Financial Comparison of Incineration and Landfill Projects in Canada

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ABSTRACT

How everyday generated waste is managed has become a crucial part of municipal management. In many parts of the world, waste generation is reaching unprecedented levels as population and urbanization increases. How to manage municipal solid waste is even more of a problem in a country like Canada which ranks second in per capita waste generation, only behind the United States. Residual municipal solid waste mostly goes either directly to landfill or to the incineration plant. These waste management practices have generated debates from various perspectives. Most available literature scrutinize the competing waste management practices from economic, sustainability, and environmental perspectives.

This thesis aims to compare these competing waste management practices in Canada as business from the perspective of a private investor. It employs a cash-based benefit-cost analysis to analyze the financial return to the owner. It also analyzes the projects from the perspective of the bank that will be approached for an investment loan.

The landfill project returned an NPV of C$ 23.62 million to the project owner while the incineration project resulted in a negative NPV, causing a loss of C$141.1 million below the prevailing 8% discount rate. Also, with the banker's analysis of both projects, the bank will be reluctant to give a loan to the incineration project due to the negative NPV return and inability to repay its debt unlike the landfill project.

Keywords: financial analysis, waste management, landfill, incineration

ÖZ

Günlük üretilen atığın nasıl yönetildiği kentsel yönetiminin önemli bir parçası haline gelmiştir. Dünyanın birçok yerinde, nüfus ve şehirleşme arttıkça atık üretimi daha önce görülmemiş seviyelere ulaşmaktadır. Amerika Birleşik Develtlerin'den sonra kişi başı atık üretiminde ikinci sırada yer alan Kanada gibi ülkelerde kantsel katı atıklarının nasıl yönetileceği bir sorun haline gelmiştir. Artık belediye katı atıkları çoğunlukla doğrudan depolama alanına veya yakma tesisine gider. Bu atık yönetimi uygulamaları çeşitli açılardan tartışmalara yol açmıştır.Mevcut literatürlerin farkli atık yönetimi uygulamalarını ekonomik, sürdürülebilirlik ve çevresel perspektiflerden inceler.

Bu tez, Kanada'daki bu rekabetçi atık yönetimi uygulamalarını iş olarak özel bir yatırımcı açısından karşılaştırmayı amaçlamaktadır. Mal Sahibine yapılan finansal getiriyi analiz etmek için nakit bazlı bir fayda-maliyet analizi kullanır. Ayrıca, bankaların perspektifinden projelerin yatırım kredilerini analiz eder.

Atık yakma projesi 8% indirim oranının altında CS141.1 milyon kaybına neden olarak,olumsuz NPV ile sonçlanırken, düzenli atık depolama projesi, proje sahibine C$23.62 milyon geri kazandırmıştır. Ayrıca, her iki proje de tüm faaliyet yılları için yeterli nakit akışı üretebilirken, banka olumsuz NPV getirisi nedeniyle yakma projesine kredi vermek konusunda isteksiz olacaktır.

Anahtar Kelimeler: finansal analiz, atık yönetimi, düzenli depolama, yakma

To My lovely Family

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LIST OF ABBREVIATIONS

CAPEX	Capital Expenditure
CCME	Canadian Council of Ministers of the Environment
CO2	Carbon dioxide
DSCR	Debt Service Coverage Ratio
ENG	Energy
FNPV	Financial Net Present Value
GVRD	Greater Vancouver Regional District
HC	Historical Value
INF	Inflation
IRR	Internal Rate of Return
IWM	Integrated Waste Management
LCA	Life Cycle Assessment
LLCR	Loan Life Coverage Ratio
MWH	Megawatt-hours
OPEX	Operating Expenditure
RDF	Refuse-derived-Fuels
REV	Revenue
RV	Residual Value
TP	Tipping Fee

Chapter 1

INTRODUCTION

1.1 Background

There has been an increased generation of solid waste on a global scale. The prevalence of less biodegradable products, and the rise of the urban lifestyle has poised a major challenge for the management of solid waste all around the world. Many governments around the world have begun to take seriously how their wastes are being processed. This concern has only been compounded by the increase in awareness of climate change. There are various types of solid waste namely: municipal solid waste, hazardous waste, industrial waste, agricultural waste, bio-medical waste, and so on.

Municipal solid waste refers to a significant proportion of the non-hazardous waste generated from residential communities like cities and towns. They are routinely collected to be transported to processing facilities. It comprises of materials like food leftovers, papers, plastics, aluminum (like in the case of foils), and similar materials. Though some of these wastes do come from industrial, medical, and agricultural facilities, municipal solid waste does not encompass materials like debris, sludge from sewage, industrial waste, or any other waste type which can be highly toxic and in need of special procedure to be properly disposed of. Municipal solid waste is part of the category of waste that cannot cause harm to human. These are generally referred to as “non-hazardous waste”.

Agricultural waste comprises of all waste type generated from farming processes. It is a highly recyclable waste form. This is because they often serve as input for other agricultural processes. For instance, animal dung is often used as organic manure; straw, a by-product of cereals like wheat, is usually used as animal fodder, and so on. On the other hand, hazardous wastes are directly harmful to humans alongside the environment. Some of them like pesticides are toxic or poisonous even in small amounts when exposed to humans and/or animals alike.

Some hazardous wastes like gunpowder or nitroglycerin also react violently when exposed to things which occur in the natural environment like water or air. They can cause loud explosions, shock waves, and produce gases which are highly detrimental to both the environment and people around. Hazardous waste also comprises of things like gasoline, petroleum substances, alcohol, and so on, which are highly combustible and require special attention when being transported from one point to another. Medical wastes which are infectious like used needles, bandages, and so on, are also a subset of hazardous waste as they require special treatment to reduce the risk of contamination.

Even more toxic than regular hazardous wastes are industrial wastes. This is mainly comprised of highly toxic wastes generated by various industries like fertilizer industries, pesticide industries, and special units like nuclear reactors. While some of these wastes have standardized procedures for their disposal, in reality, sometimes they are dumped either directly into water bodies, or into the earth from where they seep into nearby water bodies. Industrial waste seepage into water bodies do cause destruction to the ecosystem in that body of water. It also leads to significant health damage to the nearby inhabitants.

The most common form of waste generated globally is the municipal solid waste as it is generated from items used daily in homes, businesses, schools, hospitals, and so on. This type of waste represents the bulk of the waste problem that plagues many countries today. The rapid rate of urbanizations of many regions, as well as increase in global populations are among the main factors driving its growth. While many governments have taken the waste problem seriously in recent years and advocate important measures of reducing waste, the total waste generated worldwide has been growing and is expected to increase by 70% by 2050 (WorldBank, n.d.).

There are 4 stages of managing the municipal solid waste. They include: separation, transportation, recycling, and elimination or treatment. In some places, the waste is being separated at household level where they are disposed of based on categories. In such a situation, source separation is the first stage of municipal solid waste management. On the other hand, there are places where separation does not take place primarily at household level. For regions like this, waste collection becomes the first stage of managing municipal solid waste. In places where separation of waste occurs at household levels, the collection of said waste becomes the next stage in the waste management process. Conversely, in locations where the municipal waste is not being sorted at household levels, once collected, they are transported to sorting houses where waste is separated into designated categories like paper, plastics, metals, organic waste, and so on.

Although recycling is on the rise, their capacity is not yet at potential. Also, not all waste can be recycled. All these factors make waste management systems a very important topic in many countries. The two most common methods of dealing with waste are incineration and landfill. The decision whether “to bury it or burn it” is one that is highly debated among scholars in various disciplines. Most existing literature are more focused on the economic impacts from the perspective of the whole society and sustainability impacts on the environment, alongside the contributions to climate change. While these are critical standpoints to assess the waste management from, it can be quite removed from the how project owners assess and equity investors assess these businesses.

1.2 Aim of Study

This thesis aims to analyze both a landfill and an incineration project in Canada from a financial standpoint. This is to help understand the attractiveness of both projects from the standpoint of the financiers the relative motivation to invest in these projects. This is done by evaluating the project returns both from the owner's perspective as well as the banker's perspective.

Chapter 2

LITERATURE REVIEW

2.1 Context

Canada is the 4th largest country by land area. With a total population of about 37 million people, it ranks 39th globally among all countries. The majority of its population lives along the southern border shared with the United States. As a result, there is a large availability of space which can be used for landfill in the country. Despite this, the country is faced with a municipal solid waste problem as it relies on exporting waste to other countries to deal with significant proportion of its locally generated municipal solid waste. In 2018, Canada generated 2.33 kg of waste per capita on a daily basis. This ranked 2nd behind the States among all countries around the globe (Statista, 2020). This results in an annual generation of about 30 million tones. In 2018, the country exported about 44,000 tons of waste. Most of the waste exports are to the neighboring United States (Canadians Produce More Garbage than Anyone Else | CBC News, n.d.).

In Canada, the source collection of municipal solid waste is done daily. It is often regulated and viewed as the responsibility of the local government. The latter is also responsible for the disposal of the collected waste, although there are some federally-owned facilities which the federal government has regulatory and oversight authority over. The federal government also provides regulations to the local government on some waste management affairs like site location of local waste facilities. The federal government maintains some oversight on the transportation of waste between provinces and waste exportation to other countries, the regulations are a little varied from province to province based on regional and political discrepancies (Sawell et al., 1996).

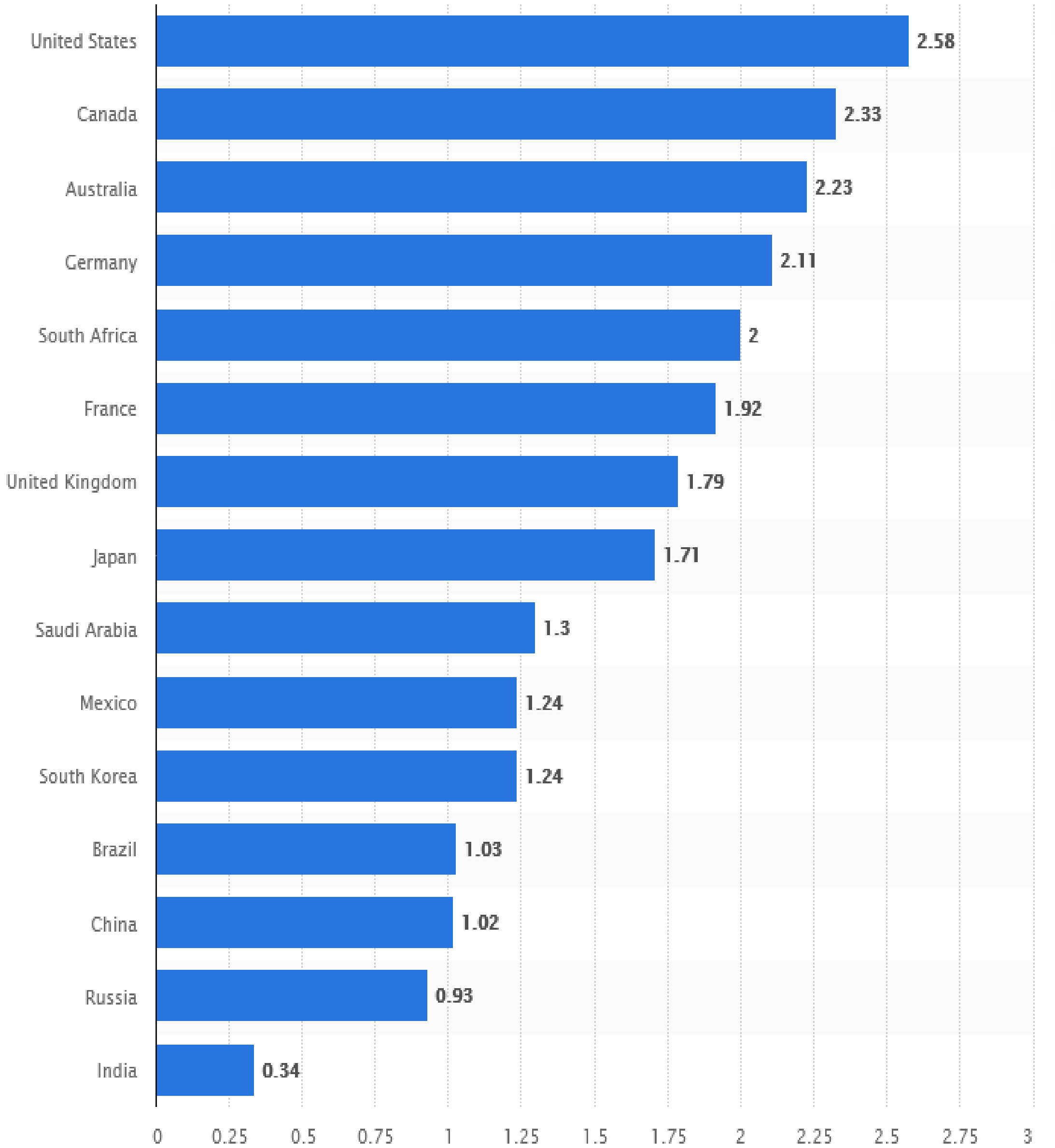

Figure 1: Waste Production in Canada (Per Capital) (Statista, 2020)

The Canadian Council of Ministers of the Environment (CCME), which was created in the 1980s, is a minister-led intergovernmental forum tasked with taking collective action on environmental issues – both of national and international concern (CCME, 2004). It is made up of ministers from the federal, provincial, and territorial governments. With regard to the management of municipal solid waste, the council sets guidelines to regulate waste processing facilities for their environmental impacts. They also have a special committee tasked with setting targets for waste reduction and waste recovery. The committee is also tasked with developing tools, data, and best practices to help reduce and recycle waste. The guidelines set by the CCME usually act as a baseline for the environmental departments of various provinces and territories.

"To burn or to bury" is a topic that is heavily debated among waste management scholars, public experts, environment advocates and other academics like economists who chime in with analysis from the perspective of their various fields. As a consequence, there are numerous literatures with analysis from various fields. Although there is existing literature comparing incineration against landfill, a bulk of them analyze the situation from the environmental and sustainability points of view. These analyses focus mainly on the cost side of things, trying to evaluate which of the waste disposal methods is less costly either only to the environment or to the society as a whole.

The most similar analysis to this thesis was that made by Assamoi and Lawryshyn (2012). They used life cycle assessment methodology to analyze and compare landfilling against waste-to-energy incineration using data from the city of Toronto. They focused on the environmental performances as well as the financial cost incurred from both alternatives while accounting for prevailing waste diversion initiatives and variation in quantities of waste generation, rate of diversion, and waste composition.

Their analysis was from the perspective of the city of Toronto as a whole, so they considered other factors handled by the government like transportation.

The prevailing scenario in the city, where all municipal solid waste was landfilled was compared to an alternative scenario where half the municipal solid waste was incinerated while the rest went to landfill. In each case, they accounted for benefit stream through electricity generation. They concluded that the waste diversion initiatives caused a reduction in the electricity generated from landfill. This is because the waste diversion initiatives reduced organic waste more than other components which made up the local municipal solid waste. They also explained that these waste diversion techniques increased the electricity generated by the waste-to-energy incinerator as opposed to its effect on landfill because the incinerator is able to generate more electricity by burning components like plastics and rubber than organic components due to the difference in heating values.

Their evaluation of the lifecycle costs yielded the conclusion that it was cheaper for the city to landfill their waste than to incinerate it. From this cost analysis perspective, they concluded that, “the incineration facility becomes competitive economically when the landfill facility is located 500 km away from the City and the incineration facility is located 50 to 100 km away with its corresponding landfill facility located 50 to 200 km away from the city.” From an environmental perspective, they concluded that the scenario with incineration was more environmentally sound than that where only landfill was used to handle the residual municipal solid waste; although, the economic valuation of the effect of the emissions was not taken into their cost considerations.

Also, Mattiello et al. (2013) investigated the health effects associated with landfills and incinerators method of waste disposal on a nearby population. In comparison of the competing waste management methods, they investigated the budding health risks associated with their different procedures of waste management. They analyzed various scientific literature through electronic searches using Web of Science, PubMed, Embase and the Cochrane Library from 1983 to 2012. From their evaluations, they concluded that the cautious precise management of landfill method leads to lesser risks than the incinerators. They argued that the incinerators mostly lead to more levels of pollution. They continued that the higher pollution levels caused by incinerators triggered congenital deformities, cardiovascular diseases, and skin disease harming the health of the nearby population. They admitted that although, the several vicissitudes in technology are producing better results, but argued that they posed new challenges for assessing the environmental impact on health in other social contexts. They pointed out that new evaluation objectives are necessary. The new objectives pointed out include size of the incinerator, precise measurement of nanoparticles; and "minor" markers, but no less important consequences for health (respiratory symptoms, residents' discomfort, risk conditions linked to stress).

Baxtar et al. (2016) studied the attitudes toward waste to energy facilities and the impacts on diversion of waste from landfill and incineration facilities towards “zero waste”. These has been widely encouraged and used as the alternative to landfill and incineration either by biogas or by production of steam to heat the buildings. They stated that the technologies needed for a new facility is both high in expense and challenged by environmental organizations and local inhabitants. They conducted a mail-back survey of 217 inhabitants in Toronto, Durham and Peel, and Ontario to find out their response toward diversion and their level of support for waste to energy incineration and waste to energy landfill facilities as well as their facility support. They discovered from the evaluations that about 14% would be reluctant to divert their waste materials if they know that it would be diverted towards waste to energy landfill or incinerator. They also realized that when they are forced to choose between the options of landfill or incineration with and without energy recovery, the most votes and favored option is waste to energy incineration with 65% in favor and landfill without waste to energy is least preferred with 61% vote. Another realization, when asked for public opinion, they discovered that the support for waste to energy incineration fell to 43% when asked as a "vote in favor".

In addition, Baetz et al. (1989) investigated the optimum sizing and timing decisions for incineration and Landfill for the treatment and disposal of wastes by the overseeing public sector authorities responsible. They stated that strict disposal of municipal waste has become even more important for the authorities responsible for waste disposal. They argued that waste disposal centers such as landfills and incinerators have significant improvement and labor costs, and the public is very concerned about the location and work. They employed a dynamic programming approach to analyze the waste management facilities. The waste management facilities analyzed are currently in the planning and development phase, to determine the appropriate size and timing of landfill and energy savings. Other municipal survey strategies are best used to promote and expand waste management systems.

Moreover, Nabavi-Pelesaraei et al. (2017) modeled energy consumption and environmental life cycle assessment for incineration and landfill systems of municipal solid waste that have been formed in recent years due to increase in population. They assessed the energy consumption and the environmental effects of incineration and landfill. They used data from a study by Waste Management Organization of Tehran Municipality, Iran and results of the energy analysis revealed that 406.08 GJ (8500 t MSW)$^{-1}$ of the energy is expended in the development of incrimination and landfill with transportation system. They explored a life cycle assessment (LCA) which indicated that incineration leads to the decrease of harmful factors that is related to the toxicity as the results of electricity generation and the development of fertilizers.

Most of the energy for transport is generated before the incineration and waste disposal process. So, you need to check the transport process inside and out. Low fuel consumption, efficient use of fuel trucks and engines for transportation, choice of shorter distances and the use of alternative truck systems can reduce energy consumption in this sector. They determine the total of consumption of transport, incineration and landfill inputs and their succeeding production rate for each output. He concluded that 406.08 GJ (8500 t MSW)$^{-1}$ consumed annually and 80.27% comes from transportation of waste to and inside incineration and landfill locations. The results gotten indicates that more attention should be targeted on providing solutions which can lead towards decrease in fuel consumption during the transporting process so as to maximize energy efficiency.

McDavid (2000) investigated the cost incurred by Canadian local governments in producing municipal solid waste management services to their citizens. In doing this, he compared various competing service delivery methods with a key assessment into the efficiency of private waste services as compared to their public counterparts. He employed the surveys of waste management services done by the Local Government Institute between 1995 and 1999 at the University of Victoria. He did this by extensively focusing on the producers of residential waste services and local government across Canada, including smaller local governments and Quebec local governments. He conducted both efficiency of landfill operation comparison and likewise, comparison of both public and private residential services. McDavid (2000) found evidence in most cases that the landfill was operated with a mix of own forces and private contractors from the solid waste landfill survey of 1995. This survey analysis of landfill efficiency could not compare the efficiency of private contractors and public producers but studies effect of the percentage contribution of own forces. Analysis done of the averages across population showed inconsistent form for different local governments where the wide difference implies the efficiency of private produces for population of 10,000 to 24,999. He stated that public producers of services are less efficient than the private producers of local government of the similar services, estimating that publicly-operated landfills cost 51% more to run per metric ton of processed waste than their privately-operated counterparts.

Furthermore, Spencer and Yasuda (2000) evaluated the fuels that can the derived from both waste management systems. The evaluation of these refuse-derived-fuels (RDF) was made from both a purely environmental perspective as well as an economic perspective – from the society as a whole. They tried to estimate the impact of the derivation of RDF – drawing on the experience of Japanese cities, if it were employed in a Canadian district like the Greater Vancouver Regional District (GVRD). They employed a model simulation analysis for their research. From their research, they understood that the construction of more waste-to-energy fuel source plants would lead to a partial reduction in greenhouse gases. They also explained that this alternative scenario will increase the length-of-life of nearby landfills. From their results, they concluded that the incorporation of refuse-derived-fuel facilities in combination with incinerators will be a better waste management practice for the country and greatly improve the social benefit of the citizens.

Mohareb, Warith, and Diaz (2008) analyzed the practices of municipal solid waste management in the city of Ottawa from a purely environmental perspective. They focused on understanding the impact of the waste management strategies on the emission of greenhouse gases into the atmosphere and their contributions to climate change. They evaluated that the landfilling in Canada as a whole is responsible for about 3.2% of the total emission of carbon oxide (CO_2) of the entire country. They employed an integrated waste management (IWM) model to analyze various scenarios of waste management that could be employed by the local government. The scenarios analyzed include: the prevailing situation which is landfill-heavy, to landfill all waste, to increase the amount of gas derived in landfills by upgrading the landfill gas capture system, increase the diversion of manufactured goods by 50%, source reduction of manufactured goods, incineration, and increase of composting by 30%. They concluded that among all the options evaluated, incineration, along with further source separation of recyclables, and anaerobic digestion of organic waste had the most benefit in reducing the amount of greenhouse gas emissions. They recommended steps to be taken to integrate more of the aforementioned systems into the waste management system of the city.

Lastly, Song, Wang, and Li (2013) made a similar analysis for the management of residual municipal solid waste for Macau in terms of comparing a variety of competing waste management scenarios. They employed a life cycle assessment for their analysis. The analysis for a region like Macau differs from Canada in the sense that land resources are less abundant in Macau. The analyzed scenarios include the prevailing situation; the use of landfill only as formerly practiced; the use of source separation, composting, and landfill; incineration and composting; source separation and incineration; and source separation, coupled with composting and incineration. They concluded that, of all the appraised scenarios, the combination of source separation and incineration had the most benefit from an environmental perspective.

This was followed by the scenario with the combination of source separation with composting and incineration. The scenario with landfill only was shown to be the worst case of all considered. They revealed that for a small country like Macau, waste management services like collection, composting and transportation was of little significance to the total cost incurred. They also employed a sensitivity analysis to decipher the influence of different waste assessment methods and recycling rates in the source separation process. From this, they concluded that there is an inverse relationship between the rate of recycling and the impact of waste management on the environment. They recommended the use of source separation coupled with the incineration of residual municipal solid waste as the premium option for the country among all the analyzed scenarios.

As formerly mentioned, a majority of the existing literature place their focus on analyzing the waste management debate from the point of view of the society as a whole. Although this is highly useful for state policymakers, and to understand the cost behavior of competing waste management systems, there exists a lack of analysis from the perspective of the project owners. This is what this analysis sheds light on.

2.2 Project Description

Incinerator facilities use high heat combustion sustained over long periods of time to burn inputted waste. The thermal treatment of waste in the incinerator does not eliminate the waste, but greatly reduces both the volume of waste and the toxicity of the waste involved. Garbage trucks usually compress the size of collected garbage by about 80%. The incinerator reduces the volume of the waste by an additional 80-85% - this refers to the volume of ash as compared with the size of the waste coming in. Waste-to-energy incineration plants can convert the heat from the waste combustion into electricity. The electricity generated can then be sold into the grid. Their energy-generating ability make them able to be substitute for other thermal plants of similar capacity and capacity rate. Owing to this, the emissions that are generated by the incinerator are somewhat offset by the emissions avoided from the fallen out thermal plant. The technical reference plant used as base representation for the assumed incinerator plant is fundamentally based on the report to the European commission by (Eunomia, 2001). Key inputs were also considered based on other works like (Assamoi & Lawryshyn, 2012; Rodríguez, 2011; Shilkina & Niyazov, 2018).

Figure 2: The "WTE" Incinerator Wastes (Gaia, 2013)

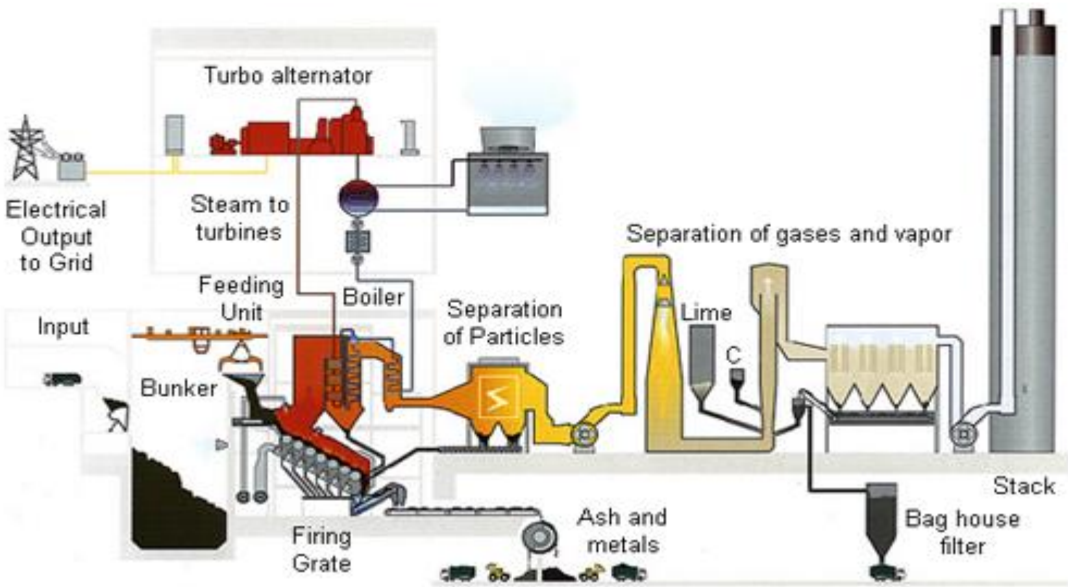

Figure 3: Waste Incineration Plant (Where Our Trash Goes, 2017)

These waste-to-energy (WtE) incinerator plants are built specifically to treat and reduce the volume of residual municipal solid waste while producing energy. The steam produced from the burning is used to fuel a steam turbine to generate energy. The WtE incinerator unit is expected to take 3 years of construction period to reach mechanical completion. The operation is expected to last for 20 years, with liquidation occurring in the following period. The bottom ash, which is the residue of burning the residual solid municipal waste that comes through is expected to be landfilled. Hence, a more accurate description of the "to bury or to burn" debate is "should we burn before burying?" Burning a ton of waste in the incinerator is expected to generate 0.6 MWh of energy (Elena Díaz Barriga Rodríguez Advisor & Nickolas Themelis, 2011). The plant itself is expected to use about 10% of the gross energy generation (Shilkina & Niyazov, 2018). The model incinerator is assumed to have a capacity of 400,000 tons per annum.

The type of incinerator selected for analysis is the moving grate incinerator. Other types are better suited for different waste types. For example, the rotary kiln is highly suited for medical waste and the fluidized bed is more suited for treating sludge waste but the moving grate incinerator is highly suited for treating municipal waste. The moving grate incinerator keeps the waste moving around in the combustion chamber to allow air flow through the waste. This allows it to combust the waste at a quicker rate. The main components of the required capital expenditure include:

1. Land cost
2. Site development
3. Construction cost
4. Machineries and electro-technical installations

The machineries include both the incinerator plant and the generator to complete a WtE incinerator plant. It covers a main proportion cost the capital requirement of the project.

While landfilling is popularly described as the oldest form of waste disposal, the modern method of landfilling which involves the use of multiple layers of cover began in the 1940s. This modern method of covering waste regularly is as opposed to the archaic method of dumping piles of refuse into a large hole in the ground. Since landfill are more prevalent in Canada, unitary costs were more easily understood. The modelled landfill was based primarily on Privato et al. (2018) and Assamoi and Lawryshyn (2012), but information was also considered from government reports (British Columbia Ministry of Environment, 2016). There are strict regulations governing where landfills can be located, but since this is a pure financial analysis from a private perspective, the transportation of waste which is borne by the local government or the federal government in the case of interstate waste transportation is not considered. The model landfill also has a waste-processing capacity of 400,000 tons per annum. The 2 model plants were assumed to have equal capacity for easy conveyance of results. The construction of a landfill electricity system was not included as the gas generated from the included landfill gas system was assumed to be sold for revenue leaving none available for electricity generation. The technical generation of the landfill gas system is based on the handbook of the environmental protection agency (Epa & Change Division, 2020). The landfill required a 2-year investment period, and operation went on for 20 years. The aftercare cost required to close the landfill were also taken into consideration. The regulations regarding landfilling demands that the site must be cared for up to 20 years after the landfilling stops. Although, the capacity of the reference landfill was slightly higher at 468,000 metric tons per annum than the modelled landfill, whose capacity was 400,000 metric tons per annum, the land requirement was adequately scaled to fit the lower capacity of the modelled landfilling site. The main components of the capital cost include:

1. Land cost
2. Site development
3. Construction cost
4. Machinery and technical installations
5. Landfill gas system
6. Construction of the final cap for closed cell.

The modelled operation process is based on reviews of landfill operation in Canada. McDavid (2000) was able to show some variations in privately operated landfill systems versus their public counterparts. The assumed is modelled more closely to the private landfill which was shown to be more efficient in its operation in contrast to publicly operated landfills especially since the financial appraisal conducted evaluates the project from the perspective of the private owners. While many landfill operations are run with a mix of own-forces and contracted labor, the model did not make a major distinction between both. While subcontracting agreements that will save cost by subcontracting some parts of operation to other firms can be made and is usually made by many landfills, in an effort to not underestimate costs, these subcontracting agreements were not assumed.

Land is an essential factor in both projects and the way it should be analyzed is integral to proper benefit-cost analysis. The principle of land treatment in a benefit-cost analysis is not to include any valuation of the change The effect of landfilling on neighboring property values has been subject to numerous literatures but from the perspective of the private investor, these externalities do not have any direct on the cash flow generated by the project. While the effect of landfill on nearby property values is being debated, there is no confusion about the effect on the residual value of the land it occurs on. A landfill operation depresses the value of the land it occupies. Apart from the aftercare regulations, which does not allow the land used for landfill to use for any other operation till the aftercare operation has been completed, which is about 20 to 30 years after the project's operation has been concluded, land area used for landfill are acquired mostly by parks and similar public services. The continuous leachate seeping into the ground and the high amount of plastic in the ground changes the chemical composition of the soil, making it unsuitable for many other purposes, including agriculture. Since the land value decreases because of the project, it was important that the real residual value of land was also reduced in similar proportion.

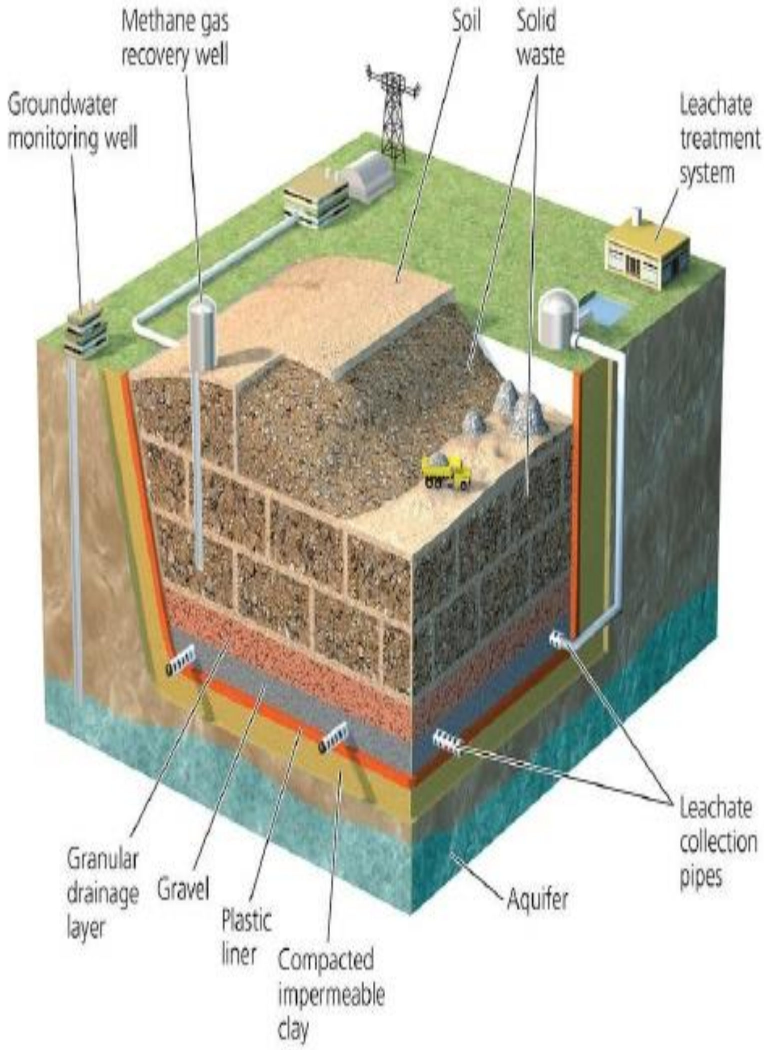

Figure 4: Landfill Site (Waste Management, 2013)

2.3 Loan

Both projects require a large capital cost to be implemented. Since this analysis appraises the project from the point of view of the private owner, it was also important to include a loan. The loans included for each project was 50% of the investment cost. The loan was to be disbursed throughout the duration that the capital cost went on for, matching the owner's investment in each year. The principal is assumed to be repaid over the first 9 years of project mechanical completion. The prevailing interest rate was assumed to be 5%. With this, the perspective of the banker was also analyzed.

Chapter 3

METHODOLOGY

A cash-based benefit cost analysis was employed in evaluating the profitability of landfill and incineration in Canada. The evaluation criteria used for assessing the profitability of each project is the financial net present value (FNPV) and the internal rate of return (IRR). The projects were analyzed from 2 perspectives. The first perspective of analysis is the total investment point of view, and the second perspective of analysis is the point of view of the project owner. In both of these perspectives, both the financial net present value and internal rate of return were used as the evaluation criteria. Mathematically, the financial NPV is denoted by equation 1 below:

$$FNPV_{t=0} = \sum_{t=0}^{k} \frac{Inf_t - Out_t}{\prod_t (1+r_t)} \qquad (1)$$

Where Inf_t denotes the total inflows in year *t*, Out_t denotes the total outflows in year *t*, r_t denotes the prevailing discount rate in year *t*, *k* denotes the total amount of year for which the projects were appraised, and *t* denotes the timing in years. The financial NPV shows in present value terms, how much return the investors will make above their opportunity cost. This opportunity cost of capital is represented by the discount rate used for the financial NPV calculation. For instance, if the investors determine that an alternative use of their funds will yield a 7% rate of return, the financial NPV of a project competing for their funds analysed with the 7% discount rate, the financial NPV of the project will represent how much more can be earned more than if they had invested their funds for a 7% rate of return.

Mathematically, the IRR is shown by equation 2 below:

$$0 = FNPV_{t=0} = \sum_{t=0}^{k} \frac{Inf_t - Out_t}{\prod(1+IRR)} \quad (2)$$

The IRR can be defined as what the prevailing discount rate has to be in order for the financial NPV to be 0. This directly shows the rate of return of the project without having to provide an external discount rate. This adds greatly to the appeal of the IRR over the NPV. But then again, the IRR has been subject to some criticisms and the NPV has been shown to be the superior evaluation criterion (Jenkins et al., 2011). The calculation of total inflow and total outflow was different for both incinerator and landfill. The following sections discuss this.

3.1 Incinerator

The net cash flow used in estimating the evaluation criteria are a function of the inflows and outflows of the project. There were 2 major revenue streams, apart from the residual value of land and machinery parts. The revenue streams come from the sale of energy generated and revenue from tipping fee paid by the municipality. The total inflow from the proposed WtE incinerator is given by equation 3 below:

$$Inf_t = Rev_t^{eng} + Rev_t^{tip} + RV_{t=k} \quad (3)$$

Where Rev_t^{eng} refers to the revenue from energy sold in year *t*, Rev_t^{tip} refers to the revenue from tipping fee in year *t*, and $RV_{t=k}$ denotes the residual value of the project which occur in the year *k* to denote the final year of appraisal. The revenue from energy sale in a year *t* is given mathematically by equation 4 below:

$$Rev_t^{eng} = NEG_t \times P^e \quad (4)$$

Where NEG_t refers to the energy available for sale in the year *t*, and P^e is the unit price of electricity sale to the grid. The annual energy available for sale was derived as equation 5 below:

$$NEG_t = (EGT \times Cap) \times (1 - PR) \quad (5)$$

Where EGT refers to the energy generated per tonne of waste incinerated, Cap refers to the capacity of the WtE incinerator in tones, and PR denotes the plant service rate of the WtE incinerator plant. This plant service rate explains the proportion of energy generated that is used by the plant itself. This energy, which is used by the plant, is what separates the gross energy generated from the net energy which is made available for sale to the grid.

The revenue stream from tipping fee is given by equation 6 below:

$$Rev_t^{tip} = Cap \times TP^u \tag{6}$$

Where TP^u refers to the prevailing unit tipping fee per tonne of waste processed.

The residual value of assets in the final year of appraisal is described mathematically by equation 7 below:

$$RV_{t=k} = HC_{t=0} \times (1 - dp)^k \tag{7}$$

Where $HC_{t=0}$ refers to the historical value of assets in the first year of appraisal which is the investment period, and dp represents the prevailing economic depreciation rate attributed to each asset. It should be noted that, for land, only the direct effects of the project on the land was accounted for. Appreciation in the price of land which did not come due to project operations was not included in the analysis.

The components of the outflow of many projects can be separated into 2 main parts which are the costs incurred during the investment period and the costs required to keep the operation running. This project is not an exception to this. Mathematically, the outflow is described by equation 8 below:

$$Out_t = Capex_t + Opex_t \tag{8}$$

Where $Capex_t$ refers to the capital expenditure required to be invested in year *t*, and $Opex_t$ refers to the total operating cost required to keep the WtE incinerator running in year *t*. It goes without saying that the capital costs and operating costs occur in different years.

The structure of the capital cost was based on the European commission report (Axelsson et al., 2017) and the cost was scaled to meet the assumed capacity. The estimation of the capital cost is described mathematically by equation 9 given below:

$$Capex = Land + Site + Const + Mach \qquad (9)$$

Where $Land$ refers to the cost of land required to build the WtE incinerator, $Site$ refers to the cost of site development required for the construction to take place, $Const$ refers to the cost of physical construction of required chambers and buildings, $Mach$ refers to the cost of machinery like the generator plants, burners, afterburners, etc. and is inclusive of their installation costs. It is important to clarify that for the purpose of analysis from the owner's point of view, interest during construction was capitalized. On the other hand, when analyzing from the perspective of the banker considering whether to give a loan, the impact of the loan financing which includes interest during construction was not included in the analysis.

The operating expenditure, which is tied to the amount of waste being processed, also considered structure from the engineering model of incineration plant by Shilkina and Niyazov (2018) as well the aforementioned European commission report (2017). It can be described mathematically by equation 10 below:

$$Opex_t = Main_t + Reag_t + Lab_t + Ash_t + Wat_t + Tax_t \qquad (10)$$

Where $Main_t$ denotes the cost of maintaining the WtE incinerator in the year *t*, $Reag_t$ denotes the cost of reagents used for smoke purification in the year *t*, Lab_t denotes the labor costs in the year *t*, Ash_t denotes the cost of landfilling residue ash in the year *t*, Wat_t denotes the cost of process water for the year *t*, and Tax_t denotes the corporate tax paid in year *t* based on the appraised net cash flow of that year. The labor cost took into consideration the extra contributions legally required to be made by firms in accordance to Canadian laws as well as pension contributions. The residual ash left after burning was assumed to be 20% of volume of the waste inputted into the plant.

3.2 Landfill

The net cash flow for the landfill is also a function of the project's inflows and outflows and the evaluation criteria are calculated as given by equation 1 and 2 above. The mathematical structure of the outflow is same as depicted by equation 8 above. The estimation of the capital expenditure was based on the EU report on landfill cost by Eunomia (Ltd, 2002). Mathematically, the investment cost was derived as equation 11 below:

$$Capex^l = Land^l + Const^l + Site^l + LFG + Mach^l + CCC \qquad (11)$$

Where $Land^l$ refers to the cost of land required for landfilling, $Const^l$ refers to the construction cost needed for landfilling, $Site^l$ refers to the cost of site development for landfilling, LFG refers to the cost of the landfill gas system, $Mach^l$ refers to the cost of machinery and technical installations for landfill, and CCC refers to the construction of final cap for closed cell which occurs after the operation is done. For the construction of the operating cost, in addition to the aforementioned report by Eunomia, the research also employed intake from Eilrich et al. (2003).

Mathematically, the operating cost is given by equation 12 below:

$$Opex_t^l = Lab_t^l + Lch_t^l + Util_t^l + DTC_t^l + Main_t^l + Tax_t^l \quad (12)$$

Where Lab_t^l refers to the labor cost incurred in the year *t*, Lch_t^l denotes the cost of leachate management for the year *t*, $Util_t^l$ refers to the cost of auxiliary materials in the year *t*, DTC_t^l refers to the cost of aftercare incurred for the year *t*, $Main_t^l$ denotes the cost of maintaining the landfill site in the year *t* and Tax_t^l shows the tax paid to the government for the year *t*.

3.3 Banker's Perspective

For evaluation from the perspective of the bankers, the evaluation criteria used were the debt service coverage ratio (DSCR), the loan life coverage ratio (LLCR). The debt service coverage ratio is a measurement of the cash flow generated in a year available to pay the debt due for the same year. It is given as equation 13 below:

$$DSCR_t = \frac{CFADS_t}{P_t + I_t} \quad (13)$$

Where $CFADS_t$ refers to the cash flow generated in year *t* that is available for debt servicing, P_t refers to the principal due in year *t*, and I_t refers to the interest due to be paid in year *t*. Typically, the cash flow available for debt financing can easily differ from the net cash flow due to various terms that are agreed upon in the term sheet like various drawdowns, but they are both synonymous in this case.

The loan life coverage ratio is the summary ratio, showing the ratio between the present values of the cash flow available for debt servicing for the rest of the loan duration as compared with the present value of the remaining debt balance. It is usually employed to better analyze a loan in cases where the DSCR is shaky in some years. As the LLCR is a summary of the DSCR for all the years of the loan duration, it follows that if the DSCR is buoyant for all the years, then the LLCR will also be strong. Mathematically, it is given by equation 14 below:

$$LLCR_t = \frac{PV(CFADS_t{:}CFADS_m)}{PV(Debt\ service_t{:}Debt\ service_m)} \tag{14}$$

Where m refers to the duration of the loan in years, and $Debt\ service_t$ refers to the principal payment and interest repayment due in the year t. Both the DSCR and the LLCR are the evaluation criteria chosen to be the ones with which the bank will either approve or reject giving a loan to the business owners.

Chapter 4

RESULTS

The motivation of investing one’s equity in a business is largely a function of the profitability of the business, among other factors especially risk. The profitability of both projects largely depends on the perspective of evaluation. Since this analysis is purely about the financial assessment of both projects, the results are shown both from the perspective of the project owner as well as that of the banker. The analysis of both projects began with the construction period in 2004. The landfill project required 2 years to complete mechanically while the WtE incinerator project required 3 years of investment period. Operation for both projects was evaluated for 20 years. This means that the landfill project ended a year prior to the incineration alternative.

An important factor in the evaluation of both projects is that it assumed the same tipping fee for both projects. Since the appraisals examine each project financially from the perspective of the private owner, for fair comparison, it was essential, to keep external factors constant. This also means that no grant, subsidy, or tax holiday was assumed for any of the plants. Wherever prevailing, the rates of taxes and tariffs were kept same in both analyses. Some municipalities might give some benefits especially to incineration plants if the waste management department believe it to be economically beneficial from a societal standpoint. Transportation cost is a factor in this. With the municipality managing the transportation of waste, it might be willing to pay a higher tipping fee for a nearer plant that will save some transportation cost.

The increase in tipping fee that the city will be willing to pay will be directly proportional to the savings in transportation cost if other factors are held constant. That said, both the landfill sites and incineration plants must be away from main residential areas, farmland, schools, and hospitals. Factors like these, while important to the economic analysis of both projects, have no direct impact on the project's financial cash flow from a private perspective.

Both projects were appraised from the perspective of the private owner as well as the financing partner, which in both cases is the bank. The first section below compares both projects from the owner's perspective. This is followed by the discussion of both project from the banker's perspective. Finally, a sensitivity analysis was conducted to estimate the variables with the most risk and what their impact might look like.

4.1 Owner's Perspective

This perspective examines the net cash flow available to the project owner as equity return based on the amount invested. This evaluation assumes that the loan worth 50% of investment cost was granted in accordance with the terms explained in 2.3. This means that the impact of financing like loan disbursement, interest paid, and principal repayment have been considered as cash outlays. The NPV from the owners' perspective shows how much return the owner can reap for his investments above the opportunity cost of funds which is represented by the prevailing discount rate. The incineration project required an equity investment of C$162.72 million from the project owner. In contrast to this, the implementation of the landfill project required C$37.33 million of owner's equity for the first 2 years. This investment from the owner is in addition to the 50% assumed to be contributed by the financing partner, which in this case is the bank, as explained in 2.3 above. It is imperative to clarify that this investment equity required is inclusive of the payment of interest during construction.

Table 1: Real Financial Cash Flow- Incineration Plant (2004-2027) (Million C$)

		2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
Inflows	**Total**																
Annual Energy Revenue	461.05	-	-	-	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	-
Annual Revenue from Tipping Fee	262.71	-	-	-	13.14	13.14	13.14	13.14	13.14	13.14	13.14	13.14	13.14	13.14	13.14	13.14	-
Residual Value	24.49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24.49
Residual value of land	0.91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.91
Total Inflows	**749.17**	**-**	**-**	**-**	**36.19**	**36.19**	**36.19**	**36.19**	**36.19**	**36.19**	**36.19**	**36.19**	**36.19**	**36.19**	**36.19**	**36.19**	**25.41**
Out Flows																	
Land Cost	0.91	0.91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Investment Cost	318.47	113.39	105.69	99.39	-	-	-	-	-	-	-	-	-	-	-	-	-
Interest During Construction	7.87	-	2.66	5.21	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Capital Cost	**327.26**	**114.30**	**108.35**	**104.60**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Operating Expenditure																	
Maintenance Cost	120.14	-	-	-	7.05	6.90	6.74	6.72	6.60	5.65	5.54	5.43	5.32	5.21	5.10	5.00	-
Reagent Cost	36.04	-	-	-	2.11	2.07	2.02	2.02	1.98	1.70	1.66	1.63	1.60	1.56	1.53	1.50	-
Labor Cost	103.60	-	-	-	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18	-
Landfilling Residue Ash cost	27.43	-	-	-	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	-
Water Supply Cost	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Operating Expenditures	**287.21**	**0.00**	**0.00**	**0.00**	**15.71**	**15.52**	**15.31**	**15.29**	**15.14**	**13.90**	**13.75**	**13.61**	**13.46**	**13.32**	**13.19**	**13.05**	**0.00**
Tax Accrued	79.85	-	-	-	-	-	-	-	-	5.56	5.60	5.64	5.68	5.72	5.75	5.78	-

Table 1 (Continued)

	Total	2004	2005	2006	2007	2008	2009	2010	2011	2020	2021	2022	2023	2024	2025	2026	2027
Total Outflow	**694.31**	**114.30**	**108.35**	**104.60**	**15.71**	**15.52**	**15.31**	**15.29**	**15.14**	**19.46**	**19.35**	**19.25**	**19.14**	**19.03**	**18.94**	**18.83**	**0.00**
Net Cash Flow before Financing	**54.86**	**(114.30)**	**(108.35)**	**(104.60)**	**20.47**	**20.67**	**20.87**	**20.90**	**21.05**	**16.73**	**16.84**	**16.94**	**17.05**	**17.15**	**17.25**	**17.35**	**25.41**
Financing Impacts																	
Loan Drawdown	159.59	54.24	53.25	52.10	-	-	-	-	-	-	-	-	-	-	-	-	-
Principal Repayment	142.90	-	-	-	17.02	16.67	16.28	16.23	15.95	-	-	-	-	-	-	-	-
Interest Repayment	36.53	-	-	-	7.66	6.67	5.70	4.87	3.99	-	-	-	-	-	-	-	-
Net Cash Flow after Financing	**35.02**	**(60.06)**	**(55.10)**	**(52.50)**	**(4.21)**	**(2.67)**	**(1.11)**	**(0.20)**	**1.11**	**16.73**	**16.84**	**16.94**	**17.05**	**17.15**	**17.25**	**17.35**	**25.41**

Table 2: Real Financial Cash Flow- Landfill Site (2004-2026) (Million C$)

		2004	2005	2006	2007	2008	2009	2010	2020	2021	2022	2023	2024	2025	2026
Inflows	**Total**														
Annual Energy Revenue	6.91	-	-	-	-	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	-
Annual Revenue from Tipping fee	262.71	-	-	13.14	13.14	13.14	13.14	13.14	13.14	13.14	13.14	13.14	13.14	13.14	-
Total Residual Value	1.21	-	-	-	-	-	-	-	-	-	-	-	-	-	1.21
Residual value of land	2.44	-	-	-		-	-	-	-	-	-	-	-	-	2.44
Total Inflows	**273.27**	**-**	**-**	**13.14**	**13.14**	**13.52**	**13.52**	**13.52**	**13.52**	**13.52**	**13.52**	**13.52**	**13.52**	**13.52**	**3.65**
Out Flows															
Land Cost	4.88	4.88	-	-	-	-	-	-	-	-	-	-	-	-	-
Interest During Construction	0.91	-	0.92	-	-	-	-	-	-	-	-	-	-	-	-
Total Capital Cost	**74.96**	**40.68**	**34.28**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Operating Expenditures															
Maintenance Cost	0.44	-	-	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	-
Labor Costs	31.07	-	-	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	-
Auxiliary Material	0.63	-	-	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	-
Leachate Management Cost	0.69	-	-	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	-
After Care Cost	1.95	-	-	0.09	0.09	0.09	0.09	0.08	0.11	0.11	0.11	0.11	0.11	0.11	-

Table 2 (Continued)

	Total	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
Total Operating Expenditure	**34.81**	**-**	**-**	**1.73**	**1.72**	**1.72**	**1.73**	**1.71**	**1.76**	**1.77**	**1.76**	**1.77**	**1.76**	**1.76**	**-**
Tax Accrued	56.09	-	-	2.35	2.42	2.58	2.63	2.69	2.93	2.93	2.93	2.93	2.93	2.93	-
Total Outflow	**165.87**	**40.68**	**34.28**	**4.08**	**4.14**	**4.30**	**4.36**	**4.40**	**4.69**	**4.69**	**4.69**	**4.69**	**4.69**	**4.69**	**-**
Net Cash Flow before Financing	**107.39**	**(40.68)**	**(34.28)**	**9.06**	**9.00**	**9.22**	**9.15**	**9.12**	**8.83**	**8.83**	**8.83**	**8.83**	**8.83**	**8.83**	**3.65**
Financing Impacts															
Loan Drawdown	36.99	18.67	18.33	-	-	-	-	-	-	-	-	-	-	-	-
Principal Repayment	33.36	-	-	3.98	3.91	3.82	3.74	3.72	-	-	-	-	-	-	-
Interest Repayment	8.53	-	-	1.79	1.56	1.34	1.12	0.93	-	-	-	-	-	-	-
Net Cash Flow after Financing	**102.49**	**(22.01)**	**(15.96)**	**3.28**	**3.53**	**4.06**	**4.30**	**4.46**	**8.83**	**8.83**	**8.83**	**8.83**	**8.83**	**8.83**	**3.65**

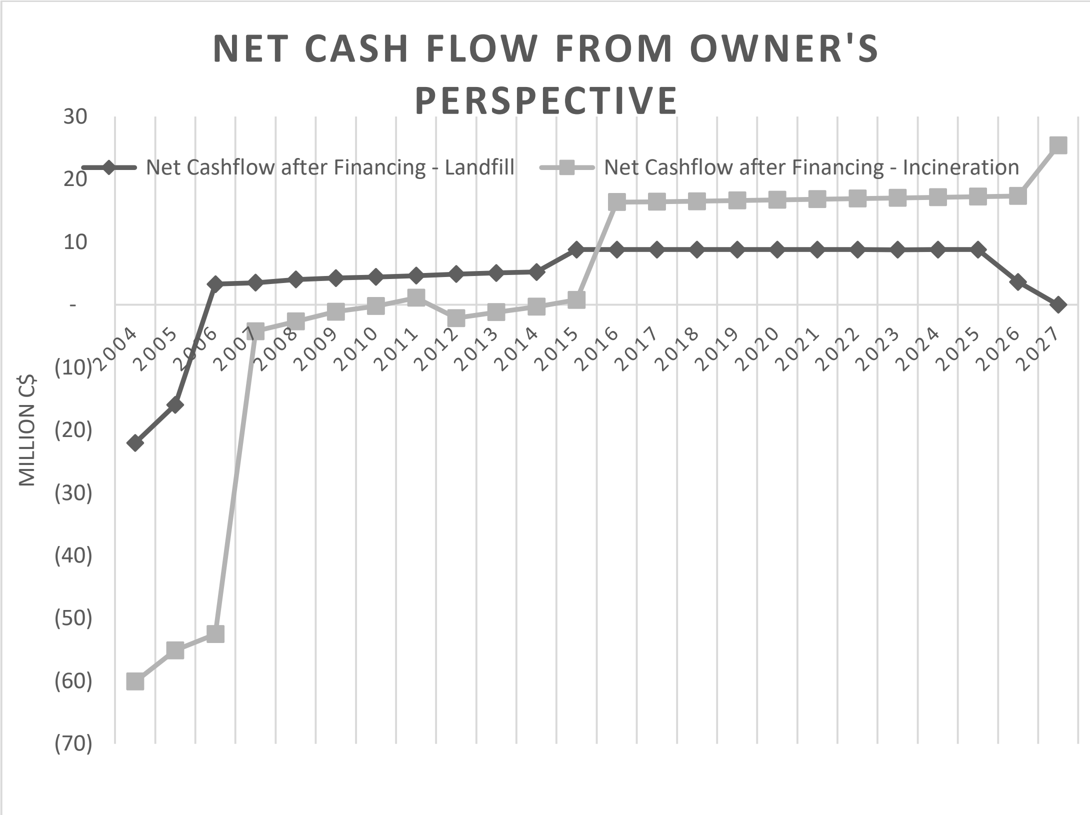

Figure 5: Comparison of Owner's Net Cash Flow for Landfill and Incineration Projects (Real 2004 Values)

The net cash flow shown above for both projects is inclusive of the financing impact of both projects. From Figure 5, it is depicted that the incineration project struggled to provide positive returns to the project owner throughout the loan life. With the landfill project mechanically completed a year before the incinerator is ready, as shown in Figure 5, it begins to generate positive net cash flow for the project owner before the incinerator does. In fact, the incinerator project was only able to generate positive net cash flow for the project owner twice throughout the loan life. With the landfill project starting operation a year before the incineration project, it is able to complete the loan repayment a year faster.

Interestingly, at the end of the loan repayment, the net cash flow from the incineration plant is substantially higher than the landfill. This is because without considering the capital cost, the incineration plant generates more return from operation than the landfill system through revenue from energy generation. What kills the incineration project relative to its counterpart is the large capital cost requirement. The repayment of loan collected in order to cover the huge capital cost of the Assuming capital requirements for both projects were similar, perhaps due to the municipality giving grants to incinerator project due to its economic benefits, then the incinerator plant will be much more competitive from a financial standpoint of the project owners. The financial returns of both projects are compared in Table 3.

Table 3: Financial Impacts of Both Project from the Owner's Perspective

	Landfill	**Unit**	**Incinerator**
Discount Rate	8.00%	Per Cent	8.00%
NPV	23.62	Million CAD	-141.10
IRR	12.32%	Per Cent	1.10%

The analysis revealed that the landfill project will return a net present value of C$23.62 million (2020 value) to the project owner. This is the return that will be generated above an alternative project with an 8% rate of return over the same period. The landfill project had an IRR of 12.32%. The IRR, which represents the rate of return of the project, is higher than the discount rate applied. This shows that the project has a higher return rate than an alternative project that might be competing for the owner’s fund.

Furthermore, the financial examination of the incineration project revealed that the project will return a net present value loss of C$141.10 (2020 value) million to the project owner. This does not necessarily mean that the project owner will make a loss from investing capital in the project, instead it translates that the project owner will make C$141.10 less than if they had invested their funds in an alternative project that would generate an 8% rate of return. The other investment criterion, the IRR, reveals that the project owner will only get a 1.10% rate of return on his invested capital by investing it in the incineration project. This rate of return is way lower than the 8% discount rate used in the NPV calculation and represents the rate of return that the project owner can realize by investing his capital in an alternative project instead of this one. The results of the analysis clearly show that it would not be of the best interest of the project owner to invest in an incinerator plant. On the other hand, it shows the landfill project to be very competitive and financially appealing to the project owner. In total, it also displays how much better the business of implementing a landfill site in Canada is to project owners as compared with the incinerator counterpart.

4.2 Banker's Perspective

From the point of view of a banker, the net return of the project to the owner is not the direct interest. The most direct interest of the bank is the overall capacity of the project to repay the loan which has been requested. In evaluating this, the total financial worthiness of the project itself is called into question. In order to understand how financially sound the project is, the banker evaluates the project without considering the financing impacts that will be derived from the loan in question. This perspective considers the overall return of the projects, as well as the capacity of the projects to generate enough cash flow to repay the loan being negotiated. This also translates that historical costs of assets are not usually considered in this perspective as bankers primarily look to have first claim on the net cash flows of the project. In contrast to the owner's perspective where the net cash flow after financing is used to evaluate the project, the banker will make use of the net cash flow before financing impacts to evaluate the overall project. The net cash flow before financing impact was used to estimate the financial IRR from the banker's perspective.

In addition to evaluating the overall soundness of the project using the financial IRR derived from net cash flow before financing impacts, the banker will also evaluate the projects ability to finance its debt primarily by the project's cash flow. This is one of the key discrepancies between project financing and corporate financing – instead of looking primarily to the project's cash flow for debt repayment, corporate financing looks to the cash flow and assets generated by all of the company's asset and acquisition for its debt financing. Figure 6, shows the net cash flow of both projects from the banker's perspective.

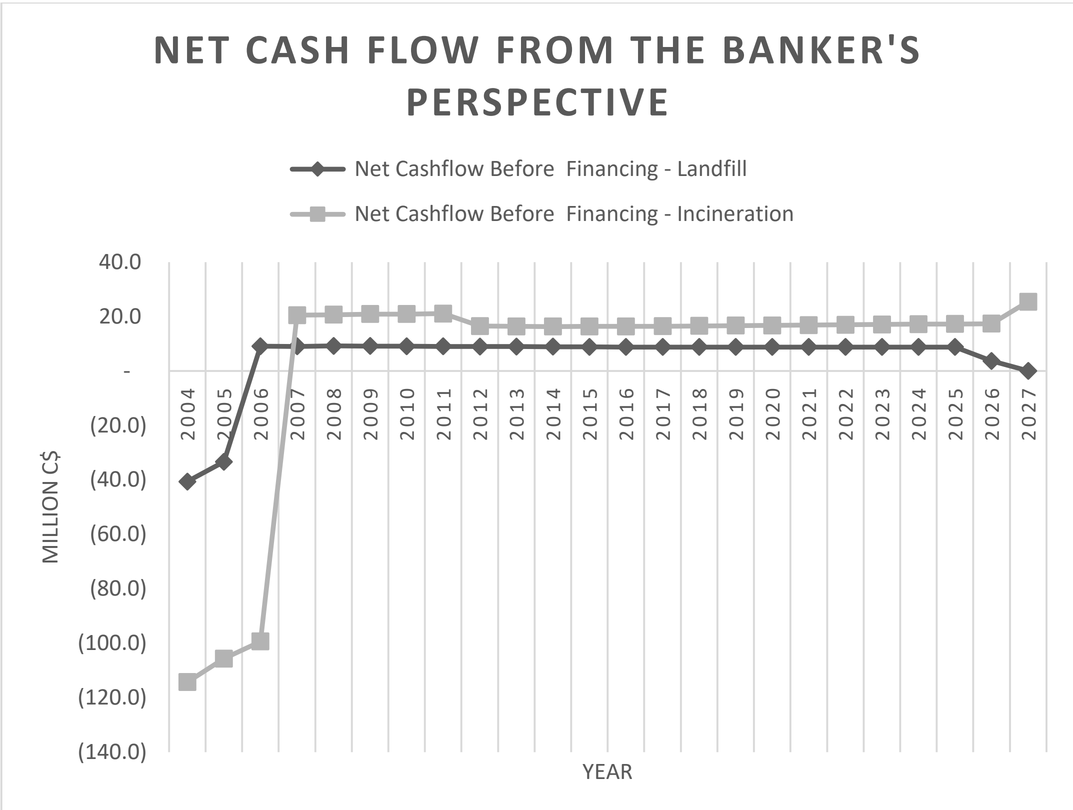

Figure 6: Comparison of Landfill and Incineration Net Cash Flow before Financing

As depicted above, the investment cost required to set up the incinerator is over 3 times that required by the landfill. Although the net cash flow of the incineration during the operating years is about double that of the landfill, as shown in Table 4, it was not enough to cover the huge capital requirement of the project.

Table 4: Financial Returns of Landfill and Incineration Projects from the Banker's Perspective (2020 values)

	Landfill	Unit	Incinerator
IRR	9.77%	Per Cent	1.56%

Table 4 shows that the landfill project, without considering financing impacts, will have a 9.77% rate of return. The incinerator project, akin to the owner's scenario in 4.1, will have a 1.56% return rate. From these results, the banker will still be interested in financing the landfill project but will back away from the incinerator counterpart.

The landfill project will not be accepted directly, but will still be subject to further scrutiny, mostly to evaluate whether it will be able to generate enough cash flow to cover the annual debt repayments. The DSCR is an important tool which helps understand if the project is able to generate enough cash flow in each year of operation to cover for the debt repayment that is due to be paid in the same year. It allows the banker to figure out year that might be quite problematic for the project to cover its debts.

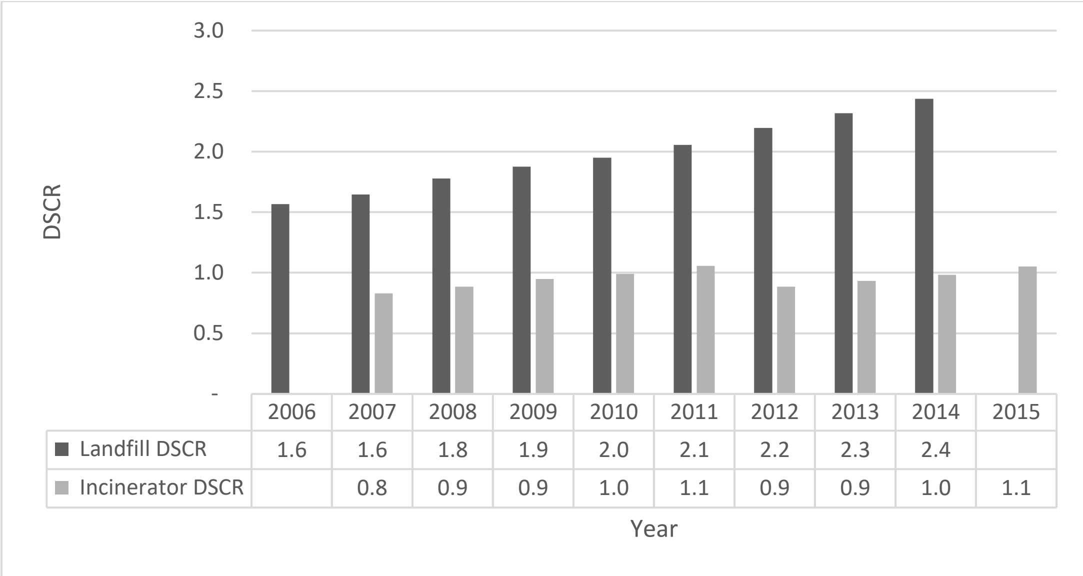

Figure 7: Annual Debt Service Coverage Ratios (DSCR) of Landfill and Incineration Projects

As depicted above, the landfill project had a minimum DSCR of 1.6, which occurred in the first 2 years of operation. This means that in the most difficult year of debt repayment of the assumed loan explained in 2.3, it is projected to generate a net cash flow that is 1.6 times the debt owed in that year. The minimum acceptable DSCR vary from bank to bank and from project to project. It is usually inversely related with the perceived risk from the lenders. Usually, security arrangements can be made to reduce the riskiness of the project leading to lower minimum acceptable DSCR ratios. For the landfill project, the DSCR was buoyant for all the years of principal repayment. It ranged from 1.6 in the first year of operation and debt repayment to 2.4 in the final year of debt repayment. Equal amounts of principal were assumed to be paid in each year, as a result, the improvement of the DSCR over the years of debt repayment came mostly due to lower interest payments as overall debt owed reduced with each principal payment. The DSCR was passable for all years if the project has tight security arrangements, but that depends on the bank's practices.

In contrast to the DSCR ratios of the landfill project, the incinerator project had DSCRs ranging from 0.8 to 1.1. With the DSCR that subpar, bankers will not be willing to invest in such project. To analyze if the DSCR can be improved, it is common to evaluate using the LLCR. The LLCR analysis was also carried out for both projects and the results are shown below.

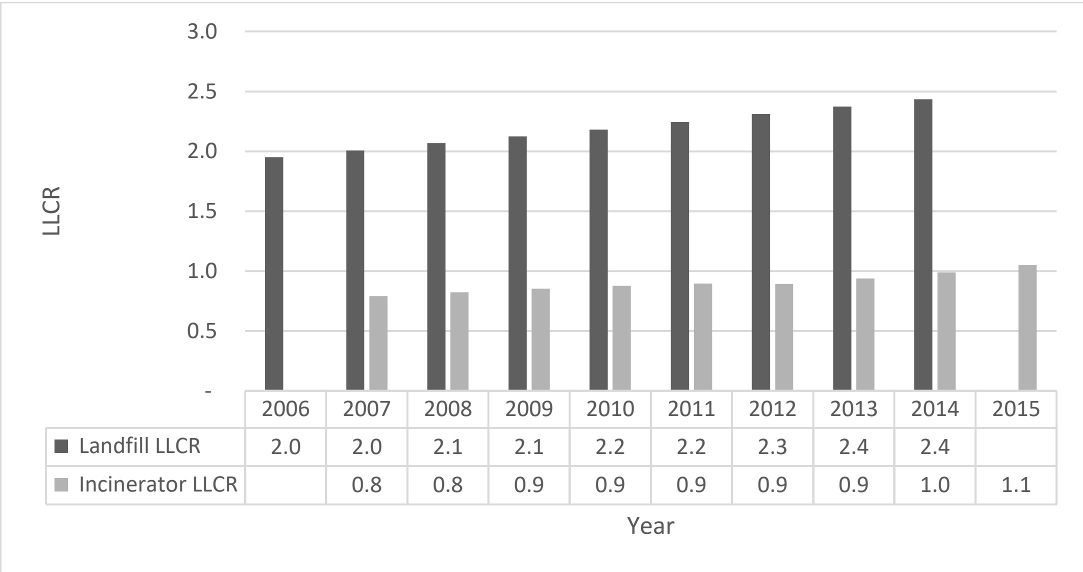

Figure 8: Loan Life Coverage Ratio (LLCR) of the Landfill and Incineration Projects

From the LLCR above, it was clear that the incinerator project will not be able to generate enough cash flow throughout the loan life to cover its debt repayment. The LLCR ranged from 0.8 to 1.1, further reinforcing that no bank will be interested in financing such loan. Conversely, the landfill project was appraised to generate cash flow that is two times the required debt repayment across the loan life.

Chapter 5

SENSITIVITY ANALYSIS

A sensitivity analysis, often referred to as 'what-if' analysis is an excellent means to understand how much output factors vary based on input parameters. It helps to identify the risk variables in an analysis and shows the relationship between these risk variables and the output parameters of the project. While it has its limitations, it is an important tool in risk analysis. A sensitivity analysis was conducted for various variables of both the landfill and incineration analyses. Notable results of the analyses are shown below.

5.1 Incineration

The most notable results of the conducted sensitivity analysis for the incineration project are shown below.

5.1.1 Sale Price of Electricity

Electricity sale to the grid is one of the 2 operating revenue streams of the incinerator project, with the other revenue from tipping fee. In the base case scenario, electricity generated from the incinerator plant was assumed to be sold to the grid at C$0.13 per kWh. The result of the sensitivity analysis is illustrated in Table 5.

Table 5: Sensitivity of the Incineration Project to Electricity Sale Price

	FNPV	IRR	Min DSCR	Avg DSCR	Min LLCR	Avg LLCR
	million CAD	#	#	#	#	#
	-141.103	0.011	0.829	0.963	0.799	0.917
0.16	-94.313	0.035	1.045	1.175	0.975	1.120
0.15	-110.804	0.027	0.973	1.098	0.911	1.048
0.14	-127.296	0.018	0.901	1.021	0.847	0.976
0.13	-141.103	0.011	0.829	0.963	0.799	0.917
0.12	-157.937	0.002	0.758	0.884	0.732	0.843
0.11	-170.140	-0.005	0.686	0.846	0.696	0.814
0.10	-185.463	-0.014	0.614	0.785	0.640	0.771

The sensitivity table above exhibits a direct relationship between the sale price of electricity generated by the incinerator and the evaluation criteria. The base scenario assumed that the electricity generated by the incinerator will be sold at C$0.13 per kWh. The sensitivity analysis revealed that a 7.69% (C$0.13 per kWh - C$0.14 per kWh) increase in the electricity sale price will result in a 9.79% increase in the financial NPV. This means that a percentage increase in the sale price of electricity will result in a 1.27% increase in the financial NPV. A break-even analysis revealed that the in order for the financial NPV to be 0, that is for the project owner make financial return similar to the opportunity cost of their capital, the electricity generated need to be sold at C$0.22 per kWh.

From the DSCR, the sensitivity analysis revealed that the 7.69% (C$0.13 per kWh - C$0.14 per kWh) increase in the electricity sale price will lead to an 8.66% increase in the minimum DSCR. This increase is still not enough for the net cash flow to cover the debt obligations of that year. It was not until the sale of electricity price reached C$0.16 per kWh that the cash flow available for debt financing for the year was just enough to cover the debts of the same year. Interestingly, the average DSCR was less sensitive to the sale price of electricity generation than the minimum DSCR. A percentage change in the electricity sale price, which resulted in a 1.13% increase in the minimum DSCR, led to a damper 0.78% increase in the average DSCR. The minimum LLCR, which represents the LLCR in the first year of debt repayment, improves by 6.05% as a result of C$0.01 per kWh increment in the sale price of electricity generated. A break-even analysis revealed that in order for the minimum LLCR to equal 2 that is for the project to generate twice the debt repayment in present value the electricity generated should be sold at C$0.35 per kWh.

5.1.2 Cost of Machinery and Electro-Technical Installations

A huge part of why the incineration project is not profitable is the capital cost. With the cost of machinery and technical installations being a major part of this cost, it is important to see how the project will react to variation in its price. These results are shown below.

Table 6: Sensitivity of the Incineration Project to Cost of Machinery Including Installation

	FNPV	IRR	Min DSCR	Avg DSCR	Min LLCR	Avg LLCR
	million CAD	#	#	#	#	#
	-141.103	0.011	0.829	0.963	0.799	0.917
85,000,000	-197.828	-0.007	0.677	0.836	0.688	0.805
80,000,000	-180.084	-0.002	0.723	0.866	0.716	0.827
75,000,000	-162.447	0.004	0.772	0.900	0.746	0.859
69,740,000	-141.103	0.011	0.829	0.963	0.799	0.917
65,000,000	-124.698	0.017	0.886	1.004	0.833	0.960
60,000,000	-104.562	0.025	0.952	1.075	0.892	1.026
55,000,000	-87.318	0.032	1.025	1.131	0.938	1.088

As expected, the financial NPV of the incineration project is sensitive to the machinery cost. A 7.5% increase (C$69.74 million to C$75 million) of the machinery cost including installation will result in a 15.13% reduction in the financial NPV. This represents a 2% decrease in the financial NPV for every percentage increase in the machinery cost. With the IRR being prone to problems due to irregular cash flows, the result it exhibits is not as trusted as the financial NPV. A break-even analysis revealed that the cost of machinery and installation has to reduce to C$31.2 million in order for the project owner to generate a rate of return that is similar to the opportunity cost of the invested capital.

The loan criteria exhibit similar sensitivity to the machinery and installation cost. They were all less sensitive to the machinery cost when compared to the financial NPV. The same 7.5% increase (C$69.74 million to C$75 million) of the machinery cost including installation resulted in 6.89%, 6.54%, 6.59%, and 6.40% reductions in the minimum DSCR, average DSCR, minimum LLCR, and average LLCR respectively.

5.1.3 Tipping Fee

Revenue from tipping fee is the primary source of operating revenue for the project. Being the primary source of compensation from the municipality, the price determination can be a useful tool in improving the attractiveness of incineration projects. As explained in Chapter 4, the tipping fee is usually a function of any economic savings that might be derived from the use of either plants. A key part of this is the transportation. If the incinerator is located closer to the municipality than the landfill, with the municipality in charge of collection and transportation, it will offer a higher tipping fee to the plant that is closer located. This is because the plant that is located closer to the sorting-houses will cause the municipality to save on transportation cost. The municipality will be willing to transfer the transportation cost saving to the closer site in the form of tipping fee when comparing the cheaper alternative between both plants. For The results from the sensitivity analysis can be seen in Table 7.

Table 7: Sensitivity of the Incineration Project to Tipping Fee

	FNPV	IRR	Min DSCR	Avg DSCR	Min LLCR	Avg LLCR
	million CAD	#	#	#	#	#
`	-141.103	0.011	0.829	0.963	0.799	0.917
46.00	-125.463	0.019	0.909	1.029	0.854	0.984
44.00	-128.633	0.018	0.883	1.022	0.848	0.972
42.00	-134.868	0.014	0.856	0.993	0.823	0.945
40.00	-141.103	0.011	0.829	0.963	0.799	0.917
38.00	-147.338	0.008	0.803	0.934	0.774	0.890
36.00	-153.573	0.004	0.776	0.905	0.750	0.863
34.00	-157.263	0.002	0.750	0.896	0.741	0.855

From the analysis, a 5% increase (C$40 to C$42) in the tipping fee will only result in a 4.4% increase in the financial NPV. Since a percentage change in the tipping fee results in less percentage change (0.884%) in the financial NPV, this shows that the financial NPV of the incineration project is not sensitive to the tipping fee. A break-even analysis revealed that for the project to recover its costs and opportunity cost of capital, the tipping fee will have to be increased to C$90.07 per metric ton of waste. While some municipalities may be willing to pay a surcharge on the tipping fee to the incinerator plant, perhaps due to perceived economic benefits of incineration over landfilling, the economic benefits of the incineration plant might not be enough to justify a 89.70% surcharge on the tipping fee. Also, a percentage increase in the tipping fee received by the incinerator project resulted in 0.64% increase in the minimum DSCR and 0.61% increase in the average DSCR. Similarly, the percentage increase in the tipping fee led the minimum LLCR to increase by 0.61% and the average DSCR to increase by 0.59%. This result shows that the financial evaluation criteria are not sensitive to the tipping fee received by the project.

5.2 Landfill

The most notable results of the sensitivity analysis conducted for the landfill analysis are explained below.

5.2.1 Tipping Fee

Revenue from tipping fee represents a larger share of the operating revenue of the landfill project than its incineration counterpart. This might make the landfill project more sensitive to the tipping fee than the incineration project. The actual result of the sensitivity analysis is shown below.

Table 8: Sensitivity of the Landfill Project to Tipping Fee

	FNPV	**IRR**	**Min DSCR**	**Avg DSCR**	**Min LLCR**	**Avg LLCR**
	million CAD	#	#	#	#	#
	23.62	0.12	1.57	1.99	1.96	2.17
46.00	41.40	0.15	1.82	2.31	2.28	2.52
44.00	35.47	0.14	1.74	2.20	2.17	2.40
42.00	29.54	0.13	1.65	2.10	2.06	2.29
40.00	23.62	0.12	1.57	1.99	1.96	2.17
38.00	17.69	0.11	1.48	1.88	1.85	2.05
36.00	11.76	0.10	1.40	1.77	1.75	1.93
34.00	5.83	0.09	1.31	1.66	1.64	1.81

From the result above, a percentage increase in the tipping fee results in 5% increase in the financial NPV of the project. This shows that the financial NPV of the landfill project is very sensitive to the tipping fee. This is to be expected as it represents a major proportion of the operating revenue generated by the project, with the other operating revenue coming from the sale of landfill gas. Both the DSCR and LLCR are less sensitive to the tipping fee compared to the financial NPV. A percentage increase in the tipping fee results in 5% increase in the financial NPV and 1% increase for the minimum DSCR, average DSCR, minimum LLCR, and average LLCR.

5.2.2 Inflation

The direction of the impact of inflation on any project is not straightforward. It is responsible for changing various factors; hence the net impact of its impact depends on the relative strength of the factors which it influences. For the analyses, the actual inflation data of Canada from 2004 to 2019 was used, while the inflation projections were employed for the further years till 2027. Hence, to test for the evaluation criteria for inflation sensitivity, an inflation sensitivity parameter was included in the estimations of the price indices. It is this inflation sensitivity parameter, which is 0 in the base case that is being adjusted to test how sensitive the landfill operation is to inflation.

Table 9: Sensitivity of the Landfill Project to Inflation

	FNPV	IRR	Min DSCR	Avg DSCR	Min LLCR	Avg LLCR
	million CAD	#	#	#	#	#
	23.62	0.12	1.57	1.99	1.96	2.17
60.00%	17.13	0.11	1.44	1.91	1.88	2.11
40.00%	19.46	0.11	1.48	1.93	1.90	2.13
20.00%	21.62	0.12	1.52	1.96	1.93	2.15
-	23.62	0.12	1.57	1.99	1.96	2.17
-20.00%	25.46	0.13	1.61	2.02	1.99	2.19
-40.00%	27.15	0.13	1.66	2.04	2.02	2.21
-60.00%	28.71	0.14	1.71	2.07	2.05	2.22

From the results shown in Table 9, for the range of inflation change tested (+60% to -60%), the resulting financial NPV remained positive. The sensitivity analysis revealed that the landfill project performed better with lower inflation rates. The impact of inflation swayed throughout the tested changes in inflation.

Chapter 6

CONCLUSION

To sum it all up, this thesis employs a cash-based benefit-cost analysis to analyze competing landfilling and incinerator projects in Canada from the point of view of a private project owner and the bank from which a loan is required. It found that landfilling is a more profitable business to invest in than the alternative incinerator project. This sheds light on why, despite multiple analysis on the economic benefits of incineration of waste prior to landfilling, landfilling continues to be the more prevalent system of waste processing in the country.

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REFERENCES

Assamoi, B., & Lawryshyn, Y. (2012). The environmental comparison of landfilling vs. incineration of MSW accounting for waste diversion. *Waste Management*, *32*(5), 1019–1030. https://doi.org/10.1016/j.wasman.2011.10.023

Axelsson, L., Franzén, M., Ostwald, M., Berndes, G., Lakshmi, G., Ravindranath, N. H., Hogg, D. D., Haddadi, M. H., Aiyelabegan, H. T., Negahdari, B., Winans, K., Kendall, A., Deng, H., Hayes, D. J., Giaouris, E., Chorianopoulos, N., Skandamis, P. y Nychas, G., ISWA, European Parliament, Coma, M., Martinez-Hernandez, E., … Sarkar, O. (2017). Costs for Municipal Waste Management in the UE. *Bioresource Technology*, *T42*(01), 1–16. https://doi.org/10.1016/j.rser.2016.09.123

Baetz, B. W., Pas, E. I., & Neebe, A. W. (1989). Trash Management: Sizing and Timing Decisions for Incineration and Landfill Facilities. *Interfaces*, *19*(6), 52–61. https://doi.org/10.1287/inte.19.6.52

Baxter, J., Ho, Y., Rollins, Y., & Maclaren, V. (2016). Attitudes toward waste to energy facilities and impacts on diversion in Ontario, Canada. *Waste Management*, *50*, 75–85. https://doi.org/https://doi.org/10.1016/j.wasman.2016.02.017

British Columbia Ministry of Environment. (2016). *LANDFILL CRITERIA FOR MUNICIPAL SOLID WASTE Second Edition BRITISH COLUMBIA BC Ministry of Environment*.

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjHwoXmhInqAhWE_aQKHdagArUQFjABegQIAxAB&url=http%3A%2F%2Fwww2.gov.bc.ca%2Fassets%2Fgov%2Fenvironment%2Fwaste-management%2Fgarbage%2Flandfill_criteria.pdf&usg=AOvVaw2rs

Canadians produce more garbage than anyone else | CBC News. (n.d.). Retrieved 17 June 2020, from https://www.cbc.ca/news/business/canadians-produce-more-garbage-than-anyone-else-1.1394020

CCME. (2004). *About CCME*. https://www.ccme.ca/en/about/index.html

Eilrich, F. C., Doeksen, G., & Van Fleet, H. (2003). An Economic Analysis of Landfill Costs to Demonstrate the Economies of Size and Determine the Feasibility of a Community Owned Landfill in Rural Oklahoma. *Southern Agricultural Economics Association Annual Meeting*.

Elena Díaz Barriga Rodríguez Advisor, M., & Nickolas Themelis, P. J. (2011). *COST-BENEFIT ANALYSIS OF A WASTE TO ENERGY PLANT FOR MONTEVIDEO; AND WASTE TO ENERGY IN SMALL ISLANDS*.

Epa, U., & Change Division, C. (2020). Landfill Gas Energy Basics Landfill Gas Modeling Project Technology Options Project Economics and Financing Landfill Gas Contracts and Regulations Best Practices for Landfill Gas Collection System Design and Installation Best Practices for Landfill Gas Collection System Operation and Maintenance Evaluating and Working with

Project Partners LFG Energy Project Development Handbook LFG Energy Project Development Handbook Contents i.

Eunomia. (2001). *Costs for Municipal Waste Management in the EU Final Report to Directorate General Environment, European Commission on behalf of*.

Jenkins, G. P., Kuo, C.-Y., Harberger, A. C., P, J. G., K Kuo, C. Y., & Harberger, A. (2011). discounting and Alternative Investment Criteria. *Cost-Benefit Analysis for Investment Decisions, Chapter 4: Discounting and Alternative Investment Criteria*.

Ltd, E. R. & C. (2002). Contents 1.0. In *Building* (Issue June). https://ec.europa.eu/environment/waste/studies/pdf/euwastemanagement_annexes.pdf

Mattiello, A., Chiodini, P., Bianco, E., Forgione, N., Flammia, I., Gallo, C., Pizzuti, R., & Panico, S. (2013). Health effects associated with the disposal of solid waste in landfills and incinerators in populations living in surrounding areas: a systematic review. *International Journal of Public Health*, *58*(5), 725–735. https://doi.org/10.1007/s00038-013-0496-8

McDavid, J. (2000). Alternative service delivery in Canadian local governments: The costs of producing solid waste management services. *Canadian Journal of Regional …*, *1*, 157–174. http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Alternative+Service+Delivery+in+Canadian+Local+Governments:+The+Costs+of+Produci

ng+Solid+Waste+Management+Services#0

Mohareb, A. K., Warith, M. A., & Diaz, R. (2008). Modelling greenhouse gas emissions for municipal solid waste management strategies in Ottawa, Ontario, Canada. *Resources, Conservation and Recycling*, *52*(11), 1241–1251. https://doi.org/https://doi.org/10.1016/j.resconrec.2008.06.006

Nabavi-Pelesaraei, A., Bayat, R., Hosseinzadeh-Bandbafha, H., Afrasyabi, H., & Chau, K. (2017). Modeling of energy consumption and environmental life cycle assessment for incineration and landfill systems of municipal solid waste management - A case study in Tehran Metropolis of Iran. *Journal of Cleaner Production*, *148*, 427–440. https://doi.org/https://doi.org/10.1016/j.jclepro.2017.01.172

Pivato, A., Masi, S., Caprio, D. De, & Tommasin, A. (2018). SANITARY LANDFILL COSTS FROM DESIGN TO AFTERCARE: CRITERIA FOR DEFINING UNIT COST. *Detritus 2018 - Volume* , *4*, 140. https://doi.org/10.31025/2611-4135/2018.13748

Rodríguez, M. E. D. B. (2011). Cost-Benefit Analysis Of A Waste To Energy Plant For Montevideo; And Waste To Energy In Small Islands Executive Summary. October,66.http://www.seas.columbia.edu/earth/wtert/newwtert/Research/sofos/Rodriguez_thesis.pdf

Sawell, S. E., Hetherington, S. A., & Chandler, A. J. (1996). An overview of municipal solid waste management in Canada. *Waste Management*, *16*(5), 351–359.

https://doi.org/https://doi.org/10.1016/S0956-053X(96)00098-0

Shilkina, S., & Niyazov, A. (2018). Financial and economic model of waste incineration plant construction. *IOP Conference Series: Materials Science and Engineering*, *365*(6). https://doi.org/10.1088/1757-899X/365/6/062024

Song, Q., Wang, Z., & Li, J. (2013). Environmental performance of municipal solid waste strategies based on LCA method: a case study of Macau. *Journal of Cleaner Production*, *57*, 92–100. https://doi.org/https://doi.org/10.1016/j.jclepro.2013.04.042

Spencer, R., & Yasuda, Y. (2000). Environmental and Economic Evaluation of Refuse Derived Fuels: With a Special Focus on the Application of Japanese Technology in Canada by.

Statista. (2020). *Daily municipal solid waste generation per capita worldwide in 2018, by select country*. Retrieved from Statista: https://www.statista.com/statistics/689809/per-capital-msw-generation-by-country-worldwide/

WorldBank. (n.d.). Retrieved from https://www.worldbank.org/en/news/press-release/2018/09/20/global-waste-to-grow-by-70-percent-by-2050-unless-urgent-action-is-taken-world-bank-report