In Sweden, waste incineration is not eligible for green certificates. It is believed that the Swedish government sees the new incineration tax as a method of creating incentives for cogeneration and therefore the use of green certificates for waste incineration is not necessary (Wiqvist, 12 May 2006). Italy is the only jurisdiction in Europe that is providing green certificates for the incineration of waste (Rylander, 11 May 2006).

Currently, in Sweden, the treatment costs for incineration are the lowest of all waste management activities, which is one factor that has influenced its development. The following are the average Swedish treatment charges for waste management, including taxes: landfill SEK 700 –1,200/tonne, incineration SEK 300–600/tonne, and biological treatment SEK 400–1,000/tonne (RVF, 2005).

However, the introduction of the waste incineration tax will increase its cost and make biological treatment more competitive.

There has been a significant improvement in the performance of waste incineration over the past 20 years. This has been a result of the both improved flue gas cleaning technology and reductions in the quantity of hazardous materials, especially batteries and mercury, in the household waste. This has improved quality of household waste as a fuel. Between 1985 and 2005 there has been a 98% reduction in emissions while doubling waste processed and tripling energy recovered (Rylander, 11 May 2006).

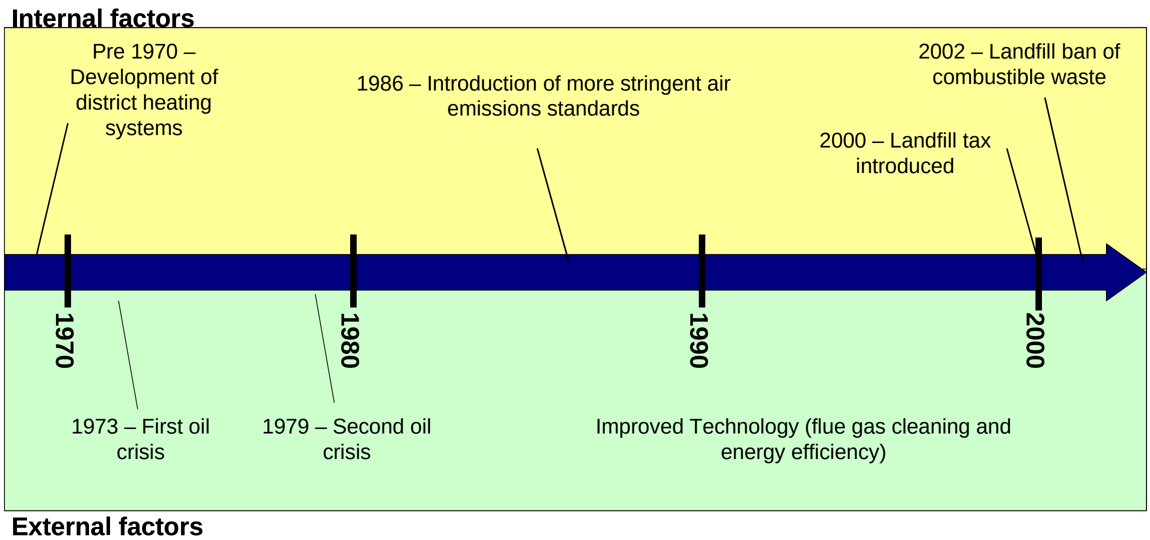
There has been a discussion lately that there might be an over development of incineration in Sweden and that there will soon be an overcapacity. Projections have indicated that in 2009 the demand for waste incineration will equal the available capacity of approximately 5 million tonnes for both household and industrial waste (Wiqvist, 12 May 2006). After that point it is unclear whether there will be an overcapacity of facilities, this will depend on the changes in waste generation, treatment costs and taxes, and the further development of proposed incineration facilities (Rylander, 11 May 2006).

4.2.2 Influencing Factors

Since the construction of the first large scale incinerators in Sweden during the 1960s the technology has developed and expanded significantly to its current state where it is now the main household waste treatment method, managing almost half of the waste generated. The development has occurred in several stages and appears to have been influenced by various factors acting at different times. From the historical review, certain factors can be seen to have impacted the development of waste incineration in Sweden.

Figure 10 illustrates the main internal and external factors that have had a significant impact on the development. A summary of these main political, economic, social, environmental, technical and legal is provided in the remainder of this section.

Figure 10: Influencing Factors in the Development of Waste Incineration in Sweden



Political

The political factors that influenced the development of waste incineration include a diverse range of regulatory aspects. The waste hierarchy has been central to the development of waste policy by the EU and Sweden since the 1970s. As such the focus of most waste policies and targets has been aimed at reducing the quantity of waste going to landfill and encourage waste up the hierarchy.

This is exemplified by the landfill ban of combustible and organic waste implemented in 2002 and 2005, respectively. The majority of actors that were interviewed as part of this investigation singled out the landfill ban of combustible waste as the largest factor in the development of incineration in Sweden. By prohibiting waste from being landfilled, the ban essentially forced the waste that was being landfilled to be incinerated since there are limited alternative treatment options for waste that are non-recyclable or residual waste that cannot be separated for recycling or biological treatment. So while the landfill ban did not explicitly direct waste from landfill to incinerators that appears to have been its result.

The landfill bans were complemented by another regulatory tool in Sweden, the landfill tax. The landfill tax created a very large economic incentive to divert waste away from landfill, which led to the development of new incineration capacity since the implementation of the landfill tax in 2000. The current landfill tax has resulted in disposal charges, including taxes, of SEK 700–1,200/tonne for landfill compared to SEK 300–600/tonne for incineration (RVF, 2005). Since the cost of landfilling is now twice that of incineration, it makes the high capital costs of incineration more economically feasible.

Economic

Economic factors are the second set of aspects that have promoted the development of waste incineration in Sweden. The external economic influence of the oil crises created an environment that promoted the use of waste incineration. The oil crises in 1973 and 1979 led to household waste becoming one of the primary fuel sources for district heating systems. As the cost of oil spiked, municipalities were forced to look for lower cost alternative fuels. Also, municipalities wanted a fuel source that was more secure and not dependent on outside markets. Household waste was seen as a fuel that met both of these criteria. This was also supported on the federal level by the national policy to reduce the country's dependence on traditional fossil fuels.

Another economic incentive that has led to the expanded use of incineration is that since up to 85% of the energy from the process can be recovered and sold, there is a constant income for the energy generated through incineration. The market for this energy is constant, reliable, especially since most of the incinerators have no direct competition since the municipalities own them. As the cost of fossil fuels continues to increase there is little threat from other fuels to replace waste as an energy source. Additionally, the carbon tax in Sweden also puts fossil fuels at a disadvantage compared to waste as a fuel source.

Social

The main social factor that influenced the development of incineration was the dioxin scare in the 1980s. The realization of the environmental and human health impacts caused by the uncontrolled emissions of incineration created a strong public opposition towards the technology. At this time the public's faith in the regulators, politicians and industry weaken. As a result the public rallied to oppose new incinerators causing a slowdown of incineration development. This was countered by a quick response by the regulators to place a short term moratorium on the construction of new facilities while it developed new emission requirements that minimize the risks associated with the technology. The WTE industry was able to meet and exceed these new standards. This led to the rebuilding of the public's faith in the technology as well as in their regulators, politicians and the incineration industry.

As a result the opposition to use and development of WTE has dissipated. This was seen through the investigations conducted for this research which was unable to indemnify an actor in Sweden that is actively opposing the WTE.

Technical

One of the primary factors that have had a positive influence on the development of incineration is technical aspects. Sweden has a cold climate and requires significant amounts of energy for space heating, which creates a large demand for heat energy in the country. This demand in combination with an extensive district heating network, especially in urban areas, makes it feasible to use almost all of the heat generated from incineration. The demand for heating and the technical ability to recover energy as heat from incineration were the major initial drivers waste incineration in Sweden. As well the efficiency of recovering energy from incineration has improved significantly over the past 20 years. As seen in Figure 8 the quantity of energy generated from waste incineration has tripled over the past 20 years while the quantity of waste being processed has only double. Almost 95% of the heat from incineration is currently being used for space heating. Sweden currently has the highest energy recovery efficiency from waste incineration in all of Europe.

Other technical aspects that have influenced the development of incineration included improvements in the air pollution control systems. During the 1980s the development of waste incineration slowed and stopped briefly over concerns about the air emissions. However, this slow down did not last long since technological advancements in pollution control were able to reduce air emissions to meet the stricter requirements that were implemented at the end of the 1980s.

Environmental

As mentioned above the poor performance of waste incinerators in Sweden prior to the 1980s slowed the development of the technology for a portion of that decade. However, the significant improvements in the technology in response to the dioxins scare and the enhanced emissions regulations restarted the development of the technology. The industry has improved the emissions as well as the efficiency of the technology therefore greatly boosted the overall environmental performance of WTE.

As well, in Sweden waste incineration is accepted as an environmentally superior waste management treatment method compared to landfill. This is supported by the country's waste management policies including the waste hierarchy and the landfill ban.

Legal

The implementation of waste management policies that supported incineration ahead of landfill, such the waste hierarchy and landfill ban, into EU and federal legislation strengthened their effect. By providing a legal framework for the policies, it ensures that they are respected and followed. This enhances the inherent effect of the policies, which in this case help make the policies stronger drivers for the development of incineration in Sweden.

4.3 Other Experiences from Europe

4.3.1 The Netherlands

Waste incinerators have been operating in the Netherlands since the early 1900s. The first incinerator in Amsterdam was opened in 1919 (McCarthy, 2004). Large scale developments of waste incinerators with energy recovery did not begin until the 1960s and 1970s. The primary objective of these facilities was to reduce the volume of waste required to be landfilled. This was essential in the Netherlands since it is a small densely populated country with limited available space for landfills (Lansink, 16 June 2006).

In 1979 a primary national waste management policy was developed. The waste hierarchy, also known as Lansink's ladder, set an order of preference for waste management treatment options. Waste reduction was the highest option while landfilling was at the bottom. The objective of the policy was to 'force waste up' the hierarchy/ladder to reduce the amount of waste being deposited in landfills while ultimately encouraging a reduction in the quantity of waste generated. The waste hierarchy was enacted into federal legislation in 1981 (Lansink, 16 June 2006).

Similar to other places in the world, there was also a major dioxin scare in the Netherlands during the 1980s. High levels of dioxins were found in cow's milk and cheese, which raised the public's concern over the use of waste incineration. To address these concerns strict emission requirements were adopted to improve the environmental performance and to reduce the risk associated with waste incineration. To meet these new standards incineration facilities had to be retrofitted, facilities that could not be upgraded economically were closed. Currently the majority of the public seems to have accepted waste incineration as an essential part of the waste management system (Lansink, 16 June 2006). Many Dutch people see WTE as commonplace and do not understand why there is such a negative attitude towards it in North America (Knox, 2005). However in areas of the Netherlands where there were poor performing incinerators located in the past, there is still some mistrust and concern over the safety of incineration.

There is also a strong political will for waste incineration in the Netherlands. All political parties are in favour of its use but also mandate that incineration does not distract from material recycling efforts. An example of this commitment occurred in 1995 when there was a proposal to develop 15 new incinerators in the country. However the Parliament was concerned that this would lead to a reduction in material recycling so it rejected the proposal and decided to focus the country's waste management efforts on recycling at that time instead. Currently, there is still strong support from the Parliament for incineration as long as it meets environmental requirements and is using the best available technology (Lansink, 16 June 2006).

One of the major differences between the situation in Sweden and Netherlands is that there is only a limited district heating system in the Netherlands, which is why it was chosen as a case study. Since the Netherlands has traditionally had access to a large reserve of natural gas, the country has depended on that as its primary fuel source for space heating. Due to this access to cheap local fuel, there was no economic incentive to use MSW as a fuel source for space heating. Therefore, waste incinerators are not connected to the district heating systems. Incinerators are used predominantly only for the production of electricity. This decreases the efficiency of the operation compared to the situation in Sweden (Lansink, 16 June 2006).

There is currently a landfill ban and landfill tax in place in the Netherlands. The landfill tax is 86 Euro/tonne for combustible and organic waste (CEWEP, 2006). The landfill ban prohibits the landfilling of 32 categories of waste, including combustible and organic waste, and currently there are proposals to ban additional categories of waste (CEWEP, 2006). There is no incineration tax in place.

Table 3 shows the increase in the cost of both incineration and landfill over the past fifteen years. The more stringent emissions requirements for both landfill and incineration have lead to significant increases in their costs (NEAA, 2003). As well since 1995 there has been a tax on the landfill of combustible waste. In 1985 the cost of incineration was 4.5 times higher than landfill whereas in 2002 incineration was 22 EUR/tonne less expensive than landfill for combustible waste.

Table 3: Cost of Landfill and Waste Incineration in the Netherlands, 1985-2002 (EUR/tonne)

	1985	1990	1995	1998	2000	2001	2002
Landfill: combustible waste	10	27	78	93	110	107	128
Landfill: non-combustible waste	10	27	48	63	60	58	58
Incineration	45	64	101	95	101	99	106

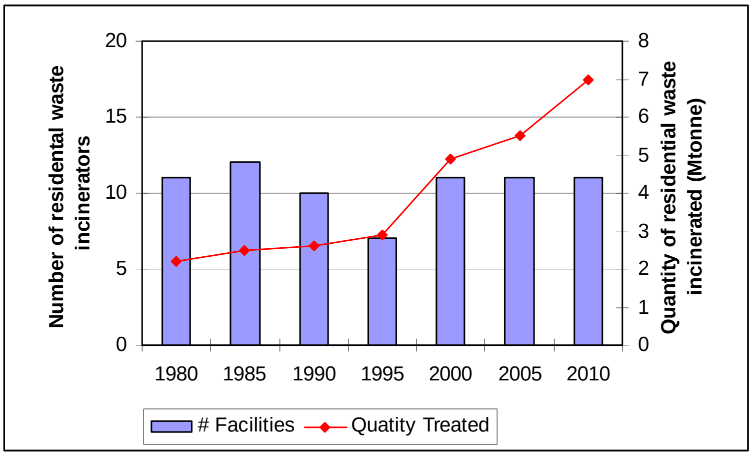
Source: NEAA, 2003

The development of incineration in the Netherlands has been driven by three factors, which are summarized in

Table 4. The first is the limited space available for landfill and therefore the volume reduction that is provided by incineration is a large incentive. The second driver is the implementation of the waste hierarchy that specifically indicates landfilling as the lowest waste management option. The waste hierarchy is enacted in federal legislation and although there are no direct economic incentives directly attached to the hierarchy, the waste management industry respects and follows the legislation (Landsink, 16 June 2006). The combination of the landfill ban and landfill tax is the final main factor that has had a significant influence on the development of waste incineration in the Netherlands. Due to these recent regulations, three new incinerators have been proposed to manage waste that can no longer be landfilled (Landsink, 16 June 2006).

Figure 11 shows the progression of residential waste incineration in Netherlands over the past 25 years with projections to 2010.

Figure 11: Development of Waste Incineration in Netherlands 1980-2010



Source: SenterNovem, 2006

Many lessons have been learned from the Dutch experience with waste incineration. The following three lessons have been highlight as particularly noteworthy:

- Changes to the waste composition can have a large effect on the energy available in the waste stream;
- Pre-sorting and pre-treatment of the waste stream improves the energy efficiency of the process; and
- Incineration does not distract from the material recycling program as long as excess incineration capacity is not built, which requires accurate forecasts of future waste generation rates.

Table 4: Factors influencing the use of WTE in the Netherlands

Factor	Description
Limited available space for landfills	• Significant volume reduction of waste is achieved through the use of WTE.
Implementation of the waste hierarchy into federal legislation	• The waste hierarchy specifically indicates landfilling as the lowest waste management option.
Implementation of the landfill ban and landfill tax	• Provided an economic and regulatory incentive to treat residual MSW by WTE instead of for landfilling.

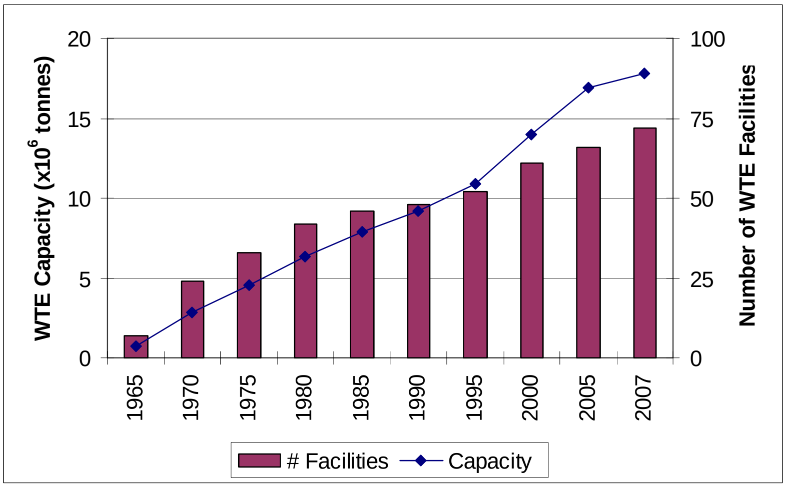
4.3.2 Germany

Germany was chosen as an additional case study to supplement the experiences from Sweden because it is one European country where there was prolonged public concern towards the increased use of WTE. Additionally, Germany is one of the few countries that implemented landfill ban without a landfill tax.

Figure 12 shows the development of waste incineration in Germany from 1965 with projections until 2007. The capacity has increased steadily over the past forty years with a slight levelling off of new facilities between 1985 and 1995, which was the same time as concerns over the release of dioxins and other toxins from waste incinerators were at their highest.

Figure 12 also shows that since 1995 there has been a significant increase in both the amount of capacity and number of facilities. In 2005 there were 67 waste incinerators thermally treating 16.5M tonnes of waste (ITAD, 2006).

Figure 12: Waste Incineration Capacity in Germany, 1965-2007(projected)



Source: FME, 2005

Historically, in Germany, waste incineration was seen as the symbol of environmental contamination due to their high levels of toxic air emissions. The public successfully mounted strong opposition against both the pollution from the waste incinerators as well as the creation of a 'throw-away society' (FME, 2005). As a result, extensive recycling programs were developed and stringent air emission regulations were enacted for waste incineration (FME, 2005).

The public opposition created a confrontation between concerned citizens groups, the federal and state ministries of the environment, and environmental NGOs against WTE operators, their organizations, and the ministry of economics (Knox, 2005). As a result of this standoff, the legislation, German TA Luft 1986, that governed incineration emission was strengthened into a more enforceable regulation, $17BlmSchV_2$ (Knox, 2005). The new regulation came into force on December 1, 1990 and contained the most stringent waste incineration air emission limits for dioxins, furans and heavy metals in the world, at that time (FME, 2005).

As part of the regulation, $17BlmSchV_2$, all new facilities constructed were required to comply with the new standards while existing WTE plants were allowed 6 years to either meet the new requirements or else shut down (FME, 2005). This was supplemented with strict requirements for emission monitoring. Since 1996 all waste incineration facilities in the country have meet the requirements of regulation $17BlmSchV_2$ and these requirements for are still in force in Germany today (FME, 2005). The EU Directive on Waste Incineration was significantly influenced by the German regulation $17BlmSchV_2$ (FME, 2005).

The result of the stringent limits on toxic air emissions from waste incineration facilities was a significant decrease in emissions since 1990. As seen in Table 5, the annual dioxin emissions from all waste incinerators in Germany decreased by 99.9% between 1990 and 2000. This reduction was possible due to advancements in the technology and improved air pollution control systems developed by German engineers, which made it feasible for Germany to meet the upgraded emissions standards (Knox, 2005). Other industries in Germany have also had significant reductions in dioxin release however, none have been as drastic as in the waste incineration industry, which has gone from being accountable for one third of the total German dioxin emissions in 1990 to less than 1% of total emissions in 2000 (FME, 2000). This reduction was achieved even though the quantity of waste incinerated over that period increased by 50%.

Table 5: Annual Dioxin Emissions in Germany, 1990-2000, in grams per toxicity unit (g TU)

	Annual Dioxin Emissions (g TU)			
	1990	1994	2000	Decrease (1990-2000)
Metal extraction and processing	740	220	40	95%
Waste incineration	400	32	0.5	99.9%
Power stations	5	3	3	40%
Industrial incineration plants	20	15	<10	>50%
domestic firing installations	20	15	<10	>50%
Traffic	10	4	<1	>90%
Crematoria	4	2	<2	>50%
Total emissions (air)	1200	330	<<70	>>94%

Source: FME, 2005

Germany implemented a landfill ban prohibiting untreated waste from being landfill on June 1, 2005. The landfill ban supported the increase use of biological treatment, material recycling and WTE treatment of waste (Greiner, 2006). It was anticipated that the legislation would lead to landfill closures since waste would be required to be managed by other treatment options. Also it was expected that there would not be enough WTE capacity to manage the residual municipal solid waste diverted from landfill (Greiner, 2006). The result of the landfill ban has been an increase in waste diversion by biological treatment and material recycling but even less available capacity than expected for the thermal treatment of the residual waste (Greiner, 2006). Unlike in Sweden and the Netherlands that both implemented a landfill tax prior to a landfill ban to provide an economic incentive to develop additional WTE capacity, Germany did not apply a landfill tax. This has been cited as one of the main reasons why the landfill ban was delayed and when it was finally executed there was still an under capacity of WTE facilities (Wiqvist, 12 May 2006).

As a result of the lack of capacity in WTE facilities for MSW and the increased demand due to the landfill ban the gate fees have increased significantly (Greiner, 2006). Currently, the cost to treat waste in a WTE facility ranges from €90-340 per tonne with the average price of €180 per tonne (ITAD, 2006). This compares to a cost for incineration of €30-50 per tonne prior to the landfill ban in (Greiner, 2006). The current landfill cost ranges from €50-200 per tonne with an average price of €110 per, €70 less than the average price of WTE (ITAD, 2006).

The German Law on renewable energies came into force in July 2004. It did not recognize waste as a renewable energy source however the law was amended on August 1 2004 to include waste as a renewable energy source (ITAD, 2004). Despite the recognition of waste as a renewable energy source it is not eligible for any financial subsidies (ITAD, 2004).

Table 6: Factors influencing the use of WTE in Germany

Factor	Description
Strong public opposition to waste incineration	• The public opposition put pressure on the government and industry to improve the performance of waste incineration.
Regulation 17BlmSchV$_2$	• In response to the public's concern regulation 17BlmSchV$_2$ was enacted containing the most stringent waste incineration air emission limits for dioxins, furans and heavy metals in the world at that time.
Development of improved	• The WTE industry was able to develop air pollution control

WTE technology	technology to meet regulation 17BlmSchV_2.
Implementation of the landfill ban	• The lack of disposal capacity caused by the implementation of the landfill ban has led to the rapid development of new WTE facilities.

4.3.3 Italy

In 2004 Italy generated 31.1M tonnes of municipal solid waste. This waste was treated through recycling (23%), composting (5%), incineration (10%) and landfill (62%) (Federambiente, 2006). The 3.1M tonnes of MSW that were thermally treated thermally were incinerated in 47 WTE facilities across the country. Four additional WTE facilities are scheduled to be built by the end of 2006, which would add 0.2M tonnes of capacity (Federambiente, 2006).

Italy has had a landfill tax in place since 1995; currently it ranges between 10-25 EUR/tonne for MSW, depending on the region. The landfill tax is also applicable to waste that is incinerated without energy recovery and residual waste from recycling and biological treatment operations but at a 20% reduction of the original tax level (Federambiente, 2004). A landfill ban has been proposed to come into force in 2007 that would prohibit combustible waste, with a CV>13MJ/kg, from being landfilled. In 2004 the treatment cost, including taxes, of incineration was 80-110 EUR/tonne, which is still higher than the cost of 30-90 EUR/tonne for landfill (Federambiente, 2006).

One unique aspect about the situation in Italy surrounding WTE is that Italy is the only jurisdiction in Europe to recognize MSW as a renewable energy source (RES) and entitles the incineration of MSW to be eligible for subsidies under their green certificate program. This is the primary reason that it was chosen as an additional case study to supplement the Swedish experiences. The green electricity generation incentive program is a competitive market mechanism system based on green certificates. It was introduced in 2000 to replace an old tariff incentive system (Federambiente, 2004).

The green certification system is based on a market approach. The supply is generated by green certificates that are issued for every 100 MWh of electricity produced from a RES. The demand is generated from the obligation of producers and importers of electricity to meet specific quotas of "renewable source-derived power equivalent to 2% of what was produced and/or imported in the previous year from traditional sources" (Federambiente, 2004). The green certificates are then sold at a market price by the green electricity generators to the electricity producers and importers. As of 2004 only 11 of the 47 Italian waste incinerators plants were receiving some form of economic incentive for the production of electricity from MSW. Four of the facilities were issued green certificates while another 7 plants received subsidies from the old tariff system, which will soon be phased out (Federambiente, 2004).

The green certificate program has been a major driver in the development of WTE in Italy. Without the program there is no economic incentive to treat waste with WTE because the cost to landfill is less than the cost of incineration (Zaniboni, 28 August 2006). The impact of the green certificate is varied across the country; it has been more effective in encouraging the use of WTE in Northern Italy where there were more developed waste management programs in place before the introduction of the green certificates Green certificates have had the biggest impact in regions that were already using the old tariff incentive system (Zaniboni, 28 August 2006).

Table 7: Factors Influencing the Use of WTE in Italy

Factor	Description
WTE eligibility for green certificates	• Green certificates have made WTE economically feasible

Implementation of the landfill tax	• The landfill tax has created an economic incentive to treat waste using WTE instead of landfill.

4.3.4 The United Kingdom

Compared to the other European countries examined in this report the United Kingdom has the lowest use of WTE. This along with the country's traditional support and reliance on landfill are the primary reasons that the UK was selected as the final European case study. Although, there are currently over 7000 incinerators in England and Wales, only twelve of them incinerate MSW (Knox, 2005). The majority of the incinerators treat chemicals, wood, waste oil, clinical waste and sewage sludge (Knox, 2005). Despite the existence of 7000 incinerators, even if they all processed MSW there would still not be enough capacity available to meet the EU Landfill Directive (Knox, 2005). Table 8 shows the breakdown of waste management in the UK.

Table 8: Waste Treatment by Region 2004-2005

Region	MSW (M tonnes/yr)	Landfill	Incineration	Recycling and Composting
England	29.7	67%	9%	23%
Wales	1.9	78%	0%	22%
Scotland	3.4	74%	2%	24%
Northern Ireland	0.9	82%	0%	18%
TOTAL	36	69%	8%	23%

Source: DEFRA, 2005

Before transposing the EU Directive on Waste Incineration in 1991 the UK had few regulations controlling the use of incineration (Knox, 2005). However in 1996, strict emission limits were adopted after pressuring from ENGOs such as Greenpeace and Friends of the Earth (Knox, 2005). The general attitude of the UK government historically, has been more relaxed about the release of dioxins and furans compared to other European countries (Knox, 2005). This lax attitude and enforcement is highlighted by the over 500 reported violations of the emission standards by incinerators between January 1, 1996 and November, 1998, which is assumed to be less than the total number of violation since it is a self-regulating system (Knox, 2005).

The waste strategies for England & Wales and Scotland state that the number of WTE facilities will increase in the short term to fulfil the criteria in the EU Landfill Directive. It has been suggested by the Department of the Environment, Transport and the Regions that between 28 to 165 new mid-sized incinerators will be needed to meet the criteria of the Directive with the mostly likely estimate of 50 new facilities by 2015 (POST, 2000).

Besides the EU Landfill Directive, another driver promoting the development of WTE in the UK is the UK electricity act, which requires public electricity suppliers to purchase a fixed percentage of their electricity from non-fossil fuel sources (Knox, 2005). MSW is considered as an acceptable non-fossil fuel energy source.

Waste policy in the UK is based on the waste management hierarchy, which sets an order of preference for waste management treatment options. The first option is waste minimization followed by reuse, recycling, energy recovery and as a last option disposal including landfill and incineration without energy recovery (POST, 2000). The strategy clearly prefers reduction, reuse and recycling over WTE but states if those are not an option that WTE should be considered before landfill.

Another waste policy is that the waste management method that is the Best Practicable Environmental Option (BPEO) should be given priority. BEPO implies that the option with the lowest environment impacts that is technical and economically feasible should be implemented. However, there is debate over how the 'feasibility' should be determined; various environmental groups have lobbied for different interpretations. The views of some of the stakeholders on this issue are listed in Table 9 below.

Table 9: Various Stakeholders Views on the Role of WTE in waste management of MSW

Group	Position
National Society for Clean Air and Environmental Protection	Incineration should play a part in an integrated waste management strategy that includes waste reduction, reuse and recycling.
Waste Watch	Incineration can play a part in a waste management strategy but only after other diversion options are maximized.
Greenpeace & Friends of the Earth	Incineration has little or no place as part of a waste management strategy. They argue that the emissions present an unacceptable risk to health and incineration would lead to diminished efforts towards waste reduction, reuse and recycling.

Source: POST, 2000

There is also a significant amount of public opposition towards WTE in the UK. The main three concerns are: the effect of other diversion efforts, location and size of a facility and the quality of emissions standards and their enforcement (POST, 2000; Knox, 2005). One method utilized to try to regain the public's trust and support has been public engagement and including the public in the planning and decision making process (POST, 2000).

Table 10: Factors influencing the use of WTE in the UK

Factor	Description
Strong public and ENGO opposition to WTE	• Due to the lax emission standards for WTE facilities in the past there is a strong legacy of opposition to WTE in the UK
EU Landfill Directive	• The EU Landfill Directive requires that the UK reduce its dependence on landfill as its primary source of waste disposal, which has lead to the development of WTE capacity
UK Electricity Act	• The requirement of public electricity suppliers to purchase a fixed percentage of their electricity from non-fossil fuel sources including MSW

5. Situation in Ontario

5.1 Ontario Overview

The situation in Ontario is quite different than in Europe surrounding the current use of WTE. At the present there is only one WTE facility treating MSW operating in the Province. The Algonquin Power WTE facility is located within the Golden Horseshoe in Peel Region. The facility was opened in 1992 and currently manages 162000 tonnes MSW from Peel Region, while generating 9 MW of electricity that is fed into the Provincial grid (Willison, 2006). The waste treated at this facility represents about 1% of the total waste generated in Ontario.

Historically, there were thousands of MSW incinerators operating in the Province, the majority of them in apartment buildings as well as some large scale facilities (Oates, 10 August 2006). Two of the largest WTE facilities that operated in the Province were the Commissioner St. incinerator in the City of Toronto and the SWARU facility in the City of Hamilton. Both of these facilities were closed due to strong public opposition over their poor environmental performance; the Commissioner St. incinerator was shut down in 1988 and the SWARU facility was closed in 2002. A more detailed description of the historical use of WTE in the Golden Horseshoe is provided in section 5.2.1.

The Environmental Commissioner of Ontario has stated that the two main reasons that there is currently limited use of WTE in Ontario is that there is a legacy of bad incineration technology in the Province that created a strong public mistrust of it and that there is still the presence of low cost landfill options available (Miller, 17 July 2006).

Decisions for waste management treatment are still being made primarily based on the internal cost of the alternatives. There is limited recognition of external costs associated with waste management treatment options such as: long term care and liability and environmental and social costs (Miller, 17 July 2006). However, the security of treatment capacity is becoming a main decision making factor surpassing cost in many situations. Municipalities that are concerned about a lack of secure waste treatment capacity are willing to pay higher costs to have access to dependable treatment options. This is mainly a result of concerns that the USA will place restrictions on the importation of Canadian waste (Miller, 17 July 2006). Additionally, increasing populations in municipalities across the Province are adding urgency to the situation.

It is assumed USA border will close to waste from Ontario at some point. When this occurs there will not be enough developed municipal capacity within Ontario so there will be the need to use private sector capacity. This will drive up the costs of landfill, eliminating the availability of cheap waste disposal (Miller, 17 July 2006).

Municipalities that are currently investigating the development of additional waste management capacity are only considering MSW, without considering IC&I waste. Municipalities are only charged with the responsibility and control of MSW, therefore the IC&I waste is generally managed separately by the private sector. This may create inefficiencies and duplication in the waste management system by the development of parallel systems to manage MSW and IC&I waste. Municipalities are wary of managing any of the IC&I waste since they do not have the same authority over it as their own MSW.

There is no clear Provincial public policy position or framework on WTE in place Ontario at the present time (Miller, 17 July 2006). Previously, the Province had a 4R (reduce, reuse, recycle, recover) waste management strategy that was then modified to a 3R strategy with the elimination of (energy) recovery. Currently, in the absence of any policy framework, each jurisdiction is making individual decisions regarding waste management (Miller, 17 July 2006).

5.2 Golden Horseshoe

5.2.1 Historical Review

The first incinerator in the Golden Horseshoe region was constructed in 1891 in the City of Toronto. The Eastern Avenue Crematory processed municipal solid waste from Toronto; however the facility was only in operation for one year because it burned down in 1892. The next major waste incinerator, the Don Destructor, was opened in 1917 at a cost $1M CDN to construct (Hostovsky, 2004). From that point forward the use of incineration continued to increase within Toronto and the surrounding urban centres. In total of eight main waste incineration facilities were built in Toronto during the 20th Century (Oates, 10 August 2006). This was in addition to the thousands of incinerators that were installed in apartment buildings across Toronto and the surrounding Golden Horseshoe Region. At the height of incineration use, 85% of Toronto's garbage was incinerated in 1965 without any energy recovery (Hostovsky, 2004).

During this same timeframe, the first half of the 20th Century, a large portion of Toronto's waste was used to infill a part of the City's waterfront to extend its harbour. There were also numerous landfills that were constructed along the edges of river valleys within the City. At this time, topography was a main determining factor when siting landfills and areas that could be infilled, such as harbourfronts and river valleys, were seen as prime locations (Hostovsky, 2004).

Beginning in the 1960s there was an environmental awakening in Toronto and the Golden Horseshoe as in many other regions across the world. This increased awareness put additional focus on the poor environmental performance of the incinerators in the region. Community members strongly opposed incineration due to concerns over the environmental and human health risks associated with it. At the time, which these concerns were raised the industry and authorities did not address them adequately. There was no immediate improvement to air pollution control systems on the incinerators and no stringent air emission requirements were introduced (Miller, 17 July 2006).

During the 1970s and 1980s, there were efforts from the industry to try to construct new incineration facilities and to advance the technology but there was little political interest due to the public's demands for improved air quality (Oates, 2004). This decreased the industry's willingness to develop new incinerators (Miller, 17 July 2006). Additionally, the existing incineration capacity in Toronto was significantly reduced at this time with the shutdown of municipal incineration facilities (Oates, 2004). Municipal by-laws were also introduced that forced the shutdown of apartment incinerators. At this time WTE was effectively abandoned as a waste management option and there was no investigation into the potential improvements of the technology. As a result the 3Rs approach plus landfill was adopted and incineration as a treatment option was virtually ignored.

The Commissioner St incinerator was the last operating incinerator in Toronto. It was opened in 1950 and faced significant amounts of public opposition during its lifespan. The facility did not have any air pollution control system in place and therefore was a major source of air emissions. The facility was closed in 1988 due to a combination of this public opposition and the need for significant upgrades to the facility. There was opposition towards upgrading the facility because there was no desire to extend the service life of the facility (Oates, 10 August 2006). At the time of its closure the facility was managing 10% of the City's municipal solid waste (Oates, 2004).

Another major incinerator that operated within the Golden Horseshoe was the City of Hamilton's Solid Waste Reduction Unit (SWARU), which operated from 1972 until 2004. The facility managed approximately 100000 tonnes per year and generated electricity and heat that was used in a nearby water treatment facility (AMRC, 2004). Similar to the Commissioner St incinerator, SWARU had major environmental problems and at one point was the largest point source of dioxins in Canada (ECO, 2004). Due to this poor performance and opposition from the public, Hamilton decided to shut down the facility instead of trying to upgrade it.

With the reduction in incineration capacity Toronto lacked disposal capacity within its own boarders. Landfills in the surrounding Golden Horseshoe region were the primary option to meet the demand for disposal capacity. Beginning in the mid 1970s Toronto began to export its waste outside its boarders. For more that one decade Toronto disposed of its garbage in two landfills in Durham Region to the east of the City (Butts, 2 August 2006). In 1986 another landfill, the Keele Valley landfill, was opened in York Region to manage waste from Toronto and York (Hostovsky, 2004).

At this time there was a shift towards mega engineered controlled landfill sites. These landfills were seen as more environmentally secure and were need to meet the Provincial Environmental Assessment Act, introduced in 1975. The mega landfills are a more expensive option and can become a large long term liability since waste in these landfills do not degrade (Miller, 17 July 2006). Currently, the Provincial government is still approving large engineered landfills without the recognition of the long term care requirements and the cost to ensure this care.

Despite the public and political support of landfill over incineration there was still significant negative opposition to landfills across the Region at this time. A landfill site in Toronto failed due to public opposition in the mid 1980s (Oates, 2004). Due to the difficultly in developing new landfills, in the mid 1980s, it was realized that there would be a shortage of landfill capacity in the Golden Horseshoe region after Keele Valley's projected 15-year lifespan was exhausted (Campbell, 26 June 2006).

Beginning in late 1980s the Province became involved in trying to develop a comprehensive waste management program. Several committees were formed to carry out this task beginning with the Solid Waste Interim Steering Committee (SWISC) in the late 1980s followed by the Interim Waste Authority (IWA) in the early 1990s (Oates, 2004). The mandate of the SWISC was to investigate all waste diversion and disposal options while the IWM was only charge with trying to site new landfills in the Toronto area (Oates, 2004). The IWA recommended 57 potential new landfill sites, many of which were located on prime agricultural land (Hostovsky, 2004). This created much controversy and outrage from the public so no immediate action was taken. In 1995 there was a change in the Provincial government and the IWA as well as its recommendations were abandoned.

Parallel to this process a waste to energy facility was being proposed in Peel Region. The Peel WTE facility received its required permits and began operation in 1992. Immediately after this WTE facility gained its necessary operating approvals, the Provincial government placed a moratorium on the development of new WTE facilities. The moratorium was lifted when there was a change of governments in 1995, however the Peel facility is the last WTE installation that has been approved in Ontario (Willison, 18 July 2006).

After the IWM process was abandoned there was a new proposal for the residual waste from Toronto and other Golden Horseshoe municipalities to be sent by rail almost 600km north of the region to be disposed of in the decommissioned Adam's Mine shaft. This proposal was also met with intense negative public pressure. Several municipalities signed a contract to send their waste to the mine site; however the City of Toronto backed away from signing a contract under the strong public pressure.

In 2002 a new Provincial government was elected and they revoked all disposal permits for Adam's Mine. Also, in 2002 the Keele Valley landfill was closed before it reached its capacity because of strong local public pressure opposed to the landfill (Campbell, 26 June 2006). The Britannia Landfill in Peel Region, another major landfill in the Region also closed in 2001. As a result, much of the Golden Horseshoe region was left without any disposal capacity. This led many municipalities to enter into a contract with a landfill in Michigan, USA for the management of their residual waste. Therefore, since 2002, the majority of residual waste from the Golden Horseshoe has been exported to Michigan, a distance of almost 500 km. The export of the waste to Michigan poses numerous problems including increased costs, the environmental impacts associated with the long haul transportation and the lack of security due to fears that the border could be closed to the waste with a very short notice. Due to these concerns, this solution is seen to be unsustainable for the long term.

The decision to export waste to Michigan instead of trying to develop a landfill in Ontario was based on the strong public opposition to landfill in Ontario and the time consuming and costly Environmental assessment process. Due to these factors, very few new MSW landfills have been developed in the Golden Horseshoe region over the past 20 years. The last main landfill to be approved in the Golden Horseshoe was in Halton Region during the 1990s after a 15 year planning, siting and approvals process costing over $100M. (Miller, 17 July 2006).

In response to the lack of waste disposal capacity, municipalities have implemented aggressive waste diversion programs to try to reduce the amount of residual waste. This includes increasing the materials that are accepted in the material recycling programs and starting new household organics collection programs. Additionally, economic incentives to encourage increased recycling in households, apartment buildings and commercial outlets have been implemented. Most municipalities in the Golden Horseshoe have a diversion target of 60% or higher, excluding energy recovery. Most the municipalities in the Golden Horseshoe are currently achieving between 30-40% diversion from landfill (MOE, 2004).

Despite this success, given if the diversion target is met at least 40% of the municipal waste stream will remain to be managed. Therefore, municipalities are actively looking for alternative treatment options for this residual waste that are more sustainable than the export of waste to Michigan. Five of the seven municipalities in the Golden Horseshoe are currently in the Environmental assessment process to evaluate alternative residual waste treatment options. Niagara and Hamilton have partnered together and York and Durham have partnered together to both evaluate alternative residual treatments for their regions. Toronto is also independently working through this same process. The two remaining municipalities have adequate disposal capacity to service their short to mid term needs. Halton Region has a landfill with a lifespan projected for 20 more years. The other municipality, Peel Region, has the only WTE in Ontario with 10 years remaining in its operating contract (Pollack, 19 June 2006).

In the past 5 years, communities have started to consider WTE more seriously and there is more interest to address the concerns associated with it (Miller, 17 July 2006). WTE is being considered as an important component of an integrated waste management recognizing that energy should be recovered from the residual waste if possible (Wiggin, 14 July 2006). The European view of landfill as the least environmentally desirable waste management option is slowly starting to be accepted in the Golden Horseshoe (Miller, 17 July 2006).

5.2.2 Influencing Factors

Political

In the province of Ontario, the responsibility for solid waste management is split between the Provincial Government and the municipalities. Municipalities are responsible for providing waste management services to their residents while the Province is in charge of issuing approvals for waste management facilities, enacting legislation and provincial policies regarding waste management as well as protection of the environment in general.

There are several pieces of Provincial legislation that regulate waste management activities in the Golden Horseshoe and across Ontario. These regulations include: landfill standards, incineration air emission standards, the Environmental Assessment Act, regulations mandating the recycling of specific materials in the MSW and IC&I waste streams, and the Waste Diversion Act that shifts some of the responsibility for waste management to the producers of designated waste streams.

The Province is trying to develop a strategy to reach the province wide goal of 60% diversion from disposal, defined as landfill and WTE. A discussion paper was released in 2004 but as of yet no formal diversion strategy has been adopted. The strategy is expected to be based on the 3Rs: waste reduction, reuse and recycling. Currently, there is no recognition of energy recovery as a diversion method; the Province considers WTE as disposal method on the same level as landfill. Previously, Ontario had a 4R strategy that recognized energy recovery above landfill, however this strategy was abandon during the 1990s and it is unlikely to be reconsidered in the short term (Miller, 17 July 2006; West, 20 July 2006).

While there is some effort on the Provincial level for developing a waste diversion strategy, no working is being done to develop an Ontario wide residual waste management strategy. However, there is a strong desire from municipalities for the Province to take a more active role both in developing residual waste treatment strategy and a waste reduction strategy targeted at producers. The Province has significantly more power and regulatory tools to address both of these issues than municipalities (Avramovic, 28 June 2006; Goddard, 23 June 2006).

In the absence of a Provincial public policy or framework surrounding residual waste management, each jurisdiction is implementing individual solutions. These decisions are partially being based on what municipalities think the Province will approved instead of solely on a quantitative analysis of waste disposal options (Miller, 17 July 2006). There is the belief that it is ineffective for the 441 municipalities in Ontario to be working individually to determine the optimal residual waste management system and that it would be more effective if the Province provided guidance to all of the municipalities through a Provincial plan or policy (Muir, 12 July 2006). However, the Ontario Ministry of the Environment feels it is not their role to dictate preferred waste disposal methods and that it is the responsibility of the municipalities to make these waste management decisions through the Environmental assessment process (West, 20 July 2006).

The Ontario Ministry of Energy has historically supported WTE and held a favourable position on the technology on condition that it meets the required environmental guidelines. The Ministry of Energy supported the construction of the WTE facility in Peel Region. Their main concern with WTE the economics of it; the Ministry of Energy believes that an economic incentive should not be needed to support the development of WTE especially since it receives payment for the fuel through the tipping fee (Jenkins, 19 July 2006).

The lack of definition at the Provincial level of acceptable residual waste management treatment has left the municipalities to tackle this issue independently. As discussed in the historical review, over the past 20 years little action has been taken on the municipal level in terms of developing new disposal capacity. This 'paralysis' was partially the result of local politicians' uncertainty in the absence of clear guidance from the Province. Many municipalities were scared to act because they were unsure if the Province would grant the required approvals (Campbell, 26 June 2006). However, currently there appears to be a shift occurring in many municipalities that now seem ready to make decisions on residual waste management issues despite of the lack of guidance from the Province (Campbell, 26 June 2006). The lack of guidance and unclear position on WTE from the Province is seen as a risk by the private sector, which has stalled the development of the technology (Cook, 28 June 2006).

WTE is gaining the support of many municipalities for consideration as a waste management treatment option, as local politicians become more aware of the waste disposal crisis in Ontario and the successful performance of WTE facilities operating in Europe and Japan (Campbell, 26 June 2006; Januskiewicz, 3 July 2006). Recent landfill closures have heightened interest in alternative treatments. There has been an increase in residual management studies that include the consideration of WTE from both large and small municipalities. Even municipalities that have sufficient landfill capacity are showing interest in WTE as a way to extend the lifetime of their landfill and recover the energy from the waste energy (Avramovic, 28 June 2006; Januskiewicz, 3 July 2006). Security issues and fears of the border closing to waste are also driving municipalities to consider WTE. Additionally, the increasing population of municipalities' is adding urgency to the situation (Miller, 17 July 2006).

Municipalities that are considering WTE are only focused on it for the management of residual MSW, not for IC&I (Miller, 17 July 2006). Since municipalities do not have control over the IC&I waste it can not be held accountable to the same diversion standards by the municipalities. Therefore, even though economies of scale could be achieved through the combination of the two waste streams there is strong public pressure to keep these waste streams separate. A Provincial policy and enforcement is needed to ensure that IC&I waste meets the same standards as MSW (Miller, 17 July 2006).

Political support in municipalities for WTE is also very dependent on their local constituencies concerns. Public perception and NIMBY act as barriers and discourage political will (Willison, 18 July 2006). In areas where there have previously been mega landfills the public is usually quite vocal in opposing new or expanded landfills. This pressure creates incentives for politicians to consider WTE as an alternative to landfill, which is exemplified by the situation in York and Durham Region (Campbell, 26 June 2006; Januskiewicz, 3 July 2006). Conversely, in areas where there have been negative experiences with incinerators in the past the public is generally quite opposed to WTE as a waste management option. This public pressure pushes politicians to oppose WTE, which is exemplified in the City of Hamilton where the SWARU incinerator was located and the City of Toronto that had the Commissioner St incinerator (Parker, 21 June 2006).

In areas where there has been success with WTE facilities operating without public concerns, there is generally strong political support for the WTE. In both Peel Region and the Greater Vancouver Region District (which is discussed in the following section) political support for WTE has increased since their facilities were constructed (Allan, 28 June 2006; Pollack, 19 June 2006).

Political support for WTE is also driven by a sense of responsibility to manage waste within their own community and to not burden another community with their waste. Furthermore, politicians see the opportunity to generate energy from WTE and reduce their community's dependence on outside energy sources (Campbell, 26 June 2006; Parker, 21 June 2006). The main political concerns about WTE are: its high capital cost, ownership issues and environmental fears (Januskiewicz, 3 July 2006).

On the federal level Natural Resources Canada (NRCan) is interested with the development of WTE technology although they have no defined responsibilities for waste management activities. NRCan has no concern with environmental impacts of WTE and believes it has the potential to provide waste management and energy generation services. However, since the Province and municipalities have all of the decision making power for waste management WTE has not been promoted at the federal level (Wiggin, 14 July 2006). NRCan will become more involved in the development of WTE when the Provinces and municipalities give the signal that they are willing to seriously consider it as a residual waste management option (Wiggin, 14 July 2006). Historically, Canada has given little attention to WTE due to the abundance of fossil fuels in the country, which is a very different situation than in Europe. However, in Canada there is currently a shift in interest towards the development of RES (Wiggin, 14 July 2006).

Table 11: Political Factors Influencing the Potential Use of WTE in the Golden Horseshoe

Concerns/Barriers	Opportunities/Drivers
• Lack of Provincial policy or framework guiding residual waste management • Local constituent's opposition	• Lack of residual waste treatment capacity • Desire for more secure local residual waste treatment options

to WTE	• Local constituent's opposition to new or expanded landfills

Economic

Municipalities are responsible for all of the costs of MSW treatment, with the exception of Blue Box Wastes, which are partially paid for by the product stewards. Municipalities primarily recover these costs from their residents through property taxes. Recently some municipalities have shifted towards a variable fee where residents pay on the basis of how much residual waste they dispose of, with the cost of recycling and biological treatment included in a base fee.

The construction of WTE facilities has a high capital cost, for example the capital cost of a WTE facility with a capacity of 100000 tonnes/year is approximately $150M USD (Merriman, 26 June 2006). This high investment cost acts as a barrier for municipalities to develop WTE facilities (Avramovic, 28 June 2006) since it would be a huge drain on municipalities' finances and it would limit its ability to invest in other diversion programs and projects (Friesen, 10 July 2006). However, other waste management treatment facilities, like material recovery facilities and anaerobic digesters, also have comparable high capital costs estimated at $100M USD (Parker, 21 June 2006).

The two main sources of revenues generated by WTE facilities are the sale of energy produced and the tipping fees. The sale of the energy, electricity and/or steam, generated from WTE facilities generally is not high enough alone to cover the operation costs. In the Algonquin Power facility in Peel Region the revenues generated from energy sales only cover approximately one third of the operating costs; the other two thirds of the operating costs are covered by the tipping fee charge (Willison, 18 July 2006).

The revenue from energy sales is highly dependent on the market price for electricity and/or steam as well as the ability to find a buyer for the excess heat produced. In Ontario there is a limited market for the excess heat since there are no well-developed district energy systems in place. The ability to sell this energy in addition the electricity greatly affects the operating costs of a facility.

The Algonquin Power WTE facility in Peel Region will soon begin to sell some of its steam generated to a neighbouring industrial process. The increase in the price of natural gas has made it more attractive for the industrial neighbour to purchase steam from Algonquin Power instead of generating it itself (Willison, 18 July 2006). Since the price for steam is higher than electricity, this switch will result in a 15% increase in energy sales revenues (Willison, 18 July 2006).

The price of the energy sold could be higher if the energy generated was considered a green or clean source of energy, which it currently is not. The Ministry of the Environment has asked the Ministry of Energy not to consider energy from waste as a clean energy source (Jenkins, 19 July 2006). The Ministry of the Environment believes that WTE should not be eligible for energy subsidies since other diversion activities do not receive similar economic incentives. The Ministry of Energy believes that WTE should not need an incentive since it receives payment for the fuel through the tipping fee (Jenkins, 19 July 2006). There are also concerns over cross subsidization between the municipalities who pay the tipping fee and the Province who would provide the energy incentive.

The Ontario Power Authority (OPA) estimates that the average cost to generate green energy is 8.6¢/kWh which compares to the current market price of 5-6¢/kWh (Medley, 2 August 2006). Since WTE is not considered a green energy source the Algonquin Power WTE facility receives only 6¢/kWh for the electricity it puts on to the grid (Willison, 18 July 2006). The OPA has recently issued a standard operating contract of 11¢/kWh for small scale energy sources, 10MW or less, which could encourage the development of pilot WTE projects (Medley, 2 August 2006). As well OPA is currently developing a standard operating contract for clean energy sources, it is anticipated that non-burning forms of WTE will be eligible for this contract (Medley, 2 August 2006).

The municipalities that are currently investigating WTE have estimated a tipping fee of $120 per tonne. This is higher than the cost of $70/tonne to ship waste to Michigan but very similar to the costs of operating the Blue Box program and household organics programs (Januskiewicz, 3 July 2006). The tipping fee of $120/tonne is a conservative estimate because it assumes that the WTE facility will only be able to sell electricity. It is believed that the actual tipping fee of a new WTE facility would be about $70/tonne (Januskiewicz, 3 July 2006; Campbell, 26 June 2006). Proponents of advanced thermal technologies claim an even lower operating costs; the Plasco pilot gasification facility in Ottawa is only charging the City a tipping fee of $40/tonne (Fowler, 28 June 2006).

The municipalities that are currently investigating WTE in the Golden Horseshoe are not being driven by economic incentives. The incentive to develop secure local residual waste management capacity, due to fear of the US boarder closing to Ontario waste, is so high that an additional economic incentive is not needed to provoke new waste management capacity to be developed (Campbell, 26 June 2006). The municipalities that are evaluating different waste management options will not make their decision based solely on costs, instead decisions will be made based on a balance of economics and environmental factors (Parker, 21 June 2006). There is a sense that the public is willing to pay more to manage waste properly and to avoid the need for landfill (Campbell, 26 June 2006).

In the private sector, decisions are primarily driven by economics. However, currently the economics of a WTE facility are unclear due to the rising electricity prices and the potential for future green or clean energy subsidies, which could significantly improve the economics of a WTE facility. Despite this there is the perception that the capital investment and the operating costs of WTE are still higher than a landfill (Cook, 28 June 2006). The private sector is concerned with trying to get a return on their investment whereas the purpose of a public facility is to manage waste not to make a profit (Campbell, 26 June 2006). These differences need to be considered when deciding ownership of WTE facilities. In Ontario there is a shift towards traditionally public infrastructure being owned and operated by the private sector (Januskiewicz, 3 July 2006).

It is generally accepted that the USA border will eventually close to Canadian waste or at least introduce a levy high enough to make the export of waste economically unfeasible. When this happens there will not be enough developed municipal capacity and consequently, it will be necessary to use the private sector waste management capacity. This will drive up the costs of landfill, eliminating the relatively cheap waste disposal alternatives that currently exist (Miller, 17 July 2006).

Table 12: Economic Factors Influencing the Potential Use of WTE in the Golden Horseshoe

Concerns/Barriers	Opportunities/Drivers
• High capital cost of WTE facilities • Current access to cheap other waste disposal options (landfills) • Limited market for the stem and excess heat generated by WTE	• Increasing energy costs results in higher revenues from energy sales • Anticipated future increase to landfill costs if Michigan stops accepting Canadian waste

Social

Discussion around waste management can be very controversial especially within the public forum. There seems to be very vocal groups on either side of most issue while the majority of the population is silent or unaware and assumed to be somewhere in the middle of the debate.

The root of most public opposition is negative historical experiences, which is also the case in the Golden Horseshoe region. Areas that have had negative experience with landfill strongly oppose it and favour WTE as a residual waste management alternative. Likewise areas that had polluting incinerators in the past oppose the proposal of new WTE facilities and favour improved engineered landfills (Parker, 21 June 2006; Merriman, 26 June 2006; Fowler, 28 June 2006).

This debate normally pits farmers against urban dwellers, as neither group wants a waste treatment facility in their 'backyard'. This opposition are examples of where the public has lost faith in their local politicians and in industry to protect their health and environment from harm. This lost of trust is a very difficult thing to regain and a slow process to try to rebuild (Jackson, 30 June 2006). Conversely, in areas where there have been positive historical experiences there seems to be a high level of public trust. This is exemplified in York Region where there is a public trust in local government, which was built when the local politicians listened to the public's concerns and fought to close Keele Valley landfill early, before it had reaches its capacity, on behalf of their constituents (Campbell, 26 June 2006).

There is hesitation to consider WTE within the private sector because of the perceived strong anti-incineration movement. The opposition to landfills is believed to be on more of a local level whereas opposition against WTE is perceived to be at a much higher and more powerful level (Cook, 28 June 2006).

Another important social factor to consider is the 'not in my backyard' (NIMBY) syndrome. NIMBY occurs when the public opposes anything that will affect them (and their backyard) directly. This is despite the fact they might have supported the project/facility before it was sited in their neighbourhood. This makes the process of siting a facility very difficult. The current proposal for a WTE facility in York and Durham Region has to date had very little objection however it is anticipated that as soon as sites are proposed there will be strong opposition by the citizens living nearby the proposed locations (Campbell, 26 June 2006; Januskiewicz, 3 July 2006).

It is unknown exactly how difficult it would be to currently site a WTE in the Golden Horseshoe since this has not been attempted in over 15 years. There is the assumption that it will be easier to site a WTE facility than a landfill however this still remains unclear (Friesen, 10 July 2006). Siting is also very dependent on local conditions, for example, siting waste disposal facilities in industrial areas generally reduces 'NIMBYism' and public opposition. Recently in Ontario two landfills were approved for expansions without any public objections since both of these landfills do not have any residential neighbours (Merriman, 26 June 2006). In Peel Region, the only municipalities that currently use WTE in the Golden Horseshoe, there is very little public opposition to the facility. The plant has received very few, if any, complaints about odour, noise or emissions from the facility. This can be attributed to the fact that the facility is sited in industrial area and very few citizens even know that the it exists (Pollack 19 June 2006).

There is a general sense that there is growing public support in the Golden Horseshoe for WTE to be considered as a waste management option. This is partially driven from public fatigue over waste being exported to Michigan and fears over the borders closing (Friesen, 10 July 2006). As well a portion of the public feels a responsibility to deal with its own waste within its own boarders and feels sympathetic towards the residents of Michigan (Merriman, 26 June 2006; Campbell, 26 June 2006; Januskiewicz, 3 July 2006). This is seen to be the growing sentiment among the public in York Region. Conversely, there is still the sense that if a remote landfill in Ontario with the capacity to take waste from the Golden Horseshoe region were developed a significant portion of the public would favour that option over handling their waste within their own municipality (Merriman, 26 June 2006).

Another portion of the public sees WTE as an opportunity to generate energy from a local source. However, there is the concern that this benefit will be overemphasized since the potential for energy generation from WTE is small relative to the energy demands of the population (Campbell, 26 June 2006; Friesen, 10 July 2006). Therefore, the message that is being conveyed to the public is that WTE has the potential managing residual waste with the added benefit of generating some energy, however not enough to offset the need for other fossil energy sources (Willison, 18 July 2006).

Another segment of the population believes that this discussion should not only be centred on the argument of WTE versus landfill but instead focus on reduction of materials that cannot be recycled or reused. There is a desire for pressure to be placed upstream to force product changes to avoid disposal completely and to develop new reuse and recycling techniques (Jackson, 30 June 2006; Goddard, 23 June 2006).

Another social factor is the effect of WTE on jobs within the waste management field. There is the concern that the use of WTE will cause a reduction in jobs when compared to alternative treatment methods such as recycling or landfill (Friesen, 10 July 2006). This has raised concerns of the labour unions representing workers in the waste management field (Muir, 12 July 2006).

Table 13: Social Factors Influencing the Potential Use of WTE in the Golden Horseshoe

Concerns/Barriers	Opportunities/Drivers
• Negative experience with waste incineration in local community • Mistrust of public authorities • NIMBY/siting difficulties • Concerns WTE will cause a reduction of waste management jobs	• Negative experience with landfills in local community • Fatigue with waste being exported – desire to take responsibility for waste generated

Technical

Since waste to energy encompasses several different technologies, as outlined in Section 2.3.2, comparing the alternative technologies is important component of the discussions surrounding the potential use of WTE. The main three categories of WTE considered in this research are: established combustion technologies, advanced thermal technologies, and solid recovered fuel systems. Opportunities and concerns associated with these technologies are described below.

Mass burn incineration is the most common type of WTE; it is seen as the most proven and reliable technology, which are important criteria for municipalities in the Golden Horseshoe (Januskiewicz, 3 July 2006). Another advantage of incineration is that it requires little pre-treatment, which can be extremely expensive. As well incinerators have the advantage of being able to be built on a larger scale than other WTE technologies (Fowler, 28 June 2006).

Historically incinerators were very polluting before the development of advanced air pollution control systems. This caused a very negative perception around the technology, and there are still many concerns over the emissions generated by the combustion of MSW. Established combustion technologies also generate a higher percentage of ash than new and emerging WTE technologies.

Despite these negative concerns most municipalities see mass burn incineration as the most feasible technology to implement in the short term since it has the best track record and there is the most experience and knowledge with it (Januskiewicz, 3 July 2006; Allan, 28 June 2006). As well a new mass burn facility required less maintenance since it can be operated at a larger scale with similar emissions to other WTE technologies (Willison, 18 July 2006).

New and emerging WTE technologies that are also referred to as advanced thermal technologies are seen as a promising options since they are perceived to be a 'cleaner' alternative to incineration and there is the belief that it might be easier to gain the required approvals for them (Fichtner, 20 June 2006). Advanced thermal technologies are seen to be cleaner since they do not involve direct burning of the waste instead the waste is converted into a synthetic gas or oil. The synthetic gas or oil is believed to burn more efficiently and therefore, to result in less ash and fewer noxious air emissions. However, advanced thermal technologies require a uniform, homogeneous infeed of material to operate efficiently. This requires that substantial pre-processing of the waste before it is suitable for use. Due to the complexity of their operations and the cost associated with them, there is limited commercial application of advanced thermal technologies for the management of MSW.

The third category of WTE technologies is solid recovered fuels, which are used to used to directly substitute conventional fossil fuels in industrial processes, utility power generation or institutional heating applications. Waste is required to be pre-processed into a homogenous refuse derived fuel (RDF) either as pellets or a loose mix. Fuel replacement is seen as a viable option and it is perceived that there is more willingness to approve the use of RDF as a fuel replacement in an industrial process by regulators compared to a traditional WTE facility. The advantage of fuel replacement is that it can be looked at on an individual level to be directly offsetting fossil fuels in an industrial process (Cook, 28 June 2006). This presents a large opportunity for energy intensive industries, such as cement manufacturing, to substitute the use of coal resulting in a reduction in greenhouse gases and other air emissions (Pollack, 19 June 2006).

As mentioned above the potential energy generation from WTE in the Golden Horseshoe is relatively low, since there is a limited market for the excess heat due to a lack of district heating systems. The Algonquin Power WTE facility generates only 9 MW of electricity this compares to an average coal fired generator that produces 650000 MW of electricity (Willison, 18 July 2006). Even if the 4M tonnes of waste that are currently being sent to Michigan were thermally treated it would only generate between 250-400 MW of energy depending on the technology used (Jenkins, 19 July 2006).

Table 14: Technical Factors Influencing the Potential Use of WTE in the Golden Horseshoe

	Concerns/Barriers	**Opportunities/Drivers**
General	• Limited district energy systems developed	• Improved energy efficiency • Improved air pollution control systems
Established Combustion Technologies	• Higher levels of bottom ash • Extensive air pollution control system required	• Most proven technology • Large scale operation
Advanced Thermal Technologies	• Unproven on a commercial scale • High levels of pre-processing required	• Lower levels of bottom ash • Cleaner and more efficient combustion from the synthetic gas or oil generated
Solid Recovered Fuel	• High levels of pre-processing required	• Direct replacement for fossil fuels • Combustion infrastructure already in place

Environmental

Unlike in Europe where environmental motives have driven waste from landfill towards alternative treatment methods including WTE; in Ontario environment benefits are not the primary driver behind the consideration of WTE. Since there is no conclusive evidence that WTE is superior environmentally to landfill this argument has been avoided by those promoting WTE technology. However the main arguments of those arguing against WTE are centred around environmental concerns. The two main environmental arguments presented against WTE in the Golden Horseshoe are: the perceived competition with recycling and the cumulative effects and health risks of air emissions (Merriman, 26 June 2006).

The first concern is that the introduction of a WTE facility would reduce the focus on recycling by creating a 'hungry monster' that constantly needs to be fed with waste. It is argued that this would decrease the incentive to reduce or recycle more of the waste stream and waste would have to be imported from other jurisdictions and the private sector to fed the facility (Friesen, 10 July 2006). This is a cause for concern since municipalities do not have the same control over waste that is imported to ensure that it meets the same recycling standards as its own waste (Friesen, 10 July 2006).

Additionally, it is suggested that WTE conveys the message that garbage is good and that it is serving a beneficial purpose of generating energy so there is no need to reduce the generation of waste (Jackson, 30 June 2006). It is argued that the reduction of waste is the only environmentally sound waste management treatment and that materials that can not be managed through reuse or recycling should not be produced (Goddard, 23 June 2006; Muir, 12 July 2006). To achieve this, it is suggested that more Extended Producer Responsibility programs are needed but the Province, which has the tools to implement EPR programs are not engaged on the issue (Jackson, 30 June 2006; Campbell, 26 June 2006).

Municipalities that are considering WTE argue that there is no evidence that the use of WTE reduces recycling rates; in fact the European countries with the highest levels of recycling also have the highest levels of WTE. In Peel Region, which is home to the only WTE facility in the Golden Horseshoe, the recycling program has expand and the diversion rate increased since the WTE facility opened. Additionally, the WTE facility is able to recover ferrous metals which would be lost if it was sent to landfill (Pollack, 19 June 2006).

Also, municipalities contend that their aim is also to reduce the generation of waste. However, municipalities do not have the power or tools to force industry to change their products but they are using economic incentives, such as bag tags, to encourage diversion as well reductions in waste generation (Januskiewicz, 3 July 2006). Furthermore, WTE has a shorter life span than a landfill so if there was a dramatic reduction in waste to the extent that residual waste management capacity is no longer needed a WTE facility could be immediately decommissioned whereas a landfill has a lifespan and an environmental legacy of an undefined length (Campbell, 26 June 2006).

Air emissions are the other main environmental concern with the potential use of WTE. Historically incinerators were a major source of heavy metal and dioxin emissions. While all sides recognize that there has been a significant improvement in air emissions control technologies, there is concern over the additional load that a WTE would put on the environment. The fear is that the additional loading of air emissions would result in a total burden that is damaging to the environment and to human health (Jackson, 30 July 2006). Additionally, despite the reduction in air emissions, the heavy metals and dioxins are still present in the fly ash, which is classified as a hazardous waste.

Many actors have pointed out that all types of waste management create environmental impacts and that these impacts must be considered along with the environmental impacts of secondary activities of each waste management system such as transportation and energy generation (Pollack, 19 June 2006). Whether waste is landfilled, used to generate energy or even recycled there will be environmental impacts (Friesen, 10 July 2006; Willison, 18 July 2006; Muir, 12 July 2006). Creating an integrated approach to waste management that relies on a wide array of waste management solutions has been proposed as the best way to minimize the environmental impacts from waste management (Muir, 12 July 2006).

While there is a lot of discussion over the potential environmental impacts of WTE there seems to be no discussion over the environmental impacts of the current waste management system or the impacts from landfilling (Miller, 17 July 2006). There seems to be no recognition of the long term liability associated with landfills, their long term care requirements and the cost to ensure this care. This is contrasted by WTE facilities where the liability is born while the facility is operating, not in the future. This short-term liability acts as an incentive for facilities to keep their emissions low and to keep the facility operating in good condition. Furthermore, the short term liability avoids intergenerational inequity (Miller, 17 July 2006).

Natural Resources Canada views WTE as a largely renewable energy source. It believes that residual municipal solid waste is comprised of approximately 85% biogenic material. Since such a high percentage of the waste is biogenic, generating energy from the waste results in an almost carbon neutral situation. The portion of the waste stream that is not biogenic is primarily plastics that have no market for recycling. If these plastics are landfilled no energy can be recovered from them, so managing them in a WTE facility is a constructive use of the fossil fuel in these plastics (Wiggin, 14 July 2006).

Table 15: Environmental Factors Influencing the Potential Use of WTE in the Golden Horseshoe

Concerns/Barriers	Opportunities/Drivers
• Reduced incentive for waste reduction and recycling programs • The additional loading to the environment of air emissions	• Potential for GHG reductions by offsetting fossil fuels through energy generation • Potential to offset long term environmental liability of landfilled waste

Legal

The main barrier to the implementation of WTE in Ontario is the Environmental assessment (EA) process and the Province's reluctance to approve WTE facilities (Avramovic, 28 June 2006). Municipalities and the private sector have been calling for reforms to the EA process to reduce its complexity and length. The Ministry of the Environment has proposed changes to simplify and speed up the process but these changes have yet to be written into the legislation (Parker, 21 June 2006). The extensive, costly and time consuming requirements of the EA Act has resulted in a shift towards the development of only large scale waste management facilities with a minimum of twenty-years service life to off-set and justify the risk, costs and time commitments associated with the process (Oates, 2004).

The EA process is perceived to be much maligned and as such it is avoided resulting in very few EA being complete. The EA process offers a formalized process to evaluate and compare the environmental impacts associated with all alternatives, however the EA is not often used as a planning and decision making tool but rather it becomes a necessity after decision is already made (Miller, 17 July 2006). Another concern is that the analysis of some recent EA studies has been solely qualitative and do include quantitative criteria to compare the alternatives (Friesen, 10 July 2006).

Landfill bans have been widely used in Europe however, it is unclear if such a ban will be implemented in Ontario. It is assumed that if a landfill ban were enacted that it would result in waste being exported to other jurisdictions. This would also be the assumed result of the implementation of a landfill tax. Currently, it is unclear how the rules of North American Free Trade Agreement would be interrupted surrounding waste management which makes it harder to predict the results of a landfill ban or tax (Cook, 28 June 2006).

Since there is no waste hierarchy policy or alternate waste management framework enacted into legislation there is no added legal driver to support a waste management strategy. There is also the desire for a additional legislative efforts to improve waste reduction and recycling, such as the introduction of more EPR programs (Friesen, 10 July 2006).

Since municipalities are only responsible for handling their resident's waste they do not have control over waste generated from the industrial, commercial and institutional sectors. Therefore, a tighter legal framework is needed to ensure that diversion requirements are met from these sectors especially since IC&I waste has a higher potential for waste diversion than MSW since it is generally composed of more homogeneous materials (Friesen, 10 July 2006).

Table 16: Legal Factors Influencing the Potential Use of WTE in the Golden Horseshoe

Concerns/Barriers	Opportunities/Drivers
• Environmental assessment process (time and financial requirements) • No overall waste management framework or strategy enacted into legislation	• Opportunity for an Environmental assessment to evaluate in an unbiased manner the impacts of WTE

5.3 Experience from Other Canadian Regions

5.3.1 Greater Vancouver Regional District (GVRD)

The Greater Vancouver Regional District in the Province of British Columbia is one of the few jurisdictions that has a WTE facility in Canada. WTE was brought forward as a waste management option in a GVRD waste management plan during the 1980s. The consideration of WTE as a waste management option was driven by the lack of local landfill capacity, opposition to local disposal and economic reasons (Fichtner, 20 June 2006). The facility came into operation in 1988 (Fichtner, 20 June 2006). It was sited in Burnaby next to a paper recycling plant so that it could sell the steam generated from the facility as a source of revenue (Anderson, 10 July 2006).

GVRD strongly supports WTE as a disposal option, which is primarily based on economics not environmental reasons (Fichtner, 20 June 2006). There is strong political support for the facility since it has had a good operational track record, and is continuously improved its performance since it opened. As well it is the lowest cost waste disposal option for the Region since its capital costs have now been paid off. Currently the revenues from the energy sales are approximately equal to the operating costs (Anderson, 10 July 2006).

Political support has grown much stronger since the WTE facility was built, even the biggest sceptics of the technology are now supportive of it. The public believes that it is an appropriate technology and is calling for additional WTE facility for the treatment of residual waste, which is putting pressure on the local politicians to support WTE. The community is impressed with the facility since it provides energy and is a local solution to waste disposal. GVRD acknowledges that there will always be residual waste and therefore they are focussed on developing the best treatment option (Allan, 28 June 2006).

Operating the facility in an open and transparent manner has fostered the strong public support for it. The facility has a policy to accept all visitors, which results in over 1000 people touring the facility per year. Despite being located close to residential areas, very few people are aware of the facility and there have been no complaints about its operations (Anderson, 10 July 2006).

When the facility was constructed there were some concerns over emissions that would be released since it was the first WTE facility in the region (Allan, 28 June 2006). Continuous monitoring has been used to address these concerns and environmental tests that have been conducted in the surrounding area are unable to detect any impacts from the facility in the environment (Anderson, 10 July 2006).

Until now the Province of British Columbia has considered WTE as waste disposal equal to landfill and had not recognized it as energy recovery, however it appears that this will be reconsidered in the near future. This trend is also seen in the Province of Alberta, which now considers WTE as a waste diversion option (Fichtner, 20 June 2006).

The main three products generated from the Burnaby WTE facility are steam, electricity and ferrous materials. Montenay, the operators, and the GVRD, the owners of the facility, have a partnership to market these products together with a revenue sharing agreement (Anderson, 10 July 2006). The increasing cost of energy coupled with the increased cost of long haul transport from the rising fuel costs is a main driver for the use of WTE. WTE is becoming more cost competitive with landfill because of the rising operational cost of landfills and their long term liability. Currently one tonne of waste generates $45-50 from its energy sales (Anderson, 10 July 2006). In 2005 the WTE facility generated $12M from energy sales and $0.5 M from recovered ferrous metal (Allan, 28 June 2006).

BC Hydro provides some subsidizes for renewable energy sources (clean and green energy sources) but WTE is not eligible. Currently BC Hydro follows the EcoLogo certification program regulated by Terrachoice to determine if a energy source can be classified as either green or clean (Lin, 18 July 2006). BC Hydro feels that WTE could be classified as a clean energy, however it doesn't meet the Terrachoice criteria. Under these criteria, biomass has to be wood waste, forest waste or clean separated organics (Lin, 18 July 2006). The green electricity that BC Hydro procures receives a premium of about 3 ¢ per kWh (Lin, 18 July 2006). However, even without the subsidy, WTE is still cost competitive with other waste management alternatives and remains the lowest cost disposal option in the GVRD (Anderson, 10 July 2006).

The Burnaby WTE is a mass burn incinerator. GVRD is pleased with the performance of this technology believing it is the most dependable and there is the more knowledge and experience with it. Gasification, and other advanced thermal options, is perceived to be unproven on a commercial scale (Allan, 28 June 2006). However, there is growing interest in gasification; it is seen as a promising option since it is regarded as a 'cleaner' alternative (Fichtner, 20 June 2006). Fuel substitution using RDF is also seen as a major opportunity for the cement industry. The main barriers to its development are concerns over the emissions and the cost to retrofit the cement kilns for its use (Fichtner, 20 June 2006). Additionally, there is debate over whether RDF should be classified as a waste or as a fuel; currently it is considered a waste and therefore facilities that are using RDF have to meet the same emission standards as WTE facilities (Anderson, 10 July 2006).

Despite concerns over the effect of the WTE facility on recycling programs, waste diversion has increased consistently throughout the facilities operations. Furthermore, ferrous metal in the residual waste stream is recovered from the bottom ash and new technology is now available to also recover other metals. GVRD currently has a diversion rate of 50% (Allan, 28 June 2006). The operators of the Burnaby facility claim that increased recycling benefits their operations since recycling programs remove materials with low calorific values such as organics, glass, metals and electronics. As recycling efforts have increased, the quality of the waste as a fuel and its calorific value has improved (Anderson, 10 July 2006).

The Burnaby WTE facility has a cogeneration process. Its efficiency ranges from 20-50%, depending on the quantity of steam that can be sold. The efficiency of the process could increase significantly if there was a district energy system in place that it could sell the excess heat to (Anderson, 10 July 2006).

In the Province of British Columbia, each region needs a waste management strategy that must be updated every 5 years. The strategy must be approved by the Province and once a strategy has been approved it is less complex, time-consuming and costly to navigate through the EA process for the development of new waste management facilities (Fichtner, 20 June 2006).

Table 17: Main Factors Influencing the Development of WTE in the Greater Vancouver Regional District

Factor	Description
Lack of landfill capacity	• The lack of available landfill capacity close to the GVRD and the public's opposition to new landfills has driven WTE as alternative residual waste management option.
Economic viability	• The ability of the Burnaby facility to be cost competitive with other waste disposal options due to the ability to sell a large percentage of the steam generated.
Waste management strategy process	• The Provincial approval of the Region's waste management strategy reduces the uncertainty over acceptable waste management options.

5.3.2 Prince Edward Island (PEI)

The Province of Prince Edward Island, which is responsible for waste management in all of its municipalities, is home to one of the few WTE facilities in Canada. The semi-continuous starved air incinerator was built in the capital city of Charlottetown during the early 1980s by PEI Energy Corporation, a provincial crown corporation (NRCAN, 2006). The facility was designed to incinerate municipal solid waste to provide steam heat for the Queen Elizabeth Hospital, which was being constructed at the same time (NRCAN, 2006).

The main driving force behind the construction of the WTE facility was the oil crisis of the 1970s since at that time PEI was totally dependent on external fossil fuel (Jardine, 13 July 2006). As a result the Province began to investigate alternate fuel sources and district energy systems. Two other district heating facilities were also built at the same time as the WTE facility. Both of these facilities were woodchip-fed systems that produced steam and heating to the buildings in the downtown core and to the university (NRCAN, 2006).

In 1995 the WTE facility along with the two woodchip-fed district heating facilities were sold by PEI Energy Corp. to a private company, Trigen Energy Canada Inc. Trigen connected the three separate energy systems into one that serves over 60 institutional and commercial customers and heats 84 buildings across Charlottetown (NRCAN, 2006). Trigen also completed several upgrades to the facilities when it was purchased, including installing new high efficiency boilers and an advanced air pollution control system (Godkin, 21 July 2006). The system has since been sold to a private owner and operator, PEI Energy System.

Currently, the facility processes 30000 tonnes of municipal solid waste per year, which results in 10000 tonnes of ash. The main drivers for the use of municipal solid waste as a fuel source was to displace fossil fuel heating needs of the hospital and downtown core and to reduce waste being landfilled by two thirds (Jardine, 13 July 2006). The facility generates 151000MWh of thermal energy, of which 128000MWh were sold, and 5000MWh of electricity (Godkin, 21 July 2006).

The Ministry of Environment monitors emissions from the WTE facility and since the installation of the new air pollution control system there have been no concerns with the emissions from the facility (Jardine, 13 July 2006). The facility is well accepted by the public and seen as a non-issue among primarily since it has been operating for so long. The majority of residents think the facility is beneficial since it is displacing oil and providing heat (Jardine, 13 July 2006). There are generally less than five complaints per year about the facility (Godkin, 21 July 2006).

The biggest advantage of WTE is the tipping fee that is for the management of the waste. The tipping fee for the WTE facility was set in 1995 at $65/tonne. This is lower than other waste management options because the capital costs for the facility were incurred in the 1980s when there were federal grants available for infrastructure development projects. In the Province, the composting tipping fee is $100/tonne and the landfilling tipping fee is also $100/tonne.

The tipping fee of $65/tonne is significant considering that other waste streams that are used in the system, such as sawmill wood waste, have to be purchased (Godkin, 21 July 2006). However, the operating costs of the WTE facility are more expensive than wood chip fed system since more extensive air pollution controls and more mechanical handling are required for the processing of MSW (Godkin, 21 July 2006). The thermal and electrical energy produced from the facility is sold for approximately 5¢/kWh (Godkin, 21 July 2006).

The main regulations that affect the operations of the WTE facility are the Air Quality Regulation and the Waste Resource Management Regulation, which is based on the 4Rs (reduce, reuse, recycle and recover). The Waste Resource Management Regulation requires that organic waste is composted, recyclables are recycled and the remaining fraction of the waste stream is either thermally treated or landfilled (Jardine, 13 July 2006). The first preference is to thermally treat the residual waste since the Province has a contract that guarantees 30000 tonnes/year of waste to be sent to WTE facility (Jardine, 13 July 2006).

The combustion of wood waste is more efficient (80-85%) compared to MSW (70%) primarily due to incombustible materials and materials with low heating value in the MSW such as glass, metal and wet organics. The Province has introduced an extensive recycling program, which has increased the net heating value of the waste. The removal of the dry recyclables decreased the heating value however the separation of the wet organic fraction has increased the heating value to a greater extent leading to a net increase in the calorific value of the waste. This is the biggest concern for the WTE facility since the facility was designed for a lower heating value, which has result in the facility having to operate below its capacity (Godkin, 21 July 2006).

Table 18: Main Factors Influencing the Development of WTE in Prince Edward Island

Factor	Description
Lack of local energy sources	• The dependence on external energy sources and their fluctuating prices created the need to develop local energy sources such as WTE.
District energy system	• Due to the presence of an extensive district energy system, the majority of the energy produced can be utilized.
Limited space available for landfill	• The reduction of waste through the WTE process is attractive to this island Province with limited land available for landfill.
Waste Resource Management Regulation	• This regulation encourages the use WTE ahead of landfill.

5.3.3 The City of Ottawa

The city of Ottawa is a municipality in Ontario that is considering the potential of using WTE as a residual waste treatment option. Currently, there is no WTE facility operating in Ottawa, however a private company, Plasco, is building a pilot scale plasma gasification facility in the City to accept MSW.

As well the City of Ottawa is planning on releasing a REOI for residual waste treatment to determine what WTE technologies are available to meet its needs (Fowler, 28 June 2006). One main constraint is that Ottawa is a relatively small city with a population of approximately 800000 and therefore it is believed that the City does not generate enough residual MSW to make a large scale facility feasible. Over 70% of the waste produced in the City is from the IC&I sector so that waste would have to be combined with the MSW to make a large scale WTE facility possible (Fowler, 28 June 2006).

Currently, there is a private sector landfill that is about to reach its capacity and is applying for a landfill expansion. However, there is strong public pressure to against the landfill expansion and so if the expansion is denied it is speculated that a WTE facility will be proposed that could manage both the City's MSW and IC&I waste (Fowler, 28 June 2006).

The Plasco's pilot scale plasma gasification facility is currently under construction; the facility has an estimated capital cost of $20M part of which has been financed by a federal subsidy. The City views the pilot facility as a method to manage residual whereas Plasco sees the facility as an opportunity to generate significant high quality energy and prove their technology (Fowler, 28 June 2006). The main concern is the level of pre-processing the waste will require for Plasco to achieve their objectives.

Currently, there is political support for WTE in Ottawa, which is driven mainly by the public's opposition to the proposed landfill expansion. However, it is uncertain if the proposal of a large scale WTE facility would decrease the political support (Fowler, 28 June 2006). Similarly, there is public support for WTE, which is mainly derived from opposition to the landfill expansion. It is expected that if the landfill expansion is approved that there will be no public willingness to consider WTE but if the expansion is not approved it is more likely that WTE would be supported by the public (Fowler, 28 June 2006). There was no opposition to the Plasco pilot facility primarily because the plant will have no smokestack (Fowler, 28 June 2006).

The tipping fee for the City of Ottawa to send MSW to the pilot Plasco facility will be $40/tonne, which is the same as the tipping fee for the landfill. Ottawa has a prearranged contract with Plasco that if the pilot facility is successful and a full scale facility is constructed the tipping fee would be $50/tonne (Fowler, 28 June 2006).

The main uncertainty is who is responsible for the pre-processing of the waste and the costs associated with it. The City of Ottawa is interested in the potential for Plasco to scale up its operation converting residual municipal solid waste into a fuel source while maintaining zero air emissions (Fowler, 28 June 2006). However, even if the Plasco pilot facility is successful and expanded to a full scale operation its technology does not have the capacity to manage the entire City's residual waste. It is estimate that seven plasma gasification facilities would be needed to meet the needs of the City; whereas an incinerator could be built on at a large scale to managed the all of the City's residual waste (Fowler, 28 June 2006).

The officials in Ottawa suggest that there should be a standard set of approved waste management technologies. This reform to the EA process would exempt technologies from having to undergo an EAs once it has initially been approved through the EA process. Therefore, once a technology is approved, the EA process would become only a siting exercise (Fowler, 28 June 2006).

Table 19: Main Factors Influencing WTE in the City of Ottawa

Factor	Description
Public opposition to landfill expansion	• There is strong public and political opposition to the expansion of a private sector landfill in Ottawa; this is resulting in support for WTE technology.
Private sector WTE development	• The Plasco pilot facility has shown a renewed private sector interest and investment into WTE technology.

6. Discussion and Analysis

6.1 Experiences from Europe

6.1.1 Driving Forces

Selected experiences with the use of WTE in Europe have been described in Chapter 4. This includes a description of the historical development and current use of WTE in Sweden, the Netherlands, Germany, Italy and the UK. The main influencing factors affecting the use of WTE in each of these countries are summarized in Figure 10 and

Table 4 to Table 7. Some of these factors are regional in scale, affecting countries throughout Europe while other factors are more localized, limited to the specific conditions of the country. These identified influencing factors can be analysed to determine the initial driving forces and their resulting actions that have advanced the use of WTE in Europe. These drivers and their resultant effects are summarized in Table 20 and are described in more details in the following paragraphs.

Table 20: Driving Forces and Resulting Action Associated with the development of WTE in selected European countries

Initial Driver	Resulting Action	Jurisdiction
Limited space available for landfill	• Volume reduction of waste through incineration	The Netherlands
District energy infrastructure in place	• Recovery of excess heat produced through waste incineration for use in district energy systems	Sweden and Germany
Oil crises during the 1970s leading to increased fossil fuel prices	• Availability and security of large quantities of waste as a low cost fuel option	Sweden and other European countries to varying degrees
The implementation and enforcement of stringent air emission requirements following the dioxin scare	• The desire of the WTE operators to improve their technologies to meet the new requirements • Successful technological improvements that drastically reduced emissions and enhanced the environmental performance of WTE facilities • Regained public trust and reduced public opposition to WTE leading to a broader acceptance of them	Sweden, the Netherlands, Germany and the EU
Political decision to adopt the waste hierarchy, which places WTE as a preferred treatment option to landfill	• The EU Landfill Directive is driving the development of WTE as an environmental safer alternative to landfilling • Implementation of landfill bans and landfill taxes is further stimulating development of new WTE facilities	The EU, Sweden, the Netherlands, Germany, Italy and the UK
Electricity policies to encourage the generation of energy from non-fossil fuel sources	• The introduction of electricity policies such as the green certificate program in Italy and the UK's Electricity Act that recognize WTE as a renewable energy source, which makes it eligible for economic incentives	Italy and the UK

Many countries in Europe are very densely populated with limited available undeveloped land appropriate for landfills, this situation is exemplified by the Netherlands. This physical condition has been a driving force in the development of WTE in some European countries. Since the volume of waste can be significantly reduction by the use of WTE it became a very attractive waste management solution beginning in the 19th Century. As pressure on undeveloped land continues to increase the benefit of WTE waste reduction ability still remains as one of the driving forces behind the technology.

District heating systems were installed in many major urban centres across Europe in the early to mid 20th Century, especially in Northern European countries such as Sweden. The development of this infrastructure led to the need for fuel to produce the energy for space heating delivered through the district heating system. The excess heat generated from waste incineration became a source of energy for the space heating in these systems. Since many of these urban centres already had waste incinerators operating, recovering their energy to feed into the district heating systems was a logical step. This also made the economics of waste incineration more feasible since there was now a market for the heat generated.

This shift towards energy recovery was augmented by the oil crises during the 1970s. Since the majority of Europe was dependent on foreign fossil fuels it was especially hard hit by the oil crises. So when the price of oil spiked, waste was increasingly seen as a feasible low cost non-fossil alternative fuel. Waste was a readily available and secure fuel source, which made it a very appealing alternative. Due to these advantages more municipalities, beyond just the major urban centres, started investigating in WTE facilities and linking them to their district heating systems.

WTE was faced with a significant barrier during the 1980s worldwide when the impacts of the air emissions from incineration began to be discovered and understood. This lead to a major public outcry against the technology due to the environmental and human health risks associated with dioxins, furans and heavy metal in the air emissions. At this time many believed that this would lead to the end of WTE technology and that the public trust could never be regained. And in many places in the world this marked the virtual end of the development of the technology but not in Europe. Some countries in Europe, especially those that were particularly dependent on the technology including Sweden, Germany and the Netherlands, worked to develop strict new air emission requirements that would allow for WTE to operate safely instead of completely abandoning the technology. In these countries the WTE industry met the challenge of the new stringent guidelines by improving their technology and developing effective air pollution control systems to enable their facilities to meet the new requirements. The advancement in technology was so effective that most air emissions decrease by greater than 95% over 15 years. The demonstration of the dramatic reduction in the emissions slowly regained the public's trust in the technology.

A European wide driver has been the EU decision to adopt the waste hierarchy into its waste policy. This has promoted WTE as a waste management option superior to landfill. This position was strengthened with the introduction EU Landfill Directive that is mandates the reduction of landfill resulting in the increased need for WTE to manage residual MSW. To achieve the requirements of the Directive many European jurisdictions have implemented landfill bans and landfill taxes to help dissuade the use of landfill. These bans and taxes have acted as regulatory and economic drivers encouraging the development of WTE.

Many European countries have developed incentive based programs and policies, such as the green certificates programs, with the aim to promote the generation of electricity from renewable energy sources. Some of these countries have classified WTE as a renewable or non-fossil energy source making them eligible for the subsidies or incentives provided by these programs. As a result WTE has become a more cost competitive option especially in countries that still have a relatively low costs for landfilling such as the UK and Italy.

6.1.2 Experience Gained

The analysis of the historical development and current use of WTE has identified the driving forces affecting the use of the technology as discussed in the section above, as well this analysis has also highlighted several lessons learned from the European experience. These experiences pertain to both addressing concerns surrounding the technology as well as strategies for advancing its use. From the European case studies examined five main lessons should be highlighted and discussed in more detail.

- ***The process of regaining the public's trust***
- ***The effects of WTE on material recycling and other diversion initiatives***
- ***The steering effects of waste management policies***
- ***The performance of WTE technology***
- ***The effect of an overarching waste management strategy***

Regaining the public's trust

As discussed previously, the fallout from the dioxin scare was the erosion of public trust in local and federal regulators and in industry. When the public discovered the serious health and environmental impacts of the uncontrolled, or poorly controlled, emissions from WTE facilities they felt that the government and industry had failed in ensuring their safety and protection. The public felt betrayed and were unwilling to believe the government's or industry's claims that improved WTE technology could operate safely.

Instead of caving into the public's opposition against WTE and abandoning the technology, many European governments decided to study it further to determine if was possible for WTE operate safely with minimal environmental or human health risks. From these studies it was concluded that if the technology could achieve specific emission standards that there would be negligible public risk. Out of these investigative processes countries like Sweden, Germany and the Netherlands developed new stringent air emissions regulations for waste incineration and WTE technologies. When these new requirements were developed it was uncertain if the industry would be able to meet them. However, industry focussed its efforts on improving the technology and developing advanced air pollution control systems. This was done in cooperation with the regulators who worked with them to achieve the new standards.

The result of this process was a drastic reduction in air emissions. The most significant reduction was in dioxin emissions, which decreased by over 99% within a 15 year period in countries that had implemented stricter emission requirements. The demonstration of this dramatic improvement in the environmental performance of the technology slowly began to rebuild the public's trust. New confidence in the technology was created by the public watching the industry be held to strict standards and in the majority of cases meeting and exceeding these requirements. This trust came from living the experience and seeing first hand the improvements as opposed to be told that the technology had achieved these successes in another jurisdiction.

The effect of WTE on material recycling and other diversion initiatives

One of the main concerns globally surrounding the use of WTE is its perceived negative effect on recycling and other diversion programs. It is believed that since such huge capital investments are required to construct WTE facilities that it will create a perverse incentive to generate more waste to be process by the facility guaranteeing a higher return on investment. This has been paraphrased as having to 'feed the monster'. The fear is that this could then result in not only funds being taken away from diversion programs but also shifting waste away from these programs to be processed by the WTE facility.

While this argument might theoretically make sense on paper, the European experience has been the opposite as long as excess capacity is not built. The countries in Europe with the highest diversion rates are also countries that are very dependent on WTE as seen in Figure 5. Diversion, including recycling and biological treatment, has steadily increased in countries such as Sweden, Germany and the Netherlands at the same time as the development of WTE.

Most of these countries have adopted an integrated waste management approach in which they recognize that not all fractions of the waste stream can be treated by the same method. While there is emphasis to maximize the quantity of waste treated with methods at the top of the waste management hierarchy, such as waste reduction, reuse and recycling, this is not technically or economically feasible for all waste materials. By using an integrated waste management approach the best treatment for each fraction of waste stream is identified. The result of this is high diversion rates complemented with the use of WTE and landfill where appropriate maximizing the overall resource efficiency.

Additionally, regulatory tools and frameworks can be used to guarantee that WTE does not distract from recycling. This could include specifications over which materials must be reused or recycled or the use of mandatory recycling targets for different fractions of the waste stream. Such regulatory approaches ensure the use of recycling and safeguard against waste simply flowing to the lowest cost treatment option.

The steering effects of waste management policies

Another lesson that has been learned from the European experience is the effect of different waste management strategies especially surrounding the use of landfill bans and landfill taxes. Most countries in Europe have adopted a landfill ban or tax or a combination of the two to encourage waste to be diverted from landfill in order to meet the requirements of the EU Landfill Directive.

The effectiveness of these tools has varied depending on their implementation. From the case studies examined it has been learned that implementing a landfill tax prior to a landfill ban increases its effectiveness. The experience from Sweden shows that by first applying a landfill tax an economic incentive is created that promotes the development of alternative treatment capacity such as WTE. The landfill tax makes alternatives more cost competitive, which results in the development of additional capacity. It is essential to have this alternative treatment capacity constructed prior to the implementation of a landfill ban. Otherwise waste cannot be diverted from landfill if there is no alternate capacity developed. This is highlighted in the German experience where a landfill tax was not applied prior to the landfill ban. Without the economic incentive that a landfill tax provides there was not a high enough stimulus to develop new alternate capacity. As a result the landfill ban had to be delayed several times due to insufficient capacity available.

The performance of WTE technology

Another experience that has been gained in Europe is regarding the use of different WTE technologies. While some jurisdictions have experimented with alternative combustion technologies and advanced thermal technologies the majority of installations are mass burn incinerators. Incineration has been the most reliable and proven technology and therefore there is little willingness to try alternate technologies.

This is partially a result of amount of experience there is with incineration technology. It has been widely used across Europe for more than 100 years creating a strong base of knowledge and comfort with the technology. There are many highly trained and skilled operators and technicians available with the required knowledge and skills to work with incineration, whereas there is limited knowledge and experience with new and emerging WTE technologies in Ontario.

Since there is such extensive experience with incineration it has been the most dependable technology. This is an important factor for municipalities and the private sector that make large capital investments to construct a WTE facility. They want the assurance and security that the facility will be able to operate as designed. This assurance is not as secure with other WTE technologies that are not as proven and therefore cannot offer the same level of guarantee that they will operate as designed.

The effect of an overarching waste management strategy

Beginning in the 1970s many European countries developed overarching national waste management strategies. The majority of these strategies were based on the waste management hierarchy, or a similar principle, which dictated an order of preference for waste management treatment options. A clear framework to develop waste management activities provided municipalities support for making local waste management decisions. Municipalities knew that they had to follow the national strategy and optimise it for their local conditions.

The EU later adopted the waste hierarchy, which strengthen and supported the national waste management strategy. By providing clear guidance from a central body it avoided uncertainty and conflict at the municipal level. The waste hierarchy policy became the core waste management framework from which additional specific policies are built off of. The waste hierarchy also supported an integrated waste management system recognized the need for all waste management activities. This integrated approach ensured that no one technology was expected to manage the entire waste stream and conversely no technology was completely abandoned.

6.2 Barriers and Driving Forces for WTE in Ontario

6.2.1 Barriers for WTE in Ontario

Chapter 5 presented the situation in Ontario surrounding WTE including an overview of the barriers the have prevented the development of the technology both in the past and at the present. All of these political, economic, social, technical, environmental and legal barriers that have limited the use of WTE in Ontario are summarized in Table 21.

Two barriers can be highlighted as the main contributing factors that have prevented the development of WTE in Ontario. The first barrier is the public and political mistrust of the technology. This mistrust was caused by the legacy of poor performing WTE facilities in Ontario, which produced negative environmental and human health impacts. The poor performance of these facilities created significant public opposition towards them. The public's concerns about the technology have yet to be adequately addressed and as result the public's mistrust has not dissipated. The problems with the technology were not immediately tackled and remedied in Ontario; instead the technology was virtually abandoned. As a result the public has not seen first hand the improvements that the technology has achieved and they mistrust claims of its successful application in other jurisdictions. The public opposition towards the technology has put pressure on politicians to also oppose it resulting in a major barrier to the development of WTE in Ontario.

The second barrier is the access, both historically and currently, to cheap alternative waste disposal options. The majority of municipalities in Ontario have access to landfills, which have costs that are significantly less than WTE. Even for municipalities that are exporting their waste to landfills in Michigan, the cost of this is still considerably less than it would be to manage their residual waste with a WTE facility. Economics are still a major driver for municipalities' evaluation of residual waste management options, so as long as there is the availability of cheap landfills the development of WTE in Ontario will be limited.

Table 21: Barriers for WTE in Ontario

	Barriers
Political	• Lack of Provincial policy or framework guiding waste disposal • Local constituent's opposition to WTE
Economic	• Access to cheap other waste disposal options (landfills) • High capital cost of WTE facilities • Limited market for the stem and excess heat generated by WTE
Social	• Negative experience with waste incineration in local community • Mistrust of public authorities • NIMBY/siting difficulties • Concerns WTE will lead to a reduction in waste management jobs
Technical	• Limited district energy systems developed
Environmental	• Reduced incentive for waste reduction and recycling programs • The additional loading to the environment of air emissions
Legal	• Environmental assessment process (time and financial requirements) • No overall waste management framework or strategy enacted into legislation

6.2.2 Driving Forces for WTE in Ontario

Chapter 5 also presented an overview of the opportunities and drivers for the development of WTE in Ontario. All of these political, economic, social, technical, environmental and legal opportunities for the use of WTE are summarized in Table 22.

There are two main driving forces that are pushing the current interest in the potential for WTE to manage MSW in Ontario. The first driver is the lack of secure residual waste management capacity in Ontario. Due to numerous factors there is limited developed capacity for residual waste in Ontario and as a result a significant portion of this waste is being exported to Michigan to be landfilled. However, this is not seen as a secure option since there is the widely held belief that Michigan will stop accepting Ontario's residual waste in the near future. If this were to happen there would not be enough developed capacity in Ontario to manage all of its residual waste. As a result this is driving municipalities to consider developing WTE facilities as a secure, local residual waste management option.

The second driver is not a waste management factor but rather an energy generation opportunity. Currently, in Ontario there is a major shortage of local energy sources especially with the proposed closure of all coal-fired generators. Therefore, there are significant efforts to develop new decentralized energy sources with a particular focus on non fossil fuel energy sources. Additionally, the increasing energy prices are providing the opportunity to develop new energy sources that previous were economical unviable. These factors have contributed to new interested in developing WTE facilities, especially for advanced thermal technologies that have the potential to generate a cleaner higher quality energy. Also there is significant interest and opportunity for RDF to substitute the use of coal in the cement manufacturing industry in Ontario. As opposed to the first driver the interest in these developments are purely based on the potential to generate energy from a fuel that has a negative value not to deliver a waste management solution, which is simply an added bonus for these opportunities.

Table 22: Driving Forces for WTE in Ontario

	Driving Forces
Political	• Lack of waste disposal capacity • Fear of the border closing to waste currently being exported - desire for more secure local waste disposal options • Local constituent's opposition to new landfills
Economic	• Increasing energy costs results in higher revenues from energy sales • Anticipated future increase to landfill costs if the USA closes its border to Canadian waste
Social	• Negative experience with landfills in local community • Fatigue with waste being exported – desire to take responsibility for waste generated
Technical	• Need for additional local, decentralized, non-fossil energy sources • Improved technology and air pollution control systems
Environmental	• Potential for GHG reductions by offsetting the use of fossil fuels • Potential to offset long term environmental liability of landfilled waste
Legal	• Opportunity for an Environmental assessment to evaluate in an unbiased manner the impacts of WTE

6.3 Experience Needed in Ontario

6.3.1 Areas of Contention

The political, economic, social, technical, environmental and legal factors surrounding the potential for the use of WTE to treat residual municipal solid waste in Ontario have been described in Chapter 5 and the barriers as well as the opportunities for each of these factors have also been discussed and analysed in the previous section. While some of the concerns and opportunities for the potential use of WTE are generally accepted others contradict each other creating areas of contention. The areas of conflict in each of the PESTEL categories are summarized in Table 23 and described in more details below.

Table 23: Main areas of contention surrounding the potential use of WTE in Ontario

	Area of Contention
Political	• Uncertainty over if the Provincial government or municipalities should be responsible for the development of a strategy to manage residual waste
Economic	• Debate over the high capital investment costs of WTE versus the potential revenues from the generation of energy especially with increasing global energy prices
Social	• Public opposition against waste management options derived from negative historical experiences • Communities opposed to landfill are fighting against communities opposed to WTE
Technical	• Debate surrounding the performance of incineration technology versus new and emerging technologies
Environmental	• Conflict between those who argue that WTE reduces recycling and those that contend that WTE encourages an integrated waste management approach with the emphasis on overall resource efficiency
Legal	• Uncertainty over the effectiveness of the Environmental assessment process and its ability ensure the best environmental option is selected

The largest area of contention that was identified from the analysis of the current situation in Ontario was the contradiction over which actor is responsible for setting a strategy for the management of residual MSW in Ontario. The Province states that it is the responsibility of the municipality to determine which waste management options to implement in its jurisdiction and that the Province's only responsibility is to grant approvals for the waste management installation decided on by the municipality. Whereas, the municipalities argue that it would be more efficient if the Province developed a province-wide strategy that each municipality could customize for its own local conditions in order to reduce the uncertainty that municipalities currently face. This conflict has lead to inaction by both sides since each feels the responsibility for developing a residual waste management strategy is not theirs. This inaction has prevented and delayed decisions about the appropriateness of WTE to treat residual MSW in Ontario.

The economics of WTE is also an area of debate. WTE requires a high capital investment which some argue is too high of a cost for the benefit that it provides. Although, the increasing energy prices are seen as an economic opportunity that is more than enough to offset the high capital costs of WTEs. Since future energy costs are unknown it is difficult to predict the economics surrounding a facility with an operational lifespan of over 25 years.

Public debate surrounding the potential for WTE centres around opposition of landfills versus opposition of WTE facilities. Communities that have had negative experiences with landfill oppose new or expanded landfills and are more willing to consider WTE as a waste management option. Conversely, communities that hosted polluting incinerators in the past are reluctant to consider WTE and are more interested in landfill as a residual waste disposal option. The opposition on both sides is rooted in mistrust and scepticism, which has resulted in a conflict between communities based on historical experiences not on the current performance and abilities of the technologies. Fuelling this conflict is the lack of a clear and definitive understanding of the environmental impacts associated with each waste management alternative.

While incineration technology is seen as proven and reliable, advanced thermal technologies and solid recovered fuels are seen as more promising technologies due to their potential for improved technical performance. This results in a debate of proven versus promising technology. In addition to this there are doubts about the technical feasibility of any of the WTE technologies. There are concerns that the calorific value of the waste is too low to be efficient and that a without district heating system to use the excess heat generated in the process the technical benefit may be too low.

The most visible and vocal debate is over the environmental impacts of WTE. Critics claim that the development of WTE will distract from other diversion efforts and that if a WTE facility is built it will be required to process a set capacity of waste in order to be economically feasible. This requirement to constantly 'feed' the WTE facility will reduce the motivation to develop and improve waste diversion and reduction initiatives and it could create a perverse incentive to generate additional waste. However, proponents of WTE counter that if a WTE facility is sized appropriately it will not lead to a perverse incentive but rather encourage an integrated waste management approach that increases the overall resource efficiency of the system.

The Environmental assessment process in Ontario is another topic of controversy. It is an extremely time consuming and expensive process, which makes it highly inefficient. However, it also provides the opportunity for an environmental assessment to evaluate and compare, in an unbiased manner, the environmental impacts of alternate waste management options. This can be used as a vehicle to determine the best environmental option considering the local situation and conditions.

6.3.2 Knowledge and Experience Needed

From the discussion of the areas of contention above it is evident that there are certain areas where knowledge is needed to move forward the debate over the potential of WTE as a residual MSW treatment option. The analysis of the areas of contention highlights what knowledge and experience is needed. Seven knowledge gaps have been identified where knowledge and experience is needed in Ontario. These seven areas of knowledge and experience needed are listed below and described in the remainder of this section.

- ***Political Approach***
- ***Regaining the Public Trust***
- ***Technology Evaluation***
- ***Economic Evaluation***
- ***Effect of WTE on Recycling***
- ***Optimisation of the EA Process***
- ***Combining Waste Management and Energy Generation Strategies***

Political Approach

As discussed in the previous section there is significant disagreement over which actor should be responsible for developing residual waste management strategies. The Provincial actors state that it is and should be the municipalities' duty to develop a plan according to their local conditions. Whereas, municipalities believe it would be more efficient if the Province developed an overarching strategy to alleviate the uncertainty of municipalities in terms of getting the required Provincial approvals for their proposed waste management installations.

This uncertainty over the division of responsibility has resulted in limited action since municipalities have hesitant to devise a plan without knowing which technologies and approaches the Province deems acceptable and are willing to approve. A better understanding of how the responsibility should be divide between these two groups is needed in order to relieve the uncertainty, provide a clearer and more efficient framework and to mitigate the current stagnation.

Regaining Public Trust

A loss of the public's trust has led to a public conflict between groups opposing landfill and groups opposing WTE. The opposition to these treatment methods are rooted in negative historical experience not based on the technologies' current capabilities. These groups endured experiences in which their political leaders and the industry did not safeguard them adequately against the risks from polluting landfills and incinerators. Since this failure of protection has not been addressed and resolved adequately, the scepticism of these groups has increased over time.

The public's trust needs to be regained in order for them to be a proactive and engaged partner in the decision making process. It is essential for the public to be involved in the decision making process to help develop successful future solutions. Their involvement cannot solely be based on opposing historical failures. For this to be achieved it is necessary to also gain a clear and definitive understanding of the environmental impacts associated with each waste management alternative that can form the basis of the decision-making process. All of this can only be accomplished if the public's faith is restored in their regulators, politicians and the industry.

Technology Evaluation

Since there is limited experience with WTE in Ontario there is little first hand knowledge about the technology and its capabilities. Therefore there is inherently a deficit in the discussions surrounding WTE in Ontario. As a result the debate surrounding the most appropriate WTE technology is based completely on other jurisdictions experiences. To evaluate the potential different WTE technologies a review of the performance of all the technologies is required. It is essential that this include all of the local factors that influence the quality of the technology such as waste composition and markets for energy generated.

This evaluation must balance the proveness of a technology versus its promise. It must be understood that just because one jurisdiction is comfortable and familiar with a technology does not, necessarily, make it the best available option. New technologies might be available that other jurisdictions have not considered because they are more comfortable staying with the technology that they have experience with. However, it is essential that a technology is reliable and proven for it to be considered. This highlights the need for a technology evaluation of potential WTE alternatives balancing their potential and reliability.

Economic Evaluation

Similar to the technology evaluation an analysis of the economics of WTE is needed. These two evaluations could be preformed together. It is necessary to understand the investment and operating costs associated with a WTE facility to determine if it is an economically feasible solution for residual waste management. There are contrasting views on its feasibility. The high investment costs of a facility are a great concern to some while others see the revenues from energy sales as a significant opportunity for the technology. A thorough evaluation is needed to understand the financial realities of WTE. Similar to the technology evaluation it is necessary to rely on the experience from other jurisdictions due to the limited experience in Ontario so it is essential to also to identify local factors that affect the economics of WTE.

Effect of WTE on Recycling

The effect of WTE on recycling and other diversion programs is one of the most contentious issues. Therefore, experiences from other jurisdictions are needed to determine how WTE affects recycling in practice. It is also important to obtain knowledge on how this affect can be avoided or even reversed by increasing diversion concurrently with the use of WTE. The necessity for regulatory tools such as mandating recycling programs and setting enforceable recycling targets to ensure the development of diversion programs should be also considered. Additionally, experience with the successful of waste reduction programs such as Extended Producer Responsibility is needed.

Optimisation of the EA Process

The majority of waste management actors agree that the Environmental assessment process in Ontario needs improvement. However there is debate over what form that improvement should take. One of the main criticisms of the current process is that it is too time consuming and costly, which acts as a barrier to engage in the process especially for small projects. On the other hand, there are suggestions that the EA process should be more thorough and based on a more quantitative analysis. Experience is needed to determine how to optimise the EA process and allow for it to be more efficient for the applicants while enhancing its evaluation of the proposed waste management installations.

Combining Waste Management and Energy Generation Strategies

The investigation into the situation in Ontario revealed that WTE is viewed separately from a waste management perspective and from an energy generation viewpoint. There is limited integration of these two areas, which results in a disjointed view of the technology. An integrated approach is needed to understand the full potential of WTE as both a waste management solution and as an energy source.

Currently, the waste management industry views WTE as an alternative residual waste management option to landfill and with the current lack of disposal capacity in Ontario WTE presents a major opportunity to fulfil this need for capacity. Within the Ontario there is a major shortage of local energy sources with the proposed closure of all coal-fired generators. Furthermore, there is the desire to shift towards cleaner, more renewable sources of energy. So from an energy generation perspective, although WTE does not represent a major source of energy it does have the potential to be a local reliable source of clean energy.

6.4 Evaluating the Relevance and Applicability of the European Experiences to the Situation in Ontario

Relevance and applicability have been selected as the two conditions that will be used to determine if the European experiences with the use of WTE could be used within the Ontario context. Relevance and applicability have been chosen as the two criteria because for a transfer of knowledge from Europe to Ontario to be successful the European experiences must be pertinent and needed in Ontario as well it must be appropriate to the conditions present in Ontario.

6.4.1 Relevance

Relevance is defined by the Oxford Dictionary as "the state of quality of being relevant" and relevant is defined as "bearing upon or pertinent to the matter in hand" (Oxford, 1991). In the context of this definition, relevance is an important determining criterion for this analysis since if a European lesson learned is not a knowledge gap in Ontario then it is irrelevant. Despite the fact that a European experience might be very valuable and interesting if that knowledge is not needed then it is not a suitable piece of experience to transfer between the two jurisdictions. Each of the five European experiences identified in section 6.1.2 are evaluated based on their relevance to the situation in Ontario. These evaluations are described in the following paragraphs and are summarized in Table 24.

Regaining the public's trust

The first lesson learned from the European experience with WTE is the process of regaining the public's trust. The fallout from the dioxin scare in many European countries led to the erosion of the publics' trust in local and federal regulators and in the industry. The public's lack of faith created a culture of opposition and scepticism towards WTE and other large waste management and industrial facilities in their communities.

A very similar loss of trust by the public occurred in many parts of Ontario as a result of the poor environmental performance of WTE and landfills. The lack of faith in regulators, politicians and industry has resulted in a public conflict between groups opposing landfill and groups opposing WTE. Since the lack of public trust has yet to be adequately addressed, the scepticism of these groups has increased over time.

This demonstrates that the European experience is very relevant to the situation in Ontario. A transfer of knowledge on how to regain the public trust is needed in order address the problem and reengage the public in Ontario.

The effect of WTE on material recycling and other diversion initiatives

There is significant concern over the effect that WTE would have on material recycling and other diversions initiatives in Ontario. There is the fear that the development of WTE in the Province will lead to reduced efforts to expand waste minimization and diversion activities. However, it is countered that the use of WTE supports an integrated waste management approach which leads to improved overall resource efficiency and complements waste diversion and reduction initiatives.

Europe has experience with extensive use of WTE and therefore its affect on waste diversion programs. This knowledge is relevant and needed in the Ontario situation. Not only are the results and statistics of the European experience needed but also an understanding of the context in which they occurred are required including the use of regulatory tools and frameworks to support waste reduction and diversion efforts simultaneously to the development of WTE.

The steering effects of waste management policies

The majority of jurisdictions in Europe have implemented waste management policy tools in order to steer their waste away from landfill and meet the requirements of the EU Landfill Directive. The main tools that have been applied are landfill bans, landfill taxes or a combination of the two. Experience has been gained on the effectiveness of these tools to divert waste from landfill and to develop alternative waste management capacity.

In Ontario, there is limited interest in implementing policy tools that are designed to steer waste away from landfill. Currently, the Provincial government has stated that they are not considering the use of a landfill ban or tax. Therefore, at the current time the European experience and knowledge surrounding the steering effects of the waste management policy tools of landfill bans and taxes are not directly relevant to the situation in Ontario. However, this experience has the potential to be very valuable in the future if the Provincial, or even a municipal, government becomes interested in using policy tools to steer waste away from landfill.

The performance of WTE technology

Europe has significantly more experience with WTE technology than the Province of Ontario. There is a wide knowledge base in the operations and performance of WTE technology especially incineration. Hard data is available on the technical performance of WTE facilities in terms of efficiency, quantity of waste processed, maintenance requirements, and the effects of changes in waste composition and calorific value of the waste.

There is the need in Ontario to gain a greater understanding of the technical performance of the varying WTE technologies in order for an evaluation. The lack of direct experience in Ontario with WTE technology makes the knowledge and lessons learned from Europe in this area relevant in this context.

The effect of an overarching waste management strategy

There a significant amount of disagreement in Ontario over if the Province or the municipalities should be responsible for developing a residual waste management strategy. This disagreement has resulted in inaction by both parties. Knowledge is needed to understand of how to best divide the responsibility in order to relieve the uncertainty and provide a clearer and more efficient framework for waste management.

Europe has a long history of using the waste hierarchy as a national and EU overarching waste management strategy. The strategy provides leadership and guidance for municipalities and acts as the foundation for all waste management policies. The knowledge gained from this approach is very needed and relevant to the situation in Ontario.

Table 24: Relevance of the European experiences to Ontario

Experience	Relevant?	Explanation
The process of regaining the public's trust	Yes	• Regaining the public's trust is an identified area of required knowledge in Ontario
The effects of WTE on material recycling and other diversion initiatives	Yes	• The effects of WTE on material recycling and other diversion initiatives is an identified area of required knowledge in Ontario
The steering effects of waste management policies	Potentially	• Ontario is currently not considering using steering waste management tools such as landfill bans or taxes therefore the European experience with this is currently not an area of required knowledge in Ontario • However this experience has the future potential of being relevant if interest develops for using policy tools to steer waste away from landfill
The performance of WTE Technology	Yes	• Knowledge is needed in Ontario to perform an evaluation of WTE technologies so the European experiences with the technical performance of WTE is relevant for Ontario
The effect of an overarching waste management strategy	Yes	• There is uncertainty in Ontario over who should be responsible for developing a waste management framework therefore Europe's experience using the waste hierarchy as a national and EU waste management strategy is very pertinent to the situation in Ontario

6.4.2 Applicability

The Oxford Dictionary definition of applicable is "suitable, appropriate" (Oxford, 1991). When deciding if European experiences can and should be transferred to Ontario it is essential to determine if these experiences are applicable to the specific situation in Ontario. For example, even if knowledge is needed in Ontario, the experiences must also be appropriate and suitable to the local conditions of Ontario. Each of the five European experiences identified in section 6.1.2 are evaluated based on their applicability to the situation in Ontario. These evaluations are described in the following paragraphs and are summarized in Table 25.

Regaining the public's trust

European countries' experience of regaining the public's trust can be applied to the situation in Ontario because the mistrust was developed due to similar occurrences. The loss of faith in regulators, politicians and industry in both cases was rooted in poor performing waste management facilities causing environmental and human health risks in local communities.

Since the erosion of public trust stems from the same causes the knowledge learned from Europe of how to remediate this situation is applicable in the Ontario context. The only consideration that should be recognized is the situation that has developed and intensified over a longer time period in Ontario. In Europe the loss in public faith was identified and addressed relatively quickly, while in Ontario, the scepticism towards regulators, politicians and industry with regards to waste management facilities has been allowed to deepen for more than 25 years. Despite this difference, since the root of the problem is the same in both situations the experience of regaining the public's trust in Europe is a relevant lesson for Ontario.

The effect of WTE on material recycling and other diversion initiatives

Since Europe has vast amounts of experiences in operating WTE facilities in conjunction with waste reduction and diversion programs there is a large opportunity for a transfer of this knowledge to Ontario. The applicability of this knowledge is based on the conditions that surround the use of WTE and diversion activities in Europe and Ontario. There are two main differences between the conditions in Europe and Ontario that need to be recognized when considering the applicability of the European experience.

The first difference is that in Europe WTE existed on a relatively large scale prior to the development of waste reduction and recycling programs. So the relationship between the use of WTE and recycling is based on a different foundation than in Ontario, where WTE would be developed after extensive reduction and diversion programs are already in place. However, the effect of the recent development of WTE in Europe, spurred by landfill bans and taxes, on the established diversion programs is comparable and applicable to the current situation in Ontario.

The second consideration is that there are different regulatory frameworks in Europe mandating recycling programs and specific recycling targets. The effect of these regulatory tools need to be determined and compared to the regulatory frameworks existing in Ontario to establish the overall applicability of the European experiences for Ontario.

However, as long as these differences are recognized, part of the European experience can be applied to the current situation in Ontario. The effect of the recent development of WTE in European countries is a very suitable and appropriate lesson for Ontario. Additionally, knowledge about the impact of different regulatory frameworks to protect recycling can be applied to help Ontario understand what support is needed to ensure that WTE does not distract from waste reduction and diversion programs.

The steering effects of waste management policies

Europe has significant experience with the steering effects of various waste management policy tools that have been implemented in order to meet the requirements of the EU Landfill Directive. In Europe, many lessons have been learned about the effectiveness of landfill taxes and bans and their effect on each other. However, in Ontario there is limited interest in using policy tools to dissuade the use of landfill or developing an overarching policy such as the Landfill Directive. Therefore, the European knowledge in this area is not applicable to the situation in Ontario. However, in the future if the if the Provincial, or even a municipal, government becomes interested in using policy tools to steer waste away from landfill this experience has to potential to be a very suitable and appropriate lesson for Ontario.

The performance of WTE technology

Europe has been depending on WTE technology as a main element of its waste management system for over 100 years. Therefore, there is a vast amount of knowledge concerning the performance and technical capabilities of the various WTE technologies. Despite the fact that there have been some WTE facilities in Ontario, also over the past 100 years, the quantity of and dependence on these facilities has been much less than in Europe. The difference in the historical legacy and use of WTE technologies needs to be examined when considering the applicability of the European experiences in this area.

Europe's extensive historical use of waste incineration has created a well-developed foundation of knowledge, experience and expertise including highly skilled incineration operators and technicians. This vast pool of resources for incineration gives it an advantage compared to new and emerging WTE technologies in Europe. In Ontario there is no similar extensive pool of resources for incineration or any other WTE technology due to the Province's limited use of it. This difference needs to be recognized when applying the European lessons to Ontario. While the European knowledge of the performance of WTE technology is appropriate to be applied to Ontario, it is necessary that the inherent advantage that incineration has in Europe due to its legacy is acknowledged since this legacy is absent in Ontario where there is limited expertise with any WTE technology.

The effect of an overarching waste management strategy

In Europe the waste hierarchy has been the central waste management strategy on a national and EU-wide level. The differences in division of responsibility for waste management between the European case studies and the Province of Ontario needs to be considered when determining the applicability of the knowledge gained in Europe from the use of a central, overarching waste management strategy.

In the majority of the European case studies examined waste management strategies have been developed at a national level, as well as at a EU level for its member states. In Canada the federal government has no jurisdiction over municipal solid waste management; it is the shared responsibility of the Provinces and municipalities. Despite these differences the experience of having a central government, whether it is national or provincial, develop a waste management strategy instead of individual municipalities is appropriate knowledge to be applied to the situation in Ontario.

Table 25: Applicability of the European experience to Ontario

Experience	Applicable?	Explanation
The process of regaining the public's trust	Yes	• The European experience in regaining the public's trust is appropriate to apply to the situation in Ontario
The effects of WTE on material recycling and other diversion initiatives	Yes (Partially)	• The European knowledge on the effects of the recent development of WTE on waste recycling and reduction efforts is appropriate to be applied to the situation in Ontario
The steering effects of waste management policies	Potentially	• Since Ontario is currently not considering using steering waste management tools such as landfill bans or taxes the European experience can not be applied to the situation in Ontario • However this experience has the potential of being applicable in the future if interest develops for using policy tools to steer waste away from landfill
The performance of WTE technology	Yes	• The knowledge gained in Europe on the performance of WTE technologies can be applied to Ontario recognizing that the legacy of incineration and its strong foundation and knowledge base is not present in Ontario as it is in Europe
The effect of an overarching waste management strategy	Yes	• Europe's experience of using the waste hierarchy as an overarching waste management strategy is appropriate to be applied to Ontario

6.5 Remaining Knowledge Gaps in Ontario

The author of this thesis has presented, in the previous section, her opinion of the European experiences that appear to be relevant and applicable to the situation in Ontario. The next step is to determine if these relevant and applicable European experiences fulfil all of the knowledge and experience requirements in Ontario. Each of the seven areas of required knowledge and experience identified in section 6.3.2 have been analysed to determine if they can be fulfilled by the relevant and applicable knowledge from Europe. These analyses are described in the following paragraphs and are summarized in Table 26.

Political Approach

In Ontario there is significant disagreement over which actor should be responsible for developing residual waste management strategies. The Province believes that the municipalities should develop individual residual waste management plans based on their local conditions, whereas municipalities would like a province-wide strategy to relieve the current uncertainty pertaining to acceptability of waste management options. Experience is needed to gain a better understanding of the most efficient division of responsibilities between the different levels of government in order to ease the uncertainty and to mitigate the current stagnation.

Europe has experience using the waste hierarchy as a national and EU waste management strategy. The effectiveness and success of having a central government set an overarching waste management strategy is a key piece of knowledge that should be transferred to Ontario. Despite the differences in federal and provincial responsibilities over waste management, the experiences from the European political approach to setting a central waste management strategy fulfils Ontario's need to gain a better understanding of the best political approach to developing waste management strategies.

Regaining Public Trust

The experience of losing the public's trust in regulators, politicians and industry to protect them from environmental and human health risks in Ontario and Europe were very similar. These erosions in public faith were both caused by polluting waste management installations. However, Europe took steps to regain the public's trust and to dispel the public's scepticism in the decision-making process for waste management treatment. These experiences can fulfil Ontario's need for knowledge in order to rebuild community's faith in regulators, politicians and industry. The European experiences have been identified to be both relevant and applicable for the Ontario context.

Technology Evaluation

There is limited experience and first hand knowledge about WTE technology and its capabilities in Ontario. Therefore there is the need for knowledge about the technical performance of the different WTE technologies. Part of the information needed to complete an evaluation of WTE technology in Ontario can be fulfilled by the European knowledge and experience with the technology.

The European experience is relevant and applicable to the situation in Ontario. The extensive use of waste incineration in Europe has developed vast foundation of knowledge, experience, and expertise creating an inherent bias in favour of mass burn incineration compared to other WTE technologies. In Ontario there is not this foundation of knowledge with incineration so for the European experiences to be transferred to it must be done recognizing the absence of this legacy of incineration as well as there is the need for additional experience on the technical performance of other, non-incineration, WTE technologies.

Economic Evaluation

Ontario also requires an analysis of the economics of WTE. This evaluation is needed in order to understand the investment and operating costs associated with a WTE facility to determine if it is an economically feasible residual waste management and energy generation solution. Currently, waste management costs and energy prices differ significantly between Europe and Ontario, which makes it difficult to compare costs between the two jurisdictions. Although waste management costs and energy prices were noted in the European case studies, a detailed analysis of the economics of WTE was not preformed due to the inherent differences in these markets. Therefore, the European experiences with the economics of WTE cannot be directly transferred to the situation in Ontario. However, generally trends and relative cost comparison can be used for Ontario to gain some experience in this area. This could partially fulfil the required knowledge if it was complemented with economic evaluations of WTE technologies from other countries as well.

Effect of WTE on Recycling

The effect of WTE on waste reduction and recycling programs is one of the most contentious issues in Ontario and therefore, it is an area where knowledge and experience is extremely needed. Therefore, the European experiences with regards to the effect of WTE on recycling is relevant to Ontario and part of it is applicable.

The relationship between WTE and recycling is based on a different foundation in Europe than in Ontario, where WTE would be developed after well established recycling programs have been in place for over 20 years. However, the effect of the current wave of WTE development in Europe on their recycling programs is applicable to the situation in Ontario. As well the differences in regulatory frameworks surrounding recycling in Europe and Ontario need to be examined and compared. Therefore, the European experience with the effects of WTE on recycling should be transferred to Ontario acknowledging these slight differences in context.

Optimisation of the EA Process

Knowledge and experience is needed in Ontario to optimise the environmental assessment process. Improvements are needed to make the process more efficient for the applicants while enhancing the quality of the environmental evaluation. This is an area that all parties recognize is not working optimally and knowledge is needed to improve the process.

However, the environmental assessment and approvals process for waste management facilities in European countries was not investigated in detail for this study. Therefore, the knowledge required for Ontario on this subject cannot be fulfilled from the experience gathered in this report. There is the potential that this knowledge and experience exists in Europe and could be relevant and applicable to the Ontario situation.

Combining Waste Management and Energy Generation Strategies

In Ontario, WTE is viewed from two different perspectives as a waste management solution and as a source of energy generation. There is limited integration of the strategies that support these two perspectives. Therefore, in Ontario knowledge and experience are needed on how to effectively merge the strategies for waste management and energy generation.

The European case studies identified some areas where there was the integration of waste management and energy generation strategies. However, further investigations are needed to determine if a fully integrated strategy on WTE is in place in those countries. As a result, there is the potential that knowledge exists in Europe regarding the combination of waste management and energy generation strategies that Ontario requires but further research is needed to determine this.

Table 26: Fulfilment of knowledge and experience required in Ontario

Experience	Fulfilment?	Explanation
Political Approach	Yes	• The European political approach to setting an overarching waste management strategy fulfils Ontario's need to gain a better understanding of the best political approach to develop waste management strategies
Regaining the Public Trust	Yes	• The European experience of regaining the public trust after the dioxin scare can fulfil the requirement for this knowledge in Ontario
Technology Evaluation	Partially	• Ontario's need for an evaluation of WTE technology can be fulfilled by the European knowledge and experience with the technology recognizing the strong legacy of incineration technology in Europe and the need for additional experience on the technical performance of other (non-incineration) WTE technologies
Economic Evaluation	Partially	• An extensive evaluation of the economics of WTE was not preformed for the European case studies due to the differences in the energy markets • However some of the European economic trends and relative costs on WTE could be used to partially fulfil the required knowledge in Ontario if it was complemented with economic evaluations of WTE technologies from other jurisdictions
Effect of WTE on Recycling	Yes	• The knowledge required in Ontario on the effect of WTE on recycling can be fulfilled by the European experiences with the effects of the recent development of WTE in Europe on their recycling programs
Optimisation of the EA Process	Potentially	• The European environmental assessment and approvals process for waste management facilities was not investigated in detail for this study and therefore the knowledge required for Ontario on this subject can not be fulfilled from the experience gathered in this report • However there is the potential that this knowledge could be gained from European experiences not examined in this study
Combining Waste Management and Energy Generation Strategies	Potentially	• The European case studies investigated showed some examples of the combination of waste management and energy generation strategies however it was not identified as a main lesson learned • Further research is required to determine if the knowledge that is needed in Ontario on this topic exists in Europe

7. Conclusions and Recommendations

7.1 Research Questions

Three research questions were posed at the commencement of this study, which have been answered through the ensuing investigation and analysis. The conclusions drawn for these three research questions are provided below.

Research Question 1: What has been the main driving forces promoting the use of WTE to manage residual waste in Europe, using Sweden as the primary example, and what lessons have been learned from its use?

The six main driving forces that have influenced the development of WTE to manage residual municipal solid waste are:

1. Since many countries in Europe are very densely populated with limited space available for landfill the ability of WTE to significantly reduce the volume of waste has and continues to be a driving forces for the development of WTE.

2. The development of district energy infrastructure led to the need for fuel to produce energy for space heating. The excess heat generated from waste incineration was and still remains a technically and economically viable source of fuel to provide space heating for these systems.

3. The oil crises during the 1970s had a major effect on Europe since the majority of European countries were dependent on foreign fossil fuels. So when the price of oil spiked waste was increasingly seen as a feasible low cost non-fossil alternative fuel. Waste was a readily available and secure fuel source, which made it a very appealing alternative.

4. The development of WTE slowed down significantly as a result of the public opposition caused by the dioxin scare. However the implementation of stringent air emission requirements and the ability for the technology to improve to meet and exceed the new standards restarted the development of the technology.

5. A European wide driver has been the EU decisions to adopt the waste hierarchy as its central waste management strategy, which promotes the use of WTE ahead of landfill.

6. Some European countries have implemented incentive based electricity policies to encourage the generation of energy from non-fossil fuel sources, including WTE. The economic incentives that these programs provide have made WTE more cost competitive and therefore driven its development

The five main lessons learned concerning the use and development of WTE that have been identified from the European case studies investigated are:

1. The dioxin scare caused an erosion of the public's trust in their local and federal regulators and in industry. However, the government and industry was able to regain the public's trust by working together to address the problem through developing strict new air emission standards and improving the technology to be able to meet and exceed these new requirements.

2. One of the main concerns surrounding the use of WTE is its perceived negative effect on recycling and other diversion programs. However, the experiences from Europe have been the opposite; the

countries with the highest waste diversion rates are also countries that are very dependent on WTE as seen in Figure 5.

3. The steering effect of different waste management policies is another lesson that has been learned. From the case studies examined it has been learned that implementing a landfill tax prior to a landfill ban increases its effectiveness.

4. Another experience gained from Europe is that mass burn incineration is the most reliable and proven WTE technology and as such there is little willingness to develop alternate WTE technologies.

5. The majority of European countries have developed national waste management strategies based on the waste hierarchy. These overarching waste management strategies have provided leadership and guidance for municipalities and acts as the foundation for all waste management policies in these countries.

Research Question 2: What barriers have prevented the implementation of WTE in Ontario, using the Golden Horseshoe region as the primary example, and what are seen as the potential opportunities for these technologies in Ontario?

An overview of the barriers that have historically and currently prevented the growth of WTE in Ontario is provided in Table 21; however two barriers can be highlighted as the main contributing factors that have prevented the development of WTE.

1. **Public and political mistrust of the technology**. Public mistrust was caused by the legacy of poor performing WTE facilities in Ontario. The public's concerns about the technology were not immediately addressed and remedied so as a result the public's mistrust has yet to dissipate. The public opposition towards the technology has put pressure on politicians to also oppose it resulting in a major barrier to the development of WTE in Ontario.

2. **Access to cheap alternative waste disposal options**. The majority of municipalities in Ontario have access to landfills, either within Ontario or in Michigan, with costs that are significantly less than WTE. As long as there is the availability of cheap landfills, the development of WTE in Ontario will be limited.

An overview of the perceived potential opportunities for the use of WTE technology in Ontario is provided in Table 22; however two of these opportunities can be highlighted as the main two factors that are currently driving the interest in WTE technology in Ontario

1. **The lack of secure residual waste management capacity in Ontario**. There is limited developed capacity for residual waste in Ontario as a result a significant portion of the residual waste is exported to a landfill in Michigan, which is not a secure option due to fears of the boarder being closed to the waste. As a result municipalities are considering developing WTE facilities as a secure, local residual waste management option.

2. **Energy generation opportunities**. Currently, there is a shortage of local decentralized energy sources in Ontario, which is contributing partially to the increasing electricity prices. These factors are providing an opportunity for new energy sources to be developed that might have before been economically unviable. This has created significant interest in the use of advanced thermal technologies and RDF with the primary objective of energy generation not waste management.

Research Question 3: Are the European experiences applicable and relevant to the situation in Ontario and if not what knowledge and experiences are needed to further foster the discussion about the potential use of WTE?

An analysis was performed to determine if any of the European experiences gained from the development and use of WTE are relevant and applicable within the context of Ontario. Details of this analysis are provided in Section 6.4. The analysis concluded that the following four European lessons learned are both relevant and applicable to the situation in Ontario:

- Regaining the public's trust;
- The effect of WTE on material recycling and other diversion initiatives;
- The performance of WTE technology; and
- The effect of an overarching waste management strategy.

The fifth identified European lesson learned, the steering effect of different waste management policies, is currently not relevant or applicable to the situation in Ontario since there is no desire to use such policy tools. However this experience has the potential of being both applicable and relevant in the future if interest develops for using policy tools to steer waste away from landfill.

After the applicability and relevance of the European experiences were determined, their ability to fulfil the knowledge gaps in Ontario was evaluated. Details on this evaluation are provided in Section 6.5. The analysis concluded that the following three identified knowledge gaps could be fulfilled by the European experience:

- Political Approach;
- Regaining the Public Trust; and
- Effect of WTE on Recycling.

The following two identified knowledge gaps can be partially fulfilled by the European experiences, however additional knowledge from other jurisdictions is required to completely satisfy the needs of Ontario:

- Technology Evaluation – additional experience is needed on the technical performance of other WTE technologies besides mass burn incineration; and
- Economic Evaluation – additional economic evaluations of WTE technologies from other jurisdictions are needed to complement the economic trends and relative costs on WTE that can be gained from Europe.

The remaining two knowledge gaps from Ontario cannot be currently fulfilled by the experiences examined in the European case studies. However, both of these areas of required knowledge could possibly be satisfied by further investigation of European experiences that were not included in this research.

- Optimisation of the EA Process – this knowledge gap could not be fulfilled since the European environmental assessment and approvals process was not investigated in detail for this study however there is the potential that this knowledge could be gained from European experiences not examined in this research; and

- Combining Waste Management and Energy Generation Strategies - the European case studies investigated showed some examples of the combination of waste management and energy generation strategies however further research is needed to determine if the knowledge that is needed in Ontario can be gained from Europe.

7.2 Recommendations for Ontario

Currently, many municipalities in the Province of Ontario, Canada are in the midst of investigating potential technologies that could increase the diversion of MSW from landfill and that can manage residual waste. As part of these discussions there is an ongoing debate over what role WTE could play in achieving these two goals.

Due to factors discussed earlier in this report there has been very limited development of residual waste management capacity over the past 20 years in Ontario and as a result the Province is facing a crisis situation if Michigan bans the importation of residual waste. This is why, now more than ever it is essential that the ongoing discussions result in action. Actions are needed to address the current capacity shortage and develop a long term waste management strategy to ensure that a similar situation is prevented in the future. Through the knowledge gained from the investigations the author can recommend three actions that are needed for fostering the debate in Ontario and ensuring that it moves forward successful resulting in action.

The first recommendation for achieving successful discussions is strong political leadership. In Ontario there is confusion over who is responsible for developing waste management strategies and as a result both the Province and the municipalities have taken limited action. It is necessary that this conflict is resolved so that a waste management framework is developed that addresses the entire municipal solid waste stream. Once a framework is established the supporting policies, tools and regulations can be created. Without strong leadership to develop such a framework the discussions will continue to be stalled due to the lack guidance and direction.

Currently a large portion of the debate surrounding the use of WTE and other waste management options is not based on facts. Rather historical experiences, promises, hearsay and emotion have been driving the debate especially within the public forum. Therefore it is essential that the unbiased facts about each waste management option are brought forward and used to support the discussions. Without the presences of these facts, which are accepted by all parties, the debate will degrade into a politicised, emotional, unsubstantiated argument.

The third recommendation for achieving successful discussions in Ontario is the engagement of the public along with all other stakeholders in the debate. It is essential that all stakeholders are part of the decision-making process and can participate in it so that they feel ownership over the solutions developed. This requires the public's faith in the decision making process and in their politicians, regulators and in the industry to be rebuilt after it was lost because of polluting historical waste management facilities. It is particularly important that the public trust is regained so that they can participate in a proactive manner rather than only offering an opposing voice.

If these three recommendations are achieved, the discussions surrounding waste management options should be successful and result in action that is accepted by all parties. Throughout this research a theme has emerged that highlights the importance of immediate action. It has been seen that once a problem is identified the faster it is remedied the more successful the response is. Conversely, problems that are not addressed immediately continue to develop into larger, more complex situations that are more difficult to solve in the future.

7.3 Future Research

Through the course of this research four areas where future research could be beneficial were identified. These areas consist of both research that could fulfil Ontario's remaining knowledge gaps and that could be valuable to all jurisdictions using or considering WTE technologies.

The first potential area for research is an investigation of the development and use of WTE in Japan. Outside of Europe, Japan is the largest user of WTE technologies. WTE is a main component of the Japanese waste management system, therefore an investigation into the factors that have driven its development and the experiences gained from its use would be valuable. The knowledge acquired from this investigation could be used to compare against the experiences from Europe as well as help satisfy some the areas of required knowledge in Ontario.

A market analysis of the potential for advanced thermal technologies and solid recovered fuels would also be very useful. Since both of these technologies have limited commercial experience there is very little information available about their capabilities. A market analysis would help determine their potential as well as the specific factors affecting their ability to break into the marketplace on a commercial level. This analysis could include a technical and economic evaluation of the technologies, which would fulfil one of the remaining knowledge gaps in Ontario.

An area of future research that would greatly benefit Ontario would be an investigation into environmental assessment processes especially within the waste management field. This has been a major barrier to the development of all residual waste management facilities in Ontario, especially landfills and WTE plants. As a result only large scale facilities, that can offset and justify the risk, costs and time commitments associated with the EA process, have been developed. Experience is needed to determine how to optimise the EA process and allow for it to be more efficient for the applicants while enhancing its evaluation of the proposed waste management options. An investigation into the structure of EA processes and their success in other jurisdictions could fulfil this need in Ontario.

A final area of future research identified from this thesis surrounds the use of WTE from an energy generation context. There is a growing global interest in shifting towards the use of more renewable non-fossil energy sources. An investigation is needed to determine what role WTE could play in this new energy generation strategy. As well research examining how the use of different policy and market based tools, such as green certificates and feed-in tariffs, would affect the development and use of WTE would be valuable.

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