LANDFILL GAS AS A CLIMATE CHANGE AND WASTE MANAGEMENT INITIATIVE

An Inquiry Paper

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ABSTRACT

The proper management of municipal solid waste has potentially great implications on the environmental and economic standing of Canada and its provinces. While there is diversity in means of waste disposal, landfilling has the added advantages of being a renewable energy source while extending to additional projects of landfill gas recovery which reduce emissions of greenhouse gases. However, there is debate about the efficiency of landfilling and landfill gas recovery, with potentially hazardous risks associated with the environmental, economic and energy system aspects allied with this practice. As such, this inquiry paper focuses on waste disposal diversity and the policy making processes that could potentially propel landfill gas recovery to the forefront of Ontario's waste disposal strategy. Literature from research on landfill gas recovery and associated policy processes were analyzed. In addition, open ended conversations with stakeholders operating in industrial and policy defining practices around waste management were carried out. Outcomes evidenced some policy recommendations for the implementation of LFG recovery as a strategic and important means of waste management diversification. It was suggested that landfill gas recovery could potentially spur climate change initiatives by reducing methane emissions to the atmosphere, thereby enhancing sustainability. Furthermore, it was inferred that a 40% increase in the demand for waste diversion rates in Ontario can be easily achieved with the incorporation of LFG recovery. Potential financial gains could avail from the Cap and Trade markets as a platform for trading offsets with other climate change initiative states.

Keywords: *Landfilling**,** Landfill Gas Recovery, Waste Disposal Diversion, Policy,*

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ACRONYMS and ABBREVIATIONS

ACRONYM	DESCRIPTION
Btu/scf	British thermal unit per standard cubic feet
CCME	Canadian Council of Ministers of the Environment
CDM	Clean Development Mechanism
CEPA	California Environmental Protection Agency
CH_4	Methane gas
CITSS	Compliance Instrument Tracking Service System
CO_2	Carbon Dioxide gas
eCO_2	Carbon Dioxide Equivalent
EGC	Exposed Geo-membrane cover
FIT	Feed-In-Tariff
GHG	Greenhouse Gas
GMI	Global Methane Initiative
HDPE	High Density polyethylene
IESO	Independent Electricity Systems Operator
Kt	Kilotonnes
LFG	Landfill Gas
LFGTE	Landfill Gas to Energy
MOE	Ontario Ministry of Environment
MMBtu	Million British Thermal Units
$MMTCO_2E$	Million Metric Ton of Carbon Dioxide-Equivalent?
Mt	Metric tonnes
MSW	Municipal Solid Waste
MW	Megawatts
OEB	Ontario Energy Board
OWMA	Ontario Waste Management Association
OPA	Ontario Power Agency
PVC	Polyvinyl Chloride
RICE	Reciprocating Internal Combustion Engine
RGGI	Regional Greenhouse Gas Initiative
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency

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1.0 INTRODUCTION

In most developed countries, there is an increasingly systemic approach to the collection, management and final disposal of waste. The general approach follows the order of the well known "3 Rs" in the priority sequence that waste should first of all be avoided (reduced), and if reduction is not possible, it should be reused. As a last resort to avoid disposal at landfills, whatever is left can be incinerated (for energy generation) and any other leftovers that cannot be incinerated[1] can be landfilled as a last resort. [Dijkgraaf & Vollebergh, 2004]. Figure 1 shows Canada's waste management hierarchy.

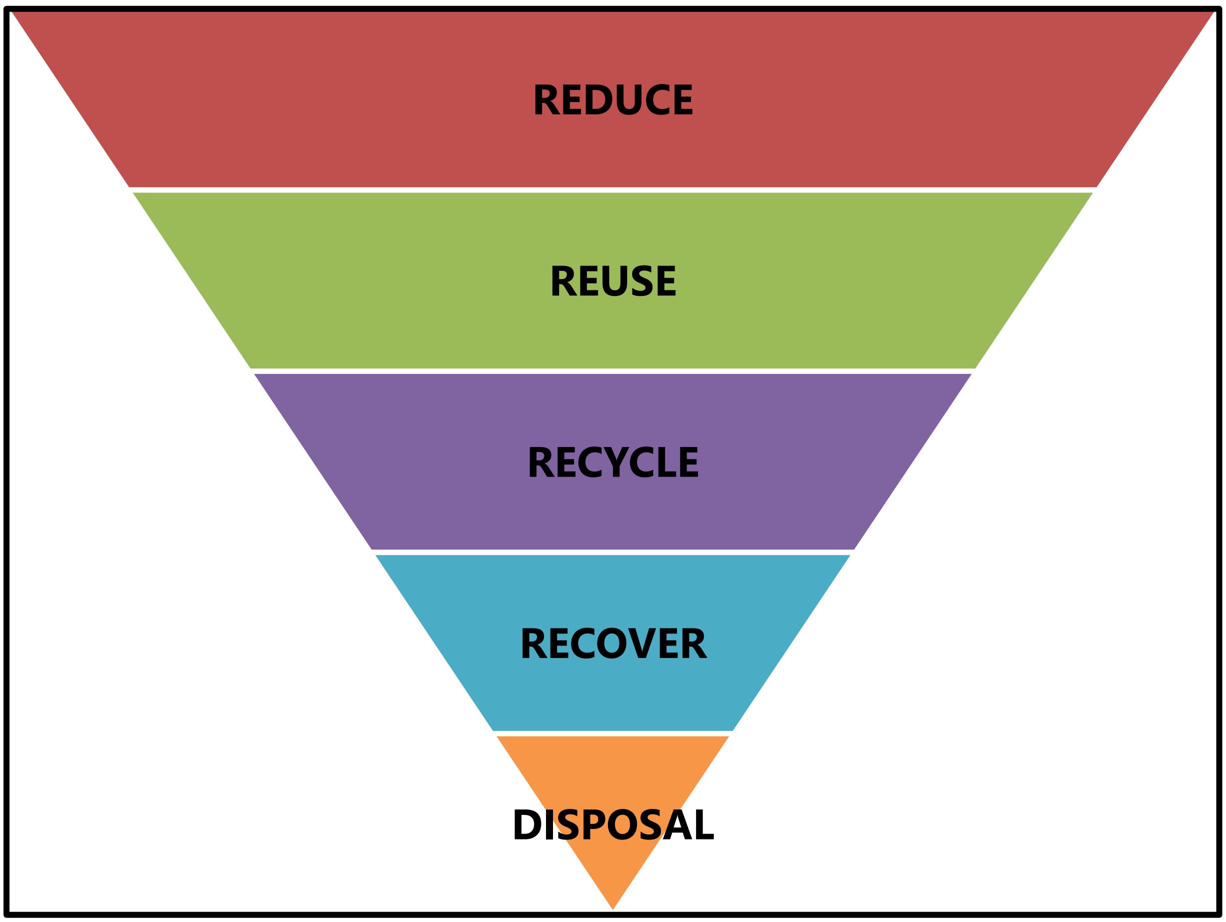

Figure 1: Canada's Waste Managemnt Hierarchy. Source CCME, 2014

[1] Incineration is a form of waste treatment technology that converts waste material to gases, particles and heat. These products are later used for electricity generation after the gases are treated for eradication of pollutants. See Waste Management Resources; online at http://www.wrfound.org.uk/articles/incineration.html

Waste management is an issue that goes beyond the harmful effects of waste on human health and the environment. The policy of "Prevention-Recycling-Disposal" is suitable to some jurisdictions. The goals of waste management include the protection of human health and the environment in a material and energy efficient manner. The developing world, with its higher population and notably expanding size has been making advancements in the improvement of waste disposal practices. Landfilling has been identified as one of the most cost effective options in achieving waste management [Blewett, 2010]. This is due to the fact that poorly managed dumpsites could be converted to effective landfill gas recovery utilization projects, and at the same time serve as a means to reduce the emissions of greenhouse gases arising from landfills [Blewett, 2010].

Landfills are the third largest source of anthropogenic methane emissions globally and account for about 799 MMTCO_2E. Fossil fuel production, transportation and use are the highest contributors of methane globally [GMI, 2013; USEPA, 2011]. Methane is estimated to be a much more powerful heat trapping gas than $CO_{2.}$ Studies have suggested that methane possesses 72 times the global warming impact of CO_2 over a 10 year period [Pelley, 2009]. Figure 2 shows the estimated global emissions from landfills in 20010. Canada was ranked sixth on that chart.

The focus of this inquiry paper is to help identify dimensions or criteria that can improve the policy-making process to promote the utilization of landfill gas technology as a waste diversion strategy in Ontario. Landfills are the most common disposal option in Canada. 97% of residual MSW is sent to landfills and there are about 2000 operating landfills in Canada. 880 are in Ontario and 28 of these landfills have utilized LFG recovery. Provinces have been regionalizing landfills by closing older and smaller unlined landfill facilities and using larger and lined landfill facilities [CCME, 2014]. The U.S. has identified the long term benefits of landfill gas as a good waste management practice. This is a practice that could become a major renewable energy source for Ontario. In addition, recent literature backs this up and has also deemed that any investment in LFG will definitely yield returns amidst any barriers to LFG collection and utilization [Sullivan, 2010].

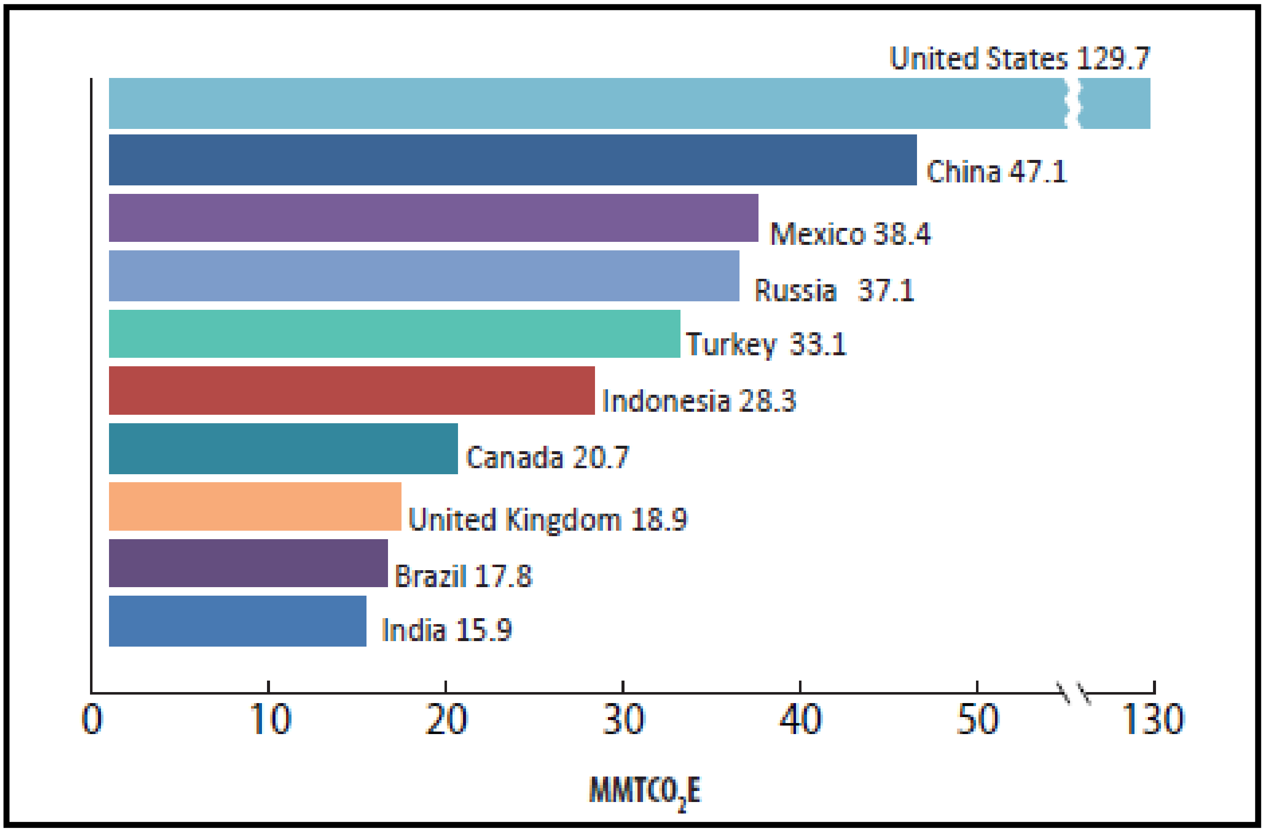

Figure 2: Estimated Global Methane Emissions from Landfills [Source GMI]

1.1 WASTE MANAGEMENT AND LFG

Although landfilling has been viewed by some as the worst option available for waste management because of the risks it poses environmentally (leakages to the air, soil and water); economically (consumes a lot of land space) and energy wise (because it is thought to use less of the potential energy content of waste when compared to waste incineration and hence it has been viewed as an "end-of-pipe solution") [Blewett, 2010; Dijkgraaf and Vollebergh, 2004]. LFG extraction and utilization has been employed in the U.S. since the 1970's and it has expanded into European shores. In 2005, about 1150 LFG extraction/utilization plants were supposedly active worldwide [Reinhart & Barlaz, 2010].

LFG is a flammable and potentially harmful gaseous mixture, which is why its extraction reduces fugitive emissions of methane into the atmosphere. it is also an eligible and alternative energy substitute for Canada when compared to fossil fuels, because the technology is advanced and available for production which typically starts immediately after municipal solid waste (MSW) is deposited, also lasting up to 20 years after initial deposition [Qin et al, 2000; Reinhart & Barlaz, 2010].

Since the carbon dioxide component of LFG is biogenic, this paper is focused on the methane component because it has a higher global warming potency than CO_2. Landfill gas collection and combustion reduces methane emissions that would normally be released into the atmosphere from the landfill. Utilization of LFG under controlled conditions includes:

- Combustion for the generation of heat, power and electricity;
- Destruction of methane during controlled flaring; and
- Pipeline distribution to an end user for combustion purposes [Alberta Environment 2013].

LFG recovery has been proven as an energy source and is commercially available. In 2007, LFG accounted for 20 percent of the emissions in Canada. An estimate of 330 Kilotonnes (Kt) of Methane (CH_4) were captured by 65 LFG collections systems or projects operating in Canada in 2007. From these 65 collection systems, 14 sites utilized the captured LFG, 36 sites flared LFG and 15 sites employed both utilization and flaring practices [Rajaram et al, 2012]. From the total amount of methane gas collected in 2007, 165 Kt was utilized for various energy purposes and the remaining LFG was flared [Rajaram et al, 2012]. A report by Environment Canada in 2011 indicated that 14 of 68 large landfill sites (active landfill sites with 40,000 tonnes per year capacity) in Canada recover methane for energy purposes, 36 flared it and18 flared and utilized LFG for energy purpose. From the information below, LFG recovery in Canada is about 3.5% [CCME, 2014]. Table 1 shows the number of landfills in Canadian provinces with landfill gas recovery facilities.

DETAILS	BC	AB	SK	MB	ON	QC	NB	NS	NL	PE	NU	NT	YT
# of Operating Landfills	92	136	338	195	880	104	92	26	88	5	25	33	29
# with LFG Recovery	8	4	2	3	28	16	6	2	1	0	0	0	0

Table 1: Number of Landfills and LFG Recovery in Canadian Provinces. Source: CCME 2014

1.2 WASTE MANAGEMENT AND DISPOSAL IN ONTARIO

About 12 million tonnes of waste is generated by Ontario residents and businesses annually. Ontario has made progress in its waste diversion programs; such as the Blue Box and Green Bin programs. However, the waste diversion framework is deficient, has been under 25% since 2008 and it shows why the vast majority of waste is being disposed off at landfills [OMWA, 2013].

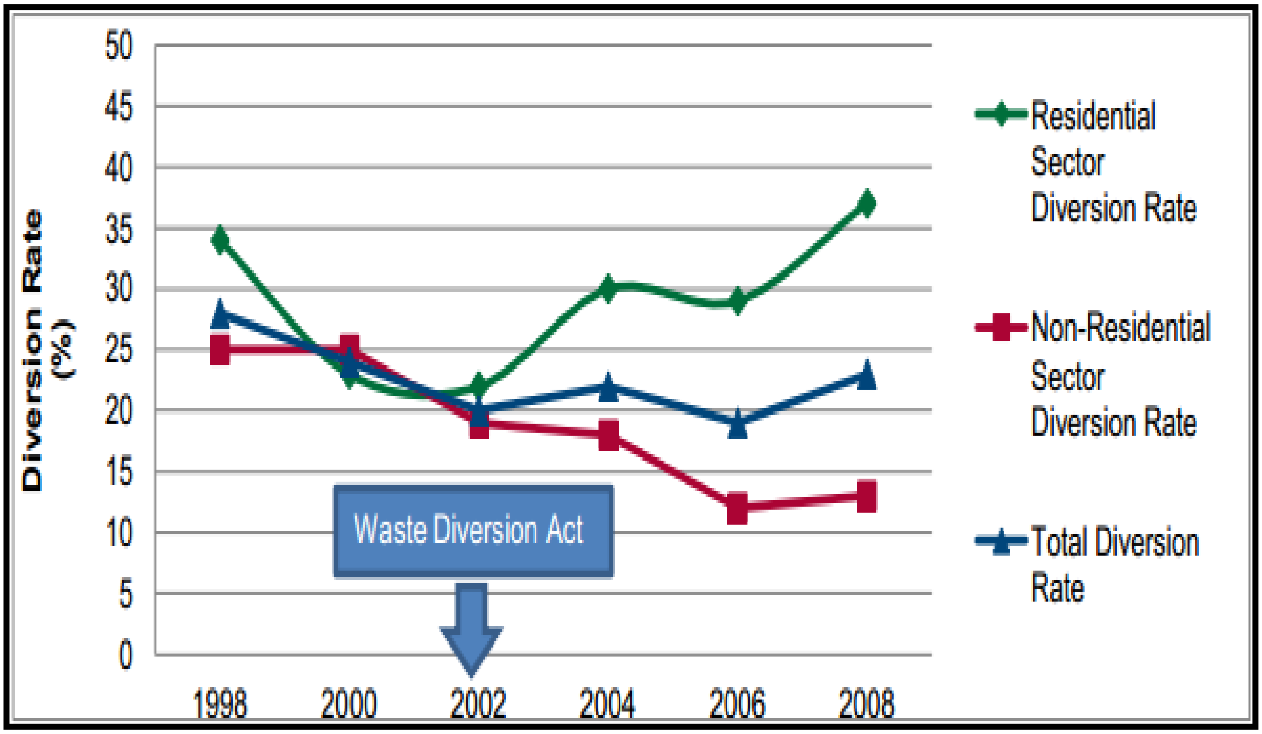

Figure 3: Combined Waste Diversion rates in Ontario; [Source: OWMA]

This is a loss in potential energy resources and economic opportunities because of the materials and businesses associated with recycling. In addition, this is occurring at a time when Ontario is experiencing waste diversion stagnation because waste disposal capacity is more than the landfill capacity and this has resulted in the transportation and disposal of waste in the United States. This is an unsustainable process because of the GHG emissions resulting from waste transportation and nothing short of legislative change in the framework and regulations will get Ontario back on track economically and environmentally [OMWA, 2013].[2] Figure 4 shows the disposal volumes per province and how little waste diversion has been effective in reducing waste disposed at landfills.

[2] See Ontario Waste Management Background; http://www.owma.org/Issues/WasteManagement.aspx

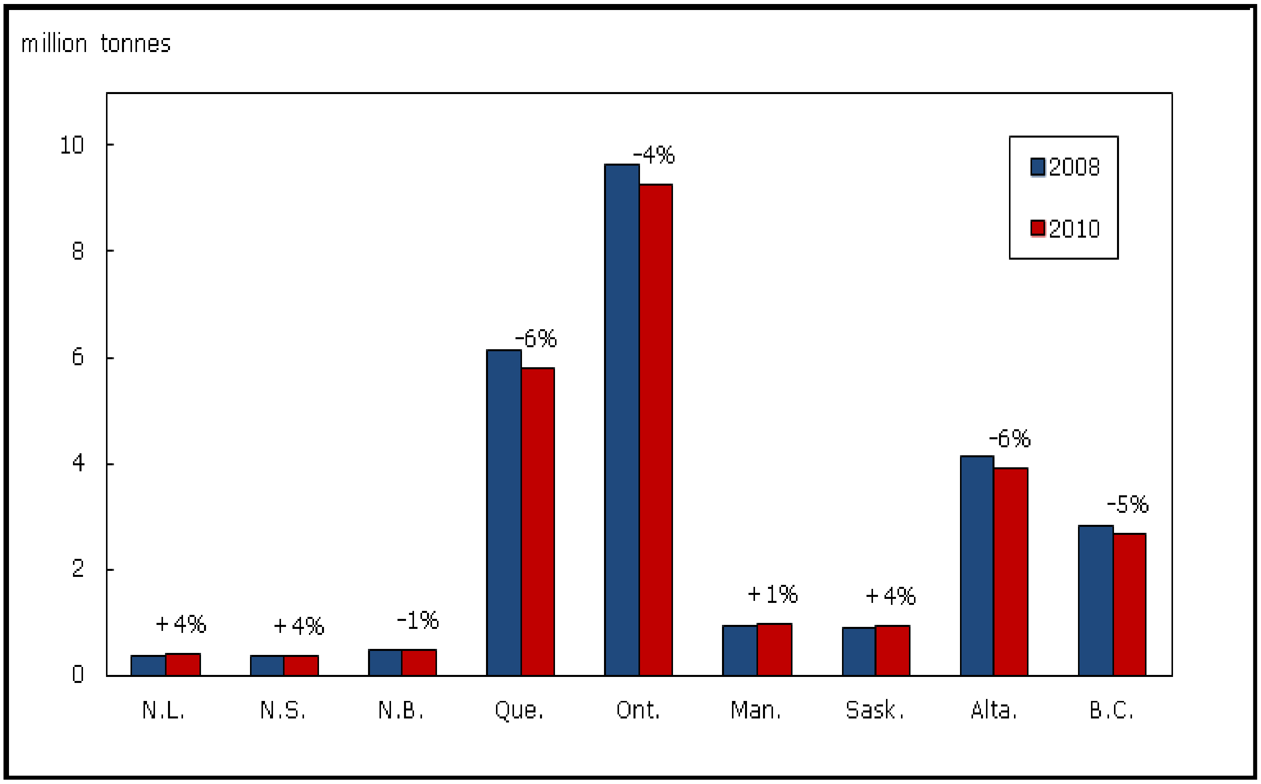

Figure 4: Waste Disposal by Provinces between 2008 and 2010; Source: [Statistics Canada]

Ontario also has been the highest waste disposal amongst other Canadian provinces, followed by Quebec, Alberta and British Columbia. Statistics Canada reported that Canada generates 936 kilograms of waste per person and 729 kilograms from that total goes to landfills [CCME, 2014].

2.0 BACKGROUND ON LANDFILL GAS

There are a wide range of treatment technologies concerned with waste to energy recovery. , These technologies are adept at extracting energy from waste while reducing the volume of excess or surplus waste. Some of these technologies are;

1. Conventional Combustion Technologies such as ;

- Batch Combustion which utilizes dual chamber controlled air technology to treat smaller amounts of waste in a non-continuous manner
- Fluidized Bed Combustion where the waste fuel is shredded and metals are separated to develop a homogenous sold fuel where combustion occurs within the inert fluidized bed

2. Advanced Thermal Treatment Technologies such as ;

- Gasification which uses MSW as a feedstock. The waste is heated to produce Hydrogen and Carbon dioxide gases that can be used to generate heat and electricity.
- Plasma Arc Gasification uses electric current passed through a gas to create plasma (collection of free moving electrons and ions) which gasifies waste into simple molecules

3. Emerging Thermal Treatment Technologies such as ;

- Thermal cracking which is also referred to as “fast pyrolysis”. It involves the heating of waste fuel in the absence of oxygen.
- Gas Plasma uses heated gas and electricity to molecularly disassemble waste, releasing waste and a synthetic gas that can be converted to fuel or combusted for electricity.

4. Energy from Waste Non Thermal Technologies such as ;

- LFGTE is generated when micro-organisms breakdown organic waste and the resulting gas (mainly methane) is used as a source of energy to create electricity or heat.

- Anaerobic Digestion is the biological degradation of organic materials in the absence of oxygen and produces a methane concentrated “biogas” used to generate electricity [OMWA, 2013].

The focus is on landfill gas generation as a waste management strategy, how it can be utilized as a climate change mitigation practice and also source of electricity or heat.

Ontario waste diversion framework does not reflect the waste management hierarchy listed above. Furthermore, the majority of waste diversion and management policies focus on recycling with little attention to reduction, reuse and recovery of energy from waste. Energy recovery from waste is treated in the same framework as equivalent to disposal and higher orders of recycling are not acknowledged within the Ontario Waste Diversion Act programs of 2002. Recycling generates by-products which cannot be utilized and these by-products or residuals can be managed through energy recovery facilities, however, there are no incentives under the framework for this value to be captured and the lack of clarity around diversion discourages investment in this sector [OWMA, 2013].

2.1 SOCIAL AND ENVIROMENTAL ISSUES WITH LANDFILL GAS

Landfill odors can be a serious social and environmental issue. These odors create a nuisance and contribute to the reduction in air quality. Odor production is inevitable and complicated due to the nature of waste and the microbial decomposition that take place prior to landfilling. Odor sources, waste composition, climatic conditions, landfill location and operations all contribute to landfill odor perception [Reinhart & Barlaz, 2010]. LFG results from the biological decomposition of municipal waste and consists of mostly equal amounts of Carbon dioxide and Methane, as well as a variety of other organic compounds such as hydrogen, sulphides and non-methane organic compounds [Qin et al, 2000]. Landfill gas emissions can be controlled by installing a network of gas collection wells, and then directing the collected gas using fans or blowers to the RICE for electricity generation, or to the flare stack for flaring (i.e. burning). Burning methane and converting it to carbon dioxide reduces its global warming potential by about 95% [Ministry of Environment, 2007]. This is dependent on the flare system being used. Normally, closed flare systems burn gas at a 95 to 98 percent destruction rate. Use of the methane for energy purposes can further reduce greenhouse gas emissions by replacing other energy sources, such as natural gas or coal [Ministry of Environment, 2008]. LFG is generated as a result of chemical and microbial processes occurring within the deposited organic waste. It is a result of those processes being environmentally sensitive and subjected to natural and artificial conditions that affect the microbial population and also the LFG generation rate [Rajaram et al, 2012], and depending on the type of waste, the moisture content of the waste and a host of other criteria, it takes months to years to reach the methanogenic phase of LFG production or generation [Sullivan, 2010]. Hence methane generation from LFG is not immediate. Conventional landfills produce methane within 3 to 5 years before measurable gas production begins, but this is very dependent on site-specific conditions [Sullivan, 2010], and the IPCC are the widest designers and evaluators of LFG generation and collection models [Reinhart & Barlaz, 2010].

2.2 LANDFILL GAS GENERATION AND COLLECTION FROM WASTE

Landfills are designed structures built into or on top of the ground to ensure refuse isolation. The design and operations act to ensure that there are minimal effects to public and environmental health. MSW landfills have 6 components: 1] Bottom liner systems, 2] Refuse wells 3] Storm-water drainage system, 4] Leachate collection systems, 5] methane collection systems, and 6] a covering cap. These components promote methane capture [Sawyer, 2007]. Figure 5 shows the components of a typical modern landfill.

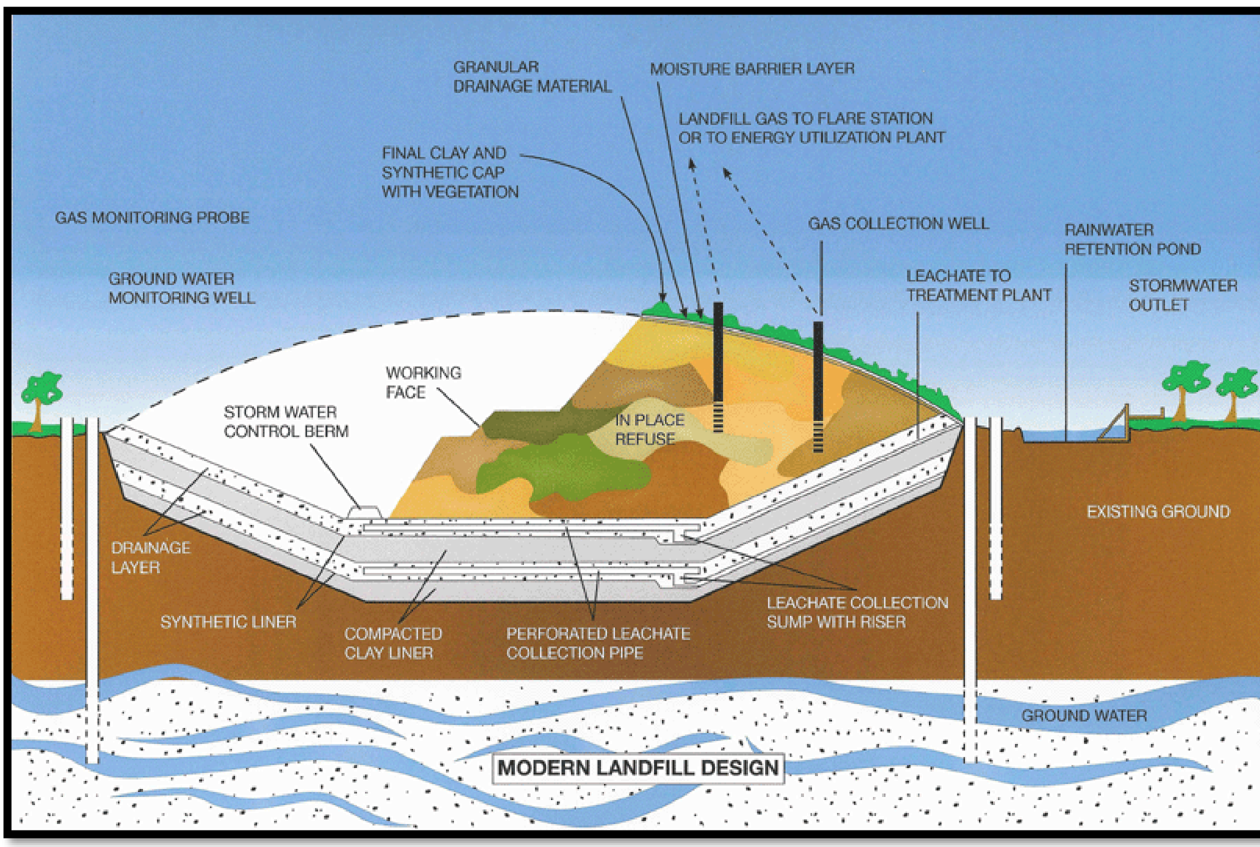

Figure 5: Cross-section of a Landfill. Source: Municipal Solid Waste; Environmental Analysis, 2015

1. Bottom Liner Systems are usually constructed from puncture-resistant, plastic HDPE or PVC. These are used to prevent the movement of leachate and LFG into the soil [Kim, 2003].

2. Wells are the most common methods of LFG extraction. Vertical Well systems and Horizontal Trench systems are the 2 well types available. The former is the simplest way of extraction since the waste is already in place. However, the disadvantage with this is the requirement for extraction pumps to be installed in each well to extract accumulated water and leachate. This causes an increase in the operation costs and frequency of maintenance for these pumps [Reinhart & Barlaz, 2010]. Horizontal trench types on the other hand require pipes or trenches that will be installed as the waste is placed in the landfill. These trenches or pipes must be covered in a thick layer of waste to prevent air infiltration [Reinhart & Barlaz, 2010].
3. Storm-water Drainage systems control rainwater infiltration to prevent the formation or production of leachate. Drainage pipes and storm water liners collect water from different areas in the landfill and channel it to collection ponds before it is pumped off-site [Freudenrich, 2005].

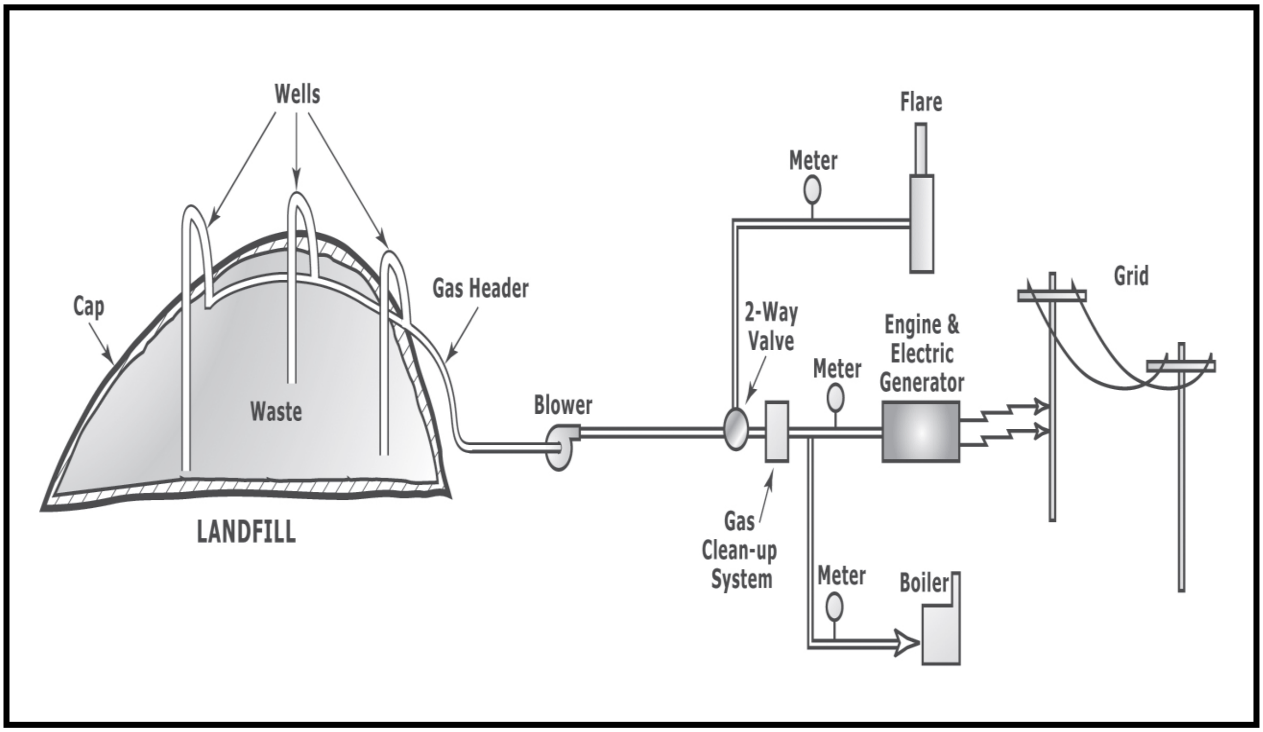

Figure 6: Typical Landfill Gas Recovery Project Diagram [Source: Globalmethane.org]

4. Leachate Collection systems optimize landfill systems and are designed as fail-safes for the storm-water drainage systems. Whenever water permeates through the landfill wells, it reacts with organic and inorganic contaminants and then becomes leachate. It is treated as sewage or wastewater before it is released [Freudenrich, 2005].
5. Methane recovery systems are used to pump methane and carbon dioxide which is then collected and then transported to processing stations [Guo & Song, 1996].
6. Landfill covers or caps are used to control moisture infiltration, mitigate the release of LFG, and prevent pests from rummaging through the refuse. It also allows the site to be re-used in the future [Kim, 2003].

2.3 FACTORS THAT AFFECT LFG GENERATION AND COLLECTION

I. Quantity of Waste Disposed: The amount disposed at the landfill is directly affects the amount of LFG generated. The more waste you have in the well, the more LFG produced [Reinhart & Barlaz, 2010].

II. Waste Composition: Waste can be defined according to the relative biodegradability:

- Readily biodegradable (such as food waste or organics)
- Moderately biodegradable (Paper waste and organic waste)
- Slowly biodegradable (Paper waste and wood waste)
- Non-biodegradable (glass, plastic metal and concrete) . These are of major concern as they can inhibit the formation of landfill gas because of they do not decompose at desirable rates. These need to be diverted from landfills to the recycling centers [Reinhart & Barlaz, 2010].

III. Moisture content: The higher the moisture content, the higher rate of LFG generation, especially in bioreactor type landfills. This usually varies with the waste composition and climatic conditions of the location [Reinhart & Barlaz, 2010].

IV. Temperature: Changes in temperature affect microbial activities which also affects degradation rates [Reinhart & Barlaz, 2010].

V. Time: This is concerned with 2 aspects; firstly the lag time prior to starting LFG generation and second, the overall time taken to generate LFG [Reinhart & Barlaz, 2010].

VI. Landfill Cover type: The amount of LFG that can be collected or emitted is affected by the type of material that is used as a permanent or temporary cover. Such cover types are Soil covers, High Density Polyethylene Covers (HDPE), Exposed Geo-membrane Covers (EGC), and Bentonitic Geo-composite covers. These covers promote the growth of methanopheric bacteria which is converted to CO_2 when oxidized. Geo-membrane covers which also increase the efficiency of the LFG collection system [Reinhart & Barlaz, 2010].

3.0 CLIMATE CHANGE MITIGATION VIA LFGTE PROJECTS

There is a lot of support for renewable energy to replace fossil fuels. Energy recovered from methane generated at landfill sites displaces energy that is produced from fossil fuel amongst other conventional sources of electricity even though it is less energy intensive than fossil fuels. Landfills continuously produce landfill gas, and the energy recovered has widespread support for Landfill Gas–To-Energy projects as it has been deemed beneficial to the public, the environment and national security [Sullivan, 2010]. Producing methane from disposed refuse is a positive benefit of landfill disposal if and when properly controlled., In addition, landfills convert methane back to biogenic carbon dioxide and aid the energy benefit of utilizing the methane at the same time which is a win-win scenario because of Ontario's commitments to cleaner and renewable energy, economic development and greenhouse gas reductions [Sullivan, 2010].

	Agriculture	Landfill Gas	SSO Residential	SSO Commercial	Wastewater	Total
GHG Reduction (million tonnes eCO2/year)	25.5	4.5	2.2	2.5	2.8	37.5
Cars Off the Road	5,100,000	900,000	430,000	490,000	560,000	7,500,000

Table 2: Potential GHG Reduction of LFG Utilization [Source: Kelleher Environmental 2013]

LFG utilization consists of five approaches for energy recovery: electricity generation, chemical feedstock, direct heating, pipeline gas purification and heat recovery [CCME, 2014]. Landfill gas to energy projects avoids the use of non-renewable resources such as coal or oil, and the burning of LFG to create electricity or flaring of LFG destroys any odorous and non-methane organic compounds present [Sullivan, 2010]. Electricity is generated from LFG via the utilization of reciprocating internal combustion engines (RICEs) or LFG-fired gas turbines or micro-turbines, boilers or other combustion systems. These systems utilize LFG to drive generators that produce electricity. In other cases LFG has been used as an alternative for natural gas in industrial combustion devices **[Sullivan, 2010]**. Besides electricity production, LFG is a medium heating value fuel with a measurement of 500 British thermal unit per standard cubic feet (Btu/scf). In its raw form prior to treatment, it contains corrosive compounds and particulates but when treated in can be utilized in direct heating applications for boilers and kilns, or it can be purified to pipeline quality gas to be used in fuel cells [Doorn et al, 1995].

	Agriculture	Landfill Gas	SSO Residential	SSO Commercial	Wastewater	Total
Electricity Production (MW)	550	95	48	54	60	810
Renewable Natural Gas (RNG) Production (million m³/year)	1,650	290	140	160	180	2,420
Contribution to Canada's Electricity Demand	0.9%	0.2%	0.1%	0.1%	0.1%	1.3%
Contribution to Canada's Natural Gas Demand	2.1%	0.4%	0.2%	0.2%	0.2%	3.0%

Table 3: Energy Potential of Landfill Gas in Canada. [Source: Kelleher Environmental 2013]

Cogeneration or combined heat and power projects utilize LFG for both thermal energy (in the form of steam) and capturing this energy can make it an attractive prospect to the communities and customers that could benefit from it [Sullivan, 2010].

- An example of a Landfill Collection and Utilization Project in Canada was a partnership between Halton Region and Oakville Hydro Energy Services Inc. to collect landfill gas and use it to produce electricity that would power 1500 homes from producing 2.1 Megawatts of electricity from green energy[3]. The Halton project became operational in 2007 and had 2 components that were implemented in 2 phases;

a. The installation of the LFG collection and enclosed flaring system at the Halton Waste Management Site by Halton region in 2006 which conformed to the combustion guidelines set by the Ministry of Environment, and

b. Integration of an LFG utilization system operated by Oakville Hydro Energy Services that generated electricity from the LFG collected and supplied by the Halton Region.[4]

- Another successful one was the Britannia Landfill[5] Gas to Energy Project in Mississauga, Ontario. This landfill received over 10 million tonnes of waste and there were about 45 wells designed to collect 2500 ft^3 of LFG which is then delivered to the electricity generation plant through an 800 metre dedicated pipeline. The production capacity of the plant was 5.5 MW, which was enough to power about 5000 homes. The electricity plant will continue to generate electricity for at least 20 years [Watts, 2009; IGRS 2007].
- Ottawa municipality had the Trail Road Landfill Gas to Energy Facility and it reduced annual GHG emissions by up to 180,000 tonnes when compared to the levels emitted from the site in 1990. In January 2007, the facility began producing 5 MW of green power unlike in the past where the LFG was collected and flared. Scheduled operation life is for 20 years and the project generates a royalty payment of $150,000 CAD annually to the City of Ottawa [Watts, 2009].

[3] See Halton Region and Oakville Hydro Gas Collection and Utilization Project Backgrounder 2007.
[4] Seehttp://webcache.googleusercontent.com/search?q=cache:uJ3vPg4POqgJ:https://www.halton.ca/common/pages/UserFile.aspx%3FfileId%3D16896+&cd=5&hl=en&ct=clnk&gl=ca
[5] This landfill was converted to a 27-hole golf course named the BraeBen Golf Course in 2002.

These projects show the feasibility in the creation of energy from waste for public use and also generated revenue for the municipal government.

3.1 LFG TECHNOLOGY ADOPTION AS AN OPTION FOR WASTE MANAGEMENT

Canada has a good record on reducing and recycling waste. This is due to the increased governmental, public and industrial awareness of and support of the waste reduction programs and waste management practices available [CCME, 2015]. LFG has been successfully used to generate electricity and heat. It has been deemed successful and a promising approach in the renewable premise in terms of conserving energy and reducing air pollution. LFG could become abundant and a stable source of energy as a result of waste generation and diversion to landfills whilst taking into consideration the type and density of waste, but it is also a problematic issue as a result of the effort made to quantify and utilize the methane extracted. The Ontario Ministry of Environment and Ministry of Energy concluded that significant potential exists for landfill gas, but has not quantified the estimate [Elwell & Rotenberg, 2002]. Another issue identified is what kind of alternative treatments of MSW could be employed by Ontario even though LFG projects are the popular type of waste management projects under the Clean Development Mechanism of the UNFCCC [Blewett, 2010].

In the U.S., policy makers were urged to not support any measures to further increase the LFG Capture and recovery as LFG capture makes composting less attractive than landfilling even though the amount of methane collected at landfills can be accurately measured [Sullivan, 2010]. Although there has been talk about composting as a favorable waste diversion tactic, soils cannot permanently sequester carbon and hence the carbon will be released back into the atmosphere in the long run [Sullivan, 2010], and defining LFG as the best demonstrated technology may remove any incentives for composting even though composting organic waste has a true cost of $19.60 per ton, whereas LFGTE cost $43.37 per ton in the U.S [Pelley, 2009].

LFG collection is well established in Canada. Provinces in Canada have guidelines covering the recovery of LFG and the GHG offset system for carbon which is due to be implemented by the federal government will provide incentives for landfill gas utilization and in addition, probably generate financial assistance for LFG projects. The focus in Canada is towards waste diversion improvement and treatment of organics which will reduce the amount of waste sent to landfills. This will aid the reduction in methane emissions from landfills in the long term for Canada [GMI, 2013]. Environment Canada estimates a GHG reduction equivalent of 6 million tonnes of CO_2 annually if half of all the landfill gas produced in Canada is combusted effectively. Canadian provinces and municipalities have been making advancements in the reduction and direction of waste away from landfills. However, there will always be the need for some waste to be landfilled and it has to be done in proper conditions to ensure that energy is created from the utilization of LFG [Watts, 2009].

4.0 WHY LFG ADOPTION HAS BEEN SLOW IN ONTARIO

- **UNDERSTANDING FEDERAL AND PROVINCIAL ENVIRONMENTAL REGULATIONS**

  Certain rules relating to Environmental Attributes of the FIT program applied to methane destruction are likely to forestall LFG projects that have taken actions to reduce emissions and benefit the environment. These environmental attributes which are designed to protect the environment and human health (air quality, odors, explosions etc.) force LFG generation companies to choose between methane destruction and electricity production. This could result in the breach of government acknowledged emission reduction purchase agreements and damages in order to produce and sell electricity in an inconsistent manner under the FIT program, dampen the price for carbon in the province and create a conflict of interest for the Ontario Power Agency which is acting as a government agency and as a regulator in the power market [Kelleher Environmental, 2013].

- **LIMITED AND OR UNSTABLE MARKET PLACE**

  Although there has been growth in LFG utilization, especially in the U.S., it has become more challenging to implement LFG projects because the success of LFG utilization is dependent on their ability to produce and provide an energy resource that will cost less than traditional or conventional fossil fuels [Dieleman & Cappel, 2014]. The economic viability of LFG projects has become more difficult to achieve in markets where LFG offsets the use of natural gas even after the significant drop in natural gas prices from $13.06 per million British thermal unit (MMBtu) in 2008 to $5/MMBtu in 2013. Industries that display an interest in LFG as a means for sustainable energy production, have a hard time being able to justify the switch because gas prices are sensitive to both fuel and electricity prices. The low cost of traditional non-renewable fossil fuels (coal and natural gas) affects the economics of LFG utilization projects as renewable projects are usually or currently measured economically against fossil fuel alternatives [Dieleman & Cappel, 2014].

- **NEGOTIATING FINANCING**

LFG projects will take years to become profitable once operational and hence will require long term power contracts to attract and justify the capital investment in the system. The negotiations of power contracts or agreements can be complex and lengthy [Watts, 2009]. If investors believe that there will be a change in the policies for LFG, they may withdraw their financing which will then cause a potential renewable energy source to lose its credibility [Stokes, 2013]. There is also the issue of unfavorable economics due to low energy prices and high debt service rates for landfill gas-to-energy projects that generate electricity or gas [Doorn et al, 1995] Profitability evaluation shows that the mean annual profit of US$5.6 million has been achieved with a payback period of 12.3 years and Net Present Value of US$111 million [Ahmed et al, 2015].

- **POWER UTILITY COMPANIES**

Most power companies are more interested in purchasing low-cost power without consideration of the environmental externalities associated with power generation. LFG is still at an early stage of development and not yet as commercially competitive with today's electricity prices but it could become more commercial under tighter environmental protection standards requiring landfill sites to collect LFG for energy generation instead flaring it. In majority of the landfills available, the gas is flared on-site and this is due to the potential detrimental effects of methane on the environment [Qin et al, 2000].

4.1 POTENTIAL METHODS TO AID LFG POLICY MAKING IN ONTARIO

The provincial government of Ontario is responsible for the approval and issuing of certificates and licenses that monitor and regulate LFG capture and utilization from landfills over a certain size [GMI, 2013]. For Ontario, Regulation 232/98[6] in the Ministry of Environment requires the mandatory collection and utilization of LFG for new or expanding sites with a total waste disposal capacity greater than 1.5 million cubic meters, which equates to about 2.5 million tonnes of waste. Previously, the total waste disposal capacity was greater than 3 million cubic meters [MOE, 2012].

The policy making process for LFG is decided upon by the Ontario Ministry of Environment with probable formal or informal consultations or participations from various stakeholders and interest groups. Mobilizing stakeholder participation is one of the most important aspects of the policy-making process as well as other factors such as economic, environmental, social and political factors which determine the failure or success of developing and implementing a policy. LFG technology offers a sustainable and potential renewable energy source, and the challenge for Ontario would be the stakeholder participation in the policy making process and ensuring a successful LFG sector that will probably be evaluated from economic and/or technical perspectives. Furthermore, the LFG sector will have to be adaptive,

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[6] See pg 56 of Ontario Ministry of Environment (2012). Landfill Standards: A Guideline on the Regulatory and Approval Requirements for New or Expanding Landfilling Sites

stable, spur investment (foreign and or domestic) and must be within a reasonable price setting or else it may or will be met with increasing resistance over time [Stokes, 2013; Heikoop, 2013].

Based on open-ended conversations and interactions with industrial experts, developers, operators of landfills and literature gathered over time, the following are policy recommendations for LFG:

- **LFGTE Projects Policy:** Implementing the collection of LFG will only go further to acknowledge the threat of climate change. While incentives can be in place to facilitate the requirement of LFGTE projects at all landfills, there have to be targets for all of this. Landfills and LFG are going to be around for a while and help to reduce methane emissions into the atmosphere. It is only ideal that if we can address the climate change threat by utilizing the methane while pricing programs can force LFGTE projects to compete against each other for zero emissions technology and public acceptance [Chen et al, 2003]. Another issue to be considered is the investment of LFGTE projects at locations where gas recovery and use is very feasible and economically attractive and have at least 1.5 million tonnes of waste to support the drilling of wells into the refuse [UNFCCC, 1995].
- **Climate Change Mitigation Policy:** The most common policy for greenhouse gas emissions reductions will focus on a Cap and Trade mechanism which allows emissions caps to be placed directly on the upstream level of the industrial sector in question or the power plant. Certain policies in the United States have considered or utilized policies that extend outside the Cap and Trade mechanism by ensuring utilization efficiency as a low cost emission strategy. Although the Cap and Trade mechanism has the flexibility and marketability that makes it popular as a climate change mitigation policy, it does not address the barriers to

LFG utilization efficiency [Prindle et al, 2007], which is why there has to be that commitment to being green, as well as gathering community support and being creative in the implementation of LFG as a successful renewable energy project in Ontario. Sustainability is enough of a priority to push the LFG agenda forward even with some economic uncertainty [Dieleman & Cappel, 2014]. Hence public engagement in the development of GHG emissions reduction is necessary in order to enhance support for the progression of Ontario's economic goals [MOE, 2013].

Landfills operators that collect LFG for electricity and thermal generation should be placed above those that collect LFG and flare it [Sullivan, 2010]. Any combustion of LFG has to be carried out under controlled conditions. Furthermore, there should be a means to measure, record and verify these practices that are conducted by landfill operators [Alberta Environmental, 2007]. California utilizes a Compliance Instrument Tracking System Service (CITSS) that provides accounts for market participants, in its GHG Cap-and-Trade program. The CITSS is used to issue allowances, compliance offsets, track compliance instruments, and facilitate emissions compliance and record compliance transfers [CEPA, 2013].

- **<u>Waste Management Policy</u>:** In 2013, the Ontario Minister of Environment proposed legislation (Bill 91; A Proposed Waste Reduction Act) for increased waste diversion rates from an overall low of 25 percent to 40 percent and then an eventual target of 60 percent [Osorio, 2013]. There is a belief that the economic and environmental impact will be good for Ontario because only 14 percent of Ontario's wastes are recycled and under the 2002 Waste Diversion Act, producer responsibility of waste diversion is not enforced and there is no room to encourage innovation in product design [Saxe, 2013].

A redefinition of Ontario's waste management hierarchy within the waste diversion framework to maximize material and energy recovery is required [OWMA, 2013]. Given the high levels of organic waste developed in landfills, it is most important that public awareness is increased on the management of MSW. By doing so, health is protected and communities are given the opportunity to develop sustainably (i.e. producing compost from biogenic waste for vegetation, utilizing LFG for power and heat etc.). What this means is that waste can be reused better instead of becoming harmful to the environment and future generations [Blewett, 2010], and the municipal and provincial governments can ensure accountability falls on each of the stakeholders involved. As an example, the inclusion of diversion costs in the price of a product will increase competition based on pricing amongst producers. This can also be an incentive for research and development by the producers on products with longer end-of-life spans [Saxe, 2013].

- **Cap and Trade Markets:** The Environmental Protection Amendment Act, 2009 provides the foundation for Ontario to implement a GHG reduction/cap-and-trade system in Ontario that will affect industries in the province by putting a price on emission reduction credits. British Columbia, Alberta and Quebec have implemented various GHG reduction policies from emission trading which is used by Alberta, to carbon taxes used by B.C. and Quebec [Welsh et al, 2013]. Ontario has been working with other jurisdictions in Canada and the United States of America to pursue a common cap-and-trade system that will allow for offsets to be traded between these jurisdictions. In 2008, an MOU was signed with Quebec to collaborate on regional cap-and-trade systems for GHGs and also explore opportunities with the federal government to develop a cap-and-trade program that will reflect Ontario's priorities and access to a more effective trading system with other Western Climate Initiative states such as California and Quebec (which Ontario is a member of since 2008) [MOE, 2009]. It is very important that policies are in place to encourage trade with other provinces and the U.S. to enable the import and export of electricity. This would help to maintain Ontario's electricity position and prevent leakages to other jurisdictions [OPA, 2010]. Landfills that would want to or can claim GHG credits for methane and carbon reductions must be able to demonstrate that their reductions are truly additional, accurate when directly measured and valid. They will have to go beyond any regulatory requirements. An active carbon trading market will be necessary as carbon credits command high value on the market and the U.S has carbon trading markets with landfill methane reduction projects that represent a large percentage of projects with verified carbon credits [Sullivan, 2010]. Ontario will be able to do the same, especially when it implements its cap-and-trade policy that will enable emission offsets to be sold to other provinces that exceed the emission threshold [MOE, 2009]. Although emission credit systems haven't been developed, companies in the U.S. and Canada have been participating in emissions trading as part of their risk mitigation plan [Watts, 2009]. This has also been an easier set up because Ontario is a member of the Western Climate Initiative and an observer on the Regional Greenhouse Gas Initiative, (a regional U.S. based regime) which is in place to ensure that the carbon market is liquid and provides a broader access to promote trade and competition [OPA, 2010].

4.2 FUTURE RESEARCH

Is Landfill Gas considered as green energy? Can GHG emission reductions be accomplished via a better waste diversion strategy in Ontario? Ontario is working to improve its waste diversion strategy from 25% to 40% in 2020 and then to 60% by 2050 [Saxe, 2013]. The benefits of LFG collection and combustion are very clear but the long term environmental impacts remain vague. While Reuse, Reduce and Recycle remain the best forms of waste management, it is unfortunate that the first two forms have been hard to achieve and hence landfills will remain for a few more years to come thus, LFG will still be created. So the debate rages; on one hand is the need to reduce GHG emissions from landfills, another is the long term health and environmental effects of landfills and the last is long term solution for waste diversion [Chen et al, 2003; GMI, 2013].

5.0 CONCLUSION

Waste management can be carried out in a number of ways, but there are certain issues that are difficult to address. Well managed landfills designed to target waste diversion and zero methane emissions is a way for Ontario to meet its target of 40% waste diversion by 2020 and to address climate change. Internalizing the externalities of carbon and methane emissions via carbon pricing, better waste diversion strategies and LFGTE requires the support of the different levels of government in Canada. In 2010, the USEPA has mentioned that landfill designs and operations have reduced GHG emissions by 15% between 1990 and 2008 despite a 24% increase in refuse disposal due to population growth in the U.S [Sullivan, 2010]. Furthermore, sustainable development benefits have been identified as greater when it comes to LFG projects because of the environmental benefits when it comes to avoiding land contamination, leachate production and hazardous air emissions [Sullivan, 2010]. Although the combustion of LFG reduces the overall toxicity and global warming impacts, there are concerns that LFG as a by-product of landfills results in fugitive emissions of methane and landfills are a poor way to manage our waste even though we can create energy from this form of waste management [Chen et al, 2003].

Government intervention is necessary to deploy LFG technologies and costs down in the process of transitioning to a low carbon economy, but like any other investment, there is always the expectation of success, especially short-term success by the government when promoting LFG policies [Stokes, 2013]. Investment in LFG will shape the electricity system in Ontario as it will de-carbonize the electricity generation system, reuse the waste generated, increase the waste diversion awareness within the public and will likely bring the most innovation in the problem of waste diversion at the lowest cost and benefits to the stakeholders [Stokes, 2013]. It is also a more cost effective manner of achieving GHG reductions than composting and other waste diversion strategies that are currently being utilized. According to the IPCC in 2006 "the estimated breakeven costs for GHG abatement ranged from -20 to +70 US$/t$CO_2$-eq. From this study breakeven costs for LFG flaring was 25 US$/t$CO_2$-eq; 240-270 US$/tCO_2-eq for composting; 40-430 US$/t$CO_2$-eq for anaerobic digestion; 360 US$/t$CO_2$-eq for mechanical biological treatment and 270 US$/t$CO_2$-eq for incineration". What this shows is how important it is to implement technologies that are the least costly and able to reduce GHG emissions effectively whilst being a very sustainable waste disposal tactic [Sullivan, 2010].

LFG collection is well established in Canada. Provinces in Canada have guidelines covering the recovery of LFG and the GHG offset system for carbon which is due to be implemented by the federal government will provide incentives for landfill gas utilization and in addition, probably generate financial assistance for LFG projects. The focus in Canada is towards waste diversion improvement and treatment of organics which will reduce the amount of waste sent to landfills. This will aid the reduction in methane emissions from landfills in the long term for Canada [GMI, 2013]. Environment Canada estimates a GHG reduction equivalent of 6 million tonnes of CO_2 annually if half of all the landfill gas produced in Canada is combusted effectively. Canadian provinces and municipalities have been making advancements in the reduction and direction of waste away from landfills but there will always be the need for some waste to be landfilled and it has to be done in proper conditions to ensure that greener energy is created from the utilization of LFG [Watts, 2009].

The most effective way to achieve a better waste management will require the commitment and leadership of the government, stakeholders and planners. However, with resource reduction and recycling as secondary priorities, landfills will maintain an importance in our environment. Thus, the advantages of landfills can be explored while the search for alternative and even more efficient means of waste disposal will continue. [Chen et al, 2003].

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APPENDIX

BILL 91: KEY ELEMENTS OF THE WASTE REDUCTION ACT PROPOSED BY JIM BRADLEY IN 2013 (PREVIOUS ONTARIO MINISTER OF ENVIRONMENT)

The proposed *Waste Reduction Act, 2013* would replace the *Waste Diversion Act, 2002,* and would:

1. `Establish **individual** producer responsibility requirements to divert end of life products which result in designated wastes, instead of putting the responsibility on entire industry sectors. The Act would enable the setting of standards related to waste diversion and services. Producers would have the flexibility to determine how best to meet the standards. It would make producers and those persons related to a producer or group of producers equally responsible for meeting the set standards.

2. Avoid consumer resistance to "eco-fees" by requiring all-in pricing (no visible fee) for products that create designated wastes. Any vendor choosing to publicly display the waste diversion costs that are embedded in the price of a product, must do so "in a transparent and accurate manner". False or misleading representations would be an offence.

3. Require producers to reimburse a municipality for the municipality's collection and handling costs for designated wastes.

4. Transform the unpopular, financially challenged Waste Diversion Ontario into a new Waste Reduction Authority with responsibility to oversee the compliance and enforcement of the new individual producer responsibility regime. It would operate a

registry, allow for inspections and enforcement, and be able to issue monetary penalties for non-compliance with the Act and regulations. The Authority would be financed by fees and administrative penalties, determined through future regulations. *Generally, one key goal of a delegated administrative authority is to make the regulated industry pay for its own regulation and enforcement*.

5. Repeal the *Waste Diversion Act, 2002*, and transition the four currently operating waste diversion programs into the new regime.

The proposed framework legislation would continue the existing Blue Box program and would permit an increase in steward funding for the program beyond the current 50 per cent.

Explanatory Note for the Proposed Waste Reduction Act

The Bill's explanatory note summarizes the Bill as follows:

"***Part I*** (General) states that the purpose of the Act is to promote the reduction, reuse and recycling of waste derived from products, and contains definitions and other provisions of general application.

Part II (Waste Reduction Authority) continues Waste Diversion Ontario, a corporation without share capital established under the old Act, under the new name of Waste Reduction Authority ("the Authority"). The objects of the Authority include ensuring that waste reduction activities are undertaken in accordance with the Act and the regulations made under it. The Minister of the Environment is allowed to appoint only a minority of the members of the board of directors of the Authority. The Authority can set and collect fees, and is required to appoint a Registrar and inspectors. The Registrar is required to establish, maintain and operate the Waste Reduction Registry ("the Registry"). The Minister may appoint an administrator of the Authority if it is in the public interest to do so because a listed condition is satisfied.

Part III (Responsibility of Producers and Intermediaries) states that the purpose of the Part is to make producers responsible for waste derived from their products. The Part provides that producers are responsible for compliance with waste reduction standards and service standards that relate to designated wastes that are derived from the producers' products. Where producers deal with producer-controlled intermediaries who broker, arrange for or facilitate the provision of waste reduction services for them, the intermediaries are also responsible for compliance. Producers and their intermediaries are required to enter into service agreements containing mandatory provisions.

Producers and intermediaries are required to register in the Registry, and municipalities may do so.

Producers are also required to collect from registered municipalities designated wastes that are derived from the producers' products, and to reimburse registered municipalities for services provided in relation to the designated wastes. The amount reimbursed may be determined by agreement between the producer and the municipality, by a compensation formula established by the Authority, or (if an Act or regulation requires the municipality to collect and process the waste) by regulation made by the Lieutenant Governor in Council.

Part IV (Integrated Pricing) states that the purposes of the Part are to promote the reduction of environmental impacts by requiring the integration of the environmental protection costs of products when the products are sold, and to ensure that purchasers of products are provided with accurate information about the environmental protection costs of the products. A seller who recovers environmental protection costs in connection with the sale of a product must include them in the price of the product and show an all-in price in any advertisement. A seller who also shows the amount of recovered environmental costs must indicate the name and amount of each cost. False, misleading or deceptive representations relating to the names and amounts of recovered environmental costs are prohibited.

Part V (Enforcement) deals with powers of inspection and seizure, compliance orders and orders imposing administrative penalties. Compliance orders (after review by the Registrar in certain circumstances) and administrative penalty orders may be appealed to the Environmental Review Tribunal. Contraventions of listed provisions of the Act or of prescribed provisions of the regulations are offences punishable, on conviction, by fines.

Part VI (Regulations) contains general regulation-making provisions as well as regulation-making provisions relating to Parts II, III and V.

Part VII (Existing Waste Diversion Programs and Existing Industry Funding Organizations) states that the purpose of the Part is to promote the reduction, reuse and recycling of Part VII designated waste, and to provide for the operation of waste diversion programs that were approved under the old Act. The Part continues those programs as existing waste diversion programs. The Part also contains regulation-making provisions to continue an industry funding organization under the old Act and to designate the organization as the existing industry funding organization for an existing waste diversion program. The Authority is required to operate the existing waste diversion programs in accordance with the Part. The board of directors of the Authority may appoint an administrator of an existing industry funding organization if it is in the public interest to do so because a listed condition is satisfied. Those conditions include where the appointment is necessary to facilitate the wind-up of the existing industry funding organization or an existing waste diversion program.

The Part contains general regulation-making provisions relating to it. Regulations made under the old Act remain in force and are deemed to be regulations made under the Part. Contraventions of the Part, the regulations made under it or the rules made by an existing industry funding organization are offences punishable, on conviction, by fines." **[Dianne Saxe, 2013]**

LANDFILL GAS UTLIZATION STAKEHOLDER MAP