HALIFAX

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Information Item No. 4
Environment & Sustainability Standing Committee
May 14, 2015

TO: Chair and Members of Environment & Sustainability Standing Committee

SUBMITTED BY: Original Signed

Mike Labrecque, D/CAO

DATE: April 24, 2015

SUBJECT: **Energy from Waste**

INFORMATION REPORT

ORIGIN

Environment & Sustainability Standing Committee, July 3, 2014, Item 8.3.2 Motion to have presentations from Sustane Technologies Inc. and Nova Renew Inc. forwarded to staff and request a staff report on their business case.

LEGISLATIVE AUTHORITY

Halifax Regional Municipality Charter, s. 336 (2) which allows the municipality to contract with persons for the use of any component of its solid-waste management program.

BACKGROUND

Energy from waste was not identified as an area of focus or a priority during the Solid Waste strategy review and the subsequent direction from Regional Council. On July 3, 2014 Environment & Sustainability Standing Committee requested staff to draft a report on a supplier's business case. Sustane Technologies Inc. and Nova Renew Inc.'s presentation outlined their intention to convert plastic into fuel. In order for staff to investigate this energy from waste proposal, Regional Council would need to rescind their January 14, 2014 direction on reconfirming the objectives of the 1995 Community Stakeholders Committee Integrated Resource Management Strategy to maximize reduction, reuse and recycling of waste resources.

Staff believe there may be merit to energy from waste technologies in the future. However within the existing regulatory, legal, financial, and contractual environment as well as the commercially unproven nature of the current technology Halifax should continue with the policy direction recently approved by Council to maximize reduction, reuse, recycling of waste resources, and improve the fiscal sustainability of the waste program by maximizing the landfill asset and reducing costs through operational efficiencies.

Over the past year and a half Regional Council has approved policy positions and provided direction to Solid Waste staff on how to evolve Halifax's solid waste system. These are outlined below.

COUNCIL DIRECTION – JANUARY 14, 2014

Confirm the objectives of the Community Stakeholders Committee Integrated Resource Management Strategy 1995:

a) Maximize reduction, reuse and recycling of waste resources;
b) Maximize environmental and fiscal sustainability of the waste program;
c) Foster public stewardship and conservation.

Direct staff to initiate development of a business case for the source separated organics program to introduce an Anaerobic Digestion processing capability and other program changes to improve system cost performance and compost quality and return to Regional Council with a revised plan by 30 June, 2014;

Direct staff to site a second household special handling waste depot and introduce annual district mobile household special handling waste events;

Direct staff to increase:

a) curb-side education and monitoring;
b) apartment tenant education and monitoring; and,
c) ICI load monitoring and inspections at the landfill;

COUNCIL DIRECTION – DECEMBER 9, 2014

Direct staff to defer any action with respect to the siting of a new landfill site in order to assess the implications of system changes currently being implemented and direct staff to increase the vertical height of existing and future cells in accordance with the approach as set out in the report of Conestoga – Rovers & Associates dated October 8, 2014, subject to maintaining the visible isolation of the cells as outlined by the SNC Lavalin Environment balloon study findings with notice to the Chair of the Community Monitoring Committee in accordance with Section 6.05 of the Agreement for Community Monitoring of Solid Waste Facilities dated February 16, 1999 once an updated design and operations plan has been prepared.

Direct staff to take the necessary steps to maintain the current operating model, including front end processor facility, waste stabilization facility and residual disposal facility other than as directed by Regional Council as a consequence of decisions arising out of the ISWMS Review –Final Report dated January 8, 2014 at the Otter Lake Landfill site. Further, to assess the effects of the system changes currently being implemented, returning to Regional Council, with input from the Community Monitoring Committee, no earlier than March, 2019 with a report and recommendation respecting the effectiveness of the front end processor facility and waste stabilization facilities based on system and other changes since conception including diversion outcomes resulting from the changes currently being implemented.

COUNCIL DIRECTION – JANUARY 13, 2015

Adopted By-law S-608, amending By-law S-600, the Solid Waste Resource Collection and Disposal By-law.

a) removing boxboard as a mandated green bin product (while still permitted as a kitchen scrap material catcher);
b) mandating use of kraft paper bags for separate collection of leaf and yard waste;
c) banning grass clippings from collection;
d) mandate clear bags (with one privacy bag) for residential collections;

e) not reduce garbage bag limits from 6 to 4;

COUNCIL DIRECTION – FEBRUARY 3, 2015

Adopted By-law S-609, amending By-law S-600, the Solid Waste Resource Collection and Disposal By-law, to allow for the export of ICI residual waste (garbage) outside HRM.

Regional Council through their policy direction as outlined above have instructed staff to initiate programs to achieve their goals. Staff are focused on these efforts and do not have the available resources or technical expertise to analyze energy from waste technologies at this time. This work will require specific skill sets and industry knowledge resulting in the need to procure an external consultant. Conestoga-Rovers and Associates, Solid Waste's external Owners Engineer, estimated a cost of $250,000 for a comprehensive industry review of energy from waste alternatives. Individual proposal/business case reviews are estimated to be $10,000 each and would depend on the complexity of the technology being proposed. Funding is not budgeted in 2015/16 for this work. If an RFP for consulting work was to be issued CRA would be engaged throughout the process and additional funding would be required for this initiative.

There have been six unsolicited proposal presentations received by ESSC from individuals and/or companies. These proposals were submitted by Nova Renew, TBL/XT Energy Group, Plasco Energy Group Inc., Fourth State Energy/Nova Waste Solutions, Sustane Technologies Inc. and Eco Resource Management/Minas Basin Pulp & Power. The technologies promoted by these businesses consisted of Polymerization, Pyrolysis, Gasification, and Plasma Arc Gasification with the input feedstock being municipal solid waste, bulky furniture, plastics, and organics. As a means to promote their technology vendors have supplied indicative figures, estimates and assertions regarding the benefits of their technology. Staff cannot use these figures as the basis to develop a business case. To ensure due diligence and fiduciary responsibilities are upheld, staff can only assess the merits of a proponent through proper procurement submissions where a contractor is bound to the terms and conditions in their proposal submitted to the Municipality.

In 2013, a comprehensive review of HRM's Solid Waste Resource Management system was completed by Stantec Engineering. It included a review of energy from waste technology (EFW) options. This was included in Section 9, titled "*Review of Energy From Waste Opportunities*". A summary of the technologies reviewed, associated input feedstocks, outputs and costs are provided below:

Table 1 – Thermal Technologies

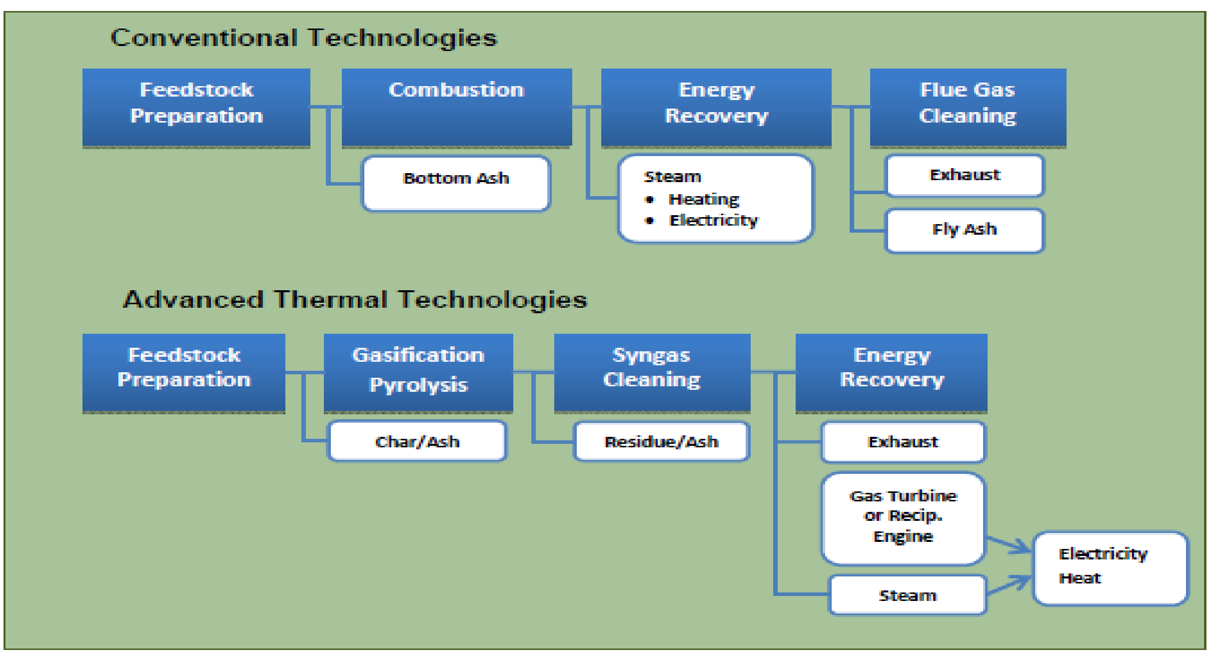
Technologies	Input Feedstock	Output	Costs
Combustion	Mixed Solid Waste (MSW)	Electricity	Median Capital: $775/Tonne +/-50% Operating $65/Tonne+/-30%
Mass burn (combustion) technology is well established, traditional and proven technology.			
Gasification	MSW Organics Plastics Biomass	Electricity Syngas	Median Capital: $850/Tonne +/- 40% Operating: $65/Tonne+/- 45%
Gasification has only recently been used for MSW and most require pre-processing of feedstock.			
Pyrolysis	MSW Plastics Biomass	Electricity Syngas as fuel	No reliable data for capital or operating costs
Pyrolysis technology has challenges with taking receipt of heterogeneous waste streams and experiences low energy outputs.			

Plasma Arc Gasification	MSW Organics Hazardous Waste	Electricity Syngas	Median Capital: $1,300/Tonne +/- 40% Operating: $120/Tonne+/-50%
Plasma Arc gasification required pre-processing of waste and consumes more energy to operate than other facilities			
Otter Lake Landfill	MSW	N/A	Estimated Capital:$290/Tonne +/- 10% Average Operating: $100/Tonne+/-20%
Landfill option assumes closure capital costs at Otter Lake for 15 years. With vertical expansion new cells are not required. The operating costs have historically been in the $80-$110 per tonne range and are anticipated to be reduced through approved Council policies and subsequent contract negotiations. Based on the 2015/16 budget, operating costs could be lowered by $60/tonne if the FEP/WSF discontinued operations. The FEP/WSF diverted only 241 tonnes of recyclables in 2014/15 and 273 tonnes in 2013/14 (0.2% diversion). This equates to a cost of approximately $32,000 per tonne for recyclables diverted through the FEP/WSF 2015/16.			

All of these options except for landfilling process waste through a form of thermal technology (Diagram 1). Examples of jurisdictions where of each of these technologies are in use is included in the Stantec report. As outlined in the below diagram residuals remain after thermal waste treatment. These residuals are required to be managed and will for the most part be disposed of in a landfill.

According to the Stantec report over 90% of EFW facilities in Europe utilize mass burn incineration technology. In Canada there are currently seven operational conventional combustion incinerators that treat municipal solid waste. The first industrial scale waste to biofuels facility in the world which turns municipal solid waste into biofuels and biochemical is operating in Edmonton. The $140 million facility has started to produce syngas and its methanol production system is 95% commissioned. Work is still required to convert the methanol to ethanol. This project is considered emerging, transitioning to proven.

Diagram 1 – Thermal Technologies



Source – Waste to Energy Background Paper, Yukon Energy

The Stantec report recommended that Halifax's first priority be directed to look at improving current facilities and operations and that energy from waste be considered a mid to long term waste management alternative.

Stantec Report 9.7 RECOMMENDED FUTURE DIRECTION

EFW is considered as a mid to long-term waste management alternative for HRM to be considered in more detail in the 5-10 year range after local efforts to improve current facilities and operations are well under way. Aside from mass burn incineration, few EFW facilities are fully operational on a commercial scale in North America. Gasification of waste and several other technologies hold promise, but in the context of priority setting at HRM, Stantec recommends that HRM address clearly identified opportunities for improvement first, before staff and financial resources are expended on what is considered a mid to long term alternative. The next five year period will be very challenging for HRM as a major infrastructure renewal program will be underway for waste management facilities. Operational changes will also consume resources. As previously discussed EFW does hold some promise, but with considerable landfill capacity available, HRM has no immediate need to pursue implementation of EFW technologies.

The Stantec report was peer reviewed by SNC Lavalin and their additional assessment is outlined below.

SNC Lavalin 11.7.3. COMMENT ON STANTEC REPORT 9.7 RECOMMENDED FUTURE DIRECTION

If the HRM system operates well, and diversion can be enhanced in future, the only reason to consider EFW would be to reduce landfilling requirements.

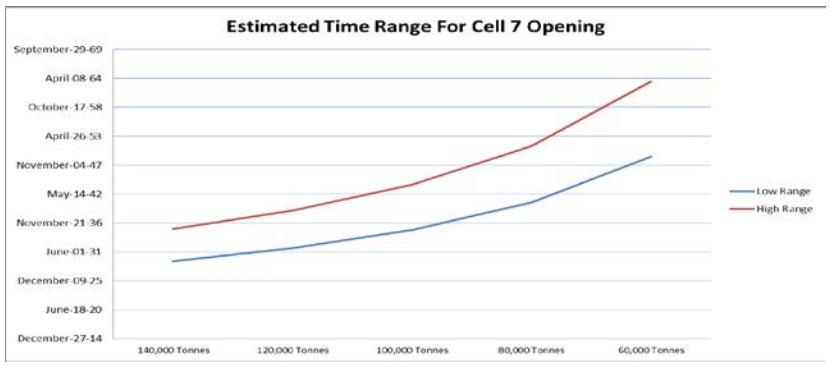
The City of Ottawa through HDR Inc. completed a more recent overview of waste technologies. The December 18, 2014 memo titled "Summary of Waste Technologies and Approaches" is attached to this report with approval from the City of Ottawa (Attachment A). Outlined in this memo are the technologies mentioned above: Pyrolysis, Gasification, and Plasma Arc Gasification. Although some of these technologies have been proven for specific homogeneous biomass none are defined as proven for municipal solid waste. Gasification and Plasma Arc Gasification are described as emerging with a cost estimate of $175 - $200 per tonne depending on facility size and negotiated rate for energy sales. Pyrolysis is defined as being in its demonstration phase with an estimated cost per tonne of $190 - $200 depending on facility size and negotiated rate for energy sales. The estimates are higher than the current cost per tonne for Halifax. Finally the only two proven waste disposal technologies identified by HDR Inc. are Mass Incineration and Landfilling.

DISCUSSION

Halifax Solid Waste staff are currently implementing a number of policy directives recently approved by Regional Council; vertical expansion, clear bags, and removal of flow control among others. Vertical expansion will maximize the current landfill asset and reduce the need for the construction of new cells at the Otter Lake site. Clear bags are anticipated to increase participation in source separation and reduce the total amount of waste landfilled each year. In addition the removal of flow control on ICI waste will reduce the annual tonnage delivered to Otter Lake as the ICI sector can deliver its waste to more convenient and cost competitive landfills. These initiatives are anticipated to decrease the total financial burden of the integrated solid waste management system.

Through vertical expansion and the removal of flow control the capacity and useful life at the Otter Lake landfill will be extended. Within the existing 6 cell footprint and with current annual tonnage rates a new cell will not be needed until between 2029 and 2035. If the site was to receive only residential waste a new cell will be needed until between 2049 and 2063. Figures are subject to change based on the final slope design (Chart 1). Solid Waste staff are currently working with the landfill operator to formalize a final work plan for vertical expansion where the lifespan and future costs can better defined. By removing the capital intensive requirement to build cells ($21.5 million estimated for Cell 7) the business case for alternate technologies and their advertised savings may not be as robust as promoted by the vendors. If for some unforeseen circumstance vertical expansion is not approved by the Province, energy from waste will not be a viable solution for waste disposal when Cell 6 is full in 2016.

Chart 1 – Estimated Time Range for Cell 7 Opening



With Council's recent decision to remove flow controls on the ICI sector there has been a shift in the Halifax waste industry and overall market conditions for Nova Scotia. Haulers of ICI waste now have the ability to send waste to other disposal sites within Nova Scotia. Energy from waste companies can now approach ICI haulers to secure feedstock for their operations and also provide an alternate disposal method for the waste. With haulers striving to secure low cost disposal sites and with approximately 80,000 tonnes of ICI garbage generated in Halifax, waste from energy technologies will have to be competitive in the open market to ensure they have appropriate levels of feedstock. In Halifax there are 3 large hauling companies that collect approximately 90% - 95% of the entire ICI sectors garbage. Energy from waste companies can initiate the development of their technologies and secure a large supply of feedstock from the private sector. In comparison to the ICI waste there is approximately 60,000 tonnes of garbage generated within the residential sector in Halifax. Overall, Nova Scotia generates approximately 148,000 tonnes of ICI waste and 136,000 tonnes of residential waste. If energy from waste technologies can provide a lower tip fee than the market currently offers there is a substantial supply of garbage available in the Province to provide proof of concept prior to Halifax being an early adopter and investing in an alternative waste disposal options.

In addition to the policy direction provided to staff by Regional Council ultimately reducing Otter Lake capital costs, Council approved staff to retain an Owner's Engineer. Solid Waste's Owner's Engineer, Conestoga-Rovers & Associates (CRA) commenced oversight and compliance work on the Otter Lake site in February 2015. In line with the Stantec recommendations on improving system performance CRA has been tasked to review and complete time in motion studies at the Front End Processor & Waste Stabilization Facility (FEP/WSF). These reviews will provide Solid Waste staff with detailed information and recommendations around generating operating efficiencies and cost reductions at the most expensive item in the entire solid waste processing system. With the FEP/WSF costing $8,160,000 of the $15,100,000 landfill operating budget (Table 2) it is the most appropriate place to start looking for cost reductions through process improvements and efficiency gains. Through this review and the impact of waste export the annual operating costs will be reduced from their current levels.

Table 2 – Operating Costs at Otter Lake

Contract Costs for Otter Lake	**15/16**
FEP/WSF	$ 8,160,000
RDF/Gas Control	$ 3,470,000
Admin/Depreciation/Fuel/Insurance	$ 2,440,000
Leachate	$ 1,030,000
Total Cost	**$ 15,100,000**

For all energy from waste processes, the Province (Nova Scotia Environment) requires the operator to hold a Municipal Waste Approval for processing municipal solid waste. In accordance with current Provincial Solid Waste Regulations, all waste processing technology options are considered disposal and not diversion. As such a move to energy from waste for some materials could, based on current regulations, increase the per capita disposal rate. This would be contrary to the Environment Goals and Sustainable Prosperity Act (EGSPA) target of 300kg's disposal per person and Council's January 14, 2014 direction. Additionally there could be a negative impact on Halifax's required diversion rate of 50% if energy from waste is implemented.

Energy from waste is not clearly defined or outlined within the regulations except for incineration. Incineration is defined by the regulation as "a facility designed or used for the primary purpose of destruction of municipal solid waste by combustion". It is unclear if combustion refers to the wide range of technological processes as outlined in the above table 1 such as pyrolysis, and gasification. Currently all items on the landfill banned material list are also banned for incineration. There are a number of energy from waste technologies which require materials that are on the banned list as feed stock, for example plastics. If plastics are converted into energy its weight is now considered to be disposed, not recycled. This would negatively impact Halifax's diversion rate. Even with the implementation of alternative technologies there will still be a requirement to landfill some material. Residual materials that remain at the end of the process, or materials that are unable to be processed by a particular technology such as fly ash, char, or slags must be managed.

The Province is in the process of a regulatory review for solid waste management. It is unknown at this time if there will be amendments to current regulations allowing for the possible benefits of alternative technologies for municipal solid waste to be realized. In March 2015 the Province released the "What We Heard" document which outlines the feedback received during the Solid Waste Regulation Public Discussion. The feedback on waste to energy ranged from "energy from waste destroys resources and should not be acceptable in Nova Scotia" to "energy from waste should be considered only after determining there is a reasonable cost for the process and that it is technically sound". It is uncertain if regulations will be changed as energy from waste regulatory amendments are not listed within the next steps outlined in the report. This has created an unknown regulatory environment for all stakeholders both in the private and public sector. Without understanding the direction the Province will take on this file there is increased risk in moving forward with energy from waste at this time.

Energy from waste project's sell energy such as syngas, fuel or electricity to an end market. The sale of energy generates revenue which offsets capital and operating costs at the facility thus reducing the cost per tonne. In Nova Scotia the Community Feed-in Tariff (COMFIT) program enables the selling of energy to the grid. Agreements can also be made directly with Nova Scotia Power on the sale of electricity, but the rates may not be as favorable as COMFIT which was 17.5 cents per kilowatt hour for combined heat and power biomas (CHP) generation. On January 15, 2015, the Minister of Energy announced that the COMFIT program will be on 'pause'. This pause is intended to provide the Department of Energy the time to evaluate the COMFIT program to ensure it continues to contribute to the province's future energy needs. It is unknown if and when the program will be revisited and an update is planned for the fall of

2015. With the selling price of energy unknown it will impact the net cost and ultimately the cost per tonne provided by an energy from waste supplier. That said, there are measures that can be put in place within a contract where municipalities can be provided lower cost per tonne fees if energy sales revenue increase.

The Environment & Sustainability Standing Committee, requested a staff report analysing the business case of unsolicited energy from waste proposals. The staffing capacity and expertise to review all unsolicited proposals does not currently exist within the organization. Solid Waste staff can financially assess the stated capital costs as well as the proposed cost per tonne and compare this information to the present integrated solid waste management system. Staff can also complete environmental scans to determine where the technology is employed. The current limitation within the department is that staff do not have the specific technical expertise required to analyze all the technology proposals to determine if the stated benefits are in fact true and will come to fruition in a commercial sized operation. In addition there are a number of energy from waste technologies/companies in the market that have not presented to ESSC. Limiting the review to unsolicited proposals will not provide the depth and breadth required to make informed decisions to proceed with an alternate technology.

Further research and analysis is required to review energy from waste technologies proposals and the market in general. After all technologies are examined, industry leading practices can be presented to ESSC and Council for consideration in moving forward. If a specific technology is chosen based on a proven ability to meet requirements, a request for proposal (RFP), request for information (RFI) or tender could then be developed and placed in the market. This would allow all proponents in that technology category to have a level playing field to bid on the project or bid for the acquisition of Halifax residential feedstock if energy from waste was to be considered an option in the future. Without fully understanding the Province of Nova Scotia’s direction on energy from waste initiating this project is premature.

FINANCIAL IMPLICATIONS

There are no financial implications with this report.

COMMUNITY ENGAGEMENT

All presentations have come through ESSC which includes provision for public engagement.

ATTACHMENTS

Attachment A – 2014 City of Ottawa Memo “Summary of Waste Technologies and Approaches”

A copy of this report can be obtained online at http://www.halifax.ca/commcoun/index.php then choose the appropriate Community Council and meeting date, or by contacting the Office of the Municipal Clerk at 902.490.4210, or Fax 902.490.4208.

Report Prepared by: Matt Keliher, Manager, Solid Waste Resources 902.490.6606

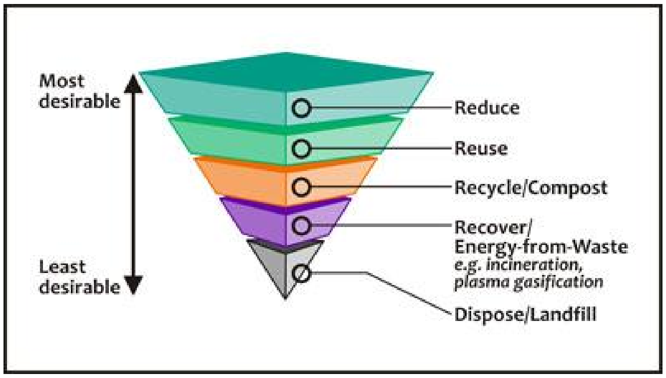
Memo

Date:	Thursday, December 18, 2014
To:	City of Ottawa, Attention: Lyndell Coates
From:	Janine Ralph, HDR
Subject:	Summary of Waste Technologies and Approaches (Updated)

Introduction

This memorandum is intended to provide a brief summary of the current range of best practices and recent advances in waste management technologies/approaches that are applicable to the waste hierarchy (waste reduction, reuse, recycling, organics processing, recovery and landfill disposal).

The following figure illustrates the waste hierarchy adopted by the City of Ottawa in the Ottawa Waste Plan, Phase 2, Discussion Paper.



Municipal waste management is an area of relatively rapid change with many new advances in technologies and waste management approaches in traditional areas such as recycling and in new areas such as recovery of energy. Some advances have been driven or encouraged by regulatory changes (such as potential changes to the Waste Diversion Act) and others by municipalities embracing a stronger role in environmental stewardship including reductions in greenhouse gas emissions.

This memo reviews, at a relatively high level the most significant advances in each area of the waste hierarchy. Emerging technologies are those where some progress has been made at either a pilot or small scale for processing materials from the solid waste stream. Proven technologies are those that are either currently being provided at a commercial scale or that are expected to reach commercial scale in the very near future.

Waste Reduction (New Approaches and Technologies)

Waste Reduction	
Approach	Avoidance of generating waste and/or use of on-site management approaches so that waste does not enter the municipal waste management system. Examples of successful approaches include backyard composting and grass-cycling. The outcome of successful waste reduction results in a decrease in the per capita waste generation rate.
Description of Approach	Municipal best practices in waste reduction often focus providing the tools and information that residents can use to avoid generating waste and vary based on the specific target material. Public education programs developed by municipalities can assist by targeting specific behaviour, for example, identifying and supporting alternatives to use of single use bottled water. Municipal campaigns targeting food waste avoidance, promoting use of on-site composting and techniques such as grass-cycling are intended to provide residents with the tools and encouragement to avoid generating organic waste. New devices have been developed to allow for on-site composting of food wastes that could benefit higher generating locations like institutional kitchens. Municipal advocacy efforts, linked with new campaigns developed by industry are advancing Extended Producer Responsibility efforts, often targeting specific material streams. The goal of Extended Producer Responsibility is to decrease the total environmental impact of a product, by making the manufacturer of the product responsible for the entire life-cycle of the product. Extended Producer Responsibility encourages waste reduction by industry, as this is the easiest means for industry to decrease environmental impacts. For example, many municipalities are working with PAC Next (a sub-organization of the Packaging Association of Canada) to develop commitments to reduce the environmental footprint of packaging. The City of Ottawa's Take it Back! program facilitates Extended Producer Responsibility by encouraging retailers to manage end-of-life products and packaging. Further advances in Extended Producer Responsibility are expected as a result of the proposed changes to the Waste Diversion Act, which would shift focus and become the Waste Reduction Act. The proposed changes to the act are expected to build on the product stewardship programs that are currently in effect for Municipal Hazardous or

Waste Reduction	
	Special Waste (MHSW), Waste Electrical and Electronic Equipment (WEEE), used tires and Blue Box recyclables. The proposed change to the Waste Reduction Act will require greater producer funding for the Blue Box program and will make individual producers more responsible for the end-of-life management of their products and packaging, which is expected to result in increased waste reduction and diversion. The Waste Reduction Act (Bill 91) was introduced for first reading in the Ontario Legislature in June, 2013. The Bill was based on the principle of full extended producer responsibility (Extended Producer Responsibility); potentially resulting in stewards of printed paper and packaging paying 100% of the Blue Box system. The Bill failed on the order paper with the calling of a provincial election in May, 2014. There has been no clarity in regards to implementation of the Waste Reduction Act as of the end of 2014.
Target Material	Components of the municipal solid waste stream that could be avoided or where the amount consumed could be reduced.
Environmental Benefit	Waste reduction provides the greatest environmental benefit, avoiding the consumption of resources, reducing Greenhouse Gas emissions and decreasing the amount of waste generated that then would have to be managed (either diverted or disposed) by the municipal waste system.

Reuse (New Approaches)

Reuse	
Approach	Reuse and repair of items so that they can be used again by the same or a different user, so that these materials would be delayed from entering the waste stream. The outcome of successful reuse approaches results in a decrease in the total solid waste managed by municipalities.
Description of Approach	Municipal reuse and repair initiatives usually focus on education and training, sharing techniques and creating reuse opportunities through specific programs and/or policies. Advances in reuse implemented in some municipal programs include: art exchange centres to redistribute materials suitable for institutional programs; giveaway events; textile collection programs; tool share programs; toy share programs; educational campaigns and internal municipal reuse policies as part of Municipal procurement. Reuse is a component of Ottawa's successful Take it Back! program, which identifies a range of partners (retailers and service providers) that are able to repair or find a new life for various durable goods such as appliances and furniture.
Target Material	Portions of the municipal solid waste stream - usually durable goods like clothing, furniture, tools, or materials that can be repurposed.
Environmental Benefit	Reuse provides the second highest environmental benefit in the waste hierarchy. It delays/reduces the consumption of resources required to generate new products, reducing Greenhouse Gas emissions and decreasing the amount of waste that would have to be managed (either diverted or disposed) by the municipal waste system.

Recycling

Source Separated Technologies	
Technology type(s)	The use of processing equipment and labour to sort a feedstock (blue and black box materials, mixed waste) and remove recyclable items for market.
Availability	**Status: Proven** Processing of source separated recyclables is the most common approach to managing recyclables across North America, with hundreds of operating facilities processing either a single stream or separated streams of recyclables. The majority of programs in Ontario either collect single streams of recyclables (e.g. Toronto), or dual streams (all paper materials, all containers) such as Ottawa.
Products	Source Separated Recyclables (single or dual stream): market grades of paper (various grades and types), cardboard, paperboard, plastic (various grades and types), metal and glass.
Description of Approach / Technology	Recycling facilities use a combination of equipment and labour to sort materials. Advances in recycling have involved the development of new equipment capable of more efficient and effective sorting such as: optical sorting devices that can recognize and separate a range of plastic and paper materials; new paper screens that allow for better separation of various streams of paper and cardboard, perforators and screens to allow for better separation of containers, bag breakers and film plastic vacuum systems to manage bagged materials. These advances have made single stream recycling more viable.
Technology Vendors	There are many vendors of recycling equipment (e.g. Bollegraaf, Universal Handling Equipment, Machinex, IPS).
Target Material / Feedstock	Blue box (and black box) Recyclables, Municipal solid waste.
Range of Costs	Recycling: The net cost of the Blue Box program in Ontario for large urban and urban regional municipalities (Waste Diversion Ontario 2013 datacall)[1], including collection and processing (less revenue) ranged from $155 to $312 per tonne marketed, with Ottawa reporting

[1] Waste Diversion Ontario, 2013 Financial Datacall

Source Separated Technologies	
	the lowest reported net cost at $155 per tonne.
Environmental Impacts/Benefits	Impacts: Minimal Benefits: A number of environmental benefits, particularly when compared with the extraction of virgin resources. For example, every tonne of paper made from recycled paper conserves about 26,000 litres of water, 2.5 cubic meters of landfill space, and reduces energy consumption and greenhouse gas emissions by 1 tonne of CO_2 equivalent[2].

[2] [2] http://www.epa.gov/osw/conserve/materials/paper/basics/index.htm

Material Handling	
Technology type(s)	These are new technologies which address the handling of materials from the point of generation in a more automated fashion as an alternative to traditional curbside collection (blue box or automated cart). It incudes the use of coloured bags with optical sorting and automated vacuum collection.
Availability	**Status: Proven** The Optibag system is being used in many Scandinavian cities and others elsewhere in Europe. Anywhere from 2 to 6 streams are collected. Oslo, Norway implemented this system in 2011 and has 2 Optibag plants. Stockholm piloted the program in 2012 and is expected to proceed with a rollout with a fully operational optical sorting plant in 2018. The Envac system is being used in Europe, Asia, the Middle East, the United States (Disney World) and Canada. Four automated vacuum waste collection systems were installed in Stockholm, Sweden which collects 3 waste streams. A similar system is used in Wembley City, London, England. The first Envac systems in North America are being installed in Montreal in the Quartiers des Spectacles and in a new development in Quebec City. This system is best suited to new developments (especially multi-residential buildings) with coordinated installation with other infrastructure.
Products	Separate streams of garbage, organics, recyclables (can be configured to individual requirements).
Description of Approach / Technology	Optibag system - Residents sort their waste into different coloured bags (green bags for food waste, blue for plastics, yellow for paper etc.) and then put the bags either down a chute or in a bin. The bags are transported to an optical sorting plant where they are separated into different containers according to colour. The system is compatible with existing waste collection trucks, bins, containers, vacuum waste and underground containers. Bags of recyclables can be processed at any single stream material recovery facility. Automated vacuum collection can also be utilized with this system or as stand alone systems to manage waste. Envac System – Bags are placed into inlets, either indoors or outdoors, a network of underground pipes transport the waste to a

Material Handling	
	collection station, into a compressor and fed into a sealed container. All streams are transported separately.
Technology Vendors	Envac, Optibag
Target Material / Feedstock	Garbage, Food, Paper, Mixed waste, Recyclables, Cardboard, can also be used for textiles, small electronics etc.
Range of Costs	Not available. Would depend on length and type of installation. Montreal's system is reported to cost $8.2 million serving an area of one square kilometer.
Environmental Impacts/Benefits	Impacts: Minimal once installed, high upfront installation costs but lower operating and maintenance costs Benefits: depending on the system it can reduce traffic from collection vehicles, provide greater convenience for residents, increases diversion, can be used with existing processing infrastructure, Vacuum collection has hermetically sealed inlets do not attract pests or insects or release odours, and can avoid onsite placement of waste bins.

Mixed Waste Processing Technologies

Mixed Waste Processing Technologies	
Technology type(s)	The use of processing equipment and labour to sort mixed waste to remove recyclable items for market and possibly recover organic material for processing, resulting in a residual waste stream that could be further processed into a refuse-derived fuel or landfilled.
Availability	**Status: Proven** Mixed waste processing facilities are becoming more common in North America; there are several operating mixed waste processing plants in Korea, Spain, Eastern Europe and the United Kingdom. The City of Edmonton has an integrated processing and transfer facility that sorts residential and suitable industrial, commercial and institutional waste into three streams; recycling, organic materials and non-recyclable/non-compostable material which is made into refuse derived fuel The City does not have a green bin program; instead the garbage stream is processed at a co-composting facility which handles 180,000 tonnes of residential waste and 22,500 tonnes of biosolids annually. Non-recyclable and non-compostable waste is made into refuse derived fuel for the waste-to-biofuels facility (Enerkem). A mechanical-biological treatment facility in Lawrenceville, Virginia was designed to process 20 tons per day of municipal solid waste and is being expanded to 300 tons per day (anticipated to be online mid-2015). This facility uses the Fiberight process (also described below). In 2008, the Dongara Pellet Plant, located in Vaughan commenced operations, processing municipal solid waste, primarily from York Region, and creating fuel pellets. At the time, it was one of the first of such plants in North America. The plant experienced operational issues with delivery of materials such as mattresses, tires and waste electronics in the waste stream. The process was more expensive than landfill and the facility was forced to drop its rates to be competitive. Financial and operational issues combined with the inability of the fuel pellets to be sold in Ontario forced the closure o f the facility in 2014.

Mixed Waste Processing Technologies	
	Two new state-of-the-art facilities have opened in 2014; one in Sun Valley, California, processing 1,500 tons of waste daily, including municipal solid waste; and, another in Montgomery, Alabama, processing 1,000 tons of waste daily. The facilities were designed, engineered, manufactured and installed by Bulk Handling Systems (BHS) and utilize BHS Screens, air and optical sorting technologies.
Products	Mixed Waste Processing: various recyclable streams; organics for processing; refuse derived fuel.
Description of Approach / Technology	Mixed waste facilities use a combination of mechanical and biological processes to sort and process the various waste streams. A more commonly known form of mixed waste processing is mechanical-biological treatment. Mixed waste facilities utilize advanced sorting equipment (e.g. optical sorters, paper screens, perforators and screens, bag breakers and film plastic vacuum systems to managed bagged materials) which improves the recovery rate of material from mixed waste processing facilities. Some facilities utilize a "wet material recovery facility" to recover and wash the recyclables. Organics are typically screened out of the remaining waste stream and can be further processed in aerobic or anaerobic systems. The remaining material may undergo further processing (e.g. screening to remove larger items (stones, non-ferrous items, large organics) and shredding) to create a refuse derived fuel. This step depends on the system configuration and suitable local markets. Refuse derived fuel may be used as alternative fuels (e.g. in cement kilns). Alternatively, the residual material may simply be landfilled.
Technology Vendors	Vendors/system designers for mixed waste processing facilities in North America include: Energy Answers; RRT; Westroc Energy; Ambient Eco Group; Cobb Creations; Fiberight, Vecoplan; BHS (Bulk Handling Systems); Komptech
Target Material / Feedstock	Recyclables, municipal solid waste, material recovery facility residue, construction and demolition waste and residue, tires.
Range of Costs	Mixed Waste Processing: Net costs depend on the market for the recovered materials, including refuse derived fuel. Reported net

Mixed Waste Processing Technologies	
	costs are in the range of $140 to $150 per tonne.[3]
Environmental Impacts/Benefits	Impacts: Minimal Benefits: A number of environmental benefits, particularly when compared with the extraction of virgin resources. For example, every tonne of paper made from recycled paper conserves about 26,000 litres of water, 2.5 cubic meters of landfill space, and reduces energy consumption and greenhouse gas emissions by 1 tonne of CO_2 equivalent[4].

[3] Peel Long Term Waste Disposal Study Report
[4] [4] http://www.epa.gov/osw/conserve/materials/paper/basics/index.htm

Organics Diversion Technologies

Organics Preprocessing	
Technology type(s)	Organic Extrusion Press (OREX).
Availability	**Status: Proven** Used as part of a 'dirty' materials recycling facility with rated capacity of 50,000 tonnes per year at the Vereco project in Latvia. Also used at a 40,000 tonnes per year plant in Kaiserslautern, Germany to process municipal solid waste and a 50,000 tonnes per year facility in Italy.
Products	Wet (organic) fraction and dry fraction containing recyclables and residual waste.
Description of Approach / Technology	The organic portion of municipal solid waste can be extracted using an extrusion-like process. Municipal solid waste is loaded into a chamber and compressed at high pressure. Wet organic waste is extracted through holes in the press leaving behind the dry fraction. The dry fraction can be sent for further processing to extract recyclables and the remainder used to derive a refuse derived fuel. The wet organic fraction can be used as a feedstock for anaerobic digestion or aerobic composting. Particularly suited for highly contaminated organic streams e.g. from commercial or multi-residential sectors.
Technology Vendors	Anaergia Inc., Intergeo
Target Material / Feedstock	Municipal solid waste, source separated organics
Range of Costs	Unavailable
Environmental Impacts/Benefits	Impacts: Odour must be managed using good operating practice and/or odour control technologies. Benefits: Diverts organics from landfill reducing Greenhouse Gas emissions and conserving landfill capacity, increased recyclable material recovery is possible with potential to generate refuse derived fuel from residual waste.

Organics Mechanical/Chemical Processing	
Technology type(s)	Mechanical Hydrolysis
Availability	**Status: Proven** Lystek produces a fertilizer product at its Southgate Organic Materials Recovery Centre in Dundalk, Ontario which is has been designed to be capable of processing 150,000 tonnes of organic materials/biosolids annually (excluding municipal source separated organics streams). Alternatively, the end product can be used in digesters to enhance gas yields. In the first 18 months of operation of the facility, 60,000 tonnes of organic materials were processed. The N-Viro process is used at a facility in Banff which processes biosolids and food scraps along with an alkaline source to produce a fertilizer product. The facility was commissioned in 2013, and was reported to be running at 55 percent capacity as of November 2014.
Products	Fertilizer product which can be used as a soil amendment or in anaerobic digestion systems. Both Lystek and N-Viro systems produce products that are registered as fertilizers under the *Fertilizers Act* by the Canadian Food Inspection Agency.
Description of Approach / Technology	The organic waste fraction is processed using high speed shearing, steam and alkali resulting in a high solids liquid “fertilizer” product. This process is typically utilized to process biosolids in conjunction with waste water treatment plants, but can also process organics.
Technology Vendors	Lystek, N-Viro
Target Material / Feedstock	Source separated organics, biosolids
Range of Costs	Total costs for installation and operation of these systems are unavailable. The Banff N-Viro facility has been reported to have a budget for installation of $1.576 million[5].
Environmental Impacts/Benefits	Impacts: Odour must be managed using good operating practice and/or odour control technologies.

[5] Town of Banff website, Major Projects

Organics Preprocessing	
	Benefits: Diverts organics from landfill, reducing Greenhouse Gas emissions, produces a fertilizer product, can be used in conjunction with biosolids processing to increase quantities of biogas produced.

Biological Processing (macro-organisms)	
Technology type(s)	Biological processing
Availability	**Status: Emerging** Enterra Feed Corporation in Langley, British Columbia is utilizing black soldier fly larva which consume pre-consumer food waste as a feedstock; grubs are harvested, washed and cooked to create animal protein and oil products for aquaculture feed, animal feed and pet food. Fertilizer is created from the insect frass (droppings). A commercial pilot facility was launched in 2014, processing 36,000 tonnes of pre-consumer food waste. Enterra has approval in Oregon and Washington States to use the end product as a feed ingredient for aquaculture and poultry farming and is waiting for the same from the Canadian Food Inspection Agency. Smaller scale units are available for home or small commercial composting. Vermicomposting is based on a similar process using red wiggler worms; however, this process is predominantly home based; no evidence of currently operating commercial scale facilities can be found. The City of Winnipeg provided support (space and utilities) for a local pilot scale vermicomposting approach for commercial organic materials; however this facility is no longer in operation.
Products	Animal feed and fertilizer
Description of Approach / Technology	As in vermicomposting, black soldier fly larvae consume food waste. However, grubs are harvested and can be used as a) whole dried grubs as a feed supplement for birds, fish, poultry, amphibians and reptiles, b) made into a meal used for fish or poultry meal, exotic animal feeds and pet food and c) a natural oil used in feed pellets or as a nutritional coating. Frass from the larvae can be made into fertilizer.
Technology Vendors	Enterra Feed Corporation, BioPod, ProtaPod
Target Material / Feedstock	Food waste

Biological Processing (macro-organisms)	
Range of Costs	Unavailable
Environmental Impacts/Benefits	Impacts: Odour must be managed using good operating practice and/or odour control technologies. Benefits: sustainable, natural process and products. Utilizes wasted food and converts to sustainable feedstock.

Aerobic Composting	
Technology type(s)	Aerobic Composting includes a variety of technologies including covered forced aeration systems (e.g. covered windrows such as the Norterra facility using Gore covers or containers such as EcoPOD (Ag-Bag), in-vessel composting ranging from forced aerated systems without turning (e.g. compost tunnels such as Orgaworld) to aerated systems with turning (e.g. wide bed systems like the Durham Region compost facility, channel systems with automatic/mechanical turners such as the Lafleche Compost facility), and batch/modular systems such as Big Hanna/HotRot.
Availability	**Status: Proven** Composting is widely used on a commercial scale for processing municipal, industrial and agricultural organic materials. Municipal organics programs generally process residential leaf and yard waste and organics generated in the home (food waste, compostable paper fibre) for composting, with over 90% of the source separated (green bin) organics in Ontario being composted. Composting may also be used for the organic stream remaining from mixed waste processing (e.g. Halifax) to either stabilize this material prior to landfill disposal and/or to prepare a drier refuse derived fuel.
Products	Composting usually produces an organic soil conditioner (compost), with a value that varies depending on quality.
Description of Approach / Technology	Composting biologically converts the organic fraction of waste using micro organisms that require oxygen. Composting systems balance the moisture content and oxygen levels to provide optimal conditions using a variety of equipment and techniques. The simplest approach is outdoor ‘turned’ windrow typically used to process leaf and yard waste (e.g. Ottawa’s Trail Road composting area). Managing moisture and oxygen levels in organics materials that include food waste usually requires greater control through technologies that control air movement and potential odours, often under cover such as the Norterra facility in Kingston, or indoors such as the compost tunnels used at the Orgaworld facility in Ottawa.
Technology Vendors	Composting technology vendors/service providers include: Maple Reinders; Orgaworld; Ebara; W. L. Gore & Associates; IPS/Siemens, Christiaens Group, Herhof, Big Hanna, HotRot, Ag-Bag

Aerobic Composting	
	Environmental, ORCA, Advetec.
Target Material / Feedstock	Organic component of municipal solid waste, biosolids; agricultural wastes; animal manure; leaf and yard waste
Range of Costs	Composting: In-vessel systems cost range from $100 to $150 per tonne processed depending on incoming material quality. Lower costs in the range of $70 to $85 per tonne have been reported for some facilities.
Environmental Impacts/Benefits	Impacts: Odour must be managed using good operating practice and odour control technologies. Benefits: Diverts organics from landfill, reducing Greenhouse Gas emissions and recovering energy and materials.

Anaerobic Digestion	
Technology type(s)	Anaerobic Digestion: Wet (low- and high-solids); Dry (or dry fermentation)
Availability	**Status: Proven** Anaerobic digestion is widely used on a commercial-scale basis for industrial and agricultural wastes, as well as wastewater sludge. There are examples of anaerobic digestion technology being applied to processing mixed municipal solid waste in Europe. There have been only limited applications for processing the organic fraction of municipal solid waste in North America. Several wet anaerobic digestion technologies are particularly suited to highly contaminated source separated organics streams (e.g. BTA, FITEC). The City of Toronto has recently expanded their Green Bin processing capacity with a second anaerobic digestion facility constructed at Disco Road, capable of processing 75,000 tonnes of source separated organics annually using BTA technology. The City's original Dufferin BTA anaerobic digestion organics processing facility is currently offline and is being expanded to enable it to process 55,000 tonnes per year. This additional capacity is needed to process materials from the multi-residential sector. Zero Waste Energy Development Company has built a 90,000 tonnes per year dry fermentation anaerobic digestion system in San Jose to process commercial organics which opened in December 2013. Harvest Power operates an anaerobic digestion facility in London, Ontario that processes food scraps, grease and oil; predominantly from the industrial, commercial and institutional sector. No municipal green bin waste is processed at this facility. Harvest Power also operates other anaerobic digestion facilities in North America, including in Richmond British Columbia using high solids anaerobic digestion to process 40,000 tonnes per year of commercial and residential organic materials and in Orlando, Florida using low solids anaerobic digestion to process 130,000 tons per year of organic materials from commercial and tourism operations.
Products	Anaerobic digestion produces biogas which can be converted to electricity or cleaned and separated to convert it into compressed

Anaerobic Digestion	
	natural gas that can be used as transportation fuel or prepared to pipeline quality natural gas. Solid materials that remain after anaerobic digestion (digestate) can be converted to organic soil amendment, usually using a secondary composting step.
Description of Approach / Technology	Anaerobic digestion biologically converts the organic fraction of waste using bacteria in an oxygen-deficient environment to produce a combustible biogas composed primarily of methane (about 40-60% by volume). It has been extensively used to digest and stabilize sewage sludge and animal manures, and has had recent application treating source separated organics The anaerobic digestion process may either be a "wet" process that converts the feedstock into a liquid slurry, or a "dry" process (also referred to as dry fermentation) where the feedstock is managed in a stacked pile as a stationary solid. Typically, anaerobic digestion is a two-phase process in which the first phase blends into the second one without a noticeable interruption. These two phases are known as the "acid phase" and the "methane-producing phase" (methanogenic phase). The biogas produced can be cleaned and sold as a fuel, or it can be combusted to produce heat and electricity.
Technology Vendors	Anaerobic technology vendors/service providers include: Arrow Ecology; Urbaser (Valorga International); Mustang Renewable Power Ventures; Ecocorp; Organic Waste Systems (Dranco); BIOGEN/Greenfinch; BTA International GmbH, CCI BioEnergy Inc. (BTA Technology); Herhof GmbH; Veolia Water Solution & Technologies Canada (Kompogas); FITEC; Harvest Power
Target Material / Feedstock	Organic component of municipal solid waste, biosolids; agricultural wastes; animal manure; leaf and yard waste
Range of Costs	$100 to $120 per tonne processed, net of energy revenue (assuming preferential pricing for the electricity produced through combustion of biogas or for the sale of biogas itself).
Environmental Impacts/Benefits	Impacts: Odour must be managed using good operating practice and odour control technologies. Benefits: Diverts organics from landfill, reducing Greenhouse Gas emissions and recovering energy and materials.

Recovery (Energy and Fuels)

Direct Combustion (Mass Burn)	
Technology type(s)	Mass burn waterwall (excess air); Rotary waterwall (excess air); Modular mass burn (starved air); Refuse derived fuel combustion; Fluidized bed combustion
Availability	**Status: Proven** Mass Burn is used world-wide. There are over 500 operating facilities in Europe, over 80 operating facilities in the United States and 6 operating facilities in Canada (Algonquin Power Energy from Waste Facility –Brampton, Ontario; Metro Vancouver Waste to Energy Facility – Burnaby, British Columbia; Wainwright Energy From Waste Facility- Wainwright, Alberta; L'incinérateur de la Ville de Québec – Quebec City, Quebec; L'incinérateur de Lévis – Lévis, Quebec; PEI Energy Systems – Charlottetown, Prince Edward Island). Note: one older facility has recently closed. The new Durham/York Energy Centre in Durham Region is a mass burn facility; construction of this facility was completed in late 2014 and this facility was being commissioned as of December 2014.
Products	Electricity and/or Steam; Metals (ferrous, aluminum)
Description of Approach / Technology	Direct combustion (also referred to as waste-to-energy (WTE), Energy from Waste (EFW) and in some cases as Advanced Thermal Recycling (ATR)) is the complete oxidation of a fuel at high temperatures under controlled conditions yielding substantial net energy production. Temperatures in the combustion zone of the units are generally in the range of 800° to 1650°C. Actual temperatures depend upon the type of fuel used, stoichiometric conditions (i.e., ratio of air to fuel), heat losses, and design of the combustion unit. The direct combustion process results in the production of hot gases (CO_2, water vapor, and some products of incomplete combustion) from which heat is recovered and converted to steam, electricity, or both, and secondly, production of ash.
Technology Vendors	Martin GmbH; Von Roll Inova; Keppel Seghers; Steinmuller; Fisia Babcock; Volund; Takuma; Detroit Stoker; Enercon; Laurent Bouillet; Consutech; and Pioneer Plus.
Target Material /	Municipal solid waste. Minimal pre-processing is required.

Direct Combustion (Mass Burn)	
Feedstock	
Range of Costs	$140 to $150 per tonne (net of energy revenue) depending on facility size and negotiated rates for energy sales.
Environmental Impacts/Benefits	Emissions: Air pollution control systems are used to comply with emission requirements. Wastewater from heat recovery and air pollution control. Residues: Solid residue (up to 1/3 by weight and 10% by volume of incoming material) depending on the technology. Benefits: Recovers energy and metals, results in net Greenhouse Gas emission reductions compared to landfill disposal, reduces quantity of material disposed by 2/3 by weight.

Gasification	
Technology type(s)	Updraft fixed bed; Downdraft fixed bed; Bubbling fluidized bed; Circulating fluidized bed; Entrained flow
Availability	**Status:** **Emerging (for municipal solid waste)** Gasification has been used successfully for select feedstock (e.g. woody biomass). There has been mixed success using municipal solid waste, with several operating facilities in Japan and some planned pilot/demonstration facilities in North America. **Proven and Emerging for Biomass** Nexterra has developed biomass CHP (combined heat and power) systems at University of British Columbia, in the United Kingdom and United States using wood, clean construction and demolition debris and biosolids. Other feedstocks are under development. Woodland Biofuels uses gasification to convert biomass (wood waste, paper, municipal solid waste and agricultural waste) to ethanol; one demonstration facility is operating in Sarnia, Ontario. PKA has a number of facilities in Germany operating on a commercial scale using a variety of feedstock (municipal solid waste, commercial waste, biosolids). Taylor Biomass Energy is involved in the development of a large 21 megawatt biomass gasification plant in Montgomery New York using municipal solid waste and construction and demolition waste.
Products	Electricity and/or Heat; Metals (ferrous, aluminum); Ethanol/Biofuels (depending on process)
Description of Approach / Technology	Conventional gasification converts solid organic matter under controlled conditions of partial oxidation into fuel gases and other by-products. In addition to producing fuel gases for purposes of direct conversion into energy, the process can be used to produce chemicals such as methanol and liquid fuels. Partial oxidation is carried out by using less air than required for complete combustion of the fuel (i.e., sub-stoichiometric air), or by indirectly heating the organic matter. Heating temperatures range from 750° to 1650°C. The gas that is produced is known as syngas. Syngas consists primarily of carbon monoxide, hydrogen, methane, and other hydrocarbons, as well as CO_2 and N_2 in some gasification

Gasification	
	processes. The relative concentration of each gas depends upon the composition of the organic matter used and process operating conditions (temperature, pressure, etc.).
Technology Vendors	Thermoselect; Ebara; Taylor Biomass Energy; Technip; Ethos Energy; PKA; and New Planet Energy, Nexterra Systems Corp.
Target Material / Feedstock	Pre-processing is required to prepare a homogenous feedstock (refuse derived fuel) from municipal solid waste.
Range of Costs	$175 to $190 per tonne depending on facility size and negotiated rate for energy sales.
Environmental Impacts/Benefits	Emissions: Air pollution control systems and/or syngas clean-up are used to comply with air emission requirements. Wastewater from syngas clean-up and air pollution control. Residues: Solid residue (up to 1/3 by weight and 10% by volume of incoming material) depending on the technology. Benefits: Recovers energy and metals, results in net Greenhouse Gas emission reductions compared to landfill disposal, reduces quantity of material disposed by 2/3 by weight.

Plasma Arc Gasification	
Technology type(s)	Plasma gasification vitrification reactors (or PGVR); Plasco conversion system; Plasma converter system; Plasma enhanced melter.
Availability	**Status: Emerging (for municipal solid waste)** Plasma arc gasification has been used for years in the gasification of hazardous waste, auto shredder fluff, to heat steel melting furnaces, and to process other homogeneous wastes. To-date it has been applied to process municipal solid waste at a demonstration scale. Plasco has completed pilot and demonstration phases using this technology, and if the Plasco facility in Ottawa is expanded as planned it would be the first large commercial scale application of this technology in North America. Westinghouse Plasma Technology (Alter NRG) has been selected for a project in Nanjing China and is being used in projects under development/construction in the United Kingdom, China and Thailand as well as in commercial operating plants in China, India and Japan. InEnTec has a number of demonstration projects in the United States and Asia. INEOS New Planet BioEnergy is operating the Indian River County BioEnergy facility located in Florida. Although anticipated to utilize municipal solid waste, to-date this facility is only operating at minimal capacity. Several other facilities in Florida never got off the ground due to funding shortfalls and other technological concerns. Note: while there are reports of commercial scale facilities operating internationally, it has been difficult to verify the status of these facilities and also whether the feedstock for these facilities is or includes municipal solid waste.
Products	Electricity and/or Heat; Metals (ferrous, aluminum); Ethanol/Biofuels (depending on process), slag
Description of Approach / Technology	Plasma gasification uses an electrical arc to generate extremely high temperatures (5000° to 10,000°C) that gasify incoming wastes to create a very high temperature gas (or plasma) that is subsequently converted to heat and electrical energy using conventional energy conversion systems. The organic materials in the waste are broken down into syngas, while the inorganic materials form a slag or aggregate type of material. The syngas could be combusted and the heat recovered in a waste heat boiler. After clean-up and

Plasma Arc Gasification	
	conditioning, the syngas could potentially be combusted in an engine or gas turbine.
Technology Vendors	Westinghouse Plasma Corp (Alter NRG, Navitus Plasma Inc.); Plasco Energy Group; Pyrogenesis; Startech; Solena Q; InEnTech; AdaptiveArc; MPM Technologies/Carbon Cycle Investments
Target Material / Feedstock	Some pre-processing (removal of unacceptable materials, size reduction) is usually required to prepare a homogenous feedstock (refuse derived fuel) from municipal solid waste, although the degree of pre-processing varies depending on the technology.
Range of Costs	$190 to $200 per tonne depending on facility size and negotiated rate for energy sales. Pricing lower than this range has been identified in some jurisdictions (i.e. Ottawa).
Environmental Impacts/Benefits	Emissions: Air pollution control systems and/or syngas clean-up are used to comply with air emission requirements.Wastewater from syngas clean-up and air pollution control. Residues: Solid residue (up to 1/3 by weight and 10% by volume of incoming material) depending on the technology. Benefits: Recovers energy and metals, results in net Greenhouse Gas emission reductions compared to landfill disposal, reduces quantity of material disposed by 2/3 by weight.

Pyrolysis	
Technology type(s)	Auger-type; Rotary kiln; Updraft and downdraft fixed bed; Bubbling and circulating fluidized bed
Availability	**Status: Demonstration** Some facilities in North America have processed municipal solid waste at pilot-scale and demonstration-scale; however, none are operating on a commercial scale. There are some commercial-scale facilities reported to be in operation in Europe and Japan, however, the feedstock for these facilities is unclear. A pyrolysis oil production plant (the Empyro Project) is under construction in the Netherlands using BTG Biomass Technology starting with a pilot plant with a goal to converting 32,000 tons of biomass (primarily residual wood) into 24,000 tons of pyrolysis oil.
Products	Electricity and/or Heat; Metals (ferrous, aluminum); Pyrolytic Oil; Ethanol/Biofuels
Description of Approach / Technology	Pyrolysis converts organic matter to gaseous, liquid, and solid fuels under high temperatures (350° to 850°C) nearly absent of oxygen. Pyrolysis is similar to the gasification process, but pyrolysis generally occurs at lower temperatures. Similar to the case of thermal gasification, the pyrolysis process can be designed to optimize the production of gases or liquids. Syngas can be used as fuel in boilers, or in internal combustion units or gas turbines, provided that the gas is adequately cleaned.
Technology Vendors	Mitsui; Compact Power; PKA; Thide Environmental; WasteGen United Kingdom; International Environmental Solutions (IES); SMUDA Technologies (plastics only); Utah Valley Energy, BTG Biomass Technology Group
Target Material / Feedstock	Pre-processing is required to prepare a homogenous feedstock (refuse derived fuel) from municipal solid waste.
Range of Costs	$190 to $200 per tonne depending on facility size and negotiated rate for energy sales.
Environmental Impacts/Benefits	Emissions: Air pollution control systems and/or syngas clean-up are used to comply with air emission requirements.

Pyrolysis	
	Wastewater from syngas clean-up and air pollution control. Residues: Solid residue (up to 1/3 by weight and 10% by volume of incoming material) depending on the technology. Benefits: Recovers energy and metals, results in net Greenhouse Gas emission reductions compared to landfill disposal, reduces quantity of material disposed by 2/3 by weight.

Thermal and Catalytic Depolymerization	
Technology type(s)	Thermal and catalytic
Availability	**Status: Demonstration** There are no large-scale commercial facilities using depolymerization technology with mixed solid wastes or municipal solid waste as feedstock. There are some facilities in Europe and one in Mexico that utilize this or a similar process to convert waste plastics, waste oils, and other select feedstocks. Agilyx is working on a somewhat similar process for converting plastics into oil in the United States. Changing World Technologies operated a facility in Missouri which processed turkey offal; however, they went bankrupt (filed for Chapter 11) in 2009. It is unclear whether this facility is still in operation.
Products	Crude oil or liquid fuel; Metals (ferrous, aluminum)
Description of Approach / Technology	The depolymerization, or cracking, process converts long-chain hydrocarbon polymers present in some waste materials into products such as diesel and gasoline. Pressure and heat are used to decompose long chain polymers composed of hydrogen, oxygen, and carbon into shorter chains of petroleum hydrocarbons. Once the hydrocarbon molecules are broken into shorter chains, additional refining steps are required to convert the molecules into oil. This process is somewhat similar to that used at an oil refinery to convert crude oil into usable products, including the use of distillation to segregate the desired hydrocarbon liquids (such as diesel fuel).
Technology Vendors	ConFuel K2; AlphaKat/KDV; SBS
Target Material / Feedstock	Pre-processing is required to prepare a homogenous feedstock (refuse derived fuel) with the required particle size < 1mm from municipal solid waste.
Range of Costs	Unavailable
Environmental Impacts/Benefits	Emissions: little data is available, likely odour management is necessary.

Thermal and Catalytic Depolymerization	
	Residues: Solid residue (up to 50% by weight). Benefits: Could recover energy and metals, results in net Greenhouse Gas emission reductions compared to landfill disposal, reduces quantity of material disposed 50% by weight.

Waste to Liquid Fuels	
Technology type(s)	Fischer-Tropsch synthesis; Methanol synthesis; Mixed alcohol synthesis; Syngas fermentation
Availability	**Status: Emerging – Transitioning to Proven** The component systems that comprise this technology, such as those used for feedstock preparation, gasification, and Fischer-Tropsch or methanol synthesis, are viable on a commercial scale. However, until recently the combination of these individual technologies in a single system using mixed waste streams as a feedstock has not been demonstrated commercially. The first commercial facility in Canada has been constructed in Edmonton intended to convert 180,000 tonnes of non-recyclable waste into 100,000 tonnes of refuse derived fuel which can be converted into 38 million litres of biofuel. Enerkem has a 25-year agreement with the City of Edmonton to supply 100,000 tonnes per year of sorted municipal solid waste. The City of Edmonton is responsible for supplying the refuse derived fuel for Enerkem; the refuse derived fuel is made from non-recyclable and non-compostable residual material. The refuse derived fuel is fed into the gasification system where it is converted to a syngas, which is then converted to methanol. While not currently in place, the plant is intended to eventually convert the methanol to ethanol. The ethanol can be further refined and blended with gasoline. Enerkem's primary focus is on the commercial production of cellulosic ethanol. INEOS has constructed the Indian River BioEnergy Center (Centre) in Vero Beach, Florida, producing cellulosic ethanol from biomass waste and municipal solid waste at a commercial scale. Fiberight has been operating a pilot plant at a mixed waste facility in Virginia (operational since 2007 and being expanded to 80,000 tonnes per year) and is developing commercial scale facilities in Iowa which will produce compressed natural gas from biogas.
Products	Diesel; Gasoline; Naptha; Ethanol; Methanol; Compressed natural gas, other organic alcohols Metals (ferrous, aluminum)
Description of Approach /	The generation of liquid fuels from biomass and organic wastes typically involves the use of a thermal conversion process to

Waste to Liquid Fuels	
Technology	generate a syngas; followed by the use a chemical catalytic process to convert the syngas into a fuel. The syngas is generated using a gasification technology. The syngas is then cleaned to remove impurities (tars, hydrocarbons, etc.). One of four types of chemical catalytic processes can be used to synthesize the syngas into a liquid fuel, they include: Fischer-Tropsch synthesis; Methanol synthesis; Mixed alcohol synthesis; or Syngas fermentation. Each process features different reaction pressures and temperatures, require different syngas compositions, and use different catalysts.
Technology Vendors	Enerkem; Green Power Inc.; CHOREN; INEOS; Fiberight
Target Material / Feedstock	Pre-processing is required to prepare a homogenous feedstock (refuse derived fuel) consisting primarily of biomass.
Range of Costs	Unavailable
Environmental Impacts/Benefits	Emissions: little data is available, likely odour management is necessary. Residues: Solid residue (up to 50% by weight). Benefits: Could recover energy and metals, results in net Greenhouse Gas emission reductions compared to landfill disposal, reduces quantity of material disposed by around 50% by weight.

Hydrolysis	
Technology type(s)	Acid-catalyzed hydrolysis
Availability	**Status: Demonstration/Pilot** The process of chemical hydrolysis is well established for some organic feedstocks, such as in the conversion of wood to paper pulp, but has only been applied to municipal solid waste-derived organics on a conceptual basis, or limited to laboratory or pilot-scale. Abengoa has a biomass demonstration facility at a commercial scale in Spain using wheat and barley straw; pilot plants are also in operation in Nebraska.
Products	Ethanol; Biogas
Description of Approach / Technology	Hydrolysis is a chemical reaction in which the organic fraction of the waste is converted to glucose or other simple sugars that can then be fermented or digested to produce other products or chemicals (e.g. ethanol). In processes used to chemically hydrolyze municipal solid waste or other organic feedstocks, an acid or enzyme is employed to break down the complex structures of the cellulosic materials contained in the feedstock (e.g., paper, food waste, and yard waste) into simpler compounds (i.e., primarily sugars). Microorganisms can then easily ferment the sugars under appropriately controlled conditions into ethanol, or convert them in an anaerobic digestion system into methane-rich biogas.
Technology Vendors	Masada OxyNol; Biofine; Arkenol Fuels, BlueFire Renewables (using Arkenol), Abengoa
Target Material / Feedstock	Pre-processing is required to separate the organic fraction of the municipal solid waste stream.
Range of Costs	Unavailable
Environmental **Landfill Disposal** Impacts/Benefits	Emissions: little data is available, likely odour management is necessary. Residues: Solid residue (up to 50% by weight). Benefits: Could recover energy, results in net Greenhouse Gas emission reductions compared to landfill disposal, reduces quantity of material disposed by around 50% by weight.

Disposal (Advances in Landfill Technologies)

Landfill Disposal	
Technology type(s)	Stabilized landfill (Halifax); landfill biocell; landfill bioreactor
Availability	**Status: Proven** Landfill disposal is widely used worldwide. Advances in landfill disposal practiced in North America include landfills in which waste decomposition is enhanced (biocell, bioreactor) or limited (stabilized landfill).
Products	Landfill gas (biogas), electricity
Description of Approach / Technology	Advances in landfill disposal include: development of liner technologies, new cover systems including flexible solar covers, improvements in landfill gas recovery and the application of new approaches to recover landfill gas more efficiently from waste. Landfill biocells are constructed to control the circulation of leachate and airflow in a specific area, to encourage anaerobic decomposition of the waste stream and enhance biogas recovery. Biocells are constructed so that they can be filled, have an active period of a year or two and then be excavated to recover material and landfill airspace. Landfill bioreactors involve the modification of large areas (and or specially constructed landfills) to recirculate leachate and to enhance biogas generation. The City of Ottawa has applied a bioreactor approach at the Trail Road landfill, recirculating leachate in the Stage III area of the site. The City collects biogas from Trail Road and contracted the development and operation of the PowerTrail landfill gas to energy facility. Stabilized landfills (e.g. Halifax) accept only pre-treated materials from which the majority of the readily degradable organics have been treated/removed through pre-processing (e.g. composting), generating less landfill gas, odour and leachate.
Target Material / Feedstock	Municipal solid waste.

Landfill Disposal	
Range of Costs (As Applicable)	Net lifecycle costs including capital, operating and closure/post-closure care range considerably depending on the scale of the site and local site conditions.
Environmental Impacts/Benefits	Emissions/Impacts: Although landfill gas recovery can be enhanced, these systems only partially recover the energy value in the organic stream. Odour and leachate emissions must be controlled. Large areas of land are required. Control or minimization of landfill impacts is dependent to a large extent on the ability of the municipality to divert various waste streams (hazardous waste, organic materials) from disposal. Benefits: Landfill biocells or bioreactors recover more landfill gas, these sites and stabilized landfills generate less Greenhouse Gas emissions than a conventional landfill site.

Closure

Municipal waste management is in a period of rapid change, with advances being made in all areas of the waste hierarchy. In the past three years, since the Ottawa City Council approved of the policy and planning elements of the Ottawa Waste Plan, there has been proposed regulatory change in Ontario which is expected to have an effect on Extended Producer Responsibility and waste reduction, and new technology applications have continued to develop. The contents of this memo should be regarded as a brief snap-shot of the status of technologies as of the fall of 2014.

As the City proceeds to develop its Waste Plan, and selects strategies intended to meet the City's objectives and targets for the future, it will apply a more comprehensive approach to examine these 'tools' and to determine which approaches best fit the City's plans.

We trust that the above will meet your requirements. Should you need any further information or additional analysis, I can be contacted at (905) 380-8568.

Janine Ralph

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