Solid Waste Master Plan | Plan directeur des déchets solides

Waste Management Technologies and Approaches

Technical Memorandum #5
January 2020

Disclaimer

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This technical memorandum was prepared by HDR Corporation, Dillon Consulting Limited and Robins Environmental.

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Executive Summary

The City of Ottawa (City) is in the process of developing a Solid Waste Master Plan (SWMP). This 30-year plan is intended to consider the successes and failures of the past and present and will define a vision for the future. The intention of this Technical Memorandum is to review and document existing, and to recognize emerging technologies and approaches to manage municipal solid waste. Technologies reviewed were those that could possibly be applicable to the City's future solid waste management system. Nine categories of technologies and approaches were included in this review:

- Waste avoidance, reduction and reuse
- Waste diversion;
- Collection fleet technologies;
- Collection approach alternatives;
- Recycling processes;
- Source separated organics;
- Mixed waste processing;
- Recovery; and,
- Landfill disposal.

While reviewing this Technical Memorandum, the following should be noted:

- Separate Technical Memoranda have been prepared as part of Phase 1 which include:
  - Solid Waste Management: Current System Summary;
  - Legislative Review Memo;
  - Policy and Trends Memo; and,
  - Comparative Scan of Municipal Strategies, Practices and Initiatives Memo.
- The purpose of this memo was to document high level attributes of different technologies and approaches (e.g., type, availability, approval requirements). Further detail, specific to the Ottawa context, will be researched in Phase 2.
- The best readily available data has been used in this Technical Memorandum, noting that some sections have more information than other sections, as some approaches and technologies are more advanced compared to emerging/new

approaches and technologies. Information was obtained via calls to municipalities, professional experience and online research. The focus of the review was on the technology or approach itself and not on the potential upstream and downstream benefits or impacts.

- Costing and revenue information has, in general, been provided at a high level as detailed information is not readily available.
- Case studies have been provided for each grouping of technologies and approaches, and where information is available, details and references are included.
- The type of regulatory requirements may not yet be known for some technologies, as similar facilities do not exist in Ontario and have not undergone the approvals and permitting processes. It is assumed that any waste management facility must meet all conditions required as part of any necessary approvals at the time which have been established to protect public health and the environment. Approval requirements for specific options under consideration (e.g., planning approvals, Environmental Assessment, Environmental Compliance Approval, etc.) will be identified in Phase 2.
- It is noted that Ontario has some of the most stringent air emissions criteria in the world and any facility operated in the province would be required to meet the limits prescribed in the legislation by demonstrating compliance prior to construction of a facility through analysis such as modelling.
- Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the Environmental Assessment process prior to issuance of the Environmental Compliance Approval.
- Information presented in this Tech Memo #4 is intended to give a general representation of the types of waste management initiatives, practices and technologies that could be considered for Ottawa's SWMP.
- Data and online research in this Technical Memorandum is based on information that was available up to and including March 1, 2020.

The technologies and approaches that were reviewed are provided by category in Sections 3 through 11. Each section includes: a brief summary of the City's current experience and current practices as it relates to that category; sub-sections for each of the technologies / approaches identified for the category; and a summary table of the technology and/or approach researched, the potential applicable material stream and the potential customers the technology and/or approach could be applied.

The customer categories considered in this memo include single family residential, multi-residential buildings (e.g., apartments, condominiums, townhouse complexes, stacked townhouses), City facilities (e.g., recreational facilities, libraries, community centres, and fire stations), public spaces and parks, and partner p program / non-City waste (e.g., Yellow Bag Program, Green Bins in Schools program, places of worship).

The following tables provide a high-level summary of each category and the approaches/technologies reviewed. Additional information can be found in the relevant sections.

Waste Avoidance, Reduction and Reuse (Section 3)

Two main categories were considered for avoidance, reduction and reuse: food waste avoidance and reuse of materials.

Summary of Information	Approach/Technology Reviewed
Food Waste Avoidance and Reduction (Section 3.1)	
This is not a new topic in solid waste management; however, there has been an increased focus on waste reduction of avoidable food waste in recent years. Many governments/municipalities are still in the data gathering phases and are not yet implementing programs to address food loss and waste.	Disposal bans, promotion and education campaigns and mobile applications.
Reuse of Materials (Section 3.2)	
Common reuse activities target items such as clothing, furniture, electronics, appliances and other household goods through give-away, buy and sell forums, donation drop-off and second-hand retail stores. With greater media attention on waste, there is more focus on and acceptance of reusing items through swaps, sharing and repairing.	Websites, mobile applications, repair cafés, sharing libraries, reuse centres, textile collection and moving-out programs.

Waste Diversion (Section 4)

Policy and regulatory approaches, promotion and education, textile collection, mattress recycling, and management of construction and demolition (C&D) materials were the five categories considered for waste diversion.

Summary of Information	Approach/Technology Reviewed
Policy and Regulatory Approaches (Section 4.1)	
Existing and proven policies and by-laws exist are available as reference/best practices documents for all material types. These should be used in the development of new waste management programs, targets and regulations. It should be noted as well that often these programs and policies are enforced through municipal by-laws.	Zero waste policy, mandatory diversion, differential tipping fees, landfill bans, pay as you throw, clear bags, development standards, by-laws and policy/by-laws for multi-residential buildings.
Promotion and Education (Section 4.2)	
Waste diversion promotion and education strategies have been used and are proven to achieve a variety of goals from promoting higher participation in diversion	Campaigns, websites, mobile applications, social media,

Summary of Information	Approach/Technology Reviewed
programs to modifying behaviour. Many municipalities and regions throughout North America undertake a variety of promotion and education targeted to residents and businesses using a variety of tools, media, resources and public outreach campaigns. External communications are central to the success of a program and provide clear, relevant and timely information.	calendars, call centres, public outreach and waste ambassadors.
Textile Collection (Section 4.3)	
The results of many municipal waste composition studies have indicated that textiles are being disposed of instead of reused or recycled. This is why textiles have become a material of interest to municipalities looking to further reduce waste going to landfill. Municipalities have targeted textile collection through curbside programs, drop-off bins, depots and swap events and have an opportunity to collaborate with non-governmental organizations. Some challenges exist with fully recycling textiles locally which may result in some of the materials being disposed of or being sent to other countries for recycling and/or disposal.	Partnership with charities/community organizations/non-profits, disposal bans and collection/sorting facilities.

Summary of Information	Approach/Technology Reviewed
Mattress Recycling (Section 4.4)	
Mattress recycling is the process of disassembling the different components (foam, wood, fabric, cotton batting and metal) of the mattress for reuse and recovery. Collection of mattresses for recycling can include curbside collection (public and private) or via drop-off at the recycling facility or another designated location (e.g., depot or transfer station).	Take-back programs, disposal bans, drop-off centres, partnerships between stores and social enterprises.
Management of C&D Materials (Section 4.5)	
Construction and demolition materials such as wood waste, asphalt and concrete are diverted from disposal and reused or recycled through donations, acceptance of source-separated materials and separation at processing facilities. In most municipalities, the C&D waste stream is mainly controlled by the private sector. Reuse programs also exist; however, they are dependent upon the need of the community/industries for these recycled products. Diversion options are emerging for other types such as window panes, insulation and painted gypsum.	Donations, separation facilities, diversion programs, differential tipping fees, project permitting and certification.

Collection Fleet Technologies (Section 5)

Four categories including electric vehicles, hybrid vehicles, autonomous vehicles and alternative fuels for collection vehicles were considered for collection fleet technologies.

Summary of Information	Approach/Technology Reviewed
Electric Vehicles (Section 5.1)	
Electric powered vehicles run on electricity and use an electric motor powered by electricity from batteries or a fuel cell. Electrical powered vehicles can reduce the carbon intensity related to industrial vehicles. In some applications, such as electricity-generating anaerobic digestion plants, use of electric waste collection vehicles can help close the energy cycle. The electricity generated at these facilities can be used to charge electric collection vehicles that deliver organics to the facilities. Truck manufacturers and waste facilities are evaluating the use of electric vehicles as an alternative to CNG and diesel-powered vehicles. Currently, there is very limited market viability and the technology for waste collection vehicles is in its infancy and is at the pilot stage.	All-electric waste collection vehicles.

Summary of Information	Approach/Technology Reviewed
Hybrid Vehicles (Section 5.2)	
A hybrid vehicle uses a combination of electricity and fuel (e.g., gasoline, diesel) to power it. This option looks at the use of hybrid vehicles for municipal fleets including for waste collection purposes. A hybrid vehicle uses more than one type of system to produce, store and deliver power such as electricity/gas and electricity/diesel. Both mechanical (hydraulic) and electric hybrids are emerging technologies in the fleet market. Hybrid-electric waste collection vehicles are being used by some municipalities such as NYC, Rotterdam, NL and Gothenburg, Sweden.	Hybrid diesel-electric waste collection vehicles.
Autonomous Vehicles (Section 5.3)	
Autonomous vehicles in the waste industry are seen as an emerging technology and are being tested by vehicle manufacturers Volvo and Renova. The use of autonomous and semi-autonomous vehicles has a number of potential uses in the waste industry including waste and recycling collection, operation of equipment at landfills, waste transfer stations, and material recycling facilities. For waste collection vehicles, there are many scenarios to design for automation including: pedestrians, safety, lining up to the garbage bin, oncoming traffic, and obstacles. The vehicle would need to be able to manoeuvre within neighbourhoods and urban areas to	Autonomous waste collection vehicles.

Summary of Information	Approach/Technology Reviewed
collect garbage. These vehicles would also need to determine where the garbage bin is and stop in front of it. They would also be required to identify and pick up the correct waste stream.	
Alternative Fuels for Collection Vehicles (Section 5.4)	
Approximately 10% of all landfill gas projects in the U.S. use RNG to power their trucks. The technology associated with RNG production is becoming more common in Canada (landfill sites and anaerobic digestion facilities). Natural gas is commonly available in highly populated areas in Canada and distributed through natural gas utility pipeline networks. CNG, CNG vehicles and CNG filling stations are growing in number (e.g., taxis, delivery trucks) and are being used for waste collection vehicles in several cities. LNG and renewable hydrotreated renewable diesel (HRD) diesel are less commonly available.	Replacing petroleum based fuel for vehicles with Compressed Natural Gas (CNG), Renewable Natural Gas (RNG), biodiesel, and Liquefied Natural Gas (LNG).

Collection Approach Alternatives (Section 6)

Seven categories were reviewed for collection approach alternatives. These include: automated cart collection, bulky item waste collection, mobile collection, in-ground containers, public spaces waste diversion, OptiBag and use of technology/data.

Summary of Information	Approach/Technology Reviewed
Automated Cart Collection (Section 6.1)	
Automated cart collection involves a specially designed truck that uses ‘arms’ to collect materials from waste carts, empty them and then return them to its original position. This alleviates the operators manually lifting and dumping carts or using semi-automated collection. Multiple jurisdictions use automated cart collection for all streams of waste. There are several manufacturers that produce vehicles and truck bodies for automated cart collection. Additionally, there are several cart manufacturers that produce carts in several sizes and colours with features such as wheels and locking lids.	Automated collection of carts for garbage, recycling and source separated organics.

Summary of Information	Approach/Technology Reviewed
Bulky Item Waste Collection (Section 6.2)	
Bulky item waste collection programs that focus on diverting and recycling collected materials increase waste diversion, saving landfill space by recycling the materials collected. Call-in collection systems provide an opportunity to educate residents about reuse opportunities, track items being collected for future planning, provide a means for introducing a service fee and enable scheduling of collection routes. A strategy to further extend the life of the landfill may include limiting the number of large items that can be set out for collection.	Programs for collection of bulky item waste too large for regular garbage collection are varied and include limiting the number of items/collections, charging fees and/or providing a call-in service.
Mobile Collection (Section 6.3)	
Mobile waste collection can be provided for materials that are not typically collected at the curbside such as MHSW or small electronics. This process will allow residents, who may not be able to drop off these materials themselves, to have access to these programs.	Collection service to divert Municipal Hazardous or Special Waste (MHSW) and electronic waste.
In-Ground Containers (Section 6.4)	

Summary of Information	Approach/Technology Reviewed
Municipalities have installed in-ground containers in areas where waste collection is not required on a daily basis or in high generating areas that would require multiple collections per day/week with a traditional, smaller garbage container. There are also some areas where these containers have been installed at multi-residential buildings by municipalities that provide collection to this sector, as well as privately by buildings responsible for their own waste collection. Deep collection systems are offered in a number of sizes ranging from 3-5 feet in diameter. Some systems consist of a main well that is made of a strong plastic which is seamless and leak proof. Inside of the well is a strong bag typically made of woven polypropylene which can be lifted out of the well to be emptied. The top of the container can be made of polyethylene or corrugated aluminum. For bins that are intended to be used by specific users, these bins can have lockable lids for safety purposes and to reduce illegal disposal.	Below grade waste collection containers with larger capacity for garbage, recycling and source separated organics for public space and multi-residential collection to reduce collection frequency and improve access compared to traditional waste collection containers placed below grade.
Public Spaces Waste Diversion (Section 6.5)	
Waste collection from parks, downtown streetscapes, recreation centres, arenas, beaches, playgrounds, bus stops, trails, cemeteries, public buildings and associated activities (farmers markets, etc.) can all be considered public spaces waste. There	Variety of containers (in-ground, solar compacting units), dog

Summary of Information	Approach/Technology Reviewed
are a variety of containers that can be used and diversion is known to be difficult because of contamination when users select an incorrect container. Capital costs for public waste receptacles can be high, depending on the types of bins selected and customization.	waste receptacles, zero waste stations.
OptiBag (Section 6.6)	
Use of different coloured plastic bags for the different waste streams that can be placed in one collection container and then sorted at an optical sorting processing facility. This technology is primarily located in Europe; however, there has been interest in North America. Currently, there are no optical sorting plants specifically for the Envac Optibag in Canada. Some Ontario municipalities have been considering using the Optibag and vacuum system/chute.	Use of colour coded plastic bags for garbage, recycling and source separated organic waste to enable collection of the bags together in a single truck or receptacle and optical sorting of the bags at a processing facility.
Technology/Data (Section 6.7)	
The objective of the use of technology is to move away from static collection routines and use real-time information to improve collection logistics and customer service.	Technology to monitor and track waste collection bins to improve

Summary of Information	Approach/Technology Reviewed
There are new and emerging technologies that assist jurisdictions with waste container management in terms of live tracking of waste, providing data and statistics to customers. RFID chips are used for tracking waste performance. This service requires collection vehicles outfitted with at least semi-automated collection technology, and wireless communication modules on both the vehicle and customer bins. Technology can also be used for enhancing waste collection operations in terms of routing, live tracking of waste vehicles, identifying potential issues/incidents through taking pictures and tracking locations and driver information. Bin sensors are designed to improve the logistical performance of collection services through the creation of data-driven collection schedules. Solar compactors use smart devices that are able to determine how full a waste container is and trigger automatic compaction of the waste when the volume reaches a certain point. Intelligent waste technologies on waste containers that have sensors to alert when the containers are full or highly odourous allow for collection routes to be altered to collect from only full or odourous containers. These are often used in Public Spaces but can also be used for multi-residential collection. Optimization in collection routing can lead to a reduction in waste collection costs; however, the return on investment may be poor for some technologies due to upfront costs.	collection logistics, performance tracking and customer service including the use of Radio Frequency Identification (RFID) chips in carts and bins, sensors in public space collection containers, GPS monitoring of collection vehicles, video capture capabilities on collection vehicles, tablets on waste collection vehicles, and solar powered compaction systems for public space recycling containers.

Recycling Processes/Technologies (Section 7)

Sorting technologies for recycling and chemical recycling were the two categories reviewed for recycling processes/technologies.

Summary of Information	Approach/Technology Reviewed
Sorting Technologies for Recycling (Section 7.1)	
Recycling facilities often use a combination of manual labour and processing equipment to sort a feedstock into various streams and remove contamination. Common MRF equipment currently used includes optical sensors, disc screens, eddy current separators, magnets, ballistic separators, cyclones and new and emerging processing technology includes robotics, artificial intelligence, ballistics, and mechanical works. 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.	Advanced processing systems and technology at materials recovery facilities (MRF) including ballistic separation, optical sorting, robotics and, artificial intelligence.

Summary of Information	Approach/Technology Reviewed
Chemical Recycling (Section 7.2)	
Chemical recycling of waste plastic is an emerging process where a polymer is chemically broken down (reduced) to its original form so that it can eventually be processed and remade into new plastic materials that are then made into new plastic products. The majority of plastics generated are never recovered, and manufacturers are more and more challenged to use recycled plastics in their current state because of degradation or contamination concerns. Current analysis indicates that chemical recycling can help meet market demands and have the potential to generate significant revenue in addition to the extensive environmental benefits recognized. In addition to the markets for plastics, there are also markets available for chemicals.	Recycling of plastics using chemical reactions to break down the plastic into other products such as waxes, oils, and chemical additives for plastics production.

Source Separated Organics (Section 8)

Seven categories were reviewed for source separated organics processing. These include aerobic composting, anaerobic digestion, mechanical/chemical processing, biological processing, co-digestion of sewage and organics, in-sink disposal units and animal feed production.

Summary of Information	Approach/Technology Reviewed
Aerobic Composting (Section 8.1)	
The target organic feedstock may depend on the type of aerobic composting technology used. Different types of aerobic composting technologies exist, including aerated windrow, aerated static pile, and in-vessel composting. Feedstock materials typically include residential leaf and yard waste, food waste, biosolids, agricultural waste and animal manure. Aerobic composting is a naturally occurring process where organisms break down organic material in the presence of oxygen. Managing the components of this process such as moisture, heat and oxygen availability requires specific controls and technology. Odour generation is common with composting thus requiring some applications to be indoors with odour abatement technology.	Systems that biologically break down organic waste in an aerobic (with oxygen) environment to produce compost, including aerated windrow, aerated static pile, and in-vessel composting processes.
Anaerobic Digestion (AD) (Section 8.2)	
The Anaerobic Digestions (AD) process biologically converts organic waste into biogas under anaerobic conditions (without oxygen). AD is used in agricultural and industrial applications. In agricultural applications, manure is harvested and digested	AD systems that biologically break down organic waste in an oxygen-free

Summary of Information	Approach/Technology Reviewed
to create biogas. The remaining product (digestate) is spread on agricultural fields as a soil amendment. AD facilities can receive many types of waste including municipal food waste, other household organics, diapers and sanitary products pet waste, sewage sludge, food industry waste, and farm waste. Some work is being done to trial including leaf and yard waste into an AD process, but this is still in the trial stage.	environment aerobic (with oxygen) to produce biogas and solids that can be used as a soil amendment or to produce a compost.
Mechanical/Chemical Processing (Section 8.3)	
This process is the mechanical breakdown and chemical hydrolysis of biosolids and some types of organics such as food waste. The technology is proven in wastewater treatment facilities and emerging in applications using food waste. It uses a combination of heat, alkali, and shear mixing to effectively breakdown the biological material in biosolids and organics. Recycling this product back into anaerobic digesters enhances the biogas production. This product could also be directly applied to land for soil enhancement. A fertilizer is produced that can be used in Class A or Class B applications under the Fertilizers Act by the Canadian Food and Inspection agency.	Processing facilities using proprietary technology systems to manage biosolids and combined feedstocks including food waste.

Summary of Information	Approach/Technology Reviewed
Biological Processing (Section 8.4)	
Typically targeted at small scale household organic waste or large scale farmers, this process involves the use of insects or worms to decompose organic waste into compost. The compost is used as a fertilizer. Some industries will also harvest the insect larvae for protein purposes in animal feed. Vermicompost or vermiculture uses insects such as fly larvae or worms to break down organics into compost. The resultant compost from the insects can be used in agricultural applications.	Small scale systems using worms and black soldier flies to break down organic waste.
Co-digestion of Sewage and Organics (Section 8.5)	
Organic food wastes from green bin programs are mixed with municipal sewage sludge and anaerobically digested. Other sources of food waste from food industries can also be mixed in this process. The biogas generated from anaerobic digestion can be used in boilers, upgraded into renewable natural gas, or combusted to create electricity. Digested organics can be used as a soil amendment or fertilizer.	AD systems at municipal wastewater treatment facilities and farms.

Summary of Information	Approach/Technology Reviewed
In-Sink Disposal Units (Section 8.6)	
In-sink disposal units are used to dispose of food waste by shredding it down the kitchen sink which then mixes with wastewater and is conveyed through the sewer system for treatment at the wastewater treatment plant. Although convenient, this approach for food waste management has increased issues with clogged sewer systems, treatment plants and discharge of organics into rivers and water bodies. This type of common technology is more prevalent in the USA than in Canada, but is also banned in many jurisdictions.	Municipal bans on the use of in-sink disposal units.
Animal Feed Production (Section 8.7)	
A fairly clean stream of food waste is heat treated and dehydrated and either mixed with dry feed or directly fed to animals.	Conversion of food waste into animal feed.

Mixed Waste Processing Approaches (Section 9)

Two categories were reviewed for mixed waste processing approaches. These include mechanical and biological treatment with refuse-derived fuels (RDF) and mixed waste processing.

Summary of Information	Approach/Technology Reviewed
Mechanical and Biological Treatment with Refuse Derived Fuels (RDF) (Section 9.1)	
Mechanical and biological treatment (MBT) facilities are typically used to recover recyclables and organic material from municipal solid waste. Typical outputs and market uses are refuse-derived fuels (RDFs), biogas, plastics, metals, minerals and inert materials (e.g., stones, glass, etc.), process water and effluent. RDFs are produced by shredding and/or pelletizing select waste and by-product materials with recoverable calorific value into a homogenous product which can be used as a fuel source.	Facility that incorporates front-end processing to separate out recyclables (sold to markets), special/hazardous waste and organics and residual waste that is sent to a waste stabilization facility.
Mixed Waste Processing (Section 9.2)	
This process starts with unsorted and unseparated solid waste being off-loaded onto a tipping floor. Materials are first sorted on the floor using manual labour and/or mobile equipment to remove larger or bulky items. Materials are then processed through multi-stage screens to separate material types. The revenue potential from the sale of recovered material streams is typically less than source-separated materials.	Facilities that recover recyclables, organics and/or reusable materials from residual waste before being sent for disposal.

Recovery Technologies (Section 10)

Categories such as mass burn incineration, gasification, pyrolysis, waste to liquid fuel, hydrolysis and landfill mining are covered in this section of the report.

Summary of Information	Approach/Technology Reviewed
Mass Burn Incineration (Section 10.1)	
The most common thermal treatment facilities used to manage residual waste are traditional combustion, or mass burn incineration. The mass incineration occurs under controlled conditions and yields a significant net energy production. At the back end, bottom and fly ashes are produced, where bottom ash can be managed at a non-hazardous landfill, whereas fly ash is typically considered hazardous thus requiring disposal at a hazardous waste landfill.	The use of traditional combustion technology facilities to manage waste and generate heat that can be converted to electricity and/or steam.
Gasification (Section 10.2)	
Gasification involves converting solid or liquid carbon-based wastes into gas form at high temperature without combustion. Technology types include - updraft fixed bed; downdraft fixed bed; bubbling fluidized bed; circulating fluidized bed; entrained flow.	Review of facilities that convert MSW into a gas.

Summary of Information	Approach/Technology Reviewed
Gasification has been used successfully for select feedstock (e.g., wood and biomass). There has been mixed success and failure using municipal solid waste.	
Pyrolysis (Section 10.3)	
Pyrolysis involves heating municipal solid waste in an oxygen-free environment to produce a combustible gaseous or liquid product and a carbon char residue. Some facilities in North America have processed municipal solid waste using this technology at a comparative pilot-scale; however, no facilities are currently operating on a commercial scale.	Review of facilities that convert MSW into a feedstock.
Waste to Liquified Fuel (Section 10.4)	
Generation of liquid fuels from biomass (carbon-rich wastes) and organic wastes. Using gasification, a thermal conversion process is used to generate syngas from the RDF which then undergoes a series of chemical reactions to convert the syngas into a liquid fuel source. The component systems that comprise this technology, including those used for feedstock preparation, gasification, and methanol synthesis, are viable on a commercial scale. However, the combination of these individual technologies in	Processing facilities converting waste to RNG.

Summary of Information	Approach/Technology Reviewed
a single system using mixed waste streams and municipal solid waste as a feedstock has not been demonstrated commercially.	
Hydrolysis (Section 10.5)	
The process of chemical hydrolysis is well established for select organic feedstocks (e.g., wood and paper pulp), but the process has only been utilized for municipal solid waste-derived organic matter on a preliminary/conceptual basis. There has been a limited number of laboratory and/or pilot-scale testing done for the application of hydrolysis for municipal solid waste.	Review of facilities that undergo processes to chemically break down MSW or other organic feedstocks so that they can be fermented or digested into other products (e.g., ethanol).
Landfill Mining (Section 10.6)	
Landfill mining is a complicated process and its economic feasibility is based on the expected content of the landfill and/or reducing long-term liabilities and recovered airspace. The suitability of landfill mining is very site-specific.	Excavation of previously landfilled waste to recover soils, gain landfill capacity, redevelop the property and/or

Summary of Information	Approach/Technology Reviewed
	mitigate environmental impacts.

Landfill Technologies (Section 11)

Three categories for landfill disposal technologies were reviewed. These include bioreactors, biocell and landfill optimization approach. It is noted that the Trail Road Facility Landfill is an engineered landfill that the City owns and operates. The landfill is anticipated to reach capacity during the planning period of the SWMP and as such, alternative disposal options, including engineered landfill(s), will be identified and evaluated in Phase 2 of the SWMP.

Summary of Information	Approach/Technology Reviewed
Bioreactor (Section 11.1)	
A bioreactor consists of the following components: composite liner, leachate collection and recirculation system, liquid injection system, gas collection and/or air injection system, intermediate covers and final cover. They are recommended for new sites in the design phase as specific infrastructure is more easily integrated	Biological processes to enhance and accelerate the degradation of landfilled materials either as aerobic reactors (which rely on

Summary of Information	Approach/Technology Reviewed
during early stages of site development as leachate recirculation system and other injection systems are easier to install during landfill construction.	oxygen to sustain bacteria), anaerobic reactors (which rely on a low oxygen environment to sustain bacteria) and hybrid reactors (which employ both types of bacteria).
Biocell (Section 11.2)	
Biocells differ from bioreactors in that there is always both anaerobic and aerobic phases, and air space is recovered through mining of residuals. They are recommended for new sites in the design phase as specific infrastructure is more easily integrated during early stages of site development.	Landfill that combines a number of technologies including anaerobic bioreactor, air injection, leachate recirculation system, LFG recovery and utilization system, and base and surface liners.

Summary of Information	Approach/Technology Reviewed
Landfill Optimization Approaches (Section 11.3)	
Many modern landfills go through a review of potential optimizations at some point during operation in order to increase additional landfill capacity.	Landfills where changes are made to the existing landfill to enhance the operations of the landfill, review landfill equipment for optimizations and improvements, adjust to a changing climate and to increase the volume of waste that can be deposited through changes in the configuration of the mound.

Next Steps

As part of Phase 2, a more detailed analysis specific to Ottawa will be undertaken. This will include consideration of the type of waste the City manages currently, and in the future based on proposed changes to Ontario regulations. It will also consider future trends in population, housing, and waste generation/composition. A list of options for consideration will be developed and evaluated using a set of criteria developed in collaboration with the City and that reflect feedback from stakeholders. Ultimately, options will be identified for the various customers served by the City for the short, mid and long-term planning period that meet Ottawa's unique needs.

1 Introduction

The City of Ottawa (City) is creating a 30-year Solid Waste Master Plan (SWMP) that includes consideration of the successes and failures of the past and present, and defines a vision for the future that will ensure its long term viability and sustainability, while ensuring flexibility to respond to an ever changing industry over the next 30 years. Some of the key questions the City will be seeking answers to through the development of the SWMP include:

- What wastes will be generated over the long-term, who will generate them and why do we expect them to be generated?
- How can wastes from the City's customer base be better managed (residential, public and park spaces, City facilities, non-City waste)?
- What role will the existing systems and facilities play in meeting future needs of the City?
- What new technologies may be available to better manage waste materials?
- What role can the City play to further reduce the materials that will eventually become waste and in a circular economy framework?

The purpose of Technical Memorandum #4 (Tech Memo 4) is to review and document existing, and to recognize emerging technologies and approaches to manage solid waste that could potentially be applicable to the City's future solid waste management system. The following nine categories of approaches and technologies were included in this review:

- Waste avoidance, reduction and reuse;
- Waste diversion;
- Collection fleet;
- Collection approach alternatives;
- Recycling processes;
- Source separated organics;
- Mixed waste processing;

- Recovery; and,
- Landfill disposal.

Waste management approaches and technologies are constantly changing as municipalities, government and industry respond to changes in consumer behaviour, waste composition, packaging types, commodity prices and regulations etc. The information in this Tech Memo is current as of February 28, 2020 and reflects the HDR project team's current knowledge and research in a number of waste management areas.

2 Methodology

Sections 3 through 11 provide summaries of the technologies and approaches listed above that were reviewed as part of Tech Memo 4. Each chapter begins with a brief summary of the City's experience and current practices as it relates to the nine categories. A review of readily available information sources was completed to identify existing, emerging and innovative technologies and approaches for managing waste. For each technology and approach, the following considerations were summarized (where information was available and applicable) in a table format:

- Approach / Technology Type(s);
- Description;
- Status (proven or demonstration/pilot, emerging);
- Availability;
- Examples and/or Case Studies;
- Regulatory Considerations;
- Targeted Material/Feedstock;
- Outputs;
- Capital and Operating Cost Range;
- Revenue Opportunities / Cost Savings;
- Risks and Benefits;
- Greenhouse Gas (GHG) Impacts;

- Potential Environmental Impacts and Health Benefits; and,
- Potential Known Health Impacts.

The review of technologies and approaches was conducted based on readily available and reliable resources such as (but not limited to):

- Reports previously prepared by the consulting team;
- Reports / data available online (e.g., municipal, industry, provincial and federal websites);
- Professional solid waste entities (e.g., National Zero Waste Council, Commission for Environmental Cooperation); and
- Industry standards.

A summary table is provided at the end of each section that lists the approaches and technologies researched in this memo and identifies the applicable material stream it relates to and the potential City customers it can be applied to. The material streams included are Blue and Black Box recyclables (recycling), source-separated organics (SSO) (which could include food/household organics, leaf and yard waste or both), garbage (residuals), bulky waste, construction and demolition (C&D) waste. The customer categories considered in this memo include single family residential, multi-residential buildings (e.g., apartments, condominiums, townhouse complexes, stacked townhouses), City facilities (e.g., recreational facilities, libraries, community centres, and fire stations), public spaces and parks, and partner p programs / non-City waste (e.g., Yellow Bag Program, Green Bins in Schools program, places of worship).

2.1 Considerations

While reviewing this Technical Memorandum, the following should be noted:

- Separate Technical Memoranda have been prepared as part of Phase 1 as follows:
  - Solid Waste Management: Current System Summary
  - Legislative Review Memo
  - Policy and Trends Memo

Comparative Scan of Municipal Strategies, Practices and Initiatives References to these Technical Memoranda are provided in this Technical Memorandum where more information can be found.

Costing and revenue information, Greenhouse Gas (GHG) impacts and potential environmental impacts have, in general, been provided at a high level. When discussing impacts and benefits this review was focused on the technologies and/or approaches itself and not on the upstream or downstream impacts and/or benefits. In some cases information is not publicly available, or the information does not exist. Where information is available, ranges have been provided. Case studies have been provided for each grouping of technologies, and where information is available, details and references are included. It should be noted that in many cases, results of pilot studies are not released, and in some cases, it is difficult to determine the validity of the results depending on the source of the information. Some pilot studies are still underway and results are not yet available.

Similarly, the type of approvals/permits may not yet be known as similar facilities do not exist in Ontario and have not undergone permitting processes. As such, the length of time required for permitting is unknown at this time and may depend on discussions with government bodies, political support, public opposition, etc. It is also unknown how regulations/legislation may change over the course of the planning period of the SWMP, so general information on the types of permits or approvals that may be required has been provided rather than speculating.

It is assumed that any waste management facility must meet all conditions required as part of any necessary approvals at the time which have been established to protect public health. Approval requirements for specific options under consideration (e.g., Environmental Assessment, Environmental Compliance Approval, etc.) will be identified in Phase 2.

It is noted that Ontario has some of the most stringent air emissions in the world and any facility operated in the province would be required to meet the limits prescribed in the legislation by demonstrating compliance prior to construction of a facility through analysis such as modelling. Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the

Environmental Assessment process prior to issuance of the Environmental Compliance Approval.

Obtaining reliable information has challenges in that information is sometimes out-dated, incomplete, not relevant to Ottawa's situation (or even to Canada/Ontario) and/or provided for a specific purpose (e.g. by a vendor). The information presented in this Technical Memorandum is intended to give a general representation of the types of waste management initiatives, practices and technologies that could be considered for Ottawa's SWMP. The best readily available data has been used in this Technical Memorandum noting that some sections had more information than other sections as some approaches and technologies are more advanced compared to emerging/new approaches and technologies. Information was obtained via calls to municipalities, professional experience and online research.

Data and online research in this Technical Memorandum is based on information that was available up to and including February 28, 2020. More research will be conducted in Phase 2 about specific options that Ottawa is considering as part of the SWMP development. In Phase 2 of the strategy development, the City's long-term waste management needs will be identified over the 30-year planning horizon, broken out by short, medium and long-term needs. An independent comprehensive needs assessment analysis will then be undertaken to identifying gaps, constraints, opportunities and risks with Ottawa's current waste management infrastructure, facilities, programs and existing third-party contracts. Options unique to Ottawa's needs will be considered in the context of its future waste management needs, and alignment with the City's vision and objectives for its SWMP.

3 Avoidance, Reduction and Reuse

This section focuses on approaches and technologies to avoid the creation of waste, reduce the amount of waste generated and the reuse of waste to the extent possible prior to sending it for processing and/or disposal.

There are two main categories considered: food waste avoidance and reduction, and reuse of materials.

Avoidance and reduction of non-food waste has and continues to be pursued by municipalities as part of efforts to divert waste from landfill. While the examples in Section 3.1 focus on food waste, the approaches apply to non-food wastes and are included in the summary for this section. Further examples of regulatory approaches and promotion and education (P&E) campaigns for non-food wastes are provided in Section 4. Full producer responsibility legislation, through the *Resource Recovery and Circular Economy Act* (RRCEA) 2016, continues to evolve in Ontario as well as changes toward increased corporate responsibility to minimize environmental impacts of operations, including waste and GHG emissions. With the planned transition of the Blue Box Program to a full producer responsibility model under the RRCEA, food and organic waste will be an important area of focus for municipalities. The City promotes the reuse of waste in its promotion and education (P&E) materials and coordinates Give Away Weekends in the spring and fall where residents place unwanted and gently used items at the curb for residents to take and reuse. The City's Take It Back! Program encourages local businesses to take back materials that they sell. The program provides residents with a directory of almost 600 retailers and charities that accept more than 100 different household items and materials for reuse, recycling or disposal.

Several examples of the City's current initiatives or other resources in the community include but are not limited to the following:

- Within the City's corporate offices, redundant office furniture is reused as much as possible;
- The internal "Green Exchange" programs provides a forum for staff to swap, buy and post "green" related advertisements;
- Waste Explorer is an online directory for waste materials that indicates where over 900 items must be disposed of and how to dispose of the items;

- Kijiji and Usedottawa.com provide a forum for the public to buy and sell their used items online;
- The City promotes two give away weekends every year where residents exchange and share reusable good by placing those items at the curb/central location where other residents can take them free of charge;
- The Ottawa Tool library allows for the public to borrow tools to use on projects. The library also offers classes and demos to the public;
- Hidden Harvester's Ottawa collects fruit and nuts that would otherwise go to waste on public and private property through harvest events run by volunteers. Harvested items are shared with home owners, volunteers, food agencies and Hidden Harvest Ottawa;
- Ottawa Cloth Diaper Service offers organic and regular cloth diaper service throughout Ottawa. The company provides an in-home consultation to show families how to use the cloth diapers and then the company exchanges dirty diapers for clean diapers on a weekly basis;
- OC Transpo has a private service provider that picks up wood pallets for reuse; and,
- Ottawa Fire Services donates uniforms to Firefighters Without Borders for reuse.

The Trail Waste Facility Landfill accepts and beneficially reuses solid non-hazardous waste soil generated within the city, including projects from the private and commercial sector and from the City's infrastructure and roads projects. The City is targeting 100 percent beneficial reuse of biosolids primarily through local agricultural land application which results in significant cost savings and reused almost 48,000 tonnes of biosolids in 2018.

The following two tables present research on food waste avoidance and reduction, and reuse of materials.

3.1 Food Waste Avoidance and Reduction

Food Waste Avoidance and Reduction	
Approach / Technology Type(s)	This option looks at ways in which the City can assist its residents in avoiding and reducing the amount of food that is wasted (either sent for processing in the Green Bin or disposed of at landfill). This is also an opportunity for the City to avoid and reduce food waste, particularly waste produced in City facilities (e.g., long-term care facilities, child care facilities, and arena concessions). Approaches such as disposal bans, promotion and education campaigns and mobile applications (apps) (e.g., cell phone and tablet 'apps') are considered.
Description	Food waste reduction is not a new topic; however, more focus has been placed on it in recent years in particular with respect to reducing avoidable food waste (i.e., food that could have been eaten but is thrown out as opposed to unavoidable food waste such as egg shells, bones) and increasing awareness about the quantity and associated costs with wasted food. It is estimated that 7% of GHG emissions produced globally are due to preventable food waste. https://changeforclimate.ca/story/the-problem-of-food-waste http://www.nzwc.ca/focus/food/national-food-wastestrategy/Documents/NZWCSubmissionOnPan-anadianFrameworkForCombattingClimateChange.pdf Avoidance and reduction of food waste is considered through the use of disposal bans on food waste in landfills, campaigns to reduce food waste, programs to avoid and reduce food waste, and the use of mobile apps. Food waste reduction apps are are being used to find charities to donate unused food to, provide a platform for stores to sell their surplus produce at a reduced rate, findi farm-to-table restaurants and food sharing purposes.

Food Waste Avoidance and Reduction	
	In Canada there are several initiatives to address food loss and waste. These include, but are not limited to, the following: ● Commission for Environmental Cooperation - Working together with Canada, Mexico and the United States to prevent and reduce food waste by working with the North American Food Supply Chain and the Food Matters Action Kit that encourages youth to reduce food loss at home, school and in the community. ● Environment and Climate Change Canada - Development of a report based on a workshop held with 100 industry experts that summarizes the presentations, information and ideas shared during the event. ● National Zero Waste Council – 1) In May 2018 the Council launched a Food Loss and Waste Strategy for Canada. The strategy provides suggested actions throughout the food supply chain that can help move Canada towards a 50 percent reduction in food waste, and 2) In 2018 the Council produced a report that recommended methodologies for measuring residential food waste.
Status	Emerging - Food waste reduction is not a new topic; however, more focus has been placed on it in recent years in particular with respect to reducing avoidable food waste. https://www.canada.ca/content/dam/eccc/food-loss-and-waste/FLW%20Workshop%20Summary%20Report%20ENG%20-%20FINAL.pdf
Availability	There are a number of reports published through the initiatives listed above; however, many governments/municipalities are still in the data gathering stages (e.g., quantifying avoidable food waste) versus implementing programs and actions to address food loss and waste. Additionally, many municipalities are focusing on diverting organics through diversion programs rather than reduction programs.

Food Waste Avoidance and Reduction	
	http://www.nzwc.ca/focus/food/Documents/LFHW_HowToMeasureFoodWaste_English.PDF http://www.nzwc.ca/focus/food/national-food-waste-strategy/Documents/NFWRS-Strategy.pdf
Examples / Case Studies	**Disposal Bans** ● **Province of Nova Scotia, Nanaimo, Metro Vancouver –** Bans are in place to restrict organic waste from being placed in landfill. This has been discussed in the Legislative Review Memo. ● A provincial landfill ban on organic matter is also expected for Quebec in 2020. There is currently an organics ban in Gatineau. **Campaigns** ● **Love Food Hate Waste** – In July 2018 the National Zero Waste Council and its campaign partners launched a national food waste reduction campaign: *Love Food Hate Waste Canada* to provide households with easy tips and ideas to assist with food waste reduction in the home including interpreting food labels. Metro Vancouver and York Region have introduced the consumer awareness campaigns aimed at changing behaviour related to food waste. http://www.nzwc.ca/focus/food/Pages/default.aspx ● **Feeding the Five Thousand** - In 2015, an event called *Feeding the Five Thousand* was held which cooked up free food for hundreds of people in downtown Vancouver using only reclaimed ingredients. Additionally, blemished produce was given out for free from the Farm 2 Food Bank. https://www.cbc.ca/news/canada/british-columbia/feeding-the-five-thousand-with-reclaimed-food-in-vancouver-1.3090416

Food Waste Avoidance and Reduction	
	● **Second Harvest** – Second Harvest has several initiatives including Food Rescue that helps businesses with excess food to donate to social service organizations and Harvest Kitchens program that trains individuals on preparing food and giving prepared healthy meals to those in need. In January 2019, Second Harvest released a research study The Avoidable Crisis of Food Waste: The Roadmap. The study found that 58 percent of all food produced in Canada is lost or wasted from production to consumption. The report outlines potential actions for industry, industry organizations and all levels of government to reduce food waste and loss throughout the system. Second Harvest is based out of Toronto; however, communities throughout British Columbia and Ontario contributed to the Food Rescue program. https://secondharvest.ca/missionadvocacy/the-avoidable-crisis-of-food-waste-report-launch/ ● **Smart Cities** - The City of Guelph and Wellington County recently received $10 million from Infrastructure Canada to implement their Smart Cities vision: *Our Food Future, Canada's first circular food economy*. The program will tackle three goals: ○ 50 percent increase in access to affordable, nutritious food; ○ 50 new circular food business and collaboration opportunities; and ○ 50 percent increase in economic revenues by reducing or transforming food waste. Our Food Future is seeking to identify food and food waste flows, leakages and opportunities to keep them in the system instead of being disposed. https://guelph.ca/2019/05/guelph-wellington-awarded-smart-cities-challenge-prize/

Food Waste Avoidance and Reduction	
	● **Imperfect Produce**. Grocery stores have recently started to promote imperfect (ugly) produce, often at reduced prices as perfect produce, to decrease the amount of edible food being sent to landfill/composting. Spud (https://www.spud.ca/) based out of Vancouver, BC, allows customers to order imperfect produce directly off of their website as part of their grocery delivery service (in addition to perfect produce and other grocery items). https://www.misfitsmarket.com/ **Applications** ● **Flashfood App** - The Flashfood App was developed for grocery stores to advertise food that they otherwise would throw out at a reduced price. Typically grocery store food items that are not sold and are approaching their best before dates by up to two weeks are thrown out. The Flashfood App allows for grocery stores to sell these items to customers who will pick up items directly from the store. https://www.flashfood.com/en/story
Target Material / Feedstock	Green Bin organics - specifically food waste.
Outputs	Potential reduction in GHG emissions. No other direct outputs, rather results are indirect benefits. A reduction in the amount of food wasted results in less material that needs to be managed (regardless of if it ends up in the garbage or the green bin).
Regulatory Considerations	Under the *Resource Recovery and Circular Economy Act (RRCEA), 2016*, organics diversion has been identified as a key initiative that will target all sectors. The Ministry of Environment,

Food Waste Avoidance and Reduction	
	Conservation and Parks' (MECP) *Food and Organic Waste Policy Framework* consists of two complementary components: ● **Food and Organic Waste Action Plan.** Outlines strategic commitments to be taken by the province to address food and organic waste. https://www.ontario.ca/page/food-and-organic-waste-framework ● **Food and Organic Waste Policy Statement**. Provides direction to the province, municipalities, producers, Industrial, Commercial and Institutional sector (e.g. retailers, manufacturers, hospitals, schools), the waste management sector and others to further the provincial interest in waste reduction and resource recovery as it relates to food and organic waste. A target of 70% reduction and recovery of food and organic waste from urban single family by 2023 has been set for municipalities with organic collection programs already in place. https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/food-loss-waste.html The RRCEA also has a Reducing Litter and Waste in Our Communities: Discussion Paper which expands upon commitments in Preserving and Protecting our Environment for Future Generations: A Made-in-Ontario Environment Plan. The paper poses questions that will help guide future decision-making to divert more waste from landfill. Government of Canada initiatives – 1) Under the Strategy on Short-Lived Climate Pollutants, Canada committed to consult on strategies that will reduce avoidable food waste in Canada, and 2) The Food Policy for Canada is a roadmap for healthier and more sustainable food systems for Canada. One initiative focuses on reducing food waste.

Food Waste Avoidance and Reduction	
	https://www.canada.ca/en/services/environment/weather/climatechange/climate-action/short-lived-climate-pollutants.html
Capital and Operating Cost Range	Operating costs are related to the level of promotion and education activities associated with reducing the amount of food waste. For landfill bans, additional staff may be required to enforce the ban and complete inspections. Additionally, more staffing resources may be required to clean up illegal dumping which may occur with ban implementation.
Revenue Opportunity / Cost Savings	• Cost savings related to a reduction in the amount of Green Bin organics that require collection and processing. • Cost savings associated with conserving landfill capacity.
Risks and Benefits	**Risks** • The current system, at both a provincial and national level, is fragmented and lacks coordination and collaboration amongst municipalities and industry. • Current risk to meeting put-or-pay obligations with the City's contractual requirements if there is a City effort to reduce food waste. Existing processing contract considerations and commitment need to be considered. • Tackling a problem like food waste requires establishing standards for quantifying amounts of food waste generated and in terms of avoidable and unavoidable food waste. • Landfill bans are commonly accompanied by enforcement in order to be effective. • Landfill bans may result in increased incidents of illegal dumping. Additional staffing resources, beyond current levels, may be required to deal with illegal dumping and is typically a short term risk when the ban is first implemented.

Food Waste Avoidance and Reduction	
	Benefits ● Preventing food waste reduces the amount of Green Bin organics that need to be managed and can reduce collection and disposal costs. ● Measurement of food waste can improve projections of capacity required for processing and disposal facilities. ● Food waste reduction programs can be tailored to major causes and sources of surplus for secondary markets or donation can be identified. ● Builds community resiliency by increasing family access to food. ● Can facilitate increased donations of food to charities.
GHG Impacts	Anticipated Reduction in GHGs ● Food waste reduction and avoidance programs can reduce the quantities of this material and reduce methane generation associated with collection or disposal.
Potential Environmental Impacts and Benefits	● Anticipated Reduction in GHGs.
Potential Known Health Impacts	● Minimal to no health impacts. ● Indirect impact of provision of food to people that may otherwise not have access to food.

3.2 Reuse of Materials

Reuse of Materials	
Approach / Technology Type(s)	Opportunities to increase the reuse of materials.
Description	The second R in the waste hierarchy is for ‘Reuse’. Common reuse activities target items such as clothing, furniture, electronics, appliances and other household goods through buy and sell forums, donation drop-off and second hand retail stores. Now there is more focus on reusing items through swaps, sharing and repairing.
Status	Proven
Availability	There are many existing and evolving forms of reuse programs and policies that are implemented within Canadian and International jurisdictions.
Examples / Case Studies	**Websites** ● **Toronto ReUseIt** – Toronto has a map of all the locations available for donation to help promote donation, borrowing and repair of waste in an effort to promote reuse and reduce waste landfilled including: bicycles, clothes, books, vehicles, tools, electronics, and furniture. The map icons are unique to what each organization accepts and clicking on the icon will provide a link to the organization's website and a brief description of the services provided and what materials are accepted. This is available online through Toronto.ca/reuseit or through the TOwaste mobile application. ● **DonateNYC** – New York City Department of Sanitation has a website with tools dedicated to helping residents of New York to donate goods and find used goods. DonateNYC is a part of NYC’s 0X30 initiative which helps New Yorkers reach the goal of sending

Reuse of Materials	
	zero waste to landfills by 2030. The website utilizes tools and search engines to help residents give or find second-hand goods, help businesses and nonprofits exchange used goods, and steps for local reuse organizations on how to join the DonateNYC Partnership. https://www.gettingtozero.nyc/ ● **King County (Seattle, Washington)** – Developed a public education campaign called “Threadcycle”. The website provides the user with information about reuse programs in their County, along with tips and suggestions on how to reuse items and safely purchase reuse items. Clicking on the link “Where to give”, the user is directed to a list of locations to drop off or donate items including the location, if they have containers for drop-off, their schedule, and which ones provide home pick-ups. The website details what items are accepted, what happens to the item at the drop-off, and lifestyle tips for reducing waste. http://your.kingcounty.gov/solidwaste/ecoconsumer/threadcycle.asp **Mobile Applications** ● **Various jurisdictions** – Similar to what Ottawa currently has in place with its “Waste Explorer”, mobile applications are becoming more common tools that jurisdictions are offering to their residents. Many jurisdictions are using “Waste Wizard” or similar tools to help inform residents about where items can be returned, reused or recycled. Typically, a reuse option is listed first and curbside/depot management is listed last. **Repair Café** ● **Various jurisdictions** – Repair Cafés are free events intended to help visitors repair items such as clothes, furniture, electrical appliances, bicycles, toys, etc. Specialists are often on site to help visitors repair items and/or tools are available to make repairs. The first Repair Café was started in 2009 in Amsterdam, Netherlands

Reuse of Materials	
	and now there are over 1,000 locations across six continents. There are 24 Repair Café locations in Canada, including in the cities of Guelph, Kitchener, and Toronto. Repair Cafés are not for profit organizations that rely on volunteerism, donations, community, and partnerships. Municipalities support by promoting events and/or highlighting on websites and communication materials. https://repaircafe.org/en/visit/ **Sharing Libraries** ● **Various jurisdictions** – Libraries are a long standing example of the sharing economy by offering a variety of books, DVDs, and CDs. Similar to existing services the City of Ottawa provides through its libraries, some cities including Toronto, Seattle, Vancouver, Guelph, Oakland, and others have share libraries through non-profit programs that allow residents to borrow items such as tools, toys, camping equipment and kitchen appliances. **Reuse Centres** ● **Various jurisdictions** - Several municipalities have established large scale Recycling/Reuse Drop-off Centres that create opportunities for household (and small business) goods to be reused and recycled rather than disposed. Some charitable organizations in Ontario (e.g., Habitat for Humanity, Goodwill, Salvation Army, Furniture Bank) are also active (both independently and in collaboration with some municipalities) in providing a range of reuse services. Some jurisdictions provide a reuse option at Municipal Hazardous Solid Waste (MHSW) depots where residents can take come products that are essentially full or unopened.

Reuse of Materials	
	Textile Collection • Textiles have become a topic of interest for municipalities looking to further reduce waste going to landfill. This topic is discussed in Section 4.3. **Move-Out Programs** • Many colleges and universities are implementing programs to recover and reuse items that students leave behind when finished school. Materials can be diverted by identifying an area where materials can be placed for other students or non-profits to take items, or by providing a storage area where students can donate and/or take items. Some municipalities are encouraging schools to provide furnished rooms/apartments to reduce quantities of materials left behind when students move out. “Operation Separation” runs for one week in a neighbourhood in the City of Guelph, home to about 800 students, half of whom move out each year. In 2018, the program collected over 450 kilograms of food and nearly 400 pieces of furniture and household goods. The New2U Move-out Collection and Move-in Tag Sale is a program run by students at the University of Massachusetts. Unwanted items are collected in the spring during move-out and sold in the fall during move-in. https://www.umass.edu/sustainability/waste-recycling/green-events/new2u-sustainable-move-out
Target Material / Feedstock	Materials such as clothing, furniture, jewelry, small household goods and electronic equipment that would otherwise be sent for disposal or processing could be reused, repaired or repurposed.
Outputs	Less waste is sent for disposal if implementation of programs and reuse of materials is successful.

Reuse of Materials	
Regulatory Considerations	Under the *Waste Free Ontario Act (WFOA)*, the province of Ontario has placed an emphasis on resource recovery, including the reuse of materials. The idea behind the Strategy for a Waste Free Ontario and the *WFOA* is to maximize value and eliminate waste by improving the design of materials, products and business models, including maximizing the useful life of materials. By instituting a circular economy, the *WFOA* drives innovation. Businesses will be encouraged to design reusable products, which will add value to the economy by creating or expanding the reuse sector.
Capital and Operating Cost Range	Potential for minimal impact to net operating cost. Minor operating costs may be required for provision of facilities for reuse activities to occur and for staff to monitor the facilities.
Revenue Opportunity / Cost Savings	Cost savings associated with preservation of landfill capacity and avoided costs of disposal. Little potential to generate revenue.
Risks and Benefits	**Risks** • Potential for items being shared to get stolen or broken, requiring replacement or maintenance. • May be difficult to find and retain volunteers for reuse workshops. • Older appliances can be less energy efficient and could potentially be hazardous to repair. • Difficult to track the impact that reuse has on diversion and the success of the program. • Can consume staff time with planning and monitoring of programs.

Reuse of Materials	
	• Potential to compete with non-profits for business and reducing their revenue sources. • Potential liability risks if a user is injured by a used item, especially if an item does not meet current safety requirements (e.g., car seats) **Benefits** • Overall societal benefit associated with lower costs of reusing an item versus purchase of a new item. • People purchasing goods are able to save money by purchasing second hand items or get them for free. • Reuse of material/items helps to decrease the amount of waste to be managed, reduces collection and disposal costs and saves landfill space. • Promoting reuse events creates opportunities for community engagement and makes everyone in the community feel equal by offering useful materials and objects regardless of family income, while also avoiding purchasing costs. • Repair Cafés and tool libraries can teach residents how to repair materials and promote the idea of fixing before tossing, leading to less waste being disposed of. It also provides opportunities for local organizations/initiatives to grow and for innovative approaches to be developed.
GHG Impacts	Anticipated Reduction in GHGs • Reuse of materials results in less materials being managed by the City which will likely reduce GHG emissions associated with collection and disposal.
Potential Environmental	• Maximize diversion and contribute towards diversion targets.

Reuse of Materials	
Impacts and Benefits	● Reduces impact of manufacturing, transportation, processing and disposal of new products.
Potential Known Health Impacts	● Minimal to no health impacts associated with the reuse of materials.

3.3 Summary of Avoidance, Reduction and Reuse

The following table summarizes the technology and/or approach researched, the potential applicable material stream and the potential customers the technology and/or approach could be applied.

Approach	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
Waste Avoidance and Reduction						
Disposal Bans	SSO (LYW and Household Organics)	X	X	X	X	X
	Appliances	X	X		X	X
	E waste	X	X		X	X
	Textiles	X	X		X	X
	Recyclables	X	X	X	X	X
Campaigns	SSO (LYW and Household Organics)	X	X	X	X	X
	Appliances	X	X		X	X
	E waste	X	X		X	X
	Textiles	X	X			X
	Recyclables	X	X	X	X	X

Approach	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
Mobile Applications	Variety	X	X		X	X
Reuse of Materials						
Websites	Variety	X	X		X	X
Mobile Applications						
Swaps						
Repair Cafe						
Sharing Libraries						
Reuse Centres						

4 Waste Diversion

This section looks at different approaches to municipal waste diversion including: regulatory approaches, promotion and education, and collection of textiles, mattresses, construction and demolition (C&D) wastes, e-waste, MHSW, scrap metal, and bulk waste.

Between 2018 and 2019 the City carried out a study of curbside waste collection system options by developing a model to assess the following waste collection options; all intended to encourage waste diversion:

- Clear bags for garbage ;
- Pay-as-you-throw (PAYT) with enforcement;
- Containerized garbage collection;
- Garbage bag/container limits with enforcement;
- Material bans with enforcement; and
- Mandatory separation.

Some of these options are highlighted in the following sections and will be considered as options in Phase 2 of the City's Solid Waste Master Plan.

The City provides collection of recyclables, household organics (Green Bin) and/or leaf and yard waste to its customers. Municipal Hazardous or Special Waste (MHSW) is managed through events. The City collaborates with the retail sector and charitable organizations through the Take It Back! Program, where residents can bring materials (e.g., pharmaceuticals, paint, CFL bulbs, textiles, electronics, household items) for reuse, recycling and/or safe disposal. Tires and electronic waste can be safely recycled through the Take It Back! Program and at the Trail Waste Facility Landfill (in addition to other drop-off locations throughout the city). Materials such as scrap metal and blue and black bin recycling are collected by the City from City facilities and at the Trail Waste Facility.

Ottawa's site plan development guidelines for multi-residential buildings were approved by Council in 2011. As part of the Site Plan approval process, all new buildings must meet minimum standards to allow for the storage and collection of recyclables and compostables in order to receive waste collection services. The City has a Green Building Policy for the Construction of Corporate Buildings. All newly constructed buildings with a footprint greater than 500 square metres (5,400 square feet) must be designed, delivered and certified by the Canada Green Building Council (CaGBC) as being LEED™ – Canada Certified at minimum.

For many years, the City has implemented differential tipping fees (e.g. double the tipping fees) for ICI and C&D waste that is mixed with recyclables.

The City offers comprehensive promotion and educational tools and resources to its customers through its call centre (311), on-line resources (Ottawa.ca), social media, printed resources and staff. This is done through regular, seasonal and individual program campaigns. An annual paper calendar is mailed to residents. Waste Diversion market research by Hill and Knowlton Strategies (H+K) in 2019 found that the calendar is the most used communication channel for curbside waste and recycling information. The research also found that the City's website and 311 were the most used channels for getting information about City services. The City also utilizes the Waste Explorer and Recollect to provide information about waste-related programs and services.

The City of Ottawa has several private donation bins located across the city, and some businesses take back their own used merchandise. As previously mentioned, consignment stores and websites exist where gently used clothing and shoes can be sold.

The following five tables present research on regulatory approaches, promotion and education, textile collection programs, mattress recycling and C&D recycling to increase waste diversion.

4.1 Policy and Regulatory Approaches

Policy and Regulatory Approaches	
Approach / Technology Type(s)	Use of policies and supporting regulations to promote, encourage or mandate waste diversion.

Policy and Regulatory Approaches	
Description	Development of municipal or regional policies and implementation of supporting systems and regulations to achieve the policy direction including zero waste goals, bag limits, mandatory diversion, tipping fees, landfill bans, pay as you throw (PAYT)/ user pay, clear bags and development standards. The policies that are developed are regulated and enforced through municipal by-laws.
Status	Proven – Policy and regulatory approaches are a proven approach to waste diversion and are currently being implemented at full scale with success in other Canadian municipalities.
Availability	Proven waste diversion policies and by-laws are available for reference from other Canadian municipalities and can be used as guidance and best practices in the development of new waste management targets, policies and regulations for the City to support waste diversion.
Examples / Case Studies	**Zero Waste** - Sets a goal of a high diversion rate for a municipality that becomes the framework for the development of waste management initiatives in a solid waste management master plan. Establishing an aspirational goal provides a context for these initiatives. The City of Toronto has set a goal of diverting 70 percent of Toronto's waste away from landfill by 2026. Their waste strategy supports the City's move towards a circular economy and a zero waste future. The City of Calgary also has a Zero Waste vision. In 2015, City of Calgary Council approved a revised target of 70 per cent waste diversion by 2025 averaged across all four sectors – single family residential, multi-family residential, business and organizations, and construction and demolition. https://www.calgary.ca/UEP/WRS/Pages/About-WRS/Calgary-Waste-Goals.aspx

Policy and Regulatory Approaches	
	Circular Economy – The idea of a circular economy has become prominent in many jurisdictions over the past several year. A circular economy is an alternative to a traditional linear economy (make, use, dispose) where resources are kept in use for as long as possible, and the maximum value is extracted from them while in use. At the end of the resource's service life products and materials are recovered and regenerated. The Government of Canada is working to support businesses and communities that are creating new economic opportunities that keep the value of resources in the economy and out of the landfill. Several municipalities have developed circular economy policies including roadmaps that focus on priority sectors in their communities. This information is summarized in the Ellen MacArthur Foundation Report titled “City Governements and their Role in Enabling a Circular Economy Transition” https://www.ellenmacarthurfoundation.org/assets/downloads/CE-in-Cities_Policy-Levers_Mar19.pdf **Mandatory Diversion** – A number of municipalities have implemented mandatory curbside recycling and food waste diversion. This is achieved by developing a corresponding by-law that prohibits or specifies how materials are to be set out and consequences of not complying (e.g. refusal of collection, fines). An enforcement strategy and communications strategy also accompany the by-law to clarify how and when the by-law will be enforced and how residents will be made aware of the changes. Examples include City of Gatineau, San Francisco, Calgary, City of Vancouver, City of Owen Sound, Region of Markham and Cape Breton Regional Municipality. A food waste ban took effect in 2015 to correspond with the landfill disposal ban implemented by Metro Vancouver. The Province of Ontario has also implemented mandatory source separation of recyclable materials for businesses and multi-residential buildings.

Policy and Regulatory Approaches	
	http://by-laws.vancouver.ca/8417c.pdf https://www.calgary.ca/CSPS/ABS/Pages/Bylaws-by-topic/Garbage.aspx https://archive.epa.gov/wastes/conserve/materials/paper/web/html/index-2.html https://www.ecocyclesolutionshub.org/wp-content/uploads/2015/07/Ontario-Mandatory-Recycling-Guide.pdf **Tipping Fees -** These fees apply to quantities of waste material brought to a disposal site for recycling or disposal. Tipping fees vary by landfill and waste materials. Municipal tipping fees are approved through the budget process and are structured to encourage waste diversion with no or low fees for materials that can be recycled compared to disposal fees as currently done by the City of Ottawa. Use of fees enables the introduction of recycling opportunities when markets become available and reduces the cost to implement the program. **Landfill Bans** - Landfill bans are regulations that are enforced at the landfill to reject any materials that are banned for disposal in the jurisdiction. In some cases, there is a tolerance for a low level of the banned material accepted in a load, or else a penalty is applied to the load or it is rejected from landfilling. Bans have previously been discussed in Section 4.1. **PAYT (Pay As You Throw)** - PAYT is a 'user pay' approach for solid waste collection services that can be used to encourage diversion through user fees. A number of fee structures have been implemented, with some programs charging for both garbage and recycling, with a lower rate for recycling while others charge a fee only for garbage and recycling is free. Cart based programs can offer variable sizes and flexibility in fees based on the size of the

Policy and Regulatory Approaches	
	container selected (e.g., City of Toronto). Programs without cart systems typically use a "bag tag" system for garbage and no fee for recycling. This approach allows flexibility in the type and number of containers for excess garbage. Bag tag systems have lower administration costs and tags can be sold through local retailers. Fees charged may cover full costs in a utility based system or a portion of the costs to provide an appropriate financial incentive. The City of Barrie (1997), the City of Sudbury (2004), City of Kingston (2012), and City of Sudbury (2018) use PAYT regulatory policies to increase waste diversion. The City of Toronto operates as a utility and has used its rate based program to increase diversion and remove solid waste costs from the tax levy. The City of Gatineau has a cart-based garbage system (all are 120L) and residents can purchase additional bags for $0.50 each. Beaconsfield QC charges residents a flat fee and a fee for the size and frequency of collection. Residents can choose the size of bin suitable for their household and the frequency of collection. The flat fee varies by size of container and assumes 12 collections per household annually. Residents pay an additional fee above the allotted 12 collections ranging from $.040 to $1.20 for each collection. Each cart has an RFID tag which links the bin to the household and records the number of lifts. Various studies have indicated that PAYT systems are a best practice and should be considered for increasing diversion. In a review of municipalities with PAYT policies with those that do not, those that do often have higher waste diversion rates. https://ecofiscal.ca/wp-content/uploads/2018/10/Ecofiscal-Commission-Solid-Waste-Report-Cutting-the-Waste-October-16-2018.pdf https://rpra.ca/wp-content/uploads/2018-Residential-Waste-Diversion.xlsx

Policy and Regulatory Approaches	
	Clear Bags – In bag-based collection systems, clear bags can be regulated for garbage collection to encourage curbside waste diversion. When clear garbage bags are required, items in the garbage that can be recycled or composted are visible which facilitates enforcement of the policy at the curb by the collector. Rejected bags are left at the curb with a notification sticker educating the user about the diversion programs. Halifax Regional Municipality (HRM) implemented a clear bag curbside garbage collection policy in 2015 and the City of Kawartha Lakes implemented a clear bag program in 2017. A number of Ontario municipalities have clear bag programs including Dufferin County (2013), Markham (2013) and West Grey (2010). **Development Standards** – Future waste diversion can be improved when new development occurs in a municipality through the development of Official Plan policies and development standards requiring appropriate space provisions and consideration of on-site waste diversion. The Official Plan and development standards can incorporate the goals set out in the municipal solid waste management plan. The City of Toronto has incorporated solid waste in the Toronto Green Standard that sets out development standards for new multi-residential buildings. It includes a range of sustainability standards including solid waste for various building types including City-owned facilities and agencies. Some of the standards are for waste collection and sorting, waste storage space, compaction, household hazardous waste and/or electronic waste. The Standard was introduced in 2006 on a voluntary basis and Version 3 of the standards took effect in 2018. The Region of Peel is currently updating their development standards. Major updates since the most recent version are regarding infill developments and multi-residential developments; however, the development standard document is for both single-family and multi-residential.

Policy and Regulatory Approaches	
	https://www.toronto.ca/services-payments/recycling-organics-garbage/long-term-waste-strategy/overview/ https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/toronto-green-standard/ **By-laws –** Municipal by-laws enable regulation of activities within the jurisdiction, once approved by Council. Solid waste by-laws are in place to regulate the operation of the collection, transfer and disposal systems and can include effective provisions that regulate or encourage waste diversion as outlined in the examples above. Additional examples include by-law requirements for set-out limits, establishments to develop waste diversion plans or provide certain infrastructure. The City of Vancouver requires non-residential properties that generate food waste, yard waste and clean wood to prepare an organic waste diversion plan to reduce and divert these wastes. It should be noted that the City of Vancouver is a charter city. The Vancouver Charter is a unique provincial statute that serves to incorporate the City of Vancouver. This legislation granted the city more and different powers than other communities possess under British Columbia's Municipalities Act. Municipal by-laws have been enacted to ban plastic bags and single use plastics, which have been challenged in court. In July 2019 British Columbia's highest court struck down the City of Victoria's single use plastics by-law. https://www.theglobeandmail.com/canada/british-columbia/article-bc-cities-urge-province-to-ban-plastic-bags-after-appeal-court/ **Policy/By-law for Multi-Residential Buildings** – Many municipalities have collection guidelines and policies stipulating the kind of chute required for larger multi-residential buildings. The City of Guelph requires a chute system comprised of three individual chutes, a tri-sort chute or a bi-sort system with a second single chute. The City of Richmond Hill requires new high-rise

Policy and Regulatory Approaches	
	buildings with five or more storeys to provide three separate waste chutes (one each for garbage, recycling and organics). The City of Toronto has a chute closure program to allow multi-residential buildings that receive City of Toronto garbage collection service to close their garbage chutes to provide greater control, save money and reduce contamination. There are a number of eligibility requirements and steps to carry out this process. https://pub-richmondhill.escribemeetings.com/filestream.ashx?DocumentId=20914
Target Material / Feedstock	All material streams handled by the City.
Outputs	Policies, Standards and By-laws.
Regulatory Considerations	Landfill bans are typically a provincial regulation; however, municipalities do have the power through their regulatory powers to ban items from their own landfill. The province of Ontario launched its Food and Organic Waste Framework in 2017 and has plans to ban all organic waste from landfills starting with a phased in approach in 2022. Provincial Regulatory Considerations are not applicable to: zero waste, PAYT, and clear bags since they fall under municipal jurisdiction. Development Standards and Official Plan Updates must be made in consideration of the Ontario Planning Act, R.S.O. 1990, c. P.13.by-laws.

Policy and Regulatory Approaches	
Capital and Operating Cost Range	Development and implementation of policies and supporting regulatory approaches would require City staff time. Implementation costs will include promotion and education of any changes and will vary based on the option and need for additional staff resources or software systems to support the regulation, e.g., enforcement, administrative costs for PAYT, development review of planning applications. Capital costs for policy and regulatory approaches are lower compared to other options, however, may include requirements for purchase of software systems to track and monitor compliance. Actual capital and operating costs will vary depending on the type of approach, level of enforcement, staffing, staff vehicles and equipment, promotion and education, and clean-up efforts for illegal dumping. Leveraging existing municipal systems and programs (e.g., water billing or tax collection systems, by-law enforcement, planning processes) or integrating waste management system changes (e.g., introducing a cart based collection program to improve collection efficiency at the same time as a PAYT program) can reduce implementation and operating costs.
Revenue Opportunity / Cost Savings	Potential revenue opportunities are landfill tipping fees, landfill levies due to bans (e.g., fines or penalties), revenue from the sale of recyclables to end markets and PAYT user fees.
Risks and Benefits	**Risks** ● Administrative requirements to administer regulatory programs. ● Enforcement requirements. ● Potential increase in illegal dumping.

Policy and Regulatory Approaches	
	• Initial public disapproval to change in policies. **Benefits** • Increased diversion. • Performance improvement in meeting diversion goals. • Potential to reduce contamination. • PAYT increases equity in the system as each household is responsible for the cost of waste they produce.
GHG Impacts	Anticipated No Change in GHGs • Development and implementation of the regulatory approaches will have no direct GHG impact; however, the indirect benefits (i.e., increased waste reduction and diversion) can reduce GHG emissions as less waste will be going to landfill.
Potential Environmental Impacts and Benefits	• Potential for illegal dumping. • Improved participation in waste diversion programs and diversion from landfill.
Potential Known Health Impacts	• Minimal to no health impacts due to regulatory approaches of waste diversion policy.

4.2 Promotion and Education

Promotion and Education	
Approach / Technology Type(s)	Extensive promotion and education (P&E) initiatives are essential to having effective waste management programs in terms of proper sorting practices and reducing contamination, as well as educating residents about the benefits of waste diversion. Some municipalities are using progressive social behaviour research (including community-based social marketing) to influence behaviour change in large scale populations. However, promotion and education on its own will not change the behaviour of all people. To increase performance promotion and education needs to be coupled with policy changes and often enforcement.
Description	Waste diversion promotion and education strategies have been used to achieve a variety of goals from promoting higher participation in diversion programs to modifying behaviour, such as wishful recycling (i.e. where residents place items they hope are recyclable or think should be recyclable in recycling containers), leading to high contamination rates in recycling programs. While promotion and education programs remain a key component of successful waste diversion programs, staff often face restricted promotion and education funds that require them to examine strategy trade-offs. A recent Continuous Improvement Fund report, “Review of CIF Funded Projects and Key Learnings” Final Report: June 28th, 2017 indicates that direct engagement strategies (face to face interactions, community events, etc.) yield the greatest immediate change in recycling behavior; however, they can be resource and time intensive. Advertising through local newspapers is a lower cost (at this time); however, only reaches a certain demographic (e.g. older residents).

Promotion and Education	
	https://thecif.ca/wp-content/uploads/2016/09/762-York_Univ_Final_Report.pdf Many municipalities and regions throughout North America provide a variety of promotion and education to residents and businesses through tools, resources and public outreach. External communications are central to the success of a program and provide clear, relevant and timely information. Multi-media approaches are required to effectively reach the target group for the promotion and education strategy. This can include via a website, mobile applications, social media, collection calendars, direct mail, a call centre, public outreach, and waste ambassador programs.
Status	Proven
Availability	Availability is dependent on resources including staffing and finances.
Examples / Case Studies	**P&E Strategies and Campaigns** ● In 2016 the Ottawa Valley Waste Recovery Centre developed their 2016 Sorting It Out Christmas Campaign which included radio and newspaper advertising, social media posts and a video. The focus of the campaign was proper sorting of waste typically generated during the holiday season as well as waste reduction messaging encouraging alternatives to over-packaged goods and toys. https://ovwrc.com/unique-campaign-wins-gold/ ● In 2017 the Township of Langley, B.C. rolled out an education campaign around reducing litter and illegal waste in the Township. The campaign included radio ads, social media, and their website to promote the program; however, the main promotion was through putting bulky items on the corner of busy intersections with the tagline “don’t be an #idiot” (illegal dumper in our township).

Promotion and Education	
	Following the launch of the education campaign the Township reported seeing 10% fewer incidents of illegal dumping when compared to the prior year. **Website -** For the majority of municipalities and regions, the website is the main source of information. This includes providing information about municipal programs, services, activities and events. Information is often available in multiple languages, and pictures and graphics are optimized for use on a mobile device. **Mobile Applications** – Specialized applications are being developed to provide residents with self-serve information about programs and services such as Recollect, which has been implemented to varying levels by many municipalities including Ottawa. Waste Wizard is another popular mobile application and is used by the City of Toronto. **Social Media -** Social media is a promotion and education mechanism that has changed the way that the public engages, consumes and shares information. It has enabled municipalities and organizations to connect and communicate in new and innovative ways. Peel Region undertook an approach to reduce contamination in their recycling stream. The approach was to test out a digital-only marketing approach focusing on one contamination issue at a time over two phases. In 2017, the campaign used the slogans “Let them Loose!” and “Set Them Free” and aimed to educate residents about the impacts of placing recyclables inside plastic shopping bags, tying them shut and placed into the carts. Tactics used included a video, website, social media (Google, Twitter, Facebook) and email. The video showed what happens to recyclables placed in small shopping bags at the Materials Recovery Facility (MRF) and how the bags can end up in landfills and had 1.9 million views. This campaign resulted in decreased

Promotion and Education	
	bagged recyclables entering the MRF and the associated savings from avoided residue costs and revenue from the sale of materials. The second phase of the campaign took place in 2018 and focused on cleaning out food from recyclable containers prior to placement in recycling carts. The slogans “sticky situations” and “Too much on your plate” were used using the same tools and tactics as the first phase, including a video that got almost 1.2 million views. The Region did not observe any significant changes in the amount of food contamination entering the MRF. https://thecif.ca/use-your-digital-media-to-get-your-message-out-peel-did/ **Calendar -** Some municipalities continue to mail out an annual calendar to residents including the City of Ottawa and the Cities of Surrey, Vancouver, Toronto, and Windsor; however, some municipalities have moved away from mailing out an annual calendar to all addresses. Instead, a digital version is provided on the website for downloading or via a mobile application, and a mailed version is only distributed if requested through an online or phone inquiry. **Call Centre -** Municipalities continue to have staff available to answer inquiries related to garbage and recycling. Some municipalities have a direct line to garbage and recycling staff (e.g., City of Surrey); however, the trend for municipalities is to have residents phone the municipality’s call centre, a single customer service number for the municipality or 311. The call centre answers routine enquiries and initiates service requests and only unique or escalated calls are redirected to subject matter experts (e.g., City of Ottawa, City of Toronto, City of Hamilton, City of Calgary). While the trend is moving towards on-line channels (websites, social media, apps), there are still people who prefer to speak with someone directly; therefore, the need for a

Promotion and Education	
	customer service line to answer inquiries is essential to a municipality. http://ottwatch.ca/meetings/file/589587 **Public Outreach -** Public outreach related to solid waste and recycling varies across municipalities and is dependent on funding, staffing, and community programming needs. Outreach can include tours at waste management facilities, attendance at community events to promote new and existing programs, compost giveaways, contests, open houses, presentations, site visits, and feedback surveys. Simcoe County utilizes a 35' trailer as a mobile education unit with a variety of interactive stations, primarily aimed at school children. **Waste Ambassadors –** Waste Ambassadors can either be municipal staff or volunteers who assist targeted communities to gain a better understanding of waste diversion in their community and general waste reduction. The use of volunteer waste ambassadors in multi-residential buildings has been popular in several jurisdictions including the Cities of Toronto, Surrey, and Richmond, Township of Langley and Metro Vancouver. The City of Ottawa hired approximately 12 part-time students in 2019 to serve as ambassadors, informing residents about changes to the Green Bin organics program. Their role was to visit targeted communities based on audience segmentation data and areas of low Green Bin participation to educate residents on the enhanced program and encourage participation. The target audiences were based on data identified in a market research study. Dillon Consulting Limited. 2015. Review of Richmond Green Ambassadors Program and Partners for Beautification Program

Promotion and Education	
Target Material / Feedstock	All waste streams.
Outputs	No direct outputs, rather results are indirect benefits such as raising awareness of recycling and waste diversion programs.
Regulatory Considerations	Accessibility for Ontarians with Disabilities Act (AODA) compliance is required for reporting, website content, educational materials and/or customer service.
Capital and Operating Cost Range	Some promotion and education activities may be executed with existing resources if completed in-house such as online communications (social media posts, keeping the website content up-to-date); however, funding will be required for items such as public outreach, ambassador programs, mail-outs, calendars, and any specialized campaigns beyond what municipalities currently dodo Anticipated cost ranges are solely dependent on the type and number of activities to be undertaken and can range from $1 to $10 per household. Capital costs may be required for the development or purchase of specialized applications or software and operating costs for ongoing licensing fees. Costs also need to consider any pre and post- performance monitoring to determine the success of specific campaigns (e.g. waste audits).
Revenue Opportunity / Cost Savings	Not applicable.
Risks and Benefits	Risks

Promotion and Education	

	● As new information and services are introduced on platforms such as a website and social media, the expectations of the target audience could grow faster than the ability to keep up with expectations.
	● One type of promotion and/or education activity may not reach all targeted audiences and a variety of tools will need to be used to reach everyone targeted.
	● Online communications will need to be monitored on an ongoing basis for any potential communication from the public.
	● Online communication through social media has the potential for the municipality to receive negative feedback. The municipality will need to either respond to the negative feedback professionally or remove the negative feedback and risk being criticized for removing the content.
	● Information needs to be routinely updated and refreshed.
	● Limited budget, including for pre and post monitoring
	
	Benefits - Benefits are varied, as they are dependent on the services that are provided.
	
	● Digital tools (City website, Waste Explorer, mobile apps, chatbot etc.)
	    o Reduced calls for simple inquiries.
	    o Improved customer service as information is provided 24 hours a day, seven days a week.
	    o Access to information without the need to physically visit an office or phone.

Promotion and Education	
	- o Up-to-date information shows that visitors to the site will have a high level of confidence in the accuracy and relevance of information and services provided. ● Social media o Can be used to engage, provide information, communicate and listen to the community. ● Public Outreach o Can provide a better understanding of the public's values, beliefs and priorities. o The community is more informed. o Assists with community buy-in and support.
GHG Impacts	Anticipated no change in GHGs impacts associated with P&E initiatives itself.
Potential Environmental Impacts and Benefits	● Promotion and education of waste diversion programs contribute to public awareness of services that are available and how to properly handle waste materials. This can contribute to waste diversion and reduction initiatives and reduce contamination in the recycling and organics streams.
Potential Known Health Impacts	● Minimal to no health impacts of P&E campaigns directed at increased waste diversion.

4.3 Textile Collection

Textile Collection	
Approach / Technology Type(s)	The results of many municipal waste composition studies have indicated that textiles such as clothing and linens are being disposed instead of reused or recycled. This approach covers the collection of textiles for reuse or recycling purposes. In a 2019 waste composition study recently completed for the City of Ottawa, textiles comprised 5% of the garbage stream (0.32 kg/hh/wk) from single family households.
Description	Textiles have become a topic of interest for municipalities looking to further reduce waste going to landfill. Most clothing ends up being disposed at the end of its life with only a small amount being donated for reuse and recycling purposes. Municipalities have targeted textile collection through curbside programs, drop-off bins, depots and swap events and have an opportunity to collaborate with non-governmental organizations. Municipalities may focus on recycling the textiles/clothing that cannot be reused anymore to avoid competing with charitable organizations for the quality or dignity-condition items that can and should be reused by residents in their communities. Many of the proceeds of selling reusable items in stores run by charitable organizations are used to operate programs to feed people, provide job training, etc. There are many outlets for diverting reusable clothing, but fewer to divert non-reusable textiles that are ripped, stained, etc. For textiles to be recycled (versus reused/resold) there are two types of processes that are dependent on the type of fabric: 1. For polyester based textiles, materials are shredded and granulated into polyester chips for processing. These are then melted and used to create new fibers for use in new polyester fabrics.

Textile Collection	
	2. For natural textiles, materials are sorted by type and colour and then pulled into fibers or shredded. This material is cleaned and then re-spun and ready for reuse in weaving or knitting. Materials that are not spun into yards are compressed for textile filling in items such as mattresses. Some challenges exist with fully recycling textiles locally which may result some of the materials being disposed of or being sent to other countries for recycling and/or disposal. There are many issues associated with the export of clothing to other countries including competition with domestic apparel manufacturers, weakening demand for locally produced clothing, allowing for-profit and non-profit agencies to focus less on domestic markets, providing a “justification” for people to buy and donate clothing as well as the GHG impacts associated with transporting these materials. Canada is the seventh largest exporter of used clothing in the world, with exports topping $185 million annually to places like Kenya, Angola, Tanzania and India. https://rco.on.ca/textileswaste/
Status	Proven for collection and sorting, but emerging for recycling technologies
Availability	Many Canadian municipalities have implemented successful textile waste diversion collection programs. Many municipalities partner with charity or community organizations or non-profits in the collection of textiles. Processing, collection and sorting facilities for textiles exist; however, they are not necessarily local to all municipalities.
Examples / Case Studies	**City of Markham, ON** - The City of Markham has banned the disposal of textiles in their garbage waste stream.

Textile Collection	
	● The ban is enforced with a clear garbage bag requirement for curbside collection by residents. Markham's unique textile recycling program accepts all adult and children's clothing and footwear, undergarments, towels, pillows, and curtains, including items that are worn, torn or stained, or single items (e.g., socks and shoes). ● Textile donation bins are conveniently located at select City facilities and apartment buildings, providing safe, 24/7 access for recycling of all unwanted textiles. They are fitted with smart technology such as volume sensors, which send a signal when bins need servicing and can track diversion data. All donations go to Markham's registered charitable partners to create jobs and support communities in need. ● Markham partners with registered charities and retail businesses, such as, The Salvation Army, Diabetes Canada and STEPS To Recovery, who service and maintain all Markham branded textile donation bins. All donated textiles are sorted to determine suitability for re-wear, reuse or recycling. Gently used items are resold through the Salvation Army's Thrift Store and Value Village locations, and in the case of charities, proceeds help support local food banks, shelters, children's camps, addiction treatment facilities and medical research. Textiles that are not suitable for resale are recycled and repurposed into industrial rags, furniture padding, insulation, car seats, recycled fabrics and more. ● By the end of 2017, there were over 50 Markham managed donation bins across the community located on City property. Markham donation bins are also found at over 60 multi-residential properties. There are non-City donation bins in the community, but they are only eligible on private lands that are not zoned as residential or industrial (By-law 2018-90).

Textile Collection	
	New York City, NY – In New York City (NYC) if 10 percent or more of commercial waste is textile material a business is required to recycle it. Several initiatives exist throughout the City including the following: ● GrowNYC**–** GrowNYC's mission is to improve NYC's quality of life through environmental programs. One of their recycling programs targets textiles including clean and dry clothing, shoes, linens and other reusable textiles. Textiles are accepted in clothing bins that are located in over 200 residential buildings and are taken to a facility where they are sorted into different grades, with an effort to recover as much usable clothing as possible. Material that is not suitable for reuse will go to recycling markets to be used as wiping rags or shredded for low grade fiber products. https://www.grownyc.org/clothing ● Re-fashioNYC **–** Re-fashioNYC is a free and convenient clothing donation and recycling service available to apartment, office and commercial buildings. Two sizes of bins are available. The service is provided by the NYC Department of Sanitation and Housing Works and tax receipts for up to $250 are available. Some of the donations are sold in thrift shops throughout NYC, donated to other countries, sold to a textile merchant or exported to overseas markets.https://www1.nyc.gov/assets/dsny/docs/re-fashionyc-brochure-re-fa-f.pdf ● FABSCRAP– FABSCRAP is a one-stop textile reuse and recycling resource that collects materials directly from clothing brands, designers, cutting rooms, tailors and any other business creating textile waste. Two types of bags are provided to be filled by customers: 1) black for proprietary materials (which are shredded into insulation), and 2) brown for everything else. FABSCRAP has two store locations which sell back to the community materials that have been collected. https://fabscrap.org/

Textile Collection	
	● Ontario Textile Diversion Collaborative (OTDC) - The OTDC is a multi-stakeholder group under the umbrella of Fashion Takes Action. OTDC is committed to minimizing the number of textiles going into landfill by increasing the rate of textile diversion and by encouraging the development of a textile recycling industry in Ontario. Stakeholders include municipalities, academics, brand owners, retailers and industry organizations, NGOs, textile collectors and charities. OTDC has been funded by the Ontario Trillium Foundation's Collective Impact grant. https://otdc.co/about/ ● Make Fashion Circular, Ellen MacArthur Foundation – In 2018 the Make Fashion Circular campaign was launched in an effort to establish a circular economy for fashion, where clothes are created from renewable materials and/or old clothes are reused to make new ones. In 2018 the campaign was launched in NYC and for one week over 1,100 collection drop off points for old clothes were available across the city.https://www.ellenmacarthurfoundation.org/news/wearnext-make-fashion-circular-joins-forces-with-city-of-new-york-and-fashion-industry-to-tackle-clothing-waste. ● **Various Jurisdictions** - Some municipalities in Ontario (Kawartha Lakes, Simcoe County, Stratford) collect textiles in a separate clear bag through curbside collection to divert the textiles from landfill disposal. Depending on the contract terms, either a contractor or the municipality collects the bags of textiles for reuse by a third party. This requires promotion and awareness of the program. Simplerecycling is a US company that collects clothing, accessories and small housewares at the curb for several US cities. They also collect from school, corporate, and/or community donation drives. Simplerecycling is a for-profit company and pays some municipalities on a per pound basis. https://simplerecycling.com/about-us/ ● **Textile Sorting -** Textile sorting facilities such as Canadian Textile Recycling Limited, located in Burlington, ON, exist that sort and

Textile Collection	
	bale containers of collected used clothing (mostly through curbside collection). Clothing is then shipped to over 25 countries as second-hand clothing. https://www.canadiantextilerecycling.com/. ● **Textile Recycling –** Transtextile, located in Surrey, BC receives and processes approximately 30 tonnes a day of textiles in a 50,000 square foot sorting facility. Useable clothing is shipped to developing countries. Approximately 4 tonnes per day is not fit for reuse and is repurposed in the facility into wiping rags for industry. The rest of the materials are sorted based on the type of material (e.g., wool, acrylics, woven, coloured) and through a process of 'pulling' are remade into thread and reused to make new clothing and textiles. http://www.transtextile.com/the_business.html
Target Material / Feedstock	Residential textiles and related materials (linens, upholstery, footwear) that are reusable and non-reusable.
Outputs	Textiles and related materials (e.g. linens, upholstery, footwear) for reuse, repurpose, resale or recycling. Yarns for repurposing, wiping rags etc.
Regulatory Considerations	Not Applicable.
Capital and Operating Cost Range	Municipalities promote textile donation and reuse in their promotion and education communications; however, many rely on charities to provide the textile donation bins. In April 2017, the City of Markham became the first municipality in North America to implement a ban on textiles in garbage placed at the curb for collection (used clear bags to enforce this ban). The success of the textile ban from curbside collection is in part due to the wide availability of their managed donation bins. In 2015, Council approved a Markham Textile Recycling Program as part of the 2016 Capital Budget process. Staff applied for and received a matching grant of $67,000 from the Federation of Canadian

Textile Collection	
	Municipalities (FCM) to support the project.https://rpra.ca/wp-content/uploads/IPAC-Awards-Backgrounder-Markham.pdf. The actual program costs are not publicly available.
Revenue Opportunity / Cost Savings	Potential for revenue from the resale of gently worn clothes, though most municipalities work with charities in textile diversion partnerships and the charity receives the revenues for sale of used clothing. Cost savings associated with preservation of landfill capacity and avoided costs of disposal.
Risks and Benefits	**Risks** ● Overfilled bins and reliance on charity organizations for operational diligence, which can be supported through the development and enforcement of municipal property standards by-law. ● Often, the public uses drop-off areas to dispose of materials that are not part of the program (e.g., toys, furniture etc.) at the cost to the municipality to collect. **Benefits** ● Charity partnerships operate the program and are well established. Rarely is the municipality required to handle the material.
GHG Impacts	Anticipated Reduction in GHGs ● The UN Alliance for Sustainable Fashion indicates that the textile industry accounts for approximately eight to ten percent of global carbon emissions – more than all international flights and maritime shipping combined. https://www.unenvironment.org/news-and-stories/press-

Textile Collection	
	release/un-alliance-sustainable-fashion-addresses-damage-fast-fashion?cmp=newsletter-What+on+Earth%3F+Nov+21 ● Reduces impact of landfill decomposition. Anticipated Increase in GHGs ● Any collection approach should be optimized to limit GHG impacts. If a separate curbside collection program for textiles was implemented in Ottawa, it would likely increase GHGs from increased emissions from transportation.
Potential Environmental Impacts and Benefits	● The UN Alliance for Sustainable Fashion indicates that the textile industry is responsible for 24 percent of insecticides and 11 percent of pesticides from the production of raw materials. Reusing an item reduces the need for new materials and reduces the use of insecticides and pesticides associated with developing new materials. Textiles are also accountable for some of the plastic waste found in the environment. ● By diverting textiles from landfill for reuse, repurpose and recycling, it reduces the amount of raw materials required from crop production, pesticides for textile crops, wastewater from manufacturing, transportation and GHG emissions from virgin material extraction and decomposition on landfills.
Potential Known Health Impacts	● Reducing the amount of textiles to landfill can reduce GHG emissions and has an indirect benefit on health. ● In several incidents across Canada, as a result of the unsafe bin design of some textile collection bins, several people have suffered fatal injuries resulting from becoming stuck inside of the donation bins. ● Health impacts of textile production was not reviewed as a part of this memo.

4.4 Mattress Recycling

Mattress Recycling	
Approach / Technology Type(s)	Recycling mattresses into component parts that would otherwise be landfilled.
Description	Mattress recycling is the process of dismantling the different components (foam, wood, fabric, cotton batting and metal) for reuse and recovery. Materials inside of the mattress are stripped, separated, sorted and baled for shipment to other facilities for reuse. Collection of mattresses for recycling can include curbside collection (public and private) or via drop-off at the recycling facility or another designated location (e.g., depot or transfer station).
Status	Proven
Availability	Not all provinces have mattress recycling processors or facilities; however, some mattress retailers have a take back program. Where possible the retailers recycle the mattresses. Should mattress recycling become a mandatory program in the future, these programs may change. The dismantling of mattresses needs to be undertaken to a level that is acceptable to scrap metal dealers and other recyclers. There is a potential need for specialized equipment. This may not be an appropriate solution for every municipality.
Examples / Case Studies	**County of Peterborough and City of Peterborough, ON** – In 2014 a mattress and box spring ban was implemented at the Peterborough County City Waste Management Facility. Clean/dry mattresses are no long accepted at the site for disposal but are part of a mandatory recycling program. Fees for mattresses dropped off are currently $12 each (fewer than 10) or $20 each (10 or more) or $20 each if collected as part of the curbside large article collection program (and must be paid in advance of

Mattress Recycling	
	pickup). It is estimated that approximately 11,000 mattresses are kept from landfilling at the site. https://www.peterborough.ca/en/news/large-article-pick-up.aspx https://www.peterborough.ca/en/city-services/landfill.aspx https://www.thepeterboroughexaminer.com/news-story/8208372-mattresses-to-be-recycled/ **Metro Vancouver, B.C**. - A disposal ban of mattresses was implemented across Metro Vancouver, in 2011 when sufficient recycling capacity was confirmed. In 2016, there were approximately 165,000 mattresses collected within Metro Vancouver for recycling. The Metro Vancouver transfer stations charge a $15 per unit fee to cover the cost of recycling the mattresses. This fee reflects the cost currently imposed on the generator to recycle the mattress. There are currently two large-scale mattress recyclers in B.C., both located in Metro Vancouver. **City of Edmonton, AB** - The City of Edmonton charges $16 per mattress, box spring, or sofa (or comparable volume) at their Eco Stations; mattresses are not accepted curbside. There are no specific requirements on the mattresses collected at the Eco Stations. http://www.cbc.ca/news/canada/edmonton/mattress-recycling-edmonton-homeless-1.4120502 **City of Winnipeg, MB** – In Winnipeg, Mother Earth Recycling (MER) and IKEA have formed a partnership backed with more than $250,000 of provincial money and the support of Take Pride Winnipeg, to recycle used mattresses while training young workers for their first job. Take Pride Winnipeg is a charity that employs four full time staff, as well as seasonal staff with the mission: “to inspire community pride, raise public awareness and promote citizen responsibility”. The organization is funded by the City of Winnipeg, the Province of Manitoba, and various private

Mattress Recycling	
	donors. MER is the only mattress recycling facility in Winnipeg. The majority of the mattress materials are sent to secondary markets for recycling. Foam is recycled into carpet underlay, metal is recycled into cans, and wood is used in crafts or fire wood. The remaining plastic and zippers are landfilled. MER charges $15 per mattress and offers a pickup service for residents. https://www.winnipegfreepress.com/local/North-End--business-to-create-jobs-while-recycling-used-mattresses--365586401.html https://www.takepride.mb.ca/about/faq http://winnipeg.ca/waterandwaste/billing/fees.stm#specialcollection **City of Chilliwack, B.C.** – Some municipalities have experienced difficulties in establishing mattress recycling. For example, the City of Chilliwack conducted a two month pilot program for recycling mattresses at their landfill (mid-November, 2013 – mid-January, 2014). All non-recyclable materials were stripped and landfilled, and the wood frames with the attached coil springs were transported to the City's scrap metal recycler. After the pilot period, the scrap metal company no longer wanted the metals from the mattresses, as the excessive amounts of wood and residual fabric attached to the coil springs had the potential to jam their shredder. The recycling program subsequently ended. This demonstrates that the dismantling of mattresses needs to be undertaken to a level that is acceptable to scrap metal dealers and other recyclers. There is a potential need for specialized equipment and indications are that this may not be an appropriate solution for every municipality. **Recyc-Mattresses** – Created in 2007, Recyc-Mattresses is a Montreal, QC based company that recycles used mattresses and box springs at their locations in Montreal, Toronto or Vancouver.

Mattress Recycling	
	A pick-up service is also available for 25 or more pieces. In partnership with Sleep Country Canada Recyc-Mattresses has established a charity program at the Toronto location to provide clean, quality and in perfect condition used mattresses to various charity organizations. Each year more than 15,000 used mattresses are provided to families in need. **Canadian Mattress Recycling** - According to Canadian Mattress Recycling (a recycling company located in Delta, B.C.), one of the challenges with furniture recycling is that many of the component materials (e.g., leather, vinyl, polyester filling) are not recovered in enough volume to be marketable. With a lack of drivers to encourage furniture recycling (e.g., landfill bans, EPR program), it takes a long time for a furniture recycler to collect enough of a material to send a load of recyclable product to markets for secondary processing. Currently, many of the furniture materials are not financially viable to stockpile until a load is large enough, and with a lot of effort many are reused by distributing them throughout the community as part of charity work. This is time consuming and costly. https://canadianmattressrecycling.com/
Target Material / Feedstock	Used residential bed mattresses and box springs.
Outputs	Materials recovered from the recycling of mattresses: wood, metal, textiles, fabrics, foam, plastics, and zippers.
Regulatory Considerations	Mattresses may be one of the next designated materials in the *Waste Free Ontario Act*. A mattress recycling facility would require an Environmental Compliance Approval.

Mattress Recycling	
Capital and Operating Cost Range	In a 2017 report commissioned by Metro Vancouver titled: Assessment of Economic and Environmental Impacts of Mattress Recycling in BC the market value for all individual component materials from one mattress ranges significantly depending on market conditions. When markets are depressed, the recycling of one mattress is costing the recycler \$0.30 per mattress (\$11 per tonne) since the recycler is still having to pay tipping fees for waste materials. When markets are favourable, the revenue is at most \$4.55 per mattress (\$169 per tonne). Mattress recycling in Metro Vancouver has reduced landfilling costs by roughly \$180,000 - \$530,000 (an average of \$350,000) based on costs to build, operate and close a landfill. http://www.metrovancouver.org/services/solid-waste/SolidWastePublications/EconomicandEnvironmentalImpactsofMattressRecyclinginBC.pdf
Revenue Opportunity / Cost Savings	Revenue potential for the fees collected per unit for recycling.
Risks and Benefits	**Risks** • The market value of the materials salvaged from mattresses recycling is generally low. • A municipally run mattress collection program may be expensive to operate. **Benefits** • Mattresses are bulky and use up a lot of volume in landfills. By diverting them from landfill a lot of valuable space is saved. Some municipalities even shred mattresses if they do landfill them to save the wasted landfill space.

Mattress Recycling	
	● Recycling can provide jobs and employment training opportunities.
GHG Impacts	Anticipated Reduction in GHGs ● GHGs are avoided due to the recovery of materials from recycled mattresses. ● The net reduction in GHG emissions from Metro Vancouver's mattress recycling is approximately 8,900 tonnes CO_2eq (equivalent of removing 2,000 cars off the road for a year) based on diverting 4,005 tonnes of mattresses from landfill. Anticipated Increase in GHGs ● If a separate collection route is established, this could add to GHGs due to increased emissions from transportation. This needs to be considered when designing a program.
Potential Environmental Impacts and Benefits	● Recycling of mattresses and their materials such as wood, metal and textiles to secondary markets diverts these materials from landfill and in turn saves landfill space and extends the life of the landfill. ● Increases diversion rate.
Potential Known Health Impacts	● Collectors have indicated concerns with bedbugs on mattresses when they are being collected by hand. These health impacts were not further reviewed as a part of this assignment. ● Regarding a mattress recycling facility, health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

4.5 Management of C&D Materials

Management of C&D Materials	
Approach / Technology Type(s)	Construction and demolition (C&D) materials such as wood waste, asphalt and concrete are diverted from disposal and reused or recycled through donations, acceptance of source-separated materials and separation at processing facilities. Other policy and permitted approaches are used to increase diversion of C&D waste from disposal such as by-laws, ordinances requiring diversion on C&D projects, landfill bans on C&D, differential tipping fees and enforcement of by-laws.
Description	In most municipalities, the C&D waste stream is mainly controlled by the private sector. Some jurisdictions have implemented their own C&D programs that target primary components of the C&D stream; however, with no direct authority over the C&D stream it is difficult to require C&D materials to be recycled. Some municipalities such as the City of Hamilton have banned C&D waste at the municipal landfill if there is sufficient private sector capacity. If there is sufficient private sector capacity locally the bans can be completed for a number of waste types; however, it is difficult to complete entirely. Even if there is private sector capacity it may not be feasible for small businesses to use the private sector sites and often they pretend to be disposing of residential waste. Encouraging the use of private sector sites can be completed by maintaining the municipal tipping fee higher than private sector sites. Some C&D facilities or drop-off depots require materials to be sorted prior to arriving at the site, whereas some facilities have a single-stream processing line for separation of materials. Separated materials (whether separated prior to arrival or on-site) may be baled for processing offsite, ground/chipped for processing offsite or processed onsite.

Management of C&D Materials	
	http://www.halton.ca/cms/One.aspx?portalId=8310&pageId=151236 http://winnipeg.ca/waterandwaste/recycle/4rdepots/acceptedMaterial.stm https://www.pembina.org/reports/alternative-fuel-use-cement.pdf
Status	Proven for some types of C&D waste materials such as wood waste, asphalt and concrete and emerging for other types such as window panes, insulation and painted gypsum,
Availability	Processing of C&D waste can be a common approach to managing C&D waste across North America with facilities processing a single stream or separated streams of C&D. The majority of programs in Ontario collect shingles, drywall, concrete, metal, clean wood waste and brush. Wood and concrete are the two primary components of C&D waste. Reuse programs vary across the province / country and may be dependent on if there is a need in the community / industry for the recycled product.
Examples / Case Studies	**Donations** ● Various jurisdictions - Habitat for Humanity has approximately 100 ReStore locations across Canada. Many communities and regional governments promote home renovation donations for reuse to Habitat for Humanity through their public education and outreach efforts online and at events. Municipalities and Habitat for Humanity partner in the building of new Habitat homes, with the donation of land by the municipality. **Separation Facilities** - Undertaken by many facilities throughout Canada.

Management of C&D Materials	
	● Countrywide Recycling Inc., Hamilton, ON - Countrywide Recycling Inc. has a 60,000 square foot facility that can process up to 800 tonnes of materials per day. Bin companies, homeowners and commercial job sites have the ability to dispose of C&D materials at this site. Materials are separated through a combination of mechanical and manual processes and includes wood, metals, cardboard, drywall, fines and aggregates. The facility reports a 90 percent diversion rate on their website. http://www.countrywiderecycling.ca/ ● Tomlinson Waste Recovery Centre, Carp, ON **–** The multi-purpose waste management centre includes a single-stream C&D processing facility that serves to reclaim, crush and reuse aggregates, rock and concrete, recycle wood and metals, and convert mixed materials into biomass or fuel sources. The goal is to recover or recycle 80 percent of the inbound materials according to the company's website. https://wasterecoverycentre.com/ **Shingles Diversion –** Undertaken by multiple communities across Canada. Examples of communities that accept shingles for recycling (collected material is sent to a third party processor) include: ● City of Barrie, ON – The City of Barrie accepts shingles at the Barrie Environmental Centre (landfill site) for recycling by a private company (Try Recycling). Shingles are charged at the same rate as garbage disposal (2020 rates $10 for the first 100k g and $150/tonne after). ● City of Calgary, AB – The City of Calgary accepts shingles for recycling at their three landfill sites. The shingles were previously sent to Alberta Waste and Recycling or Lafarge for processing and used in municipal road construction. However, the City of Calgary Roads Business Unit recently made the decision to stop accepting recycled asphalt shingles in road construction. The impact on operations and quality of their pavement is yet to be determined.

Management of C&D Materials	
	Telephone correspondence with Alberta Waste and Recycling, April 2018. ● City of Lethbridge, AB – The City of Lethbridge accepts clean asphalt shingles for recycling at the landfill in a separate collection area. The asphalt shingles are currently being stockpiled and are not being used. The City is planning on grinding the shingles and using the pellets in landfill road construction and other landfill operations. Opportunities to use the pellets in municipal road construction, and in bike and walking path construction have been investigated and decisions to use the pellets are ongoing. Telephone correspondence with City of Lethbridge, April 2018 There are several third party processors that are recycling used asphalt shingles including: ● Synchor Recycling in Calgary, AB – There is a variable tipping fee charged for shingles depending on if they are a clean load or a mixed load containing other materials such as plastics. The rate for clean asphalt shingles is $70/tonne and the rate for contaminated loads is $120/tonne. The shingles are pelletized and sold to market where they are used in hot mix asphalt, cold patches, alternative fuel, temporary roads and driveways, aggregate road bases, and as a dust control agent with gravel or other recycled aggregates. http://synchor.ca/our-rates/ ● Eco Depot in Rosslyn, ON – The rate for clean asphalt shingles is $55/tonne. Shingles are pelletized and sold to market where they are used for various construction purposes, including asphalt and aggregate for road construction. The ground shingles must meet specifications to be sold as an additive in asphalt paving mixtures. http://www.ecodepotwd.ca/pricing/

Management of C&D Materials	
	Differential Tipping Fees for C&D Waste ● Ottawa Valley Waste Recovery Centre (OVWRC) - Customers are encouraged to separate C&D materials to save on tipping fees as acceptable separated materials (lumber and pallets, painted wood, concrete, bricks, drywall and shingles) of $95/tonne. Scrap metal and corrugated cardboard are accepted at no charge; however, if loads are unsorted, tipping fees are $250/tonne. ● City of Vancouver, B.C. – As of January 1, 2020 the tipping fee for mixed C&D waste received at the City's Landfill will be $99/tonne (for nine tonnes or more of waste), and the fee for wood waste is $100/tonne. Clean wood waste is separated from finished/treated wood. Metro Vancouver and member municipalities introduced the new Clean Wood Disposal Ban in 2015. http://vancouver.ca/home-property-development/landfill.aspx **C&D Project Permitting** ● City of San Diego, California **-** Several cities in California, such as the City of San Diego, have C&D recycling ordinances which require C&D projects to divert a certain percentage of the total waste generated from the project. The City of San Diego has a 65 percent diversion requirement, determined by the weight of the total C&D waste generated. San Diego, CA https://www.sandiego.gov/environmental-services/recycling/cd ● City of San Diego and Daly City, California **–** Both municipalities have an ordinance that requires that a refundable deposit is submitted when an applicant applies for a project permit. As a condition of deposit return, documentation of recycling / diversion activities must be submitted at the completion of the project. The refundable deposit varies based on the type of project and project size. The City of San

Management of C&D Materials	
	Diego maximum deposit amount is $40,000 and Daly City's is $30,000. ● Metro Vancouver, B.C. - Metro Vancouver municipalities each have their own set of by-laws and procedures for C&D activities including salvage and recycling in some municipalities. The Cities of Coquitlam, New Westminster, North Vancouver, Port Moody, Richmond, Surrey and Vancouver, and District of West Vancouver all have demolition recycling requirements. Metro Vancouver has prepared a toolkit as a reference for contractors, design professionals and building owners to help them maximize the amount of C&D waste diverted from disposal through salvage, reuse and recycling. http://www.metrovancouver.org/services/solid-waste/SolidWastePublications/DLCToolkit.pdf ● City of Vancouver, B.C. – The City requires that a Recycling and Reuse Plan be prepared as part of a building or development permit application. A Recycling and Reuse Compliance Form is required to be submitted to the City when demolition is complete. There is no required reuse or recycling rate, but the intent of the Plan is to encourage reuse and recycling of the material as much as possible. **Certification** Some building projects seek certification under a green building rating system and the implementation of an effective construction waste management plan can assist with meeting certification requirements. This includes reusing existing structures on-site, diverting a percentage of waste from landfill and using salvaged or reused building materials, thus reducing the quantity of C&D waste requiring management. Some of these certification programs include the following: ● Leadership in Energy and Environmental Design (LEED©) for New Construction awards.

Management of C&D Materials	
	● BuiltGreenTM residential green building rating system awards. ● Building Owners and Managers Association (BOMA) Go Green. ● International Green Construction Code (IgCC). This code is a public/private collaboration that provides a green model code to government jurisdictions so that government does not have to take on the high cost of developing its own code.
Target Material / Feedstock	C&D materials including but not limited to asphalt, concrete, shingles, wood waste, gypsum.
Outputs	● Shingles are repurposed into an additive for hot-mix asphalt or cold patch to fill cracks and potholes in roads. Some municipalities are currently using recycled materials such as singles in their pavement; however, some municipalities such as the City of Toronto does not allow the pavement specifications to contain recycled materials that may contribute to a lower quality pavement. ● Recycled drywall is used to replace virgin gypsum materials in the manufacturing of new materials. ● Asphalt, concrete and rocks are typically recycled into aggregate, new asphalt or concrete products. ● Recycled metal can be used for a wide variety of purposes and primarily is used for new building materials and/or appliances. ● Clean wood waste and brush are recycled into engineered-wood products such as furniture as well as mulch and compost. ● Biomass or fuel sources. ● Potentially animal bedding (gypsum and wood).
Regulatory Considerations	Requirements for C&D sector to reduce waste and recover resources under '3Rs' regulations. *O. Reg. 102/94, O. Reg. 103/94* and *O. Reg. 104/94.*

Management of C&D Materials	
Capital and Operating Cost Range	Costs vary depending on if a municipality provides a transfer station for C&D materials, or processes some, or, all of the materials. Municipal operating costs for a C&D transfer station are not publicly available; however, based on insights on private facilities this could range from \$3 to \$20 per tonne and capital amortized costs could range from \$3 to \$10 per tonne; however, these could be higher or lower based on construction costs and/or operating procedures and/or the types of C&D wastes received.
Revenue Opportunity / Cost Savings	● There may be revenue generating opportunities through some of the recycled materials that could offset program costs. ● Landfill capacity saved through the diversion of C&D materials can create future revenue opportunities for municipalities through additional tipping fees. ● Cost savings associated with preservation of landfill capacity and avoided costs of disposal. ● Cost savings associated with lower recycling fees than disposal fees in some instances (dependent on municipality/disposal location).
Risks and Benefits	**Risks** ● A lack of local materials may make setting up a diversion program and/or sorting facility not financially viable. ● The availability of information on overall C&D waste quantities is limited; therefore, details on diversion that occurs within the sector is limited. However, ensuring that there are programs in place for recyclable materials can be an important part of a waste management strategy. ● Recycling facilities may claim that materials are being recycled and diverted from landfilling; however, materials may end up being used as landfill cover (noting that they may end up

Management of C&D Materials	
	diverting other materials that may have been used as landfill cover e.g., soil). ● Recycled materials must meet the minimum requirements for cover material and if used as landfill cover, must be approved by the MECP. ● Use of recyclable materials in other products may reduce the quality than if only virgin materials were used (e.g., shingles in pavement). ● Some municipalities have implemented their own C&D recycling programs or partnered with other municipalities; some municipalities operate their own sorting facilities while others act as a transfer station. ● Some of the risks for C&D recycling facilities can include lack of local processors or markets for recycled materials which could lead to facilities closing (e.g. as was the case for two facilities planned/operated by separate large waste management companies near Toronto). This could result in a municipality losing money, stockpiling materials and/or landfilling materials. ● Landfilled C&D waste may generate odour issues, specifically H2S gas from decomposing gypsum. ● Municipalities that have permits requiring voluntary diversion must have diversion programs locally available in order for the permits to be effective. **Benefits** ● Materials are diverted from landfills which reduces GHGs and saves landfill capacity. ● Recycling C&D materials can be a revenue source for municipalities through the tipping fee and sale of baled/sorted/processed materials.

Management of C&D Materials	
	● Potential for economic development. ● Potential for growth in circular economy for materials that would otherwise be disposed.
GHG Impacts	Anticipated Reduction in GHGs ● Reuse and recycling of materials results in materials diverted from landfill which results in a reduction in GHG emissions relative to landfilling.
Potential Environmental Impacts and Benefits	● Reduce environmental impacts for extraction and transportation of virgin materials. ● Increases diversion rate.
Potential Known Health Impacts	● Minimal to no health impacts due to separating and recycling C&D materials with proper use of PPE. Associated health impacts of managing C&D waste such as asbestos were not assessed for this memo.

4.6 Summary of Waste Diversion

The following table summarizes the technology and/or approach researched, the potential applicable material stream and the potential customers the technology and/or approach could be applied to.

Approach / Technology	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
Policy and Regulatory Approaches						
Zero Waste	All	X	X	X	X	X
By-laws/Mandatory Diversion	All	X	X	X	X	X
Tipping Fees	All	X	X		X	X
Landfill Bans	All	X	X	X	X	X
PAYT	All	X	X			X
Clear Bags	Garbage, Recycling	X				X
Development Standards	Garbage, Recycling, SSO (LYW and Household Organics)	X	X		X	
By-laws	All	X	X	X	X	X

Approach / Technology	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
Promotion and Education	All	X	X	X	X	X
Textile Collection Programs	Textiles	X	X		X	X
Mattress Recycling	Mattresses	X	X		X	X
C&D Materials / Recycling						
Donations	C&D	X	X		X	X
Source Separation	C&D	X	X		X	X
Shingles Diversion	C&D	X			X	X
Wood Waste Diversion	C&D	X	X	X	X	X
Differential Tipping Fees for C&D Waste	C&D			X	X	X
C&D Project Permitting	C&D	X	X	X	X	X

Approach / Technology	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
Certification	C&D				X	X
Landfill Ban	C&D	X	X			X

5 Collection Fleet Technologies

This section looks at alternative collection fleet technologies including electric, hybrid and autonomous vehicles and alternative fuels in an effort to reduce GHG emissions

There are five curbside collection zones within the City and the City is responsible for collection from two of the zones which is done through the use of 45 collection vehicles. Solid Waste Services also uses 15 pick-up trucks for operations and management. There are also two containerized collection zones which services the multi-residential sector and the larger City facilities.

The City has previously run a pilot on hybrid vehicles added on to a diesel collection truck. City staff indicated that no benefit was found with respect to fuel use and that there was an increase in maintenance when compared to the vehicles that the City was using. Due to the ongoing maintenance there was more down time for the vehicle and operator.

The following four tables present research on several collection fleet technologies including electric, hybrid and autonomous vehicles, and alternative fuels.

5.1 Electric Vehicles

Electric Vehicles	
Approach / Technology Type(s)	Use of electric vehicles for municipal fleets, including for waste collection purposes.
Description	Electric powered vehicles run at on electricity and use an electric motor powered by electricity from batteries or a fuel cell. Electrical powered vehicles can reduce the carbon intensity related to industrial vehicles. In some applications, such as electricity generating anaerobic digestion plants, electric vehicles can help close the energy cycle. The electricity generated at these facilities can be used to fuel electric collection vehicles that deliver organics to the facilities.

Electric Vehicles	
	Electric vehicles may contain regenerative brakes which are a feature that help to recharge the battery while on the go. They also result in less base brake wear so they last longer than non-regenerative brakes. This is a benefit to waste collection vehicles due to the nature of frequent starting and stopping. http://www.miamilakesautomall.com/chrysler-blog/understanding-brake-maintenance-regenerative-brakes/
Status	Emerging
Availability	Truck manufacturers and waste facilities are evaluating the use of electric vehicles as an alternative to CNG and diesel powered vehicles. Currently there is very limited market viability and the technology for waste collection vehicles is in its infancy. Additionally, limited case studies exist, especially in cold weather climates. This may need to be considered given Ottawa's climate. https://www.nature.com/articles/s41586-019-1682-5. Article posted November 6, 2019.
Examples / Case Studies	**Rio de Janeiro, Brazil** - The City introduced a new fleet of all electric waste collection trucks. A total of nine trucks have been deployed. These trucks are manufactured by BYD, a Chinese manufacturer of automobiles, battery-powered bicycles, buses, forklifts, rechargeable batteries, trucks, and have a range up to 200 km with 15 cubic metres of storage. https://insideevs.com/news/374832/rio-de-janeiro-byd-electric-waste-trucks/ **City of Palo Alto, California** – In 2017, the City and its waste hauler, GreenWaste, started to use an all-electric automated side loader waste collection vehicle that was manufactured by BYD as part of a one-year pilot. The first generation vehicle can range up to

Electric Vehicles	
	76 miles (122 km), and requires two to three hours to fully charge and has a 195 kWh battery capacity. The City estimates that electric vehicles will save approximately 6,000 gallons of diesel annually, save 72 tonnes of GHG emissions annually which will help the City meet its goal of 80 percent GHG emission reduction by 2030. Specific pilot results are not publicly available; however, BYD is making significant design improvements to expand its vehicle's collection capabilities. The goal is to have enough onboard battery capacity to meet the operating requirements for every type of route within the City. https://en.byd.com/news-posts/press-release-byd-delivers-worlds-first-all-electric-automated-side-loader-refuse-truck-to-city-of-palo-alto-in-california/. Article posted November 15, 2017. https://www.youtube.com/watch?v=XtVMXACxxqQ. Video posted May 2, 2019. **City of Seattle, WA** – One of the City's collection providers will be using two electric collection vehicles, developed by Chinese battery manufacturer BYD and using bodies from a U.S. based manufacturer Seattle preferred electric over hybrid to align with its master policy action plan "A Clean and Green Fleet". Seattle received two waste hauling trucks starting in May 2019 to complement its "green fleet" of waste management vehicles. https://resource-recycling.com/recycling/2018/12/01/qa-collection-goes-electric/. Article posted December 1, 2018. https://www.recology.com/recology_news/seattle-goes-electric-all-electric-refuse-trucks-delivered/ Article posted May 21, 2019. **City of Los Angeles, California** – In 2018, the City of Los Angeles piloted electric automated side load refuse collection vehicles that were zero emission trucks. It was expected that selected routes for

Electric Vehicles	
	these vehicles would save 6,000 gallons of fuel per year. Results of the pilot are not available but it is indicated that there was limited success with these vehicles so far. Results of the study are not available; however, in January 2020 the Los Angeles Bureau of Sanitation committed to transitioning to a zero-emissions fleet by 2035. The City is putting the industry on notice to figure out the hurdles to implementation. Many hurdles remain, including placement of charging stations, range, grid resilience and navigating both weather and hilly terrain in some areas. The trucks can also be costly, sometimes two to three times more than a diesel equivalent. https://www.wastetodaymagazine.com/article/la-adds-electric-garbage-trucks/. Article posted October 9, 2017. https://www.wastedive.com/news/los-angeles-sanitation-truck-fleet-100-percent-electric/571166/. Article posted January 29 2020. **City of Chicago, Illinois** – In 2012 the City agreed to purchase five electric waste collection vehicles from Motiv Power Systems, Inc. On January 6, 2014 the City received the first ERT. The City alleges that since the vehicle was received, there have been mechanical and software problems that have prevented the City from using the vehicle. The vehicle has had significant breakdowns that render it inoperable. The City is currently suing Motiv for breach of contract and warranty and Motiv is countersuing for breach of contract. https://www.courtlistener.com/docket/14756091/38/city-of-chicago-v-motiv-power-systems-inc/. Court documents dated July 9, 2019. **Truck Manufacturers:** Mack unveiled its electric LR model at the Waste Expo in May 2019 in Las Vegas which will be tested in the City of New York in 2020.

Electric Vehicles	
	Volvo debuted two electric trucks, the FE Electric and FL Electric, in 2018. Renova in Hamburg, Germany, took the first FE Electric delivery in February 2019. Peterbilt Motor Co., a division of Paccar Inc., unveiled a Class 8 heavy-duty garbage truck at the 2017 Waste Expo. Chinese automaker BYD has an order for 500 battery-powered waste haulers in Shenzhen, China. https://www.trucks.com/2019/05/10/mack-joins-growing-number-testing-electric-garbage-trucks/. Article posted May 10, 2019. **City of New York, NY** – In 2020 the City began piloting one electric vehicle in partnership with Mack Trucks as the City has a goal of reducing GHG emissions by 80% by 2035. https://www.freightwaves.com/news/nyc-sanitation-department-ready-for-macks-first-electric-refuse-truck. Article posted January 9, 2020.
Target Material / Feedstock	All waste streams collected – garbage, organics and recyclables.
Outputs	Anticipated reduction in GHGs.
Regulatory Considerations	Not applicable.
Capital and Operating Cost Range	Capital and operating costs are limited as the technology for waste collection vehicles is in its infancy and being tested; however, electric passenger vehicles are generally more costly than diesel powered passenger vehicles. In 2014 the City of Chicago's contract with Motiv was for up to $13.4 million to provide up to 20 electric waste collection vehicles (as noted above, the City is currently suing Motiv due to vehicles not apparently meeting expectations of the City).

Electric Vehicles	
	Very little information about costs of electric trucks is available but it is reported they cost two to three times the price of conventional diesel trucks. https://www.wastedive.com/news/electric-trucks-may-be-the-future-but-waste-and-recycling-market-still-cha/567651/. Article posted November 19, 2019.
Revenue Opportunity / Cost Savings	Constant stopping and starting is hard on the brakes, engine and transmission. Significant savings in maintenance costs (estimated at $20,000 per year) from regenerative braking and an electric battery can improve cost savings. https://www.pembina.org/blog/good-news-electric-garbage-trucks-do-exist. Article posted November 21, 2016. A 2018 study from the University of Michigan found that electric vehicles cost less than half as much to operate as gas-powered vehicles. However, the exact price difference depends on local gas and electricity rates. https://www.energysage.com/electric-vehicles/costs-and-benefits-evs/evs-vs-fossil-fuel-vehicles/. Article posted November 15, 2018. BYD, a battery manufacturer reports that there is a two-year payback period when switching to electric vehicles, depending on local fuel costs, utility rates, capital and operating costs (including labour rates). https://www.wastedive.com/news/electric-trucks-may-be-the-future-but-waste-and-recycling-market-still-cha/567651/. Article posted November 19, 2019.
Risks and Benefits	**Risks** ● Heavy battery. ● There are limited examples of this technology operating in climates similar to the City.

Electric Vehicles	
	• Low vehicle mileage range (reported to be about 60 kilometers). • Battery charging time (full recharge reported to be eight hours). • Batteries typically must be replaced every three to four years for large vehicles. • Cost of charging station infrastructure. • Electric vehicles may be more applicable for high operational uses (e.g., dense population, maximum distance range travelled) in order to justify the higher purchase price. • Need to use electric vehicles for high operational uses (e.g., dense population, maximum distance travelled) in order to achieve payback on the purchase price. • Existing collection system may need to be modified if electric vehicles are adopted which includes placement of charging stations and yard due to range. This may result in a reduced payload as the vehicle may take several hours to charge. • Due to the size of the City of Ottawa and potential distance to waste processing facilities, there may be a requirement for more transfer stations in the City. These would be used to reduce the total distance travelled for a lower range electric fleet. • Potential for reduced payload and more vehicles to complete servicing requirements if the battery range does not cover a full day's worth of collection. **Benefits** • Environmental benefits, especially if the electric charge is from a renewable energy source.

Electric Vehicles	
	● Potential to require less maintenance. ● Reduces GHG emissions. ● Increased fuel economy in stop-and-go traffic. ● Reduces impacts from idling through the use of the electric motor during stationary activities. ● Reduced noise emissions.
GHG Impacts	Anticipated Reduction in GHGs ● Fewer GHGs emitted compared to diesel fueled vehicles.
Potential Environmental Impacts and Benefits	● Electric powered vehicles benefit the environment as they reduce the amount of GHG emitted compared to conventional diesel powered engines. The effects of this are more impactful if the electric charge is from a renewable energy source. ● Electric powered vehicle batteries can be recycled as there is still life left in them for other applications when they are no longer suited for use in a vehicle. ● Management of batteries at their end-of-life can be costly as lithium ends up as a mixed by-product in the recycling process and is difficult (and expensive) to extract.
Potential Known Health Impacts	● Minimal to no impacts of using electric vehicles. ● Minor positive health impacts due to fewer particulates in the air and reduced GHG emissions.

5.2 Hybrid Vehicles

Hybrid Vehicles	
Approach / Technology Type(s)	A hybrid vehicle uses a combination of electricity and fuel (e.g., gasoline, diesel) to power it. This option looks at the use of hybrid vehicles for municipal fleets including for waste collection purposes.
Description	A hybrid vehicle uses more than one type of system to produce, store and deliver power such as electricity/gas and electricity/diesel. Both mechanical (hydraulic) and electric hybrids are being developed. Hydraulic hybrid **-** In hydraulic hybrids, the internal combustion system is paired with hydraulic pumps that capture and store energy in a hydraulic accumulator. When the vehicle brakes the hydraulic motor turns into a pump. https://www.solidwastemag.com/feature/hybrid-trucks/. Article posted April 1, 2006. Electric hybrid - In an electric hybrid the internal combustion engine is combined with an electric motor. When the vehicle accelerates, energy is drawn from storage to power the motor. When braking, the motor turns into a generator and stores energy. (See Section 5.1) Gas-electric - Gas-electric vehicles are also used where the drive could be gas or electric powered.
Status	Emerging (waste collection vehicles).
Availability	Trucks have been used in municipal operations for over five years.
Examples / Case Studies	**Gothenburg, Sweden** - The collaboration between Renova, Volvo, and Norba resulted in the development of the first hybrid waste collection vehicle in 2008. In 2011, 15 hybrid-electric waste

Hybrid Vehicles	
	collection vehicles were in use. The vehicle is driven by either electricity or diesel and uses the electric motor during loading and compacting of waste which reduces impacts from vehicle idling. The combination of electric and diesel resulted in a reduction of fuel consumption.. Emissions were also reduced (e.g., nitrogen oxides, carbon dioxide, and particles) as a result of lower diesel fuel consumption. No further information on the study was found online; however, Volvo and Renova continue to partner together to test waste collection vehicles. https://www.eltis.org/discover/case-studies/worlds-1st-hybrid-electric-refuse-collection-truck-goteborgsweden. Article posted August 29, 2014. https://cleantechnica.com/2017/05/17/volvo-trucks-renova-testing-autonomous-garbage-trucks/. Article posted May 17, 2017. **City of Gatineau, Quebec** – Effenco signed a contract with the City of Gatineau in 2016 to provide hybrid vehicles for the collection of waste. Effenco claims that their start-stop hybrid–electric technology stops a truck's engine as soon as it comes to a standstill while keeping all accessories and equipment in operation. These stops have been reported to be between 40% and 50% of the time of use for waste collection vehicles. https://0b648049-a48d-4ce0-b228-c3eed12f6880.filesusr.com/ugd/0172bc_9c72a83a9d8d47ac8e007bfbbcb1f4ee.pdf **City of New York, NY** – The Department of Sanitation has almost 50 hydraulic hybrid and three electric hybrid waste collection trucks (of the 2,100 collection truck fleet) that are achieving a 10 to 15 percent improvement in fuel economy which was less than originally anticipated.

Hybrid Vehicles	
	https://www.fleetowner.com/fleet-management/article/21694046/nyc-sanitation-trucks-do-much-more-than-collect-refuse. Article posted July 25, 2016. **Rotterdam, NL** – The city currently uses two hybrid garbage trucks. https://rotterdammakeithappen.nl/en/showcases/no-dirt-in-the-air-in-2030/
Target Material / Feedstock	All waste streams collected – garbage, organics and recyclables.
Outputs	Anticipated reduction in GHGs compared to traditional diesel powered vehicles.
Regulatory Considerations	Not applicable.
Capital and Operating Cost Range	Capital costs are higher than a conventional waste collection vehicle and is dependent on the battery capacity. Hybrids with enough battery to drive the whole vehicle without the engine running may cost up to more than double the price of a conventional waste collection vehicle. https://waste-management-world.com/a/hybrid-refuse-collection-vehicles-something-for-nothing. Article posted May 4, 2013.
Revenue Opportunity / Cost Savings	When compared to a conventional waste collection vehicle, a manufacturer suggests a savings of up to two litres of diesel per tonne of waste material compacted. A reduction in maintenance has also been reported. https://waste-management-world.com/a/hybrid-refuse-collection-vehicles-something-for-nothing. Article posted May 4, 2013.

Hybrid Vehicles	
Risks and Benefits	**Risks** ● Need to use hybrid vehicles for high operational uses (e.g., dense population) in order to achieve payback on the purchase price. **Benefits** ● Increased fuel economy in stop-and-go traffic. ● Reduces impacts from idling through the use of the electric motor during stationary activities. ● Reduced noise emissions.
GHG Impacts	Anticipated Reduction in GHGs. ● Fewer GHGs emitted compared to diesel fueled vehicles. ● When compared to a conventional waste collection vehicle there is a savings of up to 20 tonnes less per vehicle per year in CO_2 emissions. https://waste-management-world.com/a/hybrid-refuse-collection-vehicles-something-for-nothing. Article posted May 4, 2013.
Potential Environmental Impacts and Benefits	● Hybrid vehicles benefit the environment as they reduce the amount of GHG emitted compared to conventional diesel powered engines. The effects of this are more impactful if the electric charge is from a renewable energy source.
Potential Known Health Impacts	● Minimal to no impacts of using hybrid vehicles. Minor positive health impacts due to fewer particulates in the air and reduced GHG emissions.

5.3 Autonomous Vehicles

Autonomous Vehicles	
Approach / Technology Type(s)	Autonomous (and semi-autonomous) vehicles use sophisticated computer systems linked to cameras and sensors to pilot a vehicle without the need for a human driver (or partially without the need for a human operator).
Description	Autonomous vehicles in the waste industry are seen as an emerging technology. The use of autonomous and semi-autonomous vehicles has a number of potential uses in the waste industry including waste and recycling collection, operation equipment at landfills, waste transfer stations, and material recycling facilities. Autonomous vehicles are intended to eliminate the human driver as the operator. For waste collection vehicles, there are many scenarios to design for automation including: pedestrians, safety, lining up to the garbage bin, oncoming traffic, and obstacles. The vehicle would need to be able to maneuver within neighbourhoods and urban areas to collect garbage. These vehicles would also need to determine where the garbage bin is and stop in front of it. They would also be required to identify and pick up the correct waste stream.
Status	Emerging
Availability	Autonomous vehicles are being tested and trialed in Europe and the US. Companies like Volvo and Renova are working on developing an autonomous waste collection truck, and Komatsu has been developing semi-autonomous machines (excavators, dozers, etc.). https://venturebeat.com/2019/11/22/bmw-and-olo-pilot-in-car-food-ordering-for-u-s-drivers/

Autonomous Vehicles	
	https://www.waste360.com/fleets-technology/autonomous-vehicles-next-big-trend-waste-recycling-industry
Examples / Case Studies	Technology is still being tested. Volvo has partnered with Renova (Swedish based company) and is currently in the preliminary stages of testing an autonomous garbage truck designed for use in cities. The project entails exploring how automation can contribute to enhanced traffic safety, improved working conditions and lower environmental impact. Volvo indicates that the route is preprogrammed (similar to a waste collection vehicle which typically follows the same route weekly) and onboard sensors monitor the vehicle's surroundings and stop the truck if an obstacle appears. There is a human driver inside the vehicle to ensure it arrives at its route start but then the driver exits the vehicle and walks ahead to collect waste while the truck maneuvers between obstacles. No further pilot details or results are publicly available. https://venturebeat.com/2017/05/17/volvos-testing-an-autonomous-garbage-collection-truck/
Target Material / Feedstock	All waste streams collected – garbage, organics and recyclables.
Outputs	No direct outputs, rather results are indirect benefits.
Regulatory Considerations	*O. Reg. 306/15* under the *Highway Traffic Act* describes the requirements for automated vehicles in Ontario.
Capital and Operating Cost Range	No data available.

Autonomous Vehicles	
Revenue Opportunity / Cost Savings	No data available.
Risks and Benefits	**Risks** • Public concern that technology is still in its infancy and that the vehicle will not stop when it encounters an obstacle (e.g., a child). • Currently unknown how the technology will work during heavy snowfall, heavy rains and around snowbanks. **Benefits** • Potential for efficient, cost effective waste collection service. • Improve working conditions for waste collectors and reduce occupational injuries (in the case of semi-autonomous vehicles). • Enhanced traffic safety in built-up areas and while reversing.
GHG Impacts	Anticipated Reduction in GHGs • Computer software piloting the vehicle can be designed to optimize gear shifting, steering, speed control for low fuel consumption resulting in lower emissions and production of GHGs.
Potential Environmental Impacts and Benefits	• Potential to combine automated vehicles with electric or natural gas powered vehicles to reduce the generation of GHG emissions.
Potential Known Health Impacts	• Not known at this time.

5.4 Alternative Fuels for Collection Vehicles

Alternative Fuels	
Approach / Technology Type(s)	The use of alternative fuels (e.g., Compressed Natural Gas (CNG), biodiesel, Liquefied Natural Gas (LNG)) for waste management purposes to replace the need for traditional petroleum-based fuels (e.g., diesel, gasoline). CNG and LNG require different repair facilities, infrastructure and vehicles. Biodiesel and Hydrotreated Renewable Diesel (HRD) do not require a change to infrastructure or vehicles, however biodiesel can only be used up to B20 (80% Petrodiesel and 20% Biodiesel) or both infrastructure and vehicles will fail.
Description	There is increasing momentum in the use of fuels, other than traditional diesel and gasoline, for waste management purposes such as waste collection vehicles and facility machinery. Biogas is composed of methane (60-70 percent) and carbon dioxide (30-40 percent). Biogas is generated from landfills and through anaerobic digestion facilities. Biogas can be upgraded to be approximately 95-98 percent methane, thus called renewable natural gas (RNG). Biogas is generated from waste management facilities (e.g., anaerobic digestion, landfills), is then cleaned and purified into a RNG, then compressed to produce Compressed Natural Gas (CNG) which can be directly used as a fuel for CNG vehicles. Liquefied Natural Gas (LNG) is essentially RNG that has been processed until it becomes liquefied and then can be used in LNG vehicles. A natural gas vehicle uses natural gas as its fuel either in CNG or LNG form. As of 2017 the Province of Ontario requires 4% of the total volume of diesel fuel to be bio-based. There are two types of bio-based diesel fuel commonly available:

Alternative Fuels	
	• Biodiesel is a clean-burning renewable fuel made from vegetable oils, recycled frying oils, and animal fats. A vehicle using biodiesel-blended diesel emits lower amounts of greenhouse gases and other pollutants. • Renewable diesel is made from the same materials as biodiesel but it is processed differently. It is almost the same chemically as regular diesel. You can use it anywhere you would use regular diesel. Biodiesel is an oxygenated alternative fuel made from vegetable oils, waste cooking oil, or animal fats. Biodiesel can be blended with regular diesel fuel and does not need to be labelled until over 5% Biodiesel. Renewable diesel is a conventional petroleum diesel substitute produced from renewable resources such as algae. Biodiesel is produced via transesterfication with glycerol as a by-product and HDRD is produced via hydroprocessing with propane, carbon monoxide (CO) and carbon dioxide (CO2) as by-products.
Status	Proven (biodiesel, RNG/CNG, renewable diesel) and emerging (LNG) depending on the fuel. https://www.solidwastemag.com/truck/cng-increasingly-popular-for-waste-collection-vehicles/1003282219/. Posted Feb.22, 2020.
Availability	NG is commonly produced and can be readily distributed through natural gas utility networks. CNG, CNG vehicles and CNG filling stations are becoming more prevalent (e.g., taxis, delivery trucks). LNG is less commonly available. https://www.nrel.gov/transportation/fleettest-fuels.html https://www.nrel.gov/transportation/fleettest-publications-fuels.html

Alternative Fuels	
	https://www.solidwastemag.com/feature/compressed-natural-gas-2/. Article posted August 1, 2012. Approximately 10 percent of all landfill gas projects in the U.S. use renewable natural gas to power their trucks. The technology associated with RNG production is becoming more common in Canada at anaerobic digestion facilities and landfill sites. Both petroleum diesel fuel and biodiesel will have issues in very cold temperatures. Different blends of fuel may alleviate these issues. https://www.mda.state.mn.us/sites/default/files/inline-files/B20HandlingGuide_0.pdf Report published February, 2018.
Examples / Case Studies	**City of Toronto, ON –** Toronto's Solid Waste Management Services Division has partnered with Enbridge Distribution Inc. to install biogas upgrading equipment at the Dufferin Solid Waste Management Facility which processes up to 55,000 tonnes per year of Green Bin organics. This system will upgrade biogas produced through anaerobic digestion into RNG. The City will be able to use the RNG to fuel its collection trucks. It is estimated that 3.2 million cubic metres of RNG could be produced each year at the Dufferin facility—enough to power the majority of the City's solid waste collection fleet. The City has long term plans to implement RNG production at its other AD facility (Disco Road) and two landfill sites. The City was to receive $10 million in funding through the Municipal GHG program but was cancelled with the change in provincial government. The total cost of the upgrades is estimated at $72 million. **Emterra Group –** Emterra has invested heavily in CNG. In 2012, Emterra established a CNG fueling station in Winnipeg, MB to support their 60 recycling trucks. The City's extreme cold weather was taken into consideration in the design of the fueling station and the vehicles are reportedly operating as well as diesel vehicles in extreme cold temperatures. In 2015, Emterra Environmental opened a $5.25 million CNG fueling station in Chillwack B.C. and a roughly $2 million facility in

Alternative Fuels	
	Victoria B.C. The Victoria fueling station along with 16 new trucks represent an $8 million investment. Emterra Group, in partnership with GAIN Clean Fuel and C.A.T. Inc, opened a CNG fueling station in Mississauga in 2015. The facility, is also open to other fleets and operators of CNG vehicles. The facility, along with over 100 new CNG trucks to serve Peel Region, was a $50 million investment. https://www.emterra.ca/pages/compressed-natural-gas https://www.emterra.ca/blogs/news/emterra-group-and-partners-invest-50m-in-largest-natural-gas-fleet-fuelling-station-and-operation-in-canada-open-to-public (accessed February 24, 2020) **StormFisher Environmental, London, Ontario -** StormFisher Environmental is an anaerobic digestion facility that produces biogas. StormFisher has partnered with Enbridge Distribution Inc. to supply renewable natural gas to its nearby natural gas filling stations. This natural gas station is one of three in Ontario that Enbridge owns and will fuel compressed natural gas (CNG) powered vehicles. https://www.stormfisher.com/ **City of London, ON** – The City previously used a biodiesel blended fuel starting in 2011 but noted that there were challenges associated with supply, particularly in winter months. The City is currently in the initial stages of its fuel switching project where its fleet of 37 waste collection vehicles will be transitioned to CNG as they come up for replacement. The first set of CNG powered vehicles will join the fleet in December 2019 and the full transition is anticipated to be completed in 2025. To help offset the high startup capital costs associated with the fueling station, the City will be using a commercially available fast fueling station and then will reassess options of onsite fueling stations once half of the vehicles have been transitioned in. There is a long

Alternative Fuels	
	term goal to use RNG generated from their landfill site for waste collection vehicles. https://www.london.ca/residents/Environment/Energy/Pages/Green-Fleet.aspx **City of Surrey, B.C.** – The City has a closed-loop system where Green Carts are collected via CNG powered vehicles (operated by Waste Connections of Canada) and the fuel used is generated from their AD facility which processes food and organic waste. https://www.biocycle.net/2017/05/01/canadian-city-ready-launch-ad-composting-facility/. Article posted May 1, 2017. https://www.surreybiofuel.ca/ **Examples of LNG uses:** ● Norcal Waste Systems uses LNG trucks equipped with Cummins engines. ● Waste Management, uses LNG trucks manufactured by Mack with E7G engines operating in the Washington and Pennsylvania areas. The City of Los Angeles Bureau of Sanitation uses LNG heavy-duty trucks. ● The City of Fresno, California, signed a two-year agreement for renewable liquified natural gas (RLNG) to power approximately 140 refuse trucks for an anticipated annual total of 1.6 million LNG gallons, the equivalent of just over one million GGEs. The fuel enables at least 70 per cent reduction in carbon emissions when displacing diesel or gasoline, according to California Air Resources Board (CARB) estimates. ● The City of Long Beach has entered into a new two-year contract to fuel 77 vehicles with an expected 225,000 GGEs of Redeem, including its 35 LNG refuse trucks

Alternative Fuels	
	• https://www.solidwastemag.com/truck/cng-increasingly-popular-for-waste-collection-vehicles/1003282219/. Posted Feb 22, 2020. Filling stations for LNG are typically built by the collection contractor. **National Resources Canada (NRCan)** – In 2010, NRCan published the *National Gas Use in the Canadian Transportation Sector: Deployment Roadmap* which is a collaboration between governments, industry, academia and non-government organizations to identify the optimal use of natural gas in the Canadian transportation sector. The roadmap identified that medium and heavy duty vehicles, including waste collection vehicles, were the optimal use of Canada's natural gas supplies. In 2019 the report was updated and indicated that there were several challenges to using natural gas vehicles including upfront capital costs, how to integrate RNG into the market and the changing dynamics in the market such as carbon pricing, the Clean Fuel Standard and technology advances that influence the use of natural gas as a transportation fuel. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/oee/pdf/transportation/alternative-fuels/resources/pdf/NRCan_NGRoadmap_e_WEB.pdf. Report published 2019.
Target Material / Feedstock	All waste streams collected – garbage, organics and recyclables.
Outputs	Alternative fuel sources.
Regulatory Considerations	Not applicable (considerations associated with facilities generating alternative fuels are noted in Section 10.0).
Capital and Operating Cost Range	The difference between CNG and LNG vehicles and traditional vehicles is the engine. The remainder of the vehicle is the same, so the costs and effort required to convert to CNG and LNG involves a

Alternative Fuels	
	different type of engine. CNG vehicles are more common than LNG vehicles. Capital costs are required to install a CNG and LNG fueling station where the fleet is located. Typical payback for CNG fueling stations is 10 years and cost recovery can be built into collection contracts. Biodiesel fuel costs less than diesel and has a similar fuel economy compared to conventional fuel. CNG and LNG have similar fuel economies compared to conventional fuels. With the price of diesel continuing to rise, the cost for CNG is becoming more affordable. In Ontario, as of March 1, 2020, the cost of diesel was $1.15 /L and CNG was $0.66 L. https://www.ontario.ca/page/motor-fuel-prices The Clean Cities Alternative Fuel Price Report (US) provides regional alternative and conventional fuel prices for biodiesel, compressed natural gas, ethanol, hydrogen, propane, gasoline, and diesel. The Alternative Fuel Price Report is a snapshot in time of retail fuel prices. Alternative fuel fleets can obtain significantly lower fuel prices than those reported by entering into contracts directly with local fuel suppliers. The national average price for fuels in Oct 2019 for gasoline-gallon equivalents (GGEs) was: • Biodiesel (B20) $2.87/gallon • Biodiesel (B99-B100) $3.73/gallon • Electricity $0.13/kWh • Ethanol (E85) $2.28/gallon • Natural Gas (CNG) $2.20/GGE • Liquefied Natural Gas $2.69/DGE • Propane $2.76/gallon

Alternative Fuels	
	• Gasoline $2.68/gallon • Diesel $3.08/gallon https://afdc.energy.gov/fuels/prices.html
Revenue Opportunity/ Cost Savings	Financial savings, from a life-cycle perspective, of using RNG as opposed to traditional fuels such as diesel. At present, CNG is cheapest, then LNG and then regular diesel in terms of fuel costs. In BC, Fortis Energy (supplier of CNG and LNG) provides financial incentives to waste management companies to convert to CNG trucks. Their financial incentives can help with the cost of upgrading to natural gas vehicles, so fleets can take advantage of the cost-saving benefits and emission reductions that compressed natural gas (CNG) or liquefied natural gas (LNG) fuel provides. They can provide 10 to 60 per cent of the incremental cost of upgrading to a vehicle fuelled with CNG or LNG, compared to an equivalent diesel vehicle. https://www.fortisbc.com/est/truck-fleets/medium-heavy-duty-natural-gas-truck-fleet-incentives. **Future Clean Fuel Costs** The Canadian federal government is developing a fuel carbon intensity (CI) based regulation called the Clean Fuel Standard (CFS). The CFS will require a reduction in the life-cycle carbon intensity of transportation fuels. Unlike these policies, the CFS extends to other liquid fuels outside of the transportation sector. The CFS will eventually also apply to gaseous and solid fuels produced and imported into Canada. The final CFS regulation for the liquid fuel stream is expected to be published in 2020, with the policy coming into force in 2022. https://www.naviusresearch.com/wp-content/uploads/2019/05/Biofuels-in-Canada-2019-2019-04-25-final.pdf. April 1, 2019.

Alternative Fuels	
Risks and Benefits	**Risks:** ● CNG may not be available; ● Cost to upfit existing garage and build infrastructure to accommodate CNG or LNG can be prohibitive (more than 10 years to pay off – and for 13% or so reduction.) ● May be issues with biodiesel in cold months depending on the blend. ● Alternate fuels not as readily available when compared to traditional fuels. ● Biodiesel (depending on the blend) can be as expensive as diesel. **Benefits:** ● The use of CNG can create a closed-loop system by having a facility that generates CNG that can fuel collection vehicles to collect Green Bin organics and bring it back to the facility for processing. ● CNG and LNG are typically less expensive and more environmentally friendly than extraction of fossil fuels such as diesel.
GHG Impacts	Anticipated Reduction in GHGs Natural gas fuel (CNG, LNG) can reduce GHG emissions from trucks by up to 30 per cent compared to petrodiesel and gasoline. https://www.fortisbc.com/est/truck-fleets/environmental-benefits-of-lng-or-cng-fuelled-truck-fleets ● The Government of Canada’s estimate on the CO_2 equivalent emissions emitted per unit of energy consumed by fossil fuel types include the following:

Alternative Fuels	
	○ biodiesel 8.3 CO_2 eq, ○ bio mass 4.6 CO_2 eq, ○ diesel 74.1 CO_2 eq, ○ gasoline 68.5 CO_2 eq, ○ natural gas (CNG, LNG), 49.9 CO_2 eq. https://www.canada.ca/en/environment-climate-change/services/climate-change/publications/emission-trends-2014/annex-2.html. Article posted 2014.
Potential Environmental Impacts and Benefits	● Biodiesel does produce some emissions but reduces air pollution emissions and carbon dioxide when used as a replacement to petrodiesel. ● Compared to conventional petrodiesel, alternative fuels are cleaner in terms of air pollution emissions(e.g., nitrogen oxides and particulates) and also reduce GHG emissions (carbon dioxide and methane). Natural gas vehicles emit up to 95 per cent less nitrogen oxides (NOx). Carbon dioxide (CO2) emissions, the principal greenhouse gas that contributes to global warming, are reduced by up to 30 per cent. Natural gas vehicles emit virtually no particulate matter, the harmful microscopic component of air pollution that penetrates deeply into the lungs. ● Provides an end market for renewable energy fuel that is generated through the processing of organic waste. Supports a closed loop system to waste management especially in the CNG context and organics waste diversion and LFG recovery. https://www.fortisbc.com/est/truck-fleets/environmental-benefits-of-lng-or-cng-fuelled-truck-fleets
Potential Known Health Impacts	● Minimal to no impacts of using alternative fuels. ● Minor positive health impacts due to fewer particulates in the air and reduced GHG emissions.

5.5 Summary of Collection Fleet Technologies

The following table summarizes the technology and/or approach researched, the potential applicable material stream and the potential customers the technology and/or approach could be applied to.

Technology	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
Electric Vehicles	All	X	X	X	X	X
Hybrid Vehicles	All	X	X	X	X	X
Autonomous Vehicles	All	X	X	X	X	X
Alternative Fuels	All	X	X	X	X	X

6 Collection Approach Alternatives

This section reviews various waste collection approach alternatives to ‘traditional’ waste collection methods. It explores the use of automated waste cart collection, the provision of bulk waste collection to single family and multi-residential buildings, and reviews opportunities for providing waste collection services typically provided at a depot, such as mobile waste collection. Best practices for public space waste containers, a description of the Optibag and in-ground container systems, as well as various waste collection technologies for waste collection efficiencies are highlighted.

The City of Ottawa currently utilizes some of the discussed waste collection approaches. Public space containers are provided in parks, bus depots, light rail stations, BIAs and most major residential streets and a pilot is currently being undertaken until November 2020 for Green Bin organics and Blue and Black Box recycling in parks. There are approximately 750 on-street waste collection containers across the city. The City also uses some deep collection containers in a few parks as part of a pilot.

The City provides containerized collection for approximately 1,700 multi-residential properties on a weekly basis. Bulky item waste collection is provided to single family and multi-residential properties and acceptable items can be placed out for collection on the regular garbage collection day. Bulky items are included in the six-item limit for garbage collection – there is no separate collection of bulky items. The City does offer mobile MHSW events which are held at one location for a day throughout the city between spring and fall each year. The City of Ottawa has included a cart collection option in the containerized collection contract that will start on June 1, 2020 for multi-residential.

The City’s contractor for multi-residential has used “Fleetmind Systems” to track weights; however, there have been some software challenges with obtaining accurate weights and consistently providing data.

The following seven tables present research on various collection approach alternatives. These include automated cart collection, bulky item waste collection, mobile collection, in-ground container, public space container, the Optibag and several other technologies.

6.1 Automated Cart Collection

Automated Cart Collection	
Approach / Technology Type(s)	The use of automated collection to collect waste carts.
Description	Automated collection involves a specially designed truck that uses ‘arms’ to pick up carts, empty them and then return them to its original position as opposed to collection operators manually lifting and dumping carts or using semi-automated collection, whereby an operator places the cart on a lifter, which empties the cart. Trucks can have “arms” to pick up carts at the side of the vehicle or an “arm” that empties carts into a container at the front of the truck, which is then emptied into the truck. http://www.bra.org/my-services/middlesex-centre-municipality https://www.denverpost.com/2017/03/16/denver-curbside-compost-pickup-trash
Status	Proven - Complies with best management practices as identified by Waste Diversion Ontario (WDO), Ontario Waste Management Association (OWMA) and Solid Waste Association of North America (SWANA).
Availability	Multiple jurisdictions use automated cart collection for all streams of waste. There are several manufacturers that produce vehicles and truck bodies for automated cart collection. Additionally, there are several cart manufacturers that produce carts in several sizes and colours with features such as wheels and locking lids.
Examples / Case Studies	**City of Gatineau, Quebec** – The City of Gatineau has curbside cart collection for garbage, recycling and organics. Under the new system residents must pay $0.50 extra per bag for any garbage that does not fit into the 120L garbage cart (collected bi-weekly). There

Automated Cart Collection	
	are eligible bags that can be purchased and must be used, Recycling is collected bi-weekly with organics being collected every week. The release of this program has been a success in Gatineau with 2019 showing increased diversion rates. Organics tonnages increased by approximately 18% (by weight) and garbage tonnages decreasing by 15%. **City of Toronto, ON** – The City uses automated side load vehicles for the collection of curbside garbage, single stream recyclables and Green Bin organics. Fully automated vehicles cost approximately $73,000 more per vehicle than semi-automated vehicles. With Toronto's collection frequency, garbage (biweekly), single stream recyclables (biweekly) and Green Bin organics (weekly), collection operations was able to achieve an overall efficiency of two staff reductions for every two routes amounting to a savings of $1,425,000 annually. Repair and maintenance costs were modestly higher for fully automated vehicles, whereas fuel costs were less. The most significant saving; however, was realized due to reductions in staff. https://www.toronto.ca/services-payments/recycling-organics-garbage/houses http://thecif.ca/projects/documents/548.11-Toronto_Final_Report.pdf **City of Guelph, ON** – The City uses automated side load vehicles for the collection of garbage, single stream recyclables and green bin organics. Waste Diversion Ontario's (WDO) Continuous Improvement Fund (CIF) committed over $1.3 million in funding to the City to convert from a plastic bag-based collection system to a fully automated cart based collection system for the three streams. The costs for the carts was almost $5.1 million plus another $330,000 for delivery to homes (approximately 30,000 single family households). The cart-based collection was phased in over a three year period from 2012 to 2014. Stakeholder support and adoption

Automated Cart Collection	
	was essential to the success of the program. A survey of Guelph households revealed 80 percent of residents using waste carts were satisfied with the City's automated collection system when compared to the previous system. The City also achieved the highest waste diversion rate in Ontario at 69 percent in 2013 (result is a combination of all waste policies). The program successfully reduced the collection fleet by four trucks, which resulted in operational savings of over $460,000 per year through reduced capital replacement costs, maintenance, fuel costs, and injury and labour costs. The City of Guelph is currently piloting the use of a Curotto Can removable truck attachment. Guelph Automated Waste Cart Collection System Curbside Collection Performance and Monitoring Report Quarterly Report No.4 Final Report 2016 Excellence Awards Entry -Collection System City of Guelph **Region of Peel, ON** – The Region uses automated side load vehicles for the collection of garbage (biweekly), single stream recyclables (biweekly) and Green Bin organics (weekly). As per a Regional report, "Residents in our cart-based pilot area continue to express their contentment with the new cart collection system and encourage staff to share the benefits with all residents of Peel. The reduction of litter and odours, especially on collection days, as well as the ease of maneuvering the carts are still the biggest benefits to the residents. From the perspective of value, the annual estimated amortized cost of carts (approximately $5 per cart per year) is less than the annual cost of bags (approximately $20-30 per year)." In January 2016, Peel's full scale program commenced with automated collection for garbage, recycling and organics to most areas. http://www.peelregion.ca/waste/collection-schedules

Automated Cart Collection	
	Region of Peel, Commissioner of Public Works in Report "Implementation Plan for Cart-Based Garbage and Recycling Collection", October 2013.
Target Material / Feedstock	Garbage, recycling and household organic waste. Some vehicles (e.g. Curotto Cans) can handle some bulky waste.
Outputs	No direct outputs, rather results are indirect benefits.
Regulatory Considerations	Not applicable.
Capital and Operating Cost Range	Higher capital cost investment for purchase of vehicle compared to manual collection vehicles. The City of Guelph paid approximately $300,000 per truck between 2012 and 2014. Capital cost for larger carts are between $50 and $60 and smaller carts (120 L) range from $30 to $40. Some dual/two-cart costs have been reported as approximately $74 each. Carts often come with a ten year warranty. Capital costs for a cart-based program could cost in the order of $8.8 - $14.6 million (based on providing one cart to 290,732 curbside units and 1,986 curbside apartment units at a cart cost of $30-$50). There would be additional annual costs for maintenance and replacement of carts. Roll-outs would include delivery costs and a specific P&E campaign. https://thecif.ca/projects/documents/888-Autocarts_Study_FINALv2_Jun2016.pdf
Revenue Opportunity / Cost Savings	The automated collection program reduces costs related to replacement labour associated with staff injuries, illness rates, and modified job duties, as well as, reduces Workplace Safety and Insurance Board costs. The reduction in physical activity and

Automated Cart Collection	
	disagreeable conditions may also have a positive financial effect on the inputs for job compensation and lower labour costs. Additionally, most trucks are operated on the right hand side allowing the driver an unobstructed view of pedestrians on the sidewalk. Automated collection can reduce labour headcount to one from two per vehicle, allowing for operating cost savings. Lifecycle costs of carts can demonstrate lower annual costs compared to purchase of waste container bags.
Risks and Benefits	**Risks** ● Some municipalities report a significant increase in contamination, especially medical waste, by moving to a cart-based recycling program, since collection operators can't see all the contents before dumping and therefore can't enforce any by-law infractions. This reduces the value of the recyclable material, increasing the costs to sort the material at the MRF and reducing the revenue received for the material. ● Delivering a new system of carts requires a significant one-time cost for carts, additional customer service staff, delivery and communications. ● Bulky waste will need to be removed manually by collection staff and likely collected in another vehicle as the item may not be able to safely be placed into the collection vehicle. ● Storage of the carts can be challenging in high density areas and areas that do not have garages (or small garages that only fit a small vehicle). Additionally, some by-laws prohibit the storage of waste in front of a home. ● Waste in carts may be difficult for rural households to bring to the end of the driveway as often garbage is driven in a vehicle.

Automated Cart Collection	
	- A cart replacement system would need to be implemented and administered. - Support for bulky collection, enforcing potential organics/material bans. - Infrastructure issues such as overhead wires can be an issue for collection. - Wind and snow can become a factor in either tipping the cart or making access difficult for the collection vehicle or uneven terrain. - Potential for loss of revenue due to lower market value of recyclables. - Potential for increased MRF processing costs due to high contamination rates. **Benefits** - Reduces the number of collection vehicles, which provides annual operating savings. - Allows for a more diverse workforce (e.g., physical ability, gender, age). - Curbside collection efficiency may be increased by eliminating the collection of multiple smaller containers (e.g., compared to using blue boxes or black boxes). The sizes of carts enable adequate space to accommodate collection needs from households. - Potential to provide residents with more recycling capacity. - Potential to implement a cart-based pay as you throw system based on volume.

Automated Cart Collection	
	● Improves customer satisfaction. Residents no longer need to purchase bags for collection. All materials can be placed loosely into carts thereby reducing the cost to the residents. ● Carts also reduce the time and cost in dealing with issues related to bag collection on snow banks, as the automated arm has the ability to collect and return the carts to the top of a snow bank. ● Facilitates the transition for collecting multi-residential properties by acquiring collection equipment appropriate for this sector. For multi-residential complexes where space is very limited (i.e., no garages, no backyards, small porches) an individual set of carts for each waste stream is not always feasible. In these cases communal carts are recommended which allow residents to bring waste to one or several central cart locations, shared by other residents in their complex. ● Being able to close lids on containers helps to contain material and minimize waste and recyclables blowing onto streets prior to service. ● Operating efficiencies are gained by eliminating “thrower fatigue” as collection is mechanical. ● Collection is at the front or the side of the collection vehicle, which is safer for the driver to observe the cart and surroundings. ● Since the introduction of automated collection municipalities have reported a steady decrease in ergonomic related injuries. This validates the overall ergonomic injury risk reducing benefits of automated collection.
GHG Impacts	● Anticipated Reduction in GHGs

Automated Cart Collection	
	• No impact anticipated unless use of carts allows for less frequent collection (e.g. reduced transportation emissions from biweekly collection).
Potential Environmental Impacts and Benefits	• The size of the recycling and organic carts allows for new materials to be added to the collection streams in the future without disruption to the collection process. • Use of carts with lids reduces litter occurrences.
Potential Known Health Impacts	• Automated collection has been shown to reduce staff injuries (e.g., minimizes repetitive strain injuries to shoulder, knees, back; minimizes physical fatigue for collection staff; and minimizes exposure to traffic risks while working at the side and rear of the collection vehicles).

6.2 Bulky Item Waste Collection

Bulky Item Waste Collection	
Approach / Technology Type(s)	Waste collection program geared at collecting larger items that cannot fit in traditional waste containers/carts. Alternative approaches include limiting the number of items/collections, charging fees and/or providing a call-in service.
Description	Bulky items include discarded furniture, large appliances and other items that do not fit into an average garbage receptacle. Mattresses are also often categorized as bulk items; however, mattresses have been previously highlighted in Section 4.4. The collection of bulky items can enhance the reuse and recycling of materials otherwise landfilled, such as diverting gently used and unwanted furniture and household items for reuse purposes. Call-in collection systems provide an opportunity to educate residents about reuse opportunities, track items being collected for future planning, provide a means for introducing a service fee and enable scheduling of collection routes. A strategy to further extend the life of the landfill may include limiting large items accepted for landfilling. Opportunities to partner with the not-for-profit sector may also exist. Bulk Waste Data Excel file provided by Halton Region, April 2018. http://www.halton.ca/cms/One.aspx?portalId=8310&pageId=151236 https://www.gatineau.ca/portail/default.aspx?p=la_ville/salle_medias/communiques/communique_2015&id=-1175808251
Status	Proven
Availability	Many municipalities offer bulky item waste collection via curbside collection where residents can phone in or schedule online for pick-up service. Some specify the frequency of collection, for example, once per season. Alternatively, residents can drop off their bulky

Bulky Item Waste Collection	
	waste items at a transfer station, depot or the landfill. For the purposes of this section only curbside collection is discussed.
Examples / Case Studies	**City of Toronto, ON** – The City allows residents to place oversized and metal items at the curb on the regular garbage collection day (i.e., no appointment or call-in service required). There is a flat fee (currently $15 per unit) that appears on Utility Bills, which applies even if no large items are placed at the curb for collection. **City of Surrey, B.C.** - The City of Surrey offers a large item pick-up program for all single family households that receive curbside collection. Each household can have up to six large items picked up throughout the calendar year and households with registered secondary suites are eligible for up to eight scheduled items per year. All information per household is recorded on City databases. Each year, the item count starts from zero. There is no bulky waste collection for the multi-residential sector. http://prrd.bc.ca/board/agendas/2016/2016-24-997682690/pages/documents/14-b-CA-4MetroVan_Bulky_Furniture.pdf http://www.surrey.ca/city-services/4550.aspx **City of Winnipeg, MB** – The City of Winnipeg had separate contracts for regular garbage collection and bulky item collection. Residents are required to schedule a pick-up by calling the City at least three days in advance of the desired collection day. The City currently charges $10.30 per large item (e.g., furniture, mattresses), up to a maximum of ten total items per collection. https://www.winnipegfreepress.com/local/North-End--business-to-create-jobs-while-recycling-used-mattresses--365586401.html https://www.takepride.mb.ca/about/faq

Bulky Item Waste Collection	
	http://winnipeg.ca/waterandwaste/billing/fees.stm#specialcollection **Simcoe County, ON** – The County offers a call-in service that allows residents to place out up to 5 items per collection from June to September. Payment of $35 is required at the time of booking. The program uses a ticketing system to keep track of the number of bulky waste collections completed by household. Items collected are sorted into reusables, recyclables and garbage in the truck. The County estimates diverting approximately 50 percent of the material collected.
Target Material / Feedstock	Large items that cannot fit in traditional waste containers/carts.
Outputs	No direct outputs, rather results are indirect benefits.
Regulatory Considerations	Not applicable.
Capital and Operating Cost Range	Overall costs of bulky item collection service will depend on the following: ● The scale (i.e. the number of collections provided and tonnage diverted). ● The methodology e.g., collections that maximize reuse take longer and the number of collections per day are less than bulky item waste service for disposal. ● Whether a call centre function is included or not. The chosen method will determine the reuse and recycling performance of the service which will affect any income from sales and disposal savings.

Bulky Item Waste Collection	
	● An effective bulky item waste collection program can reduce illegal dumping; therefore, significantly reducing costs for collection crews to clean up illegally dumped materials.
Revenue Opportunity / Cost Savings	Bulky item waste collection programs that focus on diverting and recycling collected materials increase waste diversion, saving landfill space by recycling the materials collected. Some municipalities charge for the collection which may provide some revenues, over and above collection and processing costs. Collected materials can also be a revenue opportunity if they are sold.
Risks and Benefits	**Risks** ● Furniture that has been exposed to weather or that potentially could be infested with bugs can reduce potential for reuse and recycling. ● For call-in services, there is a potential for items that are set out to be taken (or ‘scavenged’) by neighbours before the truck arrives. ● Charging fees can lead to illegal dumping. **Benefits** ● Contribute to waste diversion objectives and avoided disposal costs if items can be sorted for reuse and/or recycling purposes. ● Convenience to residents. ● Potential avoided illegal dumping and associated costs for collection.
GHG Impacts	Anticipated Increase in GHGs

Bulky Item Waste Collection	
	● Potential for increase in GHG emissions if a dedicated, separate truck is used to collect items due to increased emissions from transportation. Anticipated Reduction in GHGs ● Reduction in GHG emissions from the reuse and recycling of bulky wastes (fewer materials being landfilled).
Potential Environmental Impacts and Benefits	● Provides an opportunity to divert waste that would otherwise be disposed. ● Create new jobs in the recycling industry.
Potential Known Health Impacts	● Potential for collection operator injuries associated with lifting heavy and large items by hand.

6.3 Mobile Collection

Mobile Collection	
Approach / Technology Type(s)	Provision of a collection service for materials that typically require residents to transport and drop-off to a retail or waste management facility such as MHSW or small electronics.
Description	Mobile waste collection can be provided for materials that are not typically collected at the curbside such as Municipal Household Solid Waste (MHSW) or small electronics. This allows residents who may not be able to drop off these materials themselves (e.g., because they don't have cars, live too far away or do not have space at home to store materials) to have access to these programs. Requires well trained staff and appropriate permitting.
Status	Proven
Availability	Mobile collection services for MHSW exist in some jurisdictions and can be offered through private or public entities.
Examples / Case Studies	The few municipalities that are using this service are included below. **City of Greater Sudbury, ON** - The City offers free home collection service for MHSW via Toxic Taxi. Households may phone the answering service 24 hours a day to leave their name and phone number. The call is returned within 24 hours to schedule an appointment. Alternatively, households may email the Toxic Taxi email address to book an appointment. Residents must be home when the MHSW is collected. https://www.greatersudbury.ca/live/garbage-and-recycling/household-hazardous-waste/toxic-taxi/ **City of Toronto, ON** - The City offers free home collection service for MHSW via Toxic Taxi. Households must schedule collection through either 311 or via the City's website. MHSW must be placed

Mobile Collection	
	on private property (versus left at the curb) and the resident does not need to be home when the MHSW is collected. https://www.toronto.ca/311/knowledgebase/kb/docs/articles/solid-waste-management-services/collections-operations/household-hazardous-waste-hhw-toxic-taxi-pick-up-scheduling-pick-up.html
Target Material / Feedstock	Most municipal programs are for MHSW. MHSW includes, but is not limited to corrosive products, flammable products or toxic products, flammable hazards, corrosive hazard or toxicity hazards, corrosive waste, and ignitable waste.
Outputs	Not applicable.
Regulatory Considerations	*Transportation of Dangerous Goods Act* MECP Environmental Compliance Approval, approval time may be longer due to the limited number of operations in Ontario.
Capital and Operating Cost Range	The programs operate based on a call for service and costs are based on how many residents request service. The service may be provided by a contractor or may be provided directly by the municipality. Municipalities with permanent locations that accept the same materials that are collected through a mobile collection program may find fewer households using the service than municipalities that only offer mobile collection and/or have few permanent locations. Operating costs can be high as an annual service is more expensive than event days or permanent depot-drop offs (where other materials non-MHSW are also collected). More trained staff are required, dedicated vehicles for collection and there is more administrative work. However, municipalities may be able to reduce operating costs if existing staff resources are used (e.g., 311) or if using a

Mobile Collection	
	messaging service versus the use of a dedicated staff person to schedule pick-ups. No costs are publicly available for the City of Toronto or City of Greater Sudbury programs
Revenue Opportunity / Cost Savings	Mobile collection is not likely to provide a revenue opportunity or cost savings. Program costs are likely to be higher than running event days.
Risks and Benefits	**Risks** ● MHSW may not be stored properly at households and there could be a risk to the public and to workers when picking up at households. ● Adverse weather can affect the containers (e.g., boxes of pesticides). ● Lab-packing of many material types may occur roadside. ● Materials will be handled multiple times which may increase potential of spills. **Benefits** ● Increased participation - Mobile collection programs reach a new sector of the population that might not otherwise travel to a permanent location (e.g., recycling centre or transfer station). ● Flexible collection schedule - Households can select the dates and times based on their needs (if they are required to be home for pick up).
GHG Impacts	Anticipated Increase in GHGs

Mobile Collection	
	● Increase in GHGs due to additional vehicles collecting materials.
Potential Environmental Impacts and Benefits	● Materials that may not have been disposed of properly due to households' lack of access to a program are disposed of properly. ● Lower risk to materials being spilled or mishandled during transport as materials are picked up from a trained / certified collector.
Potential Known Health Impacts	● Reduces the amount of MHSW in the environment which can reduce potential health impacts.

6.4 In-Ground Containers

In-Ground Containers	
Approach / Technology Type(s)	An alternative to traditional waste collection containers (e.g., roll off bins) are containers that are placed below grade.
Description	Municipalities have installed in-ground containers in areas where waste collection is not required on a daily basis (e.g., parks and trails) or in high generating areas that would require multiple collections per day/week with a traditional garbage container (e.g., downtown cores). These have also been installed at multi-residential buildings by municipalities that provide collection to this sector, as well as privately by buildings responsible for their own waste collection. Deep collection systems are offered in a number of sizes ranging from small (approximately 3' in diameter) to large (approximately 5' in diameter). Some deep collection systems (e.g., Molok) consist of a main well that is made of a strong plastic (i.e., HDPE) which is seamless and leak proof. Inside of the well is a strong bag typically made of woven polypropylene which can be lifted out of the well to be emptied. The top of the container can be made of polyethylene or corrugated aluminum (graffiti proof) and can have lockable lids for safety purposes and to reduce illegal disposal through the use of a lock/key system or an electronic key card for multiple users. Holes for disposing of materials can come in different sizes to suit the deposit needs of the material. These systems require a specialized vehicle equipped with a crane to remove the bag and empty. Other systems are available that do not require a special truck with a crane to remove and empty the bag (e.g., Groundhog, Earth Bins). Containers can be placed in-ground for collecting dog waste, particularly in high-density multi-residential areas.

In-Ground Containers	
Status	Proven.
Availability	A variety of in ground deep collection systems are available and have been in use in Ontario since the early 2000s.
Examples / Case Studies	In-ground containers have been used successfully in Belgium, Finland, France, Germany, Portugal and Sweden. The containers are used for a variety of purposes by Ontario municipalities and provincial agencies including: ● Used by smaller municipalities (such as Township of Killaloe, Hagarty and Richards and the Township of Madawaska Valley) to collect and store food waste at their landfill ● Used by the Township of Madawaska to collect food waste at its grocery stores ● Used by municipalities (such as the City of Barrie) for use in their parks system. ● Used at Provincial Parks (such as Algonquin Provincial Park) for recyclables, garbage and food waste Some condos in Toronto have installed containers to collect dog waste. It is estimated there are 230,000 dogs in Toronto and the average urban condo has seven dogs per floor, each dog producing about 340 grams of dog waste daily. The underground containers can hold up to 500 kilograms of dog waste and reduces odours and the impacts on nearby garbage containers. The material is emptied by a vacuum truck and disposed of at a waste-to-energy facility. Other communities are sending material to organic waste plants to be converted to energy/compost. In ground front-end bins also exist (e.g., Earth bin) which can be collected by any front-load vehicle. The front-end bins appear to look like a traditional front-end bin; however, they extend below

In-Ground Containers	
	ground. The Earth bin has a load height above ground of 43 inches; however, it has 66 inches of depth underneath. In Antwerp, Belgium, sorting street stations have been installed in neighbourhoods to collect residual waste; plastic bottles, metal packaging, and drink cartons; organics; paper and cardboard; and glass. Residents use special keycards linked to a pre-paid account with different rates for disposal of materials. Dillon Consulting Limited. 2006. Multi-Residential Diversion Strategy
Target Material / Feedstock	Residential and IC&I Wastes (garbage, Green Bin organics, recycling, pet waste).
Outputs	No direct outputs, rather results are indirect benefits.
Regulatory Considerations	Ontario Building Code depending on where built.
Capital and Operating Cost Range	Capital costs of containers are dependent on the type, size and features of the container and can range from $1,000 to $5,000 per container. Specialized equipment and or vehicles may need to be purchased. Anticipated costs are unknown; however, they will add to the overall cost of the in-ground containers. Antwerp municipal staff estimate that each Sorting Street station costs approximately $110,000 (€75,000) to install (including all construction and container costs). Costs per container varies from $12,000 to $22,000 (€8,000 to €15,000). Additional costs are incurred for servicing the stations – maintenance, repair, cleaning, disinfection, battery replacement etc.

In-Ground Containers	
Revenue Opportunity / Cost Savings	Potential cost savings as the large storage capacity can reduce the number of collections required.
Risks and Benefits	**Risks** ● The deep collection system may require a unique collection approach involving the use of a hydraulic crane or boom to lift out the bags of stored materials. ● Containers must be in a location that is accessible by a waste collection vehicle and there must be sufficient space above the container so that the bag can be lifted up. Some municipalities have indicated success at using a vacuum truck to extract the organic waste (e.g., Toronto). ● Containers cannot be placed in areas with a high water table. **Benefits** ● Enables larger storage area to be used as the storage compartment is hidden underground. ● Reduces the number and frequency of waste collections due to the large storage capacity. ● Allows for natural compaction by gravity which permits more material to be stored. ● Remains cool underground which reduces odour and vermin issues. ● Allows for recycling and organics options for buildings/locations where space constraints may exist that do not allow for garbage, recycling and organics containers via traditional methods/technologies. ● No heavy, manual work. ● Container, lid and door structures keep the water out.

In-Ground Containers	
	● No need for a separate waste bin shelter. ● Few moving and breakable parts. ● Maintenance and cleaning services can be provided by contractors for added convenience. ● Fee based disposal can incent participation in diversion programs.
GHG Impacts	Anticipated Reduction in GHGs ● Potential for reduced number of trips to collect waste (reduced emissions through less transportation) thereby reducing GHG emissions.
Potential Environmental Impacts and Benefits	● Increases options for diversion initiatives (e.g., dog waste in parks). ● Reduction in noise from less frequent emptying of containers.
Potential Known Health Impacts	● Mechanical collection of containers may reduce risk of injury to workers from traditional manual collection techniques. ● Minimal to no health impacts.

6.5 Public Space Waste Diversion

Public Space Waste Diversion	
Approach / Technology Type(s)	Public space containers are used to collect wastes from public spaces. From a municipal perspective public spaces can include parks, downtown streetscapes, recreation centres and arenas, beaches, playgrounds, bus stops, trails, cemeteries, public buildings and associated activities such as special events and farmers markets.
Description	Public space containers come in a variety of designs and materials depending on the type of materials to be collected and where the containers will be located.
Status	Proven; however, public space waste diversion can be challenging and there are often high contamination rates or poor use of the containers which lead to low diversion.
Availability	A variety of public space containers are available. Most can be customized depending on needs and include color coding, hole openings, and consistent graphics and signage with existing programs.
Examples / Case Studies	Case Studies **Metro Vancouver, B.C**. - In an effort to reduce the amount of pet waste entering landfills Metro Vancouver conducted three pilots in 2012 in public spaces. Pilot results indicated that a separate dog waste only receptacle where owners were required to utilize park provided pet waste bags and deposit them in red receptacles was the most effective. This was attributed to the receptacles being located directly beside a garbage receptacle. It was determined that pet waste receptacles could be partnered with other waste receptacles to form a waste station to encourage proper sorting.

Public Space Waste Diversion	
	Dillon Consulting Limited. 2015. Township of Langley Public Spaces Waste Management Strategy **Granville Island, Vancouver, B.C.** - Granville Island typically sees 50,000 tenants and visitors per day, with seasonal variations. In 2014, 14 garbage receptacles inside the public market were replaced with zero-waste stations that included separate receptacles for recycling and organics. The receptacles went through several iterations of signage, with colour coding having the largest impact. Granville Island's waste receptacles feature large graphics focused on reaching multi-lingual crowds. More detailed graphics are on the receptacle surface helping to distinguish between acceptable and non-acceptable waste. Despite a learning curve for consumers and tenants, an increase from 49 percent to 60 percent occurred in the first three quarters of the year following the pilot and contamination is nearly 0 percent. **City of Toronto, ON** - The City's revised Parks Collection System began in 2010 and was completed in approximately two years in over 1,600 parks. The City's program objective was to improve collection efficiencies and reduce rain infiltration, as well as limit animal access, illegal dumping, and worker injury. Semi-automated wheeled 360L carts were introduced for both garbage and single stream recycling. Collections switched from manual bag collection to automated lifters, while locked domed-lid carts were introduced to discourage illegal dumping. The automatic carts resulted in a yearly savings of $250,000, solely by eliminating the need for plastic bag liners required in the old wire basket garbage receptacles. In addition to the public space containers mentioned above, other options are available such as in-ground containers (previously discussed in Section 6.4), solar compactors (discussed in Section 6.7) and containers that send out a signal when they require emptying (discussed in Section 4.3).

Public Space Waste Diversion	
Target Material / Feedstock	Public space waste generated in urban areas, suburban areas, rural areas, public facilities, parks and trails.
Outputs	Not applicable.
Regulatory Considerations	Not applicable.
Capital and Operating Cost Range	Capital costs for public waste receptacles can be high, depending on the types of bins selected and customization. One waste receptacle can range from $500 to $5,000. Pilots are recommended to determine which bins are appropriate for various areas prior to ordering for the entire jurisdiction. This can reduce costs. Operating costs also are dependent on each municipality, the number of containers that require servicing and how services are provided (e.g., one vehicle collects all waste streams, or dedicated vehicle for each waste stream). There may be revenue offsets from the sale of recyclable materials; however, the materials are typically heavily contaminated and there are limited revenues (if any).
Revenue Opportunity / Cost Savings	Minimal to no potential in revenue generation or cost savings. Potential partnerships for advertising on containers which can help offset costs.
Risks and Benefits	**Risks** ● May need to purchase additional equipment for collection if all streams are to be collected at once (e.g., three or four stream collection vehicles).

Public Space Waste Diversion	
	- If all streams are not collected at once then may need to re-sort recyclables and organics prior to recycling due to heavy contamination. - Some containers may have more space dedicated to advertising than to labels that indicate where/how to dispose of each waste stream. - Residents may dispose of household waste in public space containers. - Public space recycling programs that are not well designed can provide a confusing system of bin designs and labels. The appearance, labelling and placement of bins is critical to their functionality. - Promotion and education needs to be clear and easy to understand. - There may be low participation rates and/or high contamination between streams. - Multiple inconsistent public space programs can be confusing to residents. **Benefits** - Provides recycling programs to residents that may complement existing services that they receive at home (e.g., garbage, recycling, composting). - Provides additional recycling programs (e.g., pet waste) that residents may not receive at home. - Offers recovery potential for recyclables and potentially organics.
GHG Impacts	Anticipated Increase in GHGs

Public Space Waste Diversion	
	• May increase GHG impacts if additional vehicles are required to service each type of waste stream (more emissions from transportation)
Potential Environmental Impacts and Benefits	• Provides an opportunity for consistency in waste sorting at home and in the community. • Public space containers can reinforce the community's values as inviting, clean and environmentally conscious. • While proper sorting may not necessarily be achieved, public space containers may reduce litter in neighbourhoods.
Potential Known Health Impacts	• Minimal to no health impacts of diverting waste in public spaces.

6.6 OptiBag

Optibag	
Approach / Technology Type(s)	Use of different coloured bags for the different waste streams that can be placed in one collection container and then sorted at an optical sorting processing facility. These are often used in conjunction with a vacuum system/chute collection system.
Description	The Optibag system is used in many European jurisdictions to collect multiple waste streams using colour coded bags. Customers use different coloured bags corresponding to different waste streams which can be collected via a single chute (e.g., Envac, as an example of a vacuum system/chute) or container and placed in a single location for storage. The heavy-duty colour coded bags are collected and transported with a conventional waste truck to a specialized sorting facility which separates the streams using Optibag sorting technology. At the facility, camera/software technology recognizes bag colour and simple, robust mechanical diverters separate the different coloured bags into separate roll off containers. The sorting facility is fully automated, requiring minimal labour. Every colour of bag is viewed as a “fraction” and the equipment can manage up to nine different “fractions”. The optical sorting equipment can sort up to 26 different coloured bags.
Status	Proven as this technology has been in place since 1990.
Availability	This technology is primarily located in Europe. There has been interest in North America; however, there are no optical sorting plants specifically for the Envac Optibag in Canada. Some Ontario municipalities have been considering using the Optibag and vacuum system/chute. A new development in Peel Region has proposed to incorporate sustainable design elements such as vacuum waste. The Region is considering its possible role in waste collection and develop design standards.

Optibag	
	In 2009 Envac opened an office in Montreal to oversee Canadian projects (existing and potential). To-date, Envac has a flight kitchen system running at the Toronto Airport (since 1989). Two mixed use developments, Le Quartier Des Spectacles, a major urban revitalization project in the center of Montreal and the Eco city of La Cite Verte in Quebec City utilize an Envac system. Also, the Montreal's Jewish Hospital has an Envac system for the collection of trash and linen.
Examples / Case Studies	**Oslo, Norway** - The Optibag system has been successfully employed in Oslo, Norway for almost 20 years. The coloured bags provided are free of charge to residents and can be picked up in local grocery stores (which was based on agreements with the central grocery chains). The waste bags are placed in the bin or container and then collected with a conventional waste truck and transported to the Optibag plant. The trucks have reduced compression to avoid breaking the bags during collection, transport and emptying. The bags are delivered to one of two Optibag facilities where they are sorted automatically using camera technology that recognizes the colour of the bag. For example, when a green (food waste) bag is detected, a signal is sent which pushes the bag off the main conveyor belt, onto a second belt and then directed to its appropriate container. The containers sorted by each material type are taken to their respective disposal sites for further processing. Oslo, Linköping, Tromsö, and Södertälje use optical sorting in conjunction with vacuum systems. http://www.envacgroup.com/products-and-services/our_products/optibag-optical-sorting
Target Material / Feedstock	Source separated waste (e.g., recycling, green bin organics, garbage).

Optibag	
Outputs	Sorted material streams.
Capital and Operating Cost Range	Costs depend on who is installing the system and who is operating the system. Private entities may be responsible for installing and maintaining the infrastructure in buildings. Capital and operating cost considerations include: **Capital** ● Installation of optical sorting equipment at receiving processing plant to sort different colours of bags. ● Diversion processing facilities would require bag breaker equipment at the front end of their process. ● Provision of containers to manage the bags. **Operating** ● Distribution or provision/sale of colour coded bags to residents, if provided by the jurisdiction. ● Promotion and education campaign on how to participate and/or training on the new collection system, targeted to property management staff, janitorial staff and tenants. ● Operation of the receiving processing plant. The sorting facility in Oslo cost approximately $18 million to construct in 2009. Operating costs are not publicly available; however, the facility processes 160,000 tonnes per year.
Revenue Opportunity / Cost Savings	Potential for cost savings through reduction of number of collection vehicles required since waste streams will be collected together.
Regulatory Considerations	Ontario Building Code Requirements and MECP Environmental Compliance Approval will be required for sorting facility. Timing for

Optibag	
	ECA approval is anticipated to be longer as there are currently no facilities in operation in Ontario
Risks and Benefits	**Risks** ● Potential for residents to contaminate the waste streams. ● Extensive initial and ongoing promotion and education required for new and existing tenants, property managers/superintendents and janitorial staff to reduce contamination. ● Still requires residents to source separate their waste which has been an ongoing challenge for multi-residential buildings. ● Bagged recyclables would have to be opened before going through the waste diversion processing facilities. ● Relies on residents consistently using specialized bags to maintain program. ● Residents may not have space available to store multiple bags for the different streams. ● More waste is created with each bag set out. ● Bags that are required to be used would be for a single-use. May be issues with potential future bans on single-use plastics. **Benefits** ● Reduced impacts associated with co-collection of waste streams (e.g., financial, noise, GHG emissions) as fewer vehicles will collect from houses/buildings. ● Greater convenience to users as all waste can go into plastic bags and be dropped off in one location which can lead to increased participation in diversion programs.

Optibag	
GHG Impacts	Anticipated Reduction in GHGs ● Reduction in number of collection vehicles will reduce GHG emissions from reduced transportation.
Potential Environmental Impacts and Benefits	● Increased convenience for separating waste streams can increase participation which will in turn, increase waste diverted from disposal.
Potential Known Health Impacts	● Minimal to no health impacts from using multiple coloured bags. ● For the sorting facility, health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

6.7 Technology / Data

Technology / Data	
Approach / Technology Type(s)	Use of technology to monitor and/or track bins (e.g. RFID, sensors, solar compaction)
Description	There are new and emerging technologies that assist jurisdictions with waste container management in terms of live tracking of waste, providing data and statistics to customers on waste generation rates, weight or volume of waste collected, waste densities and/or diversion and sensing when containers are near capacity or highly odourous and issuing an alert to the collection operator. Radio Frequency Identification (RFID) chips are used for tracking waste performance, determining charges for waste management and improving waste collection services in the residential and IC&I sectors. This service requires collection vehicles outfitted with at least semi-automated collection technology, and wireless communication modules on both the vehicle and customer bins. Technology can also be used for optimizing waste collection operations in terms of routing, live tracking of waste vehicles, identifying potential issues/incidents through taking pictures and tracking locations and driver information. Bin sensors are a comprehensive waste management tool designed to improve the logistical performance of collection services through the creation of data driven collection schedules. The objective of the technology is to move away from static collection routines where inefficient uses of resources may be used, either by servicing receptacles that are not full or unnecessary. Solar compactors use smart devices that are able to determine how full a waste container is and trigger an automatic compaction of the waste when the volume reaches a certain point. This can increase a waste

Technology / Data	
	container's capacity by up to five to ten times. A solar panel charges a battery that runs the compaction mechanism. Some solar powered waste compactors are also connected to a remote software platform wirelessly that allows waste collectors to access real-time data on how full the waste container is. Intelligent waste technologies on waste containers (e.g., Bigbelly, Pandora RMS) that have sensors to alert when the containers are full or highly odourous allow for collection routes to be altered to collect from only full or odourous containers. These are more commonly used in public spaces, but can be applied to multi-residential buildings as well for different waste streams. Dillon Consulting Limited. 2015. Township of Langley Public Spaces Waste Management Strategy http://www.huffingtonpost.com/entry/new-york-city-is-turning-smart-garbage-bins-into-free-wifi-hotspots_55a6925ae4b0c5f0322c0569
Status	RFID and solar compaction are proven in many communities; however the City of Ottawa has experienced issues with both technologies. Sensors are emerging.
Availability	Most of these technologies have been proven throughout North America; however, some are newer than others (e.g., sensors)
Examples / Case Studies	**RFID** ● Region of Peel, ON - The Region of Peel conducted a five-month pilot for the use of weigh scales onboard of collection trucks to measure waste generation on a per multi-residential building basis. Weights of garbage and recycling were tracked by building and diversion rates were calculated. Due to the success of the pilot, the Region required the installation of onboard scales to the

Technology / Data	
	entire front- end collection fleet as part of a new collection contract. In 2016, the Region introduced a multi- residential RFID tracking system and report card. The system is capable of generating a “Report Card” that can be sent to each building which summarizes the collection services provided and recycling performance. The intent is to provide more transparency to building owners and managers regarding the waste management services provided. With increased awareness of their recycling performance, it is hoped that building staff will become more engaged and work with residents to increase recycling rates. The system will also have the capability to integrate with a billing system should this direction be deemed desirable in the future. http://thecif.ca/projects/documents/566.4-Peel_Final_Report.pdf http://www.peelregion.ca/council/agendas/2016/2016-06-16-wmsac-agenda.pdf ● Markham, ON – As part of contract negotiations in 2016, the City of Markham worked with their contractor to integrate RFID technology into recycling and organic carts for the multi-residential collection program. The contractor, “Fleetmind Systems”, is used for all multi-residential collection services, which was implemented at no additional cost to Markham. Fleetmind Systems provides hard- and software solutions to record data from all garbage and diversion containers collected at each location, including time, date, property information, and material weights for each individual pick-up and technical services including installation of the equipment in the cab, detailed progress reports and driver training. All data is transferred in real time to a web site developed by Fleetmind and Markham’s ITS Department.

Technology / Data	
	https://www2.markham.ca/markham/ccbs/indexfile/html/general/gc140203.htm **Rubicon** ● Rubicon Global is a technology company that has developed a smart city technology suite, RUBICONSmartCity™, that helps municipalities run more efficient, effective, and sustainable waste management operations and can be deployed in other fleet services as well. ● Spokane, Washington - In December 2018 the City began to pilot the RUBICONSmartCity™ platform which uses a table-based mobile app, a plug-in device and a web-based portal. The technology allows the City's Solid Waste collection utility to track key metrics, including service confirmation, missed pickups, landfill diversion and recycling rates. Tablets loaded with the Rubicon mobile app, as well as onboard plug-in devices, were placed in the City of Spokane's fleet of residential and commercial waste and recycling collection vehicles. With the mobile app and plug-in device, the City is able to take and organize pictures at customer locations, flag locations, dispatch alerts and provide real-time GPS monitoring of each vehicle. The app will also help deliver precise pick-up times, optimize routes and reduce the need for truck repairs. The technology was installed in approximately 100 solid waste vehicles. http://www.fleetmind.com/pdfs/WA-072010-Tracking.pdf ● Atlanta, Georgia - In 2017 the City installed the Rubicon platform into the City's 89 collection vehicles for a six month pilot. Pilot results indicated annual savings of up to $780,000 for landfill diversion, optimized waste and recycling routes and reduced maintenance.

Technology / Data	
	Sensors ● Enevo Sensor and Software - The Enevo system has two components. 1) Enevo Bin Sensor - Small sensor placed in a bin to collect data; and 2) Enevo server - Software designed to analyze and report data collected by the sensor. The Enevo bin sensor is installed on waste receptacles and wirelessly transmits data to the Enevo server. The sensor can be installed in/on any receptacle for any type of waste stream (solids and liquids). The technology senses the volume of the receptacle by sending a 'wave' to the surface of the waste and measuring the return travel distance. Data is sent to the Enevo Server where real-time information (including abnormal events e.g., fire or receptacle removal) can be accessed. Data is analyzed to provide optimized collection routes and all of the information is available by the user in real-time. Example installations include: ○ Kirkland, Washington - The City of Kirkland, Washington piloted the program with sensor installations on ten receptacles at City Hall and the Justice Centre. The total savings amount was $9,650 per year, through route optimization and receptacle elimination. ○ Tufts University (Medford, Massachusetts) - In partnership with Save that Stuff Inc., the University completed a pilot project in 2014 where Enevo bin sensors were installed at five locations across campus. Results led to a reduction in collections from 11 times per week, on average, to seven per week, with an estimated cost savings of 45 percent. Tufts University is moving forward with a plan to expand the program. http://www.enevo.com/wp/wp-content/uploads/2014/09/Enevo-Case-Study-Tufts-University-Save-That-Stuff.pdf

Technology / Data	
	● Big Belly is another technology that provides solar-powered compaction. Sensors are located in waste bins and when the waste bins are full and cannot be compacted further a signal is sent to collection operators. This has also been used at the Halifax waterfront for approximately 10 years. ● University of British Columbia, Vancouver, B.C. - The University has three Big Belly four-stream stations with compaction on the garbage can only. The non-compacted streams include mixed paper, mixed containers and organics. The University found that the organics stream was highly contaminated and thoughts were that it was from people off campus. Additionally, the garbage stream was not used as much as other streams which just have hole openings as people did not want to touch the handle (yuck factor). Staff may look into a foot handle opening for garbage. http://www.seas.columbia.edu/earth/wtert/sofos/Abrashkin_Thesis.pdf ● Richmond, B.C. - The City installed eight three-stream Big Belly stations (garbage, mixed paper, bottles and cans) at all train stations. City staff found that people did not want to touch the handle of the garbage stream and put a waste basket next to the stations.
Target Material / Feedstock	Typically applied to garbage, recycling and household organic waste streams.
Outputs	No direct outputs, rather results are indirect benefits.
Regulatory Considerations	Not applicable.
Capital and Operating Cost Range	**RFID -** Capital costs to consider include: 1) the RFID reader, which can vary from \$1,000 to \$3,000, 2) installation, 3) tags, 4) software, 5) ongoing license costs and 6) maintenance.

Technology / Data	
	RFID tags can cost anywhere from $0.10 to $50 depending on the type of tag that is being used, the application and the volume of the order. It is more cost efficient for municipalities to put RFID tags on bins / carts at the time of order/purchase of the bins/cart versus putting them on after they are already in use as this will require manual labour to drive from each location that they are required. Peel Region's cost (2013-2015) to install tags at 700 multi-residential buildings (5,000 in front-end bins and 6,900 carts) and 1,000 IC&I locations, as well as a pilot ($297,655) and full scale implementation, support and maintenance ($1,028,673) was $1,326,328 in total. **Rubicon -** Their technology has been provided for free to a number of municipalities to test during a pilot first prior to committing to purchase. Costs of the technology are not published; however, the City of Atlanta reported potential savings of $780,000 annually based on a six month pilot. **Enevo -** Before committing to a long term contract, Enevo offers the option to test the service on a small scale with no up-front investment, only a fixed monthly rate per sensor. As Enevo offers an ongoing service, the cost is a subscription based on the number of sensors (approximately $10 to $25 per sensor). **Solar Compaction** – A Bigbelly unit can cost up to $10,000 per container. This cost does not include installation, servicing and ongoing maintenance.
Revenue Opportunity / Cost Savings	Optimization in collection routing can lead to a reduction in waste collection costs; however, the return on investment may be poor for some technologies due to upfront costs. Some technologies may only make sense in limited applications where volumes of waste exceed a rational collection schedule.

Technology / Data	
Risks and Benefits	Each type of technology has its own set of benefits and risks; however, there are some common elements. **Risks** ● Installation / start-up costs can be high to implement the program and there may be on-going maintenance costs. Payback periods may be a few years depending on the technology used and capital expenses. ● Some technologies are relatively new. ● Reliance on external cloud-based platform to manage data and automatic collection routing. ● Rate to maintain the utility may increase since the collection frequency and cost will decrease. **Benefits** ● Some technologies can be used with existing or new bins to optimize collection frequency thereby reducing the number of collection trips in a week. This reduces the number of trucks, fuel and labour as well as traffic congestion associated with standard waste collection routes and schedules. ● Can provide data and statistics for each customer such as waste generation rates, weight of materials collected, waste densities and/or diversion rates. ● Can increase transparency on billing since customer specific data is generated. ● Allows for municipalities to track which customers generate the most garbage and/or are not setting out expected quantities of recyclables and/or organics. This can allow for municipalities to focus their educational efforts. ● More efficient operations leads to improved service for customers.

Technology / Data	
	• Better management of public space containers. • Notifications that containers are full can lead to increased diversion efforts as customers may throw materials into undesired streams (contamination) if there is no space available in the correct stream.
GHG Impacts	Anticipated Reduction in GHGs • Reduction in emissions from trucks as fewer trucks on the road (reduced emissions from transportation).
Potential Environmental Impacts and Benefits	• Allows for municipalities to track diversion efforts and target underperformers to focus education efforts and increase waste diversion.
Potential Known Health Impacts	• Minimal to no health impacts from using different collection technologies.

6.8 Summary of Collection Approach Alternatives

The following table summarizes the technology and/or approach researched, the potential applicable material stream and the potential customers the technology and/or approach could be applied to.

Technology / Approach	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
Automated Collection	All	X	X (for smaller buildings)	X	X	X
Bulk Waste Collection						
Disposal Fee	Bulky Waste					
Limit Number of Items/ Collections	Bulky Waste	X	X		X	X
Separate Fee	Bulky Waste	X	X		X	X
Collection	Bulky Waste	X	X		X	X
EPR	Bulky Waste					
Disposal Ban	Bulky Waste	X	X	X	X	X
Other Collection Approaches						

Technology / Approach	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
Mobile Collection	MHSW, Electronics	X	X		X	X
In-Ground Containers	Garbage, Recycling, Organics		X	X	X	X
Public Space Waste Diversion	Garbage, Recycling, Organics			X	X	
Optibag	Garbage, Recycling, Organics	X	X	X	X	X
Vacuum Systems	Garbage, Recycling, Organics		X	X	X	
Technology / Data						
RFID	Garbage, Recycling, Organics	X	X			
Rubicon	Garbage, Recycling, Organics	X	X	X	X	X
Sensors	Garbage, Recycling, Organics		X	X	X	

Technology / Approach	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
Solar Compaction	Garbage, Recycling, Organics			X	X	

7 Recycling Processes / Technologies

The section reviews various recycling processes that are often used as a replacement or to supplement 'traditional' manual methods. It explores the use of source separation technologies including robotics, artificial intelligence, optical sensors, ballistics, and mechanical methods as well as chemical recycling.

The intent of this section is to provide a high–level overview of technology types and approaches, availability and status, approval requirements, costs and revenue, potential environmental impacts and benefits and potential known health impacts. Further details will be researched in Phase 2 of the development of the SWMP, including further identification of approval requirements, as applicable. It is assumed that any waste management facility developed must meet all conditions required as part of any necessary approvals at that time (e.g. Environmental Compliance Approval) which have been established to ensure protection of public health.

The City of Ottawa currently collects dual streams of recyclable materials (fibres, containers) which are each sent to contracted fibre and container recycling plants which are owned and operated by a private company. The fibre process uses disc screens and manual sorts to create three material types. The container process uses a ballistic separator, magnet, optical sorters, glass breaker, cyclone, and eddy current separator, as well as manual sorters.

The following two tables present research on source separation and chemical recycling technologies.

7.1 Sorting Technologies for Recycling

Sorting Technologies for Recycling	
Approach / Technology Type(s)	Materials either need to be sorted at the source (source separation) or they need to be sorted at a recycling facility. Source separation allows for the generator of the waste(s) to get involved in the early stages of sorting; the more a homeowner sorts at the source, the higher the quality recyclables are for processing. While multiple sorts at the source results in the highest quality of recyclable material, user convenience, collection system considerations and increasing

Sorting Technologies for Recycling	
	types of materials being recycled has resulted in the evolution of sorting technologies at recycling facilities. With these technology advancements, both dual stream and single stream recycling systems are now common practice in North America. Sorting technology makes recycling more convenient by requiring less source separation, reduces collection costs and improves sorting capabilities at the recycling facility. With reduced emphasis on source separation, however, contamination rates increase. Single stream recycling has higher contamination than dual stream systems. Both systems have been affected by the reduced availability of end markets resulting from China's National Sword Policy introduced in 2019 and single stream processing to a greater degree as a result of the higher contamination rates. Recyclables from multi-residential buildings and parks and public spaces typically have higher contamination than curbside residential and have been difficult to process at either dual or single stream recycling facilities. Removal of recyclable material from mixed waste is discussed in Section 9.2. Recycling facilities often use a combination of manual labour and processing equipment to sort a feedstock (e.g., fibres, containers, single stream recyclables) into various streams and remove contamination. Common equipment currently used includes optical sensors, disc screens, eddy current separators, magnets, ballistic separators, cyclones and new and emerging processing technology, including robotics, artificial intelligence, ballistics, and mechanical works.
Description	Using a combination of processing equipment and labour, recycling facilities sort materials into various grades and types ready for market.

Sorting Technologies for Recycling	
	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. Most robotic sorting systems include a combination of mechanical arms to physically pick up select materials from a conveyor belt, and artificial intelligence and optical sensors to create an accurate real-time analysis of the waste stream. These systems typically are fully automated and make autonomous decisions on which objects to pick and how. A typical process would include an input waste bunker to provide a continuous feed of material, a series of screens to separate materials into various size fractions, and the robotic arms and sensors to mechanically sort select materials. Each robot is guided by cameras and computer systems trained to recognize specific objects. The systems are typically able to process approximately 2,000 “picks” per hour per robot; with a throughput of approximately 11 to 12 tonnes per hour for single-stream recycling. Based on information provided by the City of Ottawa, the MRFs that process the City’s recyclables currently operate at approximately 15 tonnes per hour for dual stream recycling. The robots arms glide over a moving conveyor belt and pick up items with oversized ‘hands’. The systems can be implemented to sort plastic bags by colour for source separated household waste, to improve the efficiency of waste sorting in single stream recyclables by picking out plastics (PP, PE, PET, HDPE, PVC, etc.), foils (LDPE), lightweight packages, paper, OCC, and cartons, and sorting by shape, size, and/or colour.

Sorting Technologies for Recycling	
	City of Ottawa - Summary of Waste Technologies and Approaches (Updated) Technical Memorandum, HDR, 2014 www.zenrobotics.com https://www.recyclingtoday.com/article/recycling-robots-ai-sorting/ https://coloradosun.com/2018/09/19/meet-the-robots-and-other-contraptions-making-colorados-recycling-more-efficient/ https://www.machinexrecycling.com/ Sustainable and Safe Recycling: Protecting Workers Who Protect the Planet, GAIA, Partnership for Working Families, MassCOSH, National Council for Occupational Safety and Health, 2015 Accelerating Circular Supply Chains for Plastics: A Landscape of Transformational Technologies That Stop Plastic Waste, Keep Materials in Play and Grow Markets, Closed Loop Partners, 2019
Status	Emerging (robotics), proven (optical sorting)
Availability	Robotics technology is primarily located in Europe and the United States. Robotic sorting units have been installed in MRFs located in Granby, QC, Chatham-Kent and Toronto, ON and Winnipeg, MB.
Examples / Case Studies	**Alpine Recycling, Colorado** – This single-stream recycling facility has been piloting a robot, created by AMP Robotics which has helped reduce contamination rates to under 10 percent. The robot uses a vision system, learns from experience and can be programmed to focus on any object based on market value (e.g., if the price of oil drops, the robot can change its focus to a non-oil-based plastic). The robot is programmed to sort by showing hundreds and thousands of different materials as opposed to learning how to identify a certain plastic resin, as in the case of optical sorting. The facility also has a ballistic separator that sorts

Sorting Technologies for Recycling	
	two-dimensional materials (e.g., paper products) from three-dimensional materials (e.g., containers). **Single Stream Recyclers, Sarasota, CA** – Single Stream Recyclers operates a 100,000 square foot MRF that uses six AMP Cortex™ single-robot systems and will be adding four AMP Cortex dual-robot systems in 2019. The dual systems uses two high-speed precision robots that sort, pick and place materials at different sorting lines throughout the MRF. The robots have been able to consistently pick 70-80 items a minute which is twice as fast as humanly possible and with greater accuracy. The learning system (AMP Neuron™) applies computer vision and machine learning to recognize different colours, textures, sizes, shapes and patterns to identify material characteristics.
Target Material / Feedstock	Blue and Black Box recyclables.
Outputs	Sorted recyclables.
Regulatory Considerations	Transitioning of the Blue Box program to a full producer responsibility model under the Waste Diversion Transition Act (2016) is under development for implementation between 2023 and 2025. Facility retrofits may require ECA amendments, with normal approval timelines expected. A new facility will require an ECA and as a result approval timelines are expected to be longer because a full review is required for all aspects of the approval. Land use planning (e.g. Official Plan, Zoning, Site Plan) approvals would be required for a new facility, depending on the site.

Sorting Technologies for Recycling	
Capital and Operating Cost Range	Limited public information available on single stream recycling systems. Some studies have reported that while collection costs are lower, processing and contamination disposal costs increase by approximately $3 with single stream technologies. https://recyclenation.com/2015/03/single-stream-versus-source-separation-recycling/'' In 2015 a study was released by Wilfrid Laurier University comparing single and multi-stream recycling systems in Ontario, Canada that indicated the following costs for single-stream (SS) versus dual-stream (DS) recycling. Collection costs: $195 per tonne SS, $201 per tonne DS Processing costs: $137 per tonne SS, $92 per tonne DS Revenue: $95 per tonne SS, $105 per tonne DS Net Cost: $299 per tonne SS, $233 per tonne DS However, since the study was released the revenues per tonne for recyclables have decreased and quality requirements for end markets have increased (lower contamination rates as a result of the China's National Sword Policy) so it is anticipated that the net costs have increased for both systems. . The cost of an optical sorter varies, and is dependent on a number of factors including processed tonnes per hour, material stream(s), types of cameras used, monitoring flow, and ejection rate. Costs can be between $65,000 and $850,000. https://www.plastics.ca/?f=file_one_pager_on_automated_sorting.pdf&n=file_one_pager_on_automated_sorting.pdf

Sorting Technologies for Recycling	
Revenue Opportunity / Cost Savings	Potential increases in revenue for dual stream recycling from the sale of recyclable material with improved sorting and reduced contamination. Potential reduction in processing costs through increased efficiency in recyclable material sorting. Potential long term cost savings for processing with reduced staffing needs for a traditionally manual job and ability to operate 24/7 which will increase facility throughput.
Risks and Benefits	**Risks** ● Transitioning of the Ontario Blue Box program to a full producer responsibility model is expected to occur by the end of 2025 will shift responsibility for technology investments from municipalities to industry; ● Large capital cost requirements; ● Relatively new technology; ● Economic impact to local economy as reduces the number of workers required (fewer jobs) with more automation; and, ● Contamination rates for single stream recycling and ability to market materials. (e.g., Concern over glass shards contaminating paper loads). **Benefits** ● Replace manual processes and improve efficiency; ● Decrease health and safety risks associated with manual processes; ● Ability to adjust sorting tasks and purities; ● Potential for 24/7 non-stop material sorting; and,

Sorting Technologies for Recycling	
	● Hybrid sorting: positive and negative sorting at the same time.
GHG Impacts	Anticipated Reduction in GHGs ● Potential for reduction in GHGs due to increased recovery of materials and avoidance of extraction of virgin materials.
Potential Environmental Impacts and Benefits	● Improved efficiency and quality of material sorting based on various characteristics such as polymer, shape, size and/or colour; and, ● More efficient sorting leads to potentially more recyclables being captured at the MRF thereby increases waste diverted from disposal.
Potential Known Health Impacts	● Traditional assembly-line material sorting by mechanical labour can increase health and safety risks due to the nature and working conditions of the operations; ● Moving to automated and autonomous sorting methods reduces the risk of injury to workers; ● Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

7.2 Chemical Recycling

Chemical Recycling	
Approach / Technology Type(s)	Chemical recycling of waste plastic is a process where a polymer is chemically reduced to its original form so that it can eventually be processed and remade into new plastic materials that are made into new plastic products. Chemical recycling does not replace the sorting process. It instead, creates new markets for these materials.
Description	The demand for recycled plastics is outpacing the supply. The majority of plastics used are never recovered, and manufacturers are increasingly challenged to use recycled plastics in their current state because of degradation or contamination issues. These materials often do not perform as well as prime or virgin plastics. Without a change from a straight line to the landfill approach the challenges associated with the current state of plastic recycling and the mismanagement of recyclable plastics is only projected to become more cumbersome and difficult to meet for manufacturers. Current "mechanical" approach to recycling works well for Polyethylene terephthalate (PET) (e.g., packaging foods and beverages, soft drinks, juices and water) and High-density polyethylene (HDPE) (e.g., plastic bottles, corrosion-resistant piping, geomembranes and plastic lumber) plastics, but it cannot effectively manage complex streams of films, bags, synthetic fibers and other types of plastics that enter the waste stream. Current infrastructure and recycling technologies are narrowed in their capacity to effectively and efficiently recycle the variety of plastic types and grades used today. The products currently being produced fail to compete with prime or virgin materials. Chemical recycling technologies exist that can effectively repurpose these plastics into a valuable commodity by means of purification, decomposition, and/or conversion. Technologies that keep plastics in play can be part of the solution to reduce plastic pollution. Analysis indicates that chemical recycling can help meet market demands and have the potential to generate significant revenue in

Chemical Recycling	
	addition to the extensive environmental benefits recognized. In addition to the markets for plastics, there are also markets available for chemicals These additional markets create even more opportunity for repurposed materials to circulate through the economy. There are also markets available for fuels; however, these are not considered as recycling yet and are not part of a circular economy.
Status	Emerging.
Availability	There are currently over 40 technology providers operating commercial scale recycling plants in Canada and the US, with an additional twenty technology providers attempting to scale their operation to meet operating commercial needs. The technology is available and is continually emerging and scaling. In order to tap into the projected market, more investment and innovation in market approaches is required.
Examples / Case Studies	Companies involved in catalytic chemical recycling processes which convert plastic waste into products such as waxes, oils, lubricants and chemicals include; GreenMantra, Agilyx/Regenyx, Pyrowave, and Polystyvert. https://advancedwastesolutions.ca/green-mantra-expanding-waste-plastic-to-wax-products/ **GreenMantra, Brantford, ON** – GreenMantra uses catalytic pyrolysis to convert waste plastics into high-value additives and specialty chemicals from waste plastics. A catalyst is a substance that starts or speeds up a chemical reaction without itself being impacted and pyrolysis is the chemical decomposition of a substance by heating that spontaneously occurs at high temperatures. The products generated include a polymer additive for wood plastic composite lumber and polymer-modified asphalt roofing and roads as wells as in rubber compounding, polymer processing and adhesive applications. Some of the products are made with 100 percent recycled post-consumer

Chemical Recycling	
	plastics. The facility was built in 2010 as a demonstration facility and at the end of 2014 construction of a commercial-scale facility was completed. Canadian Waste to Resource Conference - Chemical Recycling 101 (Presentation), GreenMantra Technologies, 2019 **Pyrowave, Montreal, QC** – Technology uses microwaves to heat up and break down polystyrene molecules into their individual links (styrene) which can then be processed back into polystyrene. The process can handle more contaminated polystyrene products and generate a 100 percent recycled content new polystyrene product. The process is estimated to produce a tenth of the energy and half of the GHG emissions when compared to producing polystyrene from oil. An estimated 10 percent of the product is lost each time but can be recycled over and over again making it a circular product. Founded in 2013, Pyrowave is still in it's infancy as a startup company. Life Cycle Inventory of 100 percent Postconsumer HDPE and PET Recycled Resin from Postconsumer Containers and Packaging (Revised Final Report), Franklin Associates, 2011
Target Material / Feedstock	Recyclables, particularly plastics.
Outputs	Renewed waste plastics and petrochemicals.
Regulatory Considerations	Environmental Compliance Approval for facilities, approval timelines may be longer due to the limited number of facilities in Ontario. Land use planning (e.g. Official Plan, Zoning, Site Plan) approvals would be required for a new facility, depending on the site.

<table>
<tr><th colspan="2">Chemical Recycling</th></tr>
<tr><td>Capital and Operating Cost Range</td><td>Not publicly available.</td></tr>
<tr><td>Revenue Opportunity / Cost Savings</td><td>Research projections show that there is an estimated $120 billion available in existing markets for a better product. Projections indicate the demand for recycled plastics to be approximately 5 to 7.5 million tonnes globally by 2030. Existing technology providers are operating with higher profit margins as the operations scale and mature to match the current market.</td></tr>
<tr><td>Risks and Benefits</td><td>Risks
New approaches in plastic recycling will require an industry wide change to fully mature and reach market potentials. Of the data available from the 60 providers either in full-scale operation or attempting to scale to meet the market, it has taken on average 17 years to reach the current growth scale. The biggest risk in shifting the approach to plastic recycling is the volatility of the markets over such a significant contribution of time and resources.
Benefits
Plastic waste is a huge untapped revenue resource; and,
Using recycled plastics has benefits in many applications including:
Cheaper than prime or virgin plastics;
Pricing is less volatile relative to prime materials; and,
Does not depend on extraction of non-renewable fossil fuel resources.</td></tr>
<tr><td>GHG Impacts</td><td>Anticipated Reduction in GHGs</td></tr>
</table>

Chemical Recycling	
	● Plastics recycling significantly reduces energy use and GHG emissions in comparison to producing prime or virgin materials; and, ● https://www.americanchemistry.com/Media/PressReleasesTranscripts/ACC-news-releases/New-Study-Confirms-Recycling-Plastics-Significantly-Reduces-Energy-Use-and-Greenhouse-Gas-Emissions.html.
Potential Environmental Impacts and Benefits	● Renewed resource could displace fossil fuels currently being used in market; ● Reduction or avoidance of environmental pollution; ● Significant reduction in CO2 emissions and potentially hazardous chemical pollutants; and, ● Reduction of single use plastics and plastic waste entering landfills, marine environments, and the environment.
Potential Known Health Impacts	● Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

7.3 Summary of Recycling Processes / Technologies

The following table summarizes the technology researched, the potential applicable material stream and the potential customers the technology could be applied to.

Technology	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
Sorting Technologies	Recycling	X	X	X	X	X
Chemical Recycling	Recycling	X	X	X	X	X

8 Source Separated Organics Processing Approaches and Technologies

This section looks at different technologies that can handle source separated organics, including household organics and leaf and yard waste.

The intent of this section is to provide a high–level overview of technology types and approaches, availability and status, approval requirements, costs and revenue, potential environmental impacts and benefits and potential known health impacts. Further details will be researched in Phase 2 of the development of the SWMP, including further identification of approval requirements, as applicable. It is assumed that any waste management facility developed must meet all conditions required as part of any necessary approvals at that time (e.g. Environmental Compliance Approval) which have been established to ensure protection of public health.

The City's household organic waste, leaf and yard waste, as well as Christmas trees are processed and marketed under a contract with Renewi Canada Ltd, formally Orgaworld Canada Ltd., through a twenty-year contract, which ends in 2030. The facility is located in the southeast end of Ottawa at 5123 Hawthorne Road, near the intersection of Rideau Road and Bank Street. The Renewi facility uses an indoor tunnel composting system for both leaf and yard waste material and source separated organics.

The contract established a base-line processing rate, which was $112.45/tonne in 2019 and is subject to annual Consumer Price Index (CPI) increases. It provides for two one-year contract extensions and includes a termination for convenience clause. The Green Bin program accepts household food waste, soiled paper products, kitty litter, animal bedding and leaf and yard waste. In July 2019 the City added dog waste to the program and the allowance of plastic bags as a bagging option to contain the materials.

Separately collected leaf and yard waste is processed at the Barnsdale Road property near the Trail Waste Facility using outdoor windrow composting.

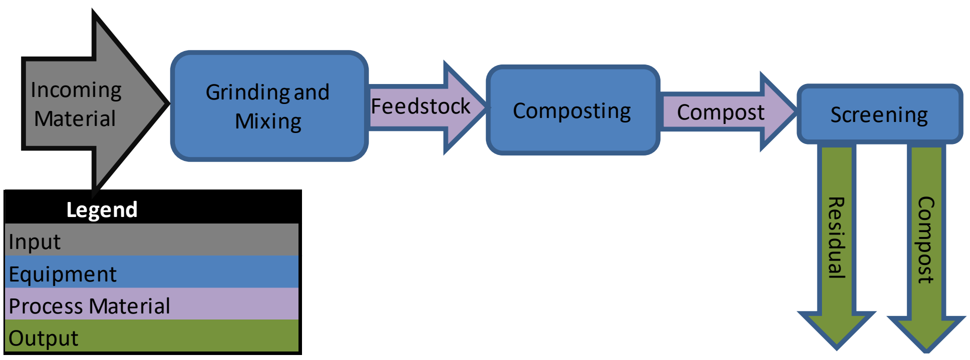
Renewi is responsible to perform testing on the end-use products to meet MECP regulatory requirements. With the expanded service that included the addition of plastic bags as a bagging option and dog waste, the amended contract changed the finished material from unrestricted use compost to beneficial use products, such as compost and non-agricultural source material (NASM).

Additionally, Renewi is required to provide the City with 2,000 tonnes of AA compost annually at no cost beginning the spring/summer of 2021.

The City's wastewater treatment facility (ROPEC) process consists of secondary treatment and dewatering, followed by anaerobic digestion where solids are heated and broken down to reduce pathogens, producing methane for energy and creating reusable biosolids. All of the biosolids are currently land applied in and around the Ottawa area.

The following eight tables present research on source separated organics processing approaches and technologies. This includes aerobic and anaerobic digestion, mechanical / chemical processing, biological processing, co-digestion of sewage and organics, and the use of in-sink disposal units.

8.1 Aerobic Composting

Aerobic Composting	
Approach / Technology Type(s)	Aerobic composting of organic materials such as household organics including food waste and leaf and yard waste.
Description	Aerobic composting is a naturally occurring process where organisms break down organic material in the presence of oxygen. Food and yard waste is collected and aerobically composted to produce compost. The process requires moisture, heat, and oxygen. There are a variety of composting techniques that can provide these conditions. The most common technique is an outdoor “turned” windrow and is typically used to process yard waste. Managing moisture, heat and oxygen availability requires specific controls and technology. Odour generation is common with composting thus requiring some applications to be indoors with odour abatement technology. Different types of aerobic composting technologies exist, including aerated windrow, aerated static pile, and in-vessel composting.
	
Status	Proven
Availability	Composting is widely used across municipal, agricultural and industrial applications. Many municipalities that have food and yard waste programs will use aerobic composting to process its waste.

Aerobic Composting	
	The type of aerobic technology used dictates the type of organics that can be processed. Not all technologies can be used to process leaf and yard waste and household organics together. Incoming feedstock ultimately determines the quality of the end-product. In Ontario, depending on the end-product, the compost generated can then be sold or given to the community (in the case of AA compost) or sold to the agricultural industry (in the case of a non-agricultural source material (NASM), with a plan and approvals in place) . Leaf and yard waste has been proven to be successfully composted through aerated windrows. Many municipalities have separated the collection of food waste from leaf and yard waste so that the smaller volume of food waste can be processed in a smaller and more efficient compost facility that can be run at capacity for most of the year, versus with Leaf and yard waste where the material can vary by weight and composition throughout the year. Additionally, some composting systems, such as accelerated in-vessel tunnel composting have issues with processing leaf and yard waste with food waste. https://www.ec.gc.ca/gdd-mw/3E8CF6C7-F214-4BA2-A1A3-163978EE9D6E/13-047-ID-458-PDF_accessible_ANG_R2-reduced%20size.pdf

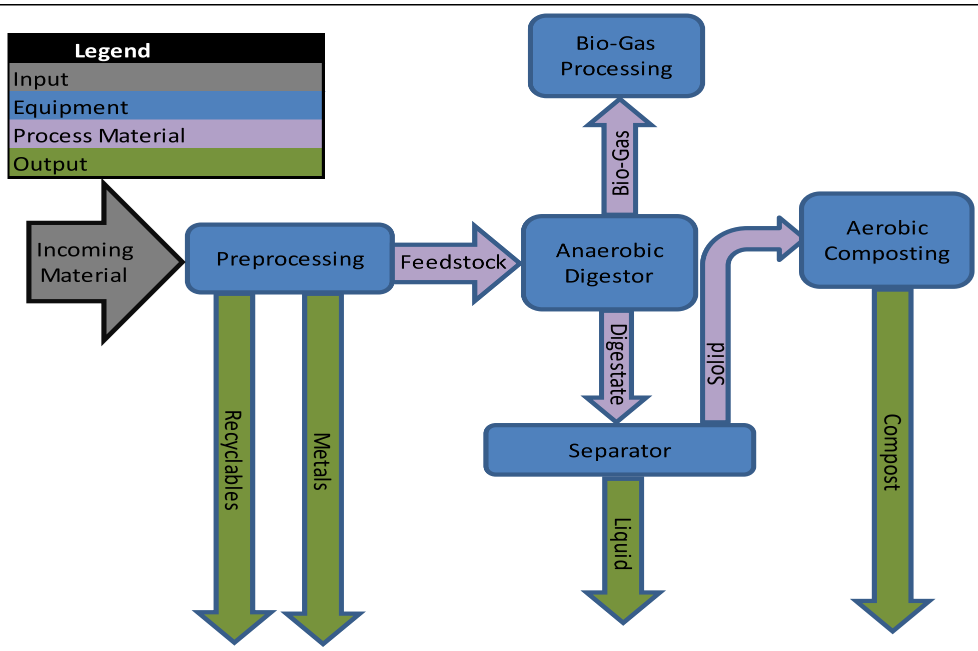
Aerobic Composting	
Examples / Case Studies	**Region of Durham, ON** - The Region of Durham's service provider uses a wide bed composting technology. Yard waste is combined with food waste and placed in a large holding container. The product is then heated and continually turned to allow for the aerobic composting. The mixture stays in the holding container for approximately 21 days and then cured outside for another 30-75 days. https://www.durhamregion.com/news-story/3491601-new-compost-facility-in-full-swing/ https://www.durhamyorkwaste.ca/Assets/PublicOutreach/EFWWMAC/Meetings/Meeting_3/WMAC_Meeting3_Presentation_MillerComposting.pdf **Calgary, AB** - The City of Calgary commissioned its 521,000 square foot aerobic composting facility in 2017. The facility receives food and yard waste from its green bin program. The product is first shredded in the receiving area then loaded into the composting vessels. The material is pasteurized for three days then aerobically composted. The whole composting process takes approximately 60 days to complete. The facility processes up to 145,500 tonnes per year noting that 100,000 tonnes is municipal organics received from the green cart program and 45,000 tonnes is municipal dewatered biosolids received from the City's Bonnybrook wastewater treatment plant. Facility operating costs are approximately $12 million per year. https://globalnews.ca/news/3604825/calgary-home-to-biggest-of-its-kind-composting-facility-in-canada/ https://aimgroup.ca/calgary-organics-composting-facility/ https://www.landscape-alberta.com/news-from-the-grand-opening-of-the-city-of-calgarys-new-compost-facility/

Aerobic Composting	
Target Material / Feedstock	The target organic feedstock may depend on the type of aerobic composting technology used. Feedstock materials typically include residential yard waste, food waste, biosolids, agricultural waste and animal manure. Some facilities can also take diapers, pet waste and sanitary waste depending on the processing equipment (breaking/screening) and end markets.
Outputs	Food waste is aerobically digested to produce unrestricted use compost or restricted use compost such as NASM. This product has a high organic content and nutrient value for soil addition. With proper approvals in place, the product can be sold or given to agricultural industry for land application as a fertilizer.
Regulatory Considerations	An Environmental Compliance Approval is required from the MECP for a Waste Disposal Site (Processing) and potentially for Air. Approvals timing depends on the technology and complexity of the facility. The Food and Organic Waste Policy Statement under the RRCEA, 2016 considers aerobic composting as “composting”. Preparation of a NASM Plan and approval by the Ministry of Agriculture, Food, and Rural Affairs to send processed material to agricultural receiver. Land use planning (e.g. Official Plan, Zoning, Site Plan) approvals would be required for a new facility, depending on the site.
Capital and Operating Cost Range	Depending on the type, size, capacity and incoming feedstock of the facility, the capital and operating costs can vary. In 2017, a study was completed for the City of Ottawa that assessed various collection, feedstock and processing costs of organics. The study indicated the following estimated costs:

Aerobic Composting	
	- Aerated Static Pile (covered). Composting using covered aerated static piles is a relatively modular approach and a phased approach to capital investment is available; - Estimated Capital Cost: $210 - $490 / tonne annual capacity; and, - Estimated Operating Cost: $25 - $85 / tonne processed; - Enclosed Aerated Static Pile (tunnel). Facilities that use enclosed aerated static pile composting have typically been implemented in Ontario to meet the full planned capacity with a single capital investment; - Estimated Capital Cost: $285 - $665 / tonne annual capacity; and, - Estimated Operating Cost: $50 - $110 / tonne processed; - Enclosed Channel, Agitated Bed; - Estimated Capital Cost: $255 - $595 / tonne annual capacity; and, - Estimated Operating Cost: $45 - $105 / tonne processed. Dillon Consulting Limited. August 2017 Task 3 Technical Memorandum - Assessment of Collection / Feedstock Scenarios and Processing Options
Revenue Opportunity / Cost Savings	Depending on how contracts are set up and whether processing is contracted out or done in-house, there is potential revenue opportunity for feedstock tipping fees and compost sales to end markets and farmers for land application.
Risks and Benefits	**Risks** Increased GHG to transfer materials to and from the facility.

Aerobic Composting	
	● If facility is not properly managed, potential for odour generation. ● The quality of the end product may make it unmarketable. **Benefits** ● Reduces GHG due to waste diversion. ● Diverts organics from landfills and delays need to locate new landfill capacity. ● Potential for material recovery. ● Composting helps close the soil nutrient cycle if end product is land applied.
GHG Impacts	Anticipated Reduction in GHGs ● Diverts organics from landfills. British Columbia Ministry of Environment. Technologies and Best Management Practices for Reducing GHG Emissions from Landfills Guidelines. June 2011.
Potential Environmental Impacts and Benefits	● Diverts organics from landfills. ● Reduces the amount of GHG produced from waste diversion of these materials. ● Closes the soil nutrient cycle.
Potential Known Health Impacts	● Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

8.2 Anaerobic Digestion

Anaerobic Digestion	
Approach / Technology Type(s)	Anaerobic Digestion (AD): Wet Digestion and Dry Digestion to manage organic material.
Description	The AD process can be a “wet” process or a “dry” process. A “wet” process will contain 10 to 20 percent dry matter content and a “dry” process will contain “20 to 40 percent” dry matter content. The biogas made from AD facilities can be used as fuel for boilers, be converted into electricity, and can be upgraded to Renewable Natural Gas (RNG). RNG is interchangeable with conventional natural gas. It can be injected into the natural gas distribution system, reducing the amount of conventional natural gas needed.
	
Status	Proven

Anaerobic Digestion	
Availability	AD is used in agricultural and industrial applications. In agricultural applications, manure is harvested and digested to create biogas. The remaining product (digestate) is spread on agricultural fields as a soil amendment. Wastewater applications can also use AD for water treatment purposes. Co-digestion processes mix organic waste with municipal sewage sludge to create a feedstock for AD. Co-digestion is rare in North America, but is starting to become more popular and is being used for processing household organics. https://sustain.ubc.ca/sites/sustain.ubc.ca/files/Sustainability%20Scholars/GCS%20reports%202014/Examining%20the%20current%20state%20of%20anaerobic%20digestion%20facilities.pdf
Examples / Case Studies	**City of Toronto, ON** - The City has two wet (low-solids) AD facilities (Dufferin and Disco Road) that process the organics collected through the Green Bin Organics program. The Dufferin AD facility capacity is 55,000 tonnes per year and the Disco Road facility can handle 75,000 tonnes per year. Green Bin materials are unloaded at the facility tipping floor, pre-processed to remove plastic bags and contaminants and the remaining material is sent to anaerobic digesters where micro-organisms, in an oxygen-free environment, decompose the materials to produce digester solids (transported to an off-site aerobic composting facility to create high-quality compost) and biogas. The biogas can be upgraded to create RNG that can then be injected directly into natural gas pipelines, or as alternative fuel (discussed in more detail in Section 5.4). **Renewi** - Renewi is a company that has three organics processing facilities located in London (Ontario), Ottawa and Surrey (B.C.). Their Surrey facility is an AD process that produces biofuel. The facility's website indicates that the facility utilizes a dry AD facility to process 115,000 tonnes per year of organic waste from household and commercial sources. However, one wet digester receives liquid

Anaerobic Digestion	
	feedstock and recycled liquids from the process. This wet digester acts as a fermentation tank and produces percolate to maintain the required biological conditions in the dry digestion reactors. The facility produces biogas which is upgraded and used as fuel for Surrey's waste collection fleet and compost from the solids. The digestion process takes place in airtight tunnels and takes 21-28 days to complete. https://www.surreybiofuel.ca/learn-the-loop/technology https://www.renewi.ca/our-divisions/surrey **StormFisher Environmental** - StormFisher Environmental is a private organization that operates an AD facility located in London, Ontario. This facility receives organic waste from food processing facilities, food scraps from restaurants, and food waste from grocery stores. StormFisher also receives source separated organics from municipalities. StormFisher is permitted to receive 120,000 tonnes of organic waste a year. The biogas made from the AD is a fuel source for two combined heat and power (CHP) units that generates electricity. StormFisher recently commissioned a RNG system that will upgrade the biogas to a higher quality for fuel purposes. The remaining product (digestate) after digestion is dried to create a fertilizer for agricultural soil purposes. **Bio-En Power** - Bio-En Power is a private AD facility located in Elmira, Ontario. The facility is permitted to receive 70,000 tonnes of feedstock a year. The facility receives municipal waste and food industry waste. The facility has CHP units on site to create electricity from the biogas generated.
Target Material / Feedstock	Depending on the application, typical feedstocks include sewage sludge, municipal food waste, other household organics (e.g., soiled

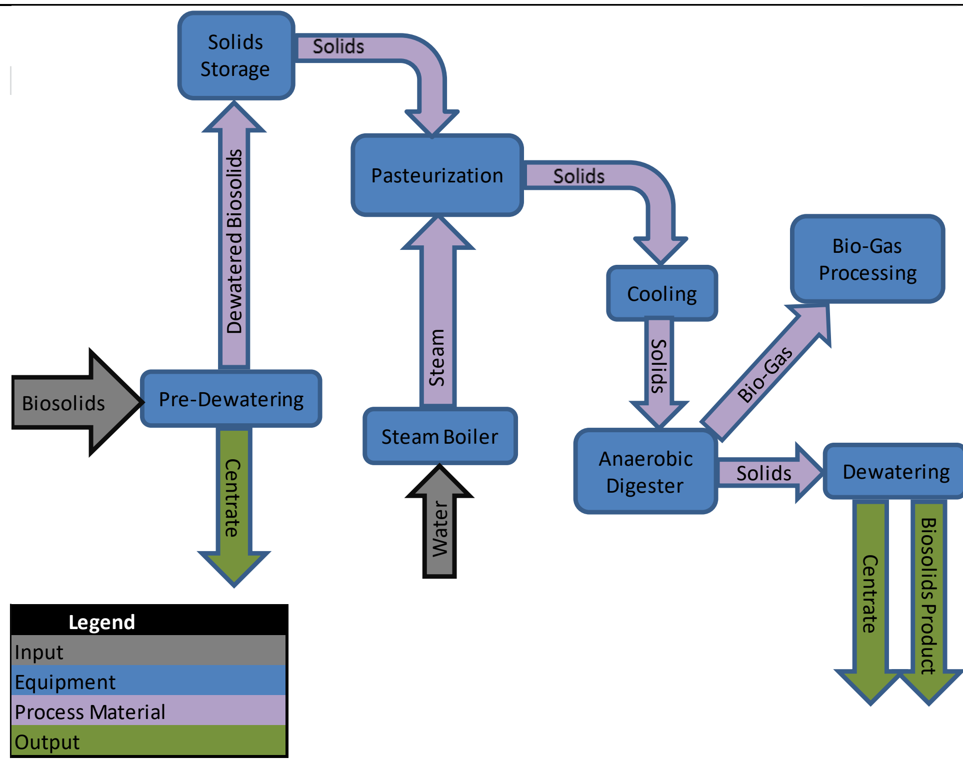
Anaerobic Digestion	
	paper products, diapers and sanitary products, pet waste), food industry waste, and/or agricultural waste.
Outputs	AD converts organic waste into biogas, which is a type of gas composed of 60 to 70 percent methane, 30 to 40 percent carbon dioxide, with some residual gases. The biogas can be burned to create electricity and heat power. The biogas can also be upgraded to a richer form of methane known as RNG that can be used as a transportation fuel (CNG) (See Section 5.4) or for natural gas in pipelines. The remaining waste (digestate), after it has been anaerobically digested, can be used as soil amendments for agricultural purposes or used in composting applications. In some cases, it can be used as a feedstock for pyrolysis (See Section 10.3).
Regulatory Considerations	An Environmental Compliance Approval for a Waste Disposal Site and likely Air is required from the MECP. A long approval time (> two years) is expected due to the facility complexity. The Food and Organic Waste Policy Statement under the RRCEA, 2016 recognizes anaerobic digestion as a method for processing food and organic waste. Land use planning (e.g. Official Plan, Zoning, Site Plan) approvals would be required for a new facility, depending on the site.
Capital and Operating Cost Range	Depending on the size and application, anaerobic digesters can range significantly in capital costs. On farm digesters have less intensive processes and therefore capital costs will range from $1 to $2 million. Sewage treatment plants and organics processing plants can range from $5 to 80 million depending on the annual tonnage received.

Anaerobic Digestion	
	The City of Surrey's 115,000 tonne per year facility cost $67.6 million to build. Annual operating costs are not publicly available. In 2014 the City of Toronto's 25,000 tonne Dufferin Organics Processing Facility closed for expansion to increase the processing to 55,000 tonnes per year. The upgrades cost the City approximately $82 million. Annual operating costs are $42 million. The City's Disco Road Organics Processing facility was completed in 2014 and processes 75,000 tonnes annually of the City's organic waste. The approximate costs to build the facility were $56.2 million with an additional $20 million for site-related items. The operating cost of an anaerobic digester can range significantly depending if the biogas is used in heating/ electrical applications. https://www.toronto.ca/legdocs/mmis/2015/pw/bgrd/backgroundfile-83441.pdf https://swana.org/Portals/0/awards/2016/winners/CityofToronto_CompostingSystem.pdf In a study completed by Dillon Consulting for the City, anaerobic digestion costs for a facility capable of processing the City's household organics were estimated at Capital Costs: $480 - $1,120 / tonne annual capacity and Operating Costs: $60 - $140 / tonne processed (not including potential revenue from the sale of biogas). Dillon Consulting Limited. August 2017 Task 3 Technical Memorandum - Assessment of Collection / Feedstock Scenarios and Processing Options.
Revenue Opportunity / Cost Savings	Revenue can be made in tipping fees, heat, electricity, or RNG produced, and land application.

Anaerobic Digestion	
Risks and Benefits	**Risks** ● Time required to site and build a facility. ● Maintenance requirements depending on the type of feedstock received. ● Some feedstocks contain plastic contamination that needs to be removed prior to digestion. ● Odour must be managed with odour control technologies. ● Waste stream variability may create operational challenges. ● Proximity to nearby users to utilize heat and biogas. ● Ability to negotiate supply agreements for RNG with the gas utility. ● Ability to supply electricity to the grid. Renewable electricity agreements are currently not an option in Ontario. ● Energy pricing and volatility of energy markets. **Benefits** ● Significantly reduces GHG emissions. ● Diverts organics from landfills, delays need to source new landfill capacity. ● Biogas is seen as a renewable energy, potential for material recovery. ● Anaerobic digestion also helps close the soil nutrient cycle if end product (digestate) is land applied.
GHG Impacts	Anticipated Reduction in GHGs ● Diverts organics from landfills.

Anaerobic Digestion	
	• Produces energy from a renewable sources which reduces fossil fuel use. British Columbia Ministry of Environment. Technologies and Best Management Practices for Reducing GHG Emissions from Landfills Guidelines. June 2011.
Potential Environmental Impacts and Benefits	• Contribution to GHGs if biosolids disposed of in landfills. • Significant reduction in CO2 emissions. • Diverts organics from landfills. • Renewable energy (RNG, electricity, heat) could displace some of the demand for fossil fuels currently being used in market.
Potential Known Health Impacts	• Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

8.3 Mechanical / Chemical Processing

Mechanical / Chemical Processing	
Approach / Technology Type(s)	Mechanical breakdown and chemical hydrolysis of biosolids and some types of organics such as food waste.
Description	The process uses a combination of heat, alkali, and shear mixing to effectively breakdown the biological material in biosolids and organics. Recycling this product back into anaerobic digesters enhances the biogas production. This product could also be directly applied to land for soil enhancement. This technology is typically used with an anaerobic digester or within a wastewater treatment plant. 

Mechanical / Chemical Processing	
Status	Proven in wastewater treatment facilities and emerging in applications using food waste.
Availability	Technology is widely used to manage biosolids and emerging for food waste.
Examples / Case Studies	**Lystek** - The LysteGrow and LysteMize are two processes invented by Lystek. LysteGrow produces a Class A fertilizer product with alkali, steam and shearing techniques. LysteMize optimizes digester and biological nutrient removal systems with the Lystek reactor within a wastewater treatment plant. The City of Guelph, St. Thomas, City of Peterborough and Township of Centre Wellington have facilities that use Lystek processes to process biosolids. **Synagro** - Synagro's BIO FIX process uses alkaline stabilization to control odours, inactivate pathogens, and prevent vector attraction. The resulting product can be used for Class B agricultural land application. http://www.synagro.com/offerings/alkaline-stabilization/ **Town of Banff, AB** – The Town has a demonstration project that involves N-Viro Systems LP constructing a facility to manage both biosolids and food waste at its wastewater treatment plant. The facility uses an alkaline stabilized treatment process to produce N-ViroSoil which can be used as an organic soil amendment. **City of Guelph, ON** - The City of Guelph contracted Lystek to manage their biosolids processing. Lystek converted their Class B biosolids into a registered (CFIA) fertilizer for land application and reducing landfill disposal costs. This is a multiyear project; costs were not publically available.

Mechanical / Chemical Processing	
Target Material / Feedstock	Sewage sludge and household organics.
Outputs	A fertilizer is produced that can be used in Class A or Class B applications under the *Fertilizers Act* by the Canadian Food and Inspection agency. The fertilizer can be used as a soil amendment in agricultural applications.
Regulatory Considerations	This technology is typically used with an anaerobic digester or within a wastewater treatment plant. An ECA would be needed in this application. A long approval time (>2 yrs) is expected due to the facility complexity. The Food and Organic Waste Policy Statement under the RRCEA, 2016 recognizes anaerobic digestion as a method for processing food and organic waste. Land use planning (e.g. Official Plan, Zoning, Site Plan) approvals would be required for a new facility, depending on the site.
Capital and Operating Cost Range	The Town of Banff demonstration project had a capital cost budget of $1,576,000. Cost information for other facilities was not publicly available. However, services may be able to be contracted out depending on local capacity / availability.
Revenue Opportunity / Cost Savings	Revenue opportunity on the fertilizer produced and optimization of digestion process.
Risks and Benefits	**Risks:** ● If facility is not properly managed, potential for odour issues; and,

Mechanical / Chemical Processing	
	• Process has been more commonly used with wastewater treatment facilities which have a more uniform feedstock when compared to household organics. **Benefits:** • Revenue from recovered resources (registered fertilizer); • Reduces GHG emissions by reducing requirement for fossil fuels; • Can be used to enhance digestion process and increase biogas production; and, • Completes the nutrient cycle in soil.
GHG Impacts	Anticipated Reduction in GHGs • Biogas can be generated which can replace fossil fuels, thereby reducing GHG emissions.
Potential Environmental Impacts and Benefits	• Contribution to GHG if biosolids disposed of in landfills; • Creates a fertilizer from a waste product; and, • Enhances the AD process and associated benefits (see Section 8.2).
Potential Known Health Impacts	• Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

8.4 Biological Processing

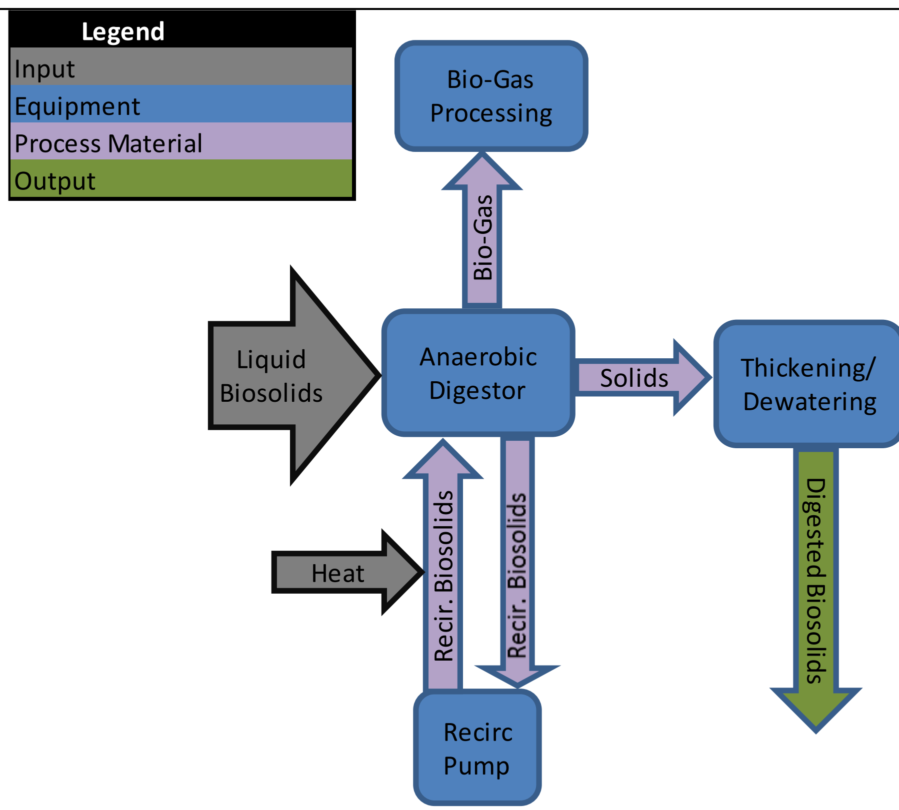
Biological Processing	
Approach / Technology Type(s)	Biological (macro-organisms) processing.
Description	Use of insects or worms to decompose organic waste (e.g., household organics, leaves) into compost. The compost is used as a fertilizer. Some industries will also harvest the insect for protein purposes in animal feed. https://www.washingtonpost.com/business/2019/07/03/maggots-could-revolutionize-global-food-supply-heres-how/?arc404=true http://enterrafeed.com/why-insects/
Status	Emerging
Availability	Vermicompost or vermiculture uses insects such as fly larvae or worms to break down organics into compost. In some industries, the insects are harvested for animal feed or fertilizer. The resultant compost from the insects can be used in agricultural applications. Vermicomposting is more popular in the household setting at a small scale.
Examples / Case Studies	**Northern Rockies Regional Municipality, B.C.** - The Northern Rockies Regional Municipality (population of 5,393 in 2016) has made vermicomposting a permanent operation at its landfill. After two pilot trials, the Region noticed that red wiggler worms successfully decomposed paper and food scraps in the landfill. To date, the landfill has been given 130 tonnes of waste including paper, cardboard, food and yard waste to vermicompost. The worm castings have been giving positive results for agricultural and landscape use.

Biological Processing	
	Enterra Feed Corporation - Enterra Feed Corporation uses recycled food including fruits, vegetables and grains to feed their black soldier fly larvae. The larvae is then used for high quality nutrients for animal feed and pet food. Black soldier fly larvae is a highly efficient low impact source of protein compared to the resource intensive alternatives (pork, beef, chicken, fish, etc.). https://www.washingtonpost.com/business/2019/07/03/maggots-could-revolutionize-global-food-supply-heres-how/?arc404=true **City of Markham Indoor Composting** -The City piloted the Oklin indoor composter at the City Civic Centre staff lunch room in 2009. The program was stopped due to slight odours being noticed given the lack of ventilation to the outside. The City is operating a larger indoor composter unit at a kitchen within a senior's home. Food waste generated from meal preparation is put into the unit, the food breaks down into a liquid which flows into York Region's sanitary sewer. This unit has been operational for several years and with the proper ventilation, no odours are noticeable.
Target Material / Feedstock	Small scale – household organic waste. Large scale – typically used by farmers with manure or by the food industry for organic waste. Target material also includes leaf and garden waste, and food scraps. Materials such as wood waste and bones would not be suitable.
Outputs	Fertilizer and animal feed.
Regulatory Considerations	Large scale facility would require an Environmental Compliance Approval by the MECP. Approval time is unknown and may be lengthy as there are currently no facilities of this type operating in Ontario.

Biological Processing	
	Land use planning (e.g. Official Plan, Zoning, Site Plan) approvals would be required for a new facility, depending on the site.
Capital and Operating Cost Range	Depending on the size of the vermicomposting facility, costs can range significantly. Information is not available for insect harvesting industries.
Revenue Opportunity / Cost Savings	Potential to generate revenue from sales of end product.
Risks and Benefits	**Risks** ● If not properly managed, potential for odour issues. ● Current applications require uniform organic waste feedstock such as manure or food waste. Process works for leaf waste but not wood wastes. It is noted that the City of Ottawa current accepts both leaf and wood waste in their program and that branches can be up to 4 inches in diameter. **Benefits** ● Production of a valuable byproduct which could be sold with appropriate approvals in place. ● Potential option for on-site organics processing of institutions and commercial establishments (e.g., restaurants, schools). ● Increases in diversion reduces landfill airspace consumption rate and extends the life of landfill.
GHG Impacts	Anticipated Reduction in GHGs ● Process does not require energy input for aeration which reduces energy requirements when compared to traditional organic processing facilities.

Biological Processing	
	- For on-site systems, reduces GHG emissions as no collection vehicle is required. - Biological processing of organics helps to maintain carbon within the terrestrial biosphere as a fertilizer instead of releasing the carbon to the atmosphere as a GHG; however, it should be noted that it does not produce energy which can displace GHGs. - Reduces methane emissions from organics managed in landfills.
Potential Environmental Impacts and Benefits	- Reduces energy consumption when compared to traditional organic processing facilities. - Creates a closed loop system for the management of the feedstock. - Diverts organics from landfill.
Potential Known Health Impacts	Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

8.5 Co-digestion of Sewage and Organics

Co-digestion of Sewage and Organics	
Approach / Technology Type(s)	Co-digestion of sewage and organics at a wastewater treatment plant.
Description	Organic food waste from the green bin programs are mixed with municipal sewage sludge and anaerobically digested. Other sources of food waste from food industries can also be mixed in this process. The biogas generated from anaerobic digestion can be used in boilers, upgraded into renewable natural gas, or combusted to create electricity.
	

Co-digestion of Sewage and Organics	
Status	Proven technology for sewage. Emerging for managing sewage and household organics jointly.
Availability	Many on farm anaerobic digesters will use a co-digestion process. This process mixes organic feedstock with manure and anaerobically digests the product. In this application, co-digestion can be used to enrich biogas and provide another income stream for the facility through tipping fees. A number of municipalities in North America are in various stages of investigating or piloting co-digestion projects. https://www.cityofkingston.ca/documents/10180/37095404/Environment-Infrastructure-Transportation-Policies-Committee_Meeting-05-2019_Report-EITP-19-011_Biosolids-Biogas-Plan.pdf/bdd091df-6d8e-498c-a71a-28800ffbc80a
Examples / Case Studies	**WM CORe®** - A process developed by Waste Management that converts food waste into an organic slurry produce that is then delivered to municipal wastewater facilities which in turn increases their energy output. Facilities are located in New Jersey, Boston, New York and Los Angeles. The City of Cambridge, Massachusetts recently (2018) implemented a curbside organics collection program and uses the facility in Boston to process organics. https://mediaroom.wm.com/core-organics-recycling-technology-that-turns-food-waste-into-energy/ **Stratford, ON** - The City of Stratford is currently working on a renewable natural gas project at its Water Pollution Control Plant. The City will combine their green bin organics with their wastewater and anaerobically digest the product. The biogas harvested off of this process would be upgraded into renewable natural gas and injected into the grid. If this proposed co-digestion facility is accepted, it would be the first of its kind in Canada.

Co-digestion of Sewage and Organics	
Target Material / Feedstock	Sewage, municipal organics, industrial organics.
Outputs	Biogas, renewable natural gas, heat, electricity and fertilizer (digested biosolids).
Regulatory Considerations	An Environmental Compliance Approval from the MECP would be required. A long approval time (>2 yrs) is expected due to the facility complexity. The Food and Organic Waste Policy Statement under the RRCEA, 2016 encourages municipalities to consider co-management of biosolids (6.16). Land use planning (e.g. Official Plan, Zoning, Site Plan) approvals may be required for a new facility, depending on the site.
Capital and Operating Cost Range	On-farm co-digestion facilities cost approximately $1 to 2 million. Sewage co-digestion plants can range from $5 to 80 million depending on the annual tonnage received. Costing information on co-digestion of food waste with biosolids was not publicly available.
Revenue Opportunity / Cost Savings	Revenue can be made from organic tipping fees and biogas production. Further energy cost savings could be realized related to wastewater treatment operations through use of heat and behind the grid electricity by incorporating organics and increasing the gas produced for useful benefit. Potential cost reduction of a combined facility due to economies of scale. A separate cost for collection must be factored into all costs as leaf and yard waste cannot be processed in these types of facilities.

Co-digestion of Sewage and Organics	
Risks and Benefits	**Risks** • Emerging technology for use with household organics. • Some feedstocks (from food industry or municipal programs that accept plastics for example) can contain plastic contamination that needs to be removed prior to digestion. • Odour must be managed with odour control technologies. • Energy pricing and volatility of energy markets. **Benefits** • The City's wastewater treatment plant (ROPEC) already employs anaerobic digestion and uses the biogas produced to generate heat and electricity used on site. Infrastructure changes would be necessary to modify the process organics, together with sewage; • Reduces GHG; • Increase in diversion reduces landfill airspace consumption rate and extends the life of landfill; • Process could generate additional renewable energy, with the addition of household organics; • Anaerobic digestion also helps close the soil nutrient cycle if end product is land applied, noting that these are already happening at the City; • Reduced energy costs for wastewater treatment operations if the biogas is used internally; and, • It may be more lucrative to export it as RNG.
GHG Impacts	Anticipated Reduction in GHGs • This type of facility diverts organics from landfills and creates a renewable fuel source and when compared to landfilling this

Co-digestion of Sewage and Organics	
	stream and extracting fossil fuels, there is a reduction in the generation of GHG emissions.
Potential Environmental Impacts and Benefits	● Contribution to GHGs if biosolids disposed of in landfills; ● Diverts organics from landfills and reduces GHG emissions; ● Renewable energy displaces fossil fuels currently being used in market. The process generates biogas or renewable natural gas, displacing some need for fossil fuels; and, ● Provides a closed loop system.
Potential Known Health Impacts	● Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

8.6 In-Sink Disposal Units

In-Sink Disposal Units	
Approach / Technology Type(s)	In-sink disposal units for households to dispose of food waste.
Description	In-sink disposal units shred food waste and mixes it with the wastewater. The wastewater then travels to the septic system or wastewater treatment plant for treatment. Some food can be screened out in the early stages of the treatment process due to its size. Some jurisdictions that have in-sink disposal units have noted issues with clogged sewer systems and increased discharge of organics into rivers and water bodies. Food waste that is not easily managed by in-sink disposal units can include: coffee grounds, fruit pits, bones, oil and grease, or non-degradable material such as plastics.
Status	Proven.
Availability	In-sink disposal units are very common in households. This type of technology is more common in the USA than in Canada. Some municipalities, including the City of Ottawa have banned them due to problems associated with clogged sewage pipes.
Examples / Case Studies	**New York City, NY** - In 1970, the City banned in-sink garbage disposal units over concerns of clogged sewer systems and the discharge of organics into nearby rivers. The ban was then lifted in 1997 as a study suggested that in-sink disposers could save the City approximately $4 million in solid waste export costs. https://www.citylab.com/environment/2017/08/garbage-disposals-new-york/538581/

In-Sink Disposal Units	
	Various Municipalities - Municipalities that have banned the use of residential in-sink disposal units include: Toronto, Ottawa, Markham, Vaughan, and Guelph. The treatment of in-sink disposal unit solids puts an extra strain on water treatment facilities and may negatively impact aquatic life by increasing nutrient loads and decreasing oxygen levels in rivers. https://www.cochranetoday.ca/local-news/council-flushes-garburators-down-drain-1451532 https://www.paradisevalleyseptic.com/can-i-use-a-garbage-disposal-if-i-have-a-septic-system/ **Metro Vancouver, BC** - Metro Vancouver has looked at banning in-sink disposal units where there is a large population of residents living in multi-residential buildings. Metro Vancouver estimates that $2 million is spent on cleaning out fats, oils, and grease from the wastewater treatment systems each year. The estimated cost per tonne to process organic waste at sewage treatment plants is $1,800 compared to $70 per tonne for source-separated organics processing at a dedicated facility. Metro Vancouver is looking into a by-law to require multi-residential buildings to have a source-separated organics collection program instead of focusing on the banning of in-sink disposal units.http://www.cbc.ca/news/canada/british-columbia/garburators-cost-metro-vancouver-2m-a-year-in-clogged-up-sewers-1.3128519
Target Material / Feedstock	Organic waste from household kitchens.
Outputs	Sewage (food waste discharged as sewage).
Regulatory Considerations	The Food and Organic Waste Policy Statement under the RRCEA, 2016 states that diversion targets cannot be achieved through the

In-Sink Disposal Units	
	discharge of food or organic waste into a municipal sewer, including when facilitated by food waste disposers or other grinding devices. Municipal bylaws could be employed to regulate the use of food waste disposers.
Capital and Operating Cost Range	Product can be bought for approximately $50 for household use. Installation costs can range from $100 to $300. Increased costs for sewer collection system maintenance and wastewater treatment facility to handle increase in organic materials.
Revenue Opportunity / Cost Savings	Not applicable, noting that this approach can handle food waste and the remaining household organic waste (e.g., soiled paper products, pet waste) would still require management.
Risks and Benefits	**Risks** ● Potential for organic material to clog building plumbing and sewage collection pipes; ● Increased use of potable water to flush food waste through piping systems; ● Capacity must be available at wastewater treatment facilities to handle increased hydraulic and organic loading; ● Could cause confusion to residents if only applies to one sector (e.g. multi-residential); ● This technology is not considered as diversion by the Province of Ontario; and, ● Increased volume of biosolids requiring disposal.

In-Sink Disposal Units	
	Benefits ● Convenience to residents for management of food scraps, reducing that amount of organics sent to landfill; ● Reduced odour generation and vermin attraction with not storing food waste; ● Diverts organics from landfill; ● Reduces collection and storage requirements for Green Bin materials since big portion would be handled through the in-sink disposal units; and, ● Can be useful for sources that do not typically have green bin collection, like multi-residential.
GHG Impacts	Anticipated Reduction in GHGs ● Diverts organics from landfill and reduces GHG emissions; and, ● Reduces transportation-related emissions from collection vehicles.
Potential Environmental Impacts and Benefits	● May encourage participation due to ease of use.
Potential Known Health Impacts	● Minimal to no health impacts of this process.

8.7 Animal Feed Production

Animal Feed Production	
Approach / Technology Type(s)	Conversion of food waste into animal feed.
Description	Food waste is heat treated and dehydrated and either mixed with dry feed or directly fed to animals.
Status	Proven, on a limited scale from a municipal perspective.
Availability	Requires a very clean stream of food scraps. No paper or leaf and yard waste is acceptable. Reduces the quantity of organics that can be diverted. Material from single family homes, and potentially facilities such as cafeterias could be accepted.
Examples / Case Studies	Sustainable Alternative Feed Enterprises (SAFE), Santa Clara, CA - This 91 tonnes/day facility takes food waste from single family residences. A pre-processing stage is used to remove contaminants, then materials go through a dehydrator, a sterilizer, and an extruder press. In addition to the extruded feed pellet, water and clean fats, oils and grease are extracted. The product can be fed to non-ruminant animals. For a 50,000 tonne/year facility, approximately 9,000 tonnes of animal feed would be produced annually. https://www.forktofeed.com/
Target Material / Feedstock	Food waste.
Outputs	Animal feed or dog treats.
Regulatory Considerations	Environmental Compliance Approval from the MECP. Approval time is unknown and may be lengthy as there are currently as there are currently no facilities of this type operating in Ontario.

Animal Feed Production	
	Approvals from the Canadian Food Inspection Agency. Land use planning (e.g. Official Plan, Zoning, Site Plan) approvals would be required for a new facility, depending on the site.
Capital and Operating Cost Range	For the above-noted facility, capital costs were approximately $13 million CAD ($10 million USD). Operating costs are about $102/tonne CAD ($79/tonne USD).
Revenue Opportunity / Cost Savings	Potential for cost savings for generators of food waste. Potential to generate revenue from sales of end product.
Risks and Benefits	**Risks** • If facility is not properly managed, potential for odour issue; • Uncertain markets; and, • Require clean stream of food scraps. **Benefits** • Reduces GHGGHG; • Diverts organics from landfills; • Potential for material recovery; and, • Potential for revenue.
GHG Impacts	Anticipated Reduction in GHGs • Diverts organics from landfills; • Maintains carbon within the terrestrial biosphere as animal feed instead of releasing the carbon to the atmosphere as a GHG.

Animal Feed Production	
Environmental Impacts and Benefits	• Diverts organics from landfills; and, • Reduces the amount of GHG produced.
Known Health Impacts	• Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

8.8 Summary of Source Separated Organics Processing Approaches and Technologies

The following table summarizes the technology and/or approach researched, the potential applicable material stream and the potential customers the technology and/or approach could be applied to.

Technology	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
Aerobic Composting	SSO (LYW and Household Organics)	X	X	X	X	X
Anaerobic Digestion	SSO (LYW and Household Organics)	X	X	X	X	X
Mechanical / Chemical Processing	SSO (LYW and Household Organics)	X	X	X	X	X
Biological Processing	SSO (LYW and Household Organics)	X (limited to on-site)	X (limited to on-site)	X	X	X
Co-Digestion of Sewage and Organics	SSO	X	X	X	X	X

Technology	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
In-Sink Disposal Units	SSO (Household Organics)	X	X		X	X
Animal Feed Production	Food waste	X	X		X (limited)	X

9 Mixed Waste Processing Approaches and Technologies

This section reviews various mixed waste processing approaches that are often used as a replacement to ‘traditional’ source separation methods. Mixed waste processing is also in some waste management systems to recover resources from the waste stream not otherwise captured through waste diversion programs and minimize wastes requiring disposal. It explores 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.

The intent of this section is to provide a high–level overview of technology types and approaches, availability and status, approval requirements, costs and revenue, potential environmental impacts and benefits and potential known health impacts. Further details will be researched in Phase 2 of the development of the SWMP, including further identification of approval requirements, as applicable. It is assumed that any waste management facility developed must meet all conditions required as part of any necessary approvals at that time (e.g. Environmental Compliance Approval) which have been established to ensure protection of public health.

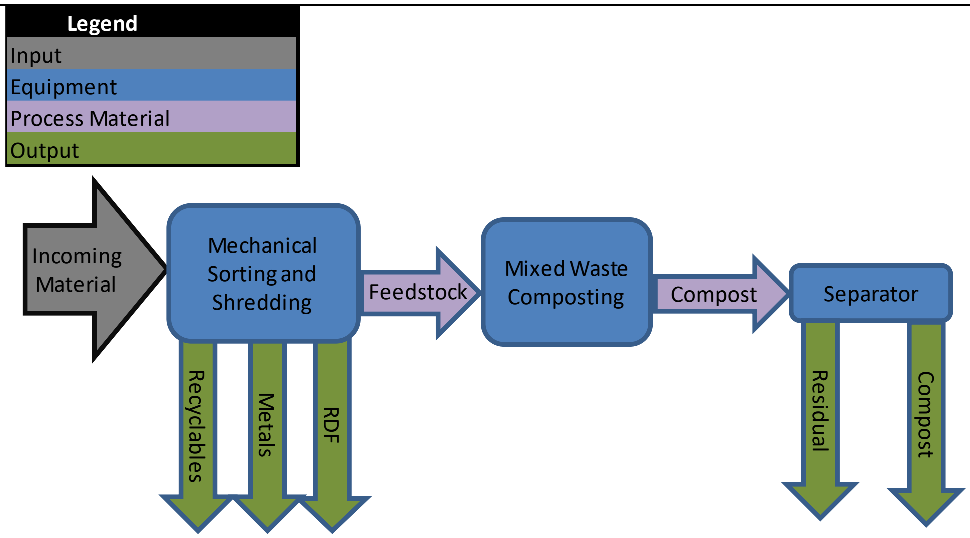
The City does not have experience with mixed waste processing facilities.

Research on mechanical and biological treatment with refuse derived fuels and mixed waste processing is presented in the following tables.

9.1 Mechanical and Biological Treatment with Refuse Derived Fuels (RDF)

Mechanical and Biological Treatment with Refuse Derived Fuels (RDF)	
Approach / Technology Type(s)	Mechanical and biological treatment (MBT) to recover recyclables and organic material.
Description	The typical process steps of a MBT plant are: • Waste acceptance; • Mechanical pre-treatment; • Biological processing; • Biological drying; and, • Mechanical material separation. The system inputs are typically municipal solid waste, bio-waste, packaging, paper and glass. Typical outputs and market uses are refuse derived fuels (RDFs), biogas, plastics, metals, minerals and inert materials (e.g., stones, glass, etc.), process water and effluent. RDFs are produced by shredding and/or pelletizing select waste and by-product materials with recoverable calorific value into a homogenous product which can be used as a fuel source. **RDFs** • Usage at power plants (co-burned with coal or used singularly), within the cement industry (RDF for energy in rotating cement kilns), direct use in bubbling fluidized bed (BFB), and potential for use in complementary processes such as chemical and/or fuel production; • Dewatered and relatively dry product; • Storable and transportable; and, • Valuable product, No need to landfill residual output.

Mechanical and Biological Treatment with Refuse Derived Fuels (RDF)	
	Biogas • High methane content; • Direct thermal utilization in combined heat and power (CHP) processes; • Can be converted to RNG for use in vehicles or insertion into the pipeline grid; and, • Potential for use in complementary processes such as chemical and/or fuel production. **Plastics** • Extracted and sorted by grade and type; • Can be thermally utilized as a fuel to generate power; • Directly utilized in a BFB; and, • Potential for use in complementary processes such as chemical and/or fuel production. **Metals** • Sorted by type and can be sold to market. **Minerals / Inerts** • Clean enough to landfill; • Potential for use in innovative aggregate blends and use as a base material (e.g., road/asphalt mix); and, • Glass could be sorted by colour and sold or landfilled. **Process Water / Effluent** • Feedstock for biogas fermenters; • Reused in MBT process to reduce the use of ‘clean’ water;

Mechanical and Biological Treatment with Refuse Derived Fuels (RDF)	
	• Possible usage as fertilizer; and, • ‘Clean’ enough to meet municipal sewer discharge limits. Many complementary technologies exist that could be used to support the MBT plant including plastic conversion, material shredding for BFB, BFB itself if no market for the RDF can be utilized, glass sorting machines, and the potential production of chemicals and fuels.
	
Status	Proven.
Availability	More and more MBT facilities in North America are becoming operational. Several operating plants in Korea, Spain, Eastern Europe, and the United Kingdom.
Examples / Case Studies	**Halifax Regional Municipality, NS** - This facility opened in 1996 to manage and dispose of wastes from the Municipality of Halifax. Material is received at the Front End Processing (FEP) facility and segregated in direct to landfill waste, waste to be processed by the onsite Waste Stabilization Facility (WSF) before disposal to landfill,

Mechanical and Biological Treatment with Refuse Derived Fuels (RDF)	
	recyclables (white goods and scrap, bottles, paper fibres, etc.), and special/hazardous wastes. Recyclables are sold to recyclers, organic waste is aerobically composted at a stabilization facility before being landfilled along with non-organic waste. The FEP receives an average of 140,000 tonnes/year with approximately 135,000 tonnes disposed of at the landfill and the remainder sent to recycling end markets. This facility was developed as part of an agreement with the community as part of the development of the landfill, and was developed prior to the implementation of Halifax's Green Bin program. The stabilization facility processes organic material not captured in the Green Bin program to minimize the amount of organic material being landfilled. https://www.municipalenvironmental.com/mirror/service/waste-processing
Target Material / Feedstock	Recyclables, municipal solid waste, organics, MRF residue and residuals, C&D waste and tires.
Outputs	Various recyclable streams; organics for processing; RDF.
Regulatory Considerations	MECP Environmental Compliance Approval for a Waste Disposal Site and potentially for Air depending on the facility design. Approval time is unknown and may be lengthy as there are currently no facilities of this type operating in Ontario. Land use planning (e.g. Official Plan, Zoning, Site Plan) approvals would be required for a new facility, depending on the site.
Capital and Operating Cost Range	Not publicly available. Net costs for materials depend on the volatility of those respective markets. Reported net costs of refuse derived fuels (RDFs) are in the order of $150/tonne.

Mechanical and Biological Treatment with Refuse Derived Fuels (RDF)	
	It should be noted that this technology has been claimed to be more expensive than other forms of processing. However, European countries have built this facilities due to 1) energy pricing – it is more expensive in Europe which changes the economic viability of the project and 2) the European ban of organics from landfill was a key driver for the development of these types of systems.
Revenue Opportunity / Cost Savings	Revenue potential from the sale of the RDF and recyclables.
Risks and Benefits	**Risks** • Potential for operational and maintenance issues associated with processing mixed waste; • As approach is more complex than typical waste management processing/transfer facilities, time for approval process may be longer than typical; and, • Availability of markets for RDF. **Benefits** • Captures organic waste and recyclables that would have otherwise been sent to landfill; • Benefits relate to higher waste capacity of the landfill and delayed need to locate new landfill capacity; • Produces a fuel and recovers recyclable material from residual waste; and, • Alternative to recover materials where source separation is not feasible or less successful (e.g., high density residential).
GHG Impacts	Anticipated Reduction in GHGs • Reduction in GHG emissions by diversion from landfill.

Mechanical and Biological Treatment with Refuse Derived Fuels (RDF)	
Potential Environmental Impacts and Benefits	• Renewable resources could displace the need for fossil fuels currently being used in market; and, • Significant reduction in CO_2 emissions.
Potential Known Health Impacts	• Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

9.2 Mixed Waste Processing

Mixed Waste Processing	
Approach / Technology Type(s)	A process to recover recyclables and/or organics and/or reusable materials leaving the residual waste for landfilling or another appropriate waste processing application. Depending on the streams processed, they are also known as "dirty" MRFs.
Description	Mixed waste processing (MWP) starts with unsorted and unseparated solid waste from residential and/or commercial collection vehicles being off-loaded onto a tipping floor. Materials are first sorted on the floor using manual labour (if appropriate) and mobile equipment to remove larger or bulky items such as appliances, dimensional wood, metal, or large pieces of plastics that might clog or interrupt operations of the processing systems. Materials are then processed through multi-stage screens to separate fibre, plastic, metal and glass containers, and small contaminants. This is usually accomplished through the use of mechanical, optical or pneumatic screening equipment to separate materials into size classifications and/or light versus heavier materials. The remaining material is shipped to a local landfill or another appropriate waste processing/conversion facility. Typically the garbage stream is the feedstock for MWP and the quantity and quality of recoverable materials depends on whether diversion programs are present (which reduces the amount of recyclable/recoverable material) or whether there are no diversion programs (which increases the amount of recyclable material). Those programs that have curbside diversion programs for recyclables and organics have less recoverable material in the garbage, and any materials recovered are typically somewhat better quality than those recovered from a system where there are no diversion programs (particularly organics).

Mixed Waste Processing	
	For those communities with no source separation, MWP is useful to divert some higher value commodities from disposal. For those communities with well-established source separation programs, there is less benefit. MWP will divert some materials from disposal but compared to a traditional waste management program with source separation, there are fewer environmental benefits due to greater contamination of materials that are not marketable and will require disposal. MWP perform better when the material source is consistent in nature, like office waste, or have had organic materials removed prior to being received at the facility.
Status	Proven.
Availability	Common throughout Europe, becoming more common in the U.S.
Examples / Case Studies	**Montgomery/RePower South (formerly Infinitus facility), Montgomery, AL** - This facility originally opened in 2014 and was expected to divert 75-85 percent of waste with revenue derived from the recycled commodities. After one year, the facility closed, for financial reasons. In 2018, the City of Montgomery acquired the $37M ($48M CAD) facility and negotiated a public private partnership with RePower South to operate the facility. More than $12M ($15M CAD) was invested in the plant prior to opening again in early 2019. The facility is designed to separate cardboard, paper, PET, some HDPE, PP, steel and aluminum. Organic material, glass and other contaminants are sent for disposal. The remaining materials are converted to a RDF product. It should be noted that the City of Montgomery, AL does not provide any curbside diversion programs (recycling or SSO). It is unknown at this time how the facility is operating and what recovery rates are being achieved. https://www.recyclingtoday.com/article/montgomery-repower-south-facility-open-january-2019/ **Sunnyvale Materials Recovery Station (SMaRT), CA** - The SMaRT Station was commissioned in 1994 and serves the Cities of

Mixed Waste Processing	
	Sunnyvale, Mountain View and Palo Alto, California (all of which have curbside diversion programs). The facility is permitted to process up to 1,400 tonnes per day and has been operating at approximately 910 tonnes per day for the past decade. The SMaRT Station has four processing lines (mixed waste, dual stream recyclables, wood/green waste and food waste preprocessing serving the SAFE animal feed material). The initial cost of the facility was approximately \$22M (\$29M CAD). Several renovations have occurred, the latest in 2010 where an additional \$10M (\$13M CAD) was expended to renovate the equipment. The facility employs 48 full time staff. The mixed waste processing facility recovers approximately 37 percent by weight of the material arriving. **Western Placer Waste Management Authority, CA** - The WPWMA materials recovery facility was constructed in the mid-1990s. The facility serves the cities of Roseville, Lincoln, and Auburn in addition to several towns and the unincorporated area of Western Placer County. The facility is permitted to process up to 1,100 tonnes per day and currently operates at approximately 725 to 825 tonnes per day. The MRF operates under a 'One Big Bin' program where the tributary communities do not have separate curbside recycling programs. The initial cost of the facility was approximately \$20M (\$26M CAD). A renovation in 2004 expanded the facility and increased its ability to process additional volume with increased recovery. The renovation cost approximately \$19M (\$25M CAD). The facility employs approximately 40 staff and recovers approximately 35 percent to 37 percent by weight of the arriving materials.
Target Material / Feedstock	Typically the garbage stream. Some jurisdictions do not provide any source separation programs and all waste is processed through the "dirty MRF". Others just manage a more contaminated stream (e.g. recyclables from multi-residential) from particular sectors.

Mixed Waste Processing	
Outputs	Various recyclable streams; organics for processing; refuse derived fuel (RDF).
Regulatory Considerations	Environmental Compliance Approval for a Waste Disposal Site and potentially for Air depending on facility design. Approval time is unknown and may be lengthy as there are currently no facilities of this type operating in Ontario. The Food and Organic Waste Policy Statement under the RRCEA, 2016 considers the used of mixed waste processing as a means to recover food and organic waste when these materials are mixed with other waste. The Policy includes a provision for municipalities to use mixed waste processing achieving the 70% reduction and recovery target in addition to curbside collection (4.1i). The Policy Statement also sets out requirements for organics recovery from mixed waste processing facilities (6.12, 6.1.3, 6.14). Land use planning (e.g. Official Plan, Zoning, Site Plan) approvals would be required for a new facility, depending on the site.
Capital and Operating Cost Range	Depends on size and capacity of facility, and materials handled. Based on examples above, capital costs are in the order of $32M to $49M USD ($42 to $64M CAD). Operating costs would depend on the size and throughput of facility. The City of Sunnyvale and Western Placer Waste Management Authority mixed waste processing facilities charge $78 USD ($103 CAD) and $65 USD ($86 CAD) per tonne respectively. This charge pays for the private operation, recovery of recyclables and other related costs of the facility.
Revenue Opportunity / Cost Savings	Revenue potential from the sale of the RDF and recyclables, although the outputs are typically less valuable compared to source separated recycling.

Mixed Waste Processing	
Risks and Benefits	**Risks** ● Potential for operational and maintenance issues associated with processing mixed waste; ● As approach is more complex than typical waste management processing/transfer facilities, time for approval process may be longer than typical; ● Lower quality of recovered material compared to source separated recycling recovery; ● Availability of markets for extracted materials may be limited given the 'dirty' nature of the process; ● Greater contamination of materials can mean less marketable products, and result in material being disposed of instead of recycled anyways; and, ● Increased organics management costs. **Benefits** ● Reduces organic waste going to landfill; ● Benefits relate to higher waste capacity of the landfill and delayed need to locate new landfill capacity; ● Potential to produce a fuel and recover recyclable material from mixed waste; and, ● Alternative to recover materials where source separation is not feasible or less successful (e.g., high density residential).
GHG Impacts	Anticipated Reduction in GHGs ● Reduction in GHG emissions with a reduction of organics disposed of in landfill.
Potential Environmental	● Provides an opportunity to divert waste that would otherwise be disposed;

Mixed Waste Processing	
Impacts and Benefits	● Reduction of landfill airspace used for disposal.
Potential Known Health Impacts	● Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

9.3 Summary of Mixed Waste Processing Approaches and Technologies

The following table summarizes the technology researched, the potential applicable material stream and the potential customers the technology could be applied to.

	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
Mechanical and Biological Treatment with Refuse Derived Fuels	Recycling, Garbage, C&D, Tires	X	X	X	X	X
Mixed Waste Processing	Recycling, Garbage, potentially SSO (LYW and Household Organics)	X	X	X	X	X

10 Recovery Technologies

This section reviews various recovery technologies (energy and fuels) that are emerging as a replacement to ‘traditional’ methods of waste disposal, e.g., landfilling. It explores the use of technology including mass burn incineration, gasification, pyrolysis, waste to liquid fuels, hydrolysis, and landfill mining.

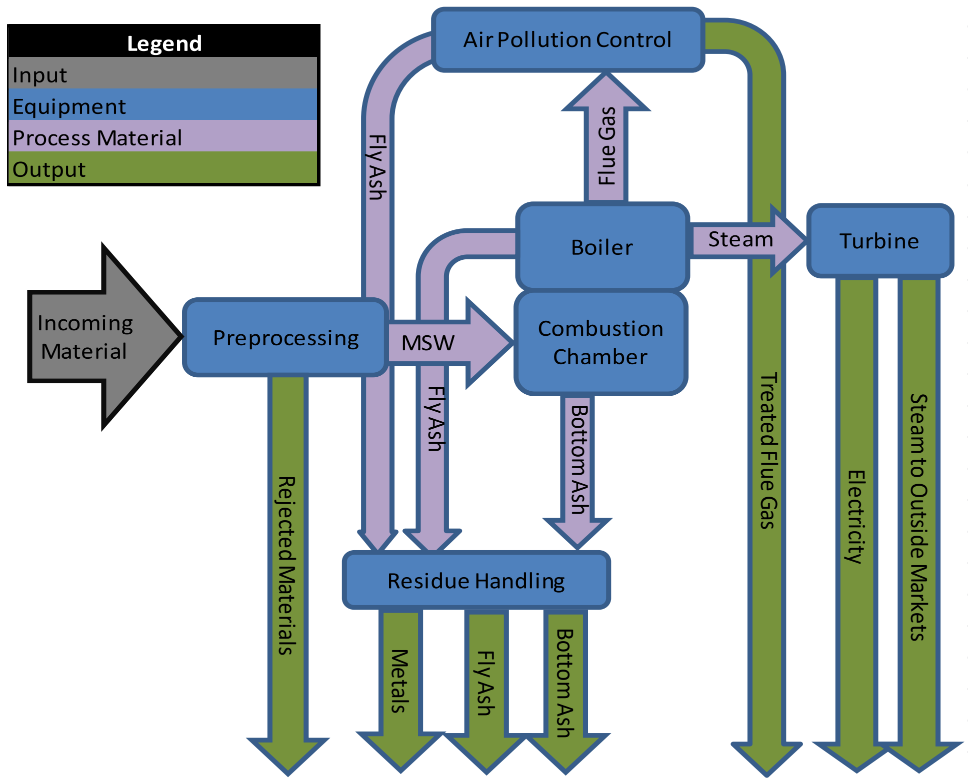
The intent of this section is to provide a high–level overview of technology types and approaches, availability and status, approval requirements, costs and revenue, potential environmental impacts and benefits and potential known health impacts. Further details will be researched in Phase 2 of the development of the SWMP, including further identification of approval requirements, as applicable. It is assumed that any waste management facility developed must meet all conditions required as part of any necessary approvals at that time (e.g. Environmental Compliance Approval) which have been established to ensure protection of public health.

A gasification recovery project was trialed in Ottawa in the past. In 2005, the City entered into a partnership agreement with Plasco Energy Group (Plasco) which operated a pilot scale gasification and plasma refining system. In 2011, Plasco applied for approval from the MOE (now MECP) for the pilot project to become a large-scale commercial plant that would process up to 300 tonnes of residential waste per day, convert it to gas and generate electricity. Approval for a large-scale commercial plant was not granted but in 2013 the maximum waste processing capacity was approved for 85 tonnes per day. The agreement was terminated in 2015 as Plasco was unable to secure the necessary funding to build a commercial size facility.

Several recovery technologies which include mass burn incineration, gasification, pyrolysis, waste to liquid fuel, hydrolysis and landfill mining are presented in the following tables.

10.1 Mass Burn Incineration

Mass Burn Incineration	
Approach / Technology Type(s)	The use of traditional combustion, or mass burn incineration, to manage waste and generation of heat that can be converted to electricity, / steam and/or hot water.
Description	The complete oxidation of a fuel at high temperatures is referred to as direct combustion (also referred to as waste-to-energy (WTE), energy from waste (EFW), or advanced thermal recycling (ATR)). The mass incineration occurs under controlled conditions and yields a significant 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. Heat is recovered from the hot gases produced and converted to electricity, steam, or both from the direct combustion process. The end result of the combustion process also produces fly ash and bottom ash. Both types of ash are then disposed at a landfill, with fly ash typically being hazardous due to concentrations of heavy metals and other pollutants, and disposed of at a hazardous waste landfill. Accelerating Circular Supply Chains for Plastics: A Landscape of Transformational Technologies That Stop Plastic Waste, Keep Materials in Play and Grow Markets, Closed Loop Partners, 2019. City of Ottawa - Summary of Waste Technologies and Approaches (Updated) Technical Memorandum, HDR, 2014. Life Cycle Inventory of 100 percent Postconsumer HDPE and PET Recycled Resin from Postconsumer Containers and Packaging (Revised Final Report), Franklin Associates, 2011

Mass Burn Incineration	
	
Status	Proven
Availability	Mass burn is used world-wide.
Examples / Case Studies	There are over 500 operating facilities in Europe and over 85 operating facilities in North America. There are currently seven operating facilities within Canada: • Durham-York Energy Center – Durham Region, Ontario; • Emerald Energy from Waste Facility –Brampton, Ontario; • Metro Vancouver Waste to Energy Facility – Burnaby, B.C; • Wainwright Energy from Waste Facility- Wainwright, Alberta;

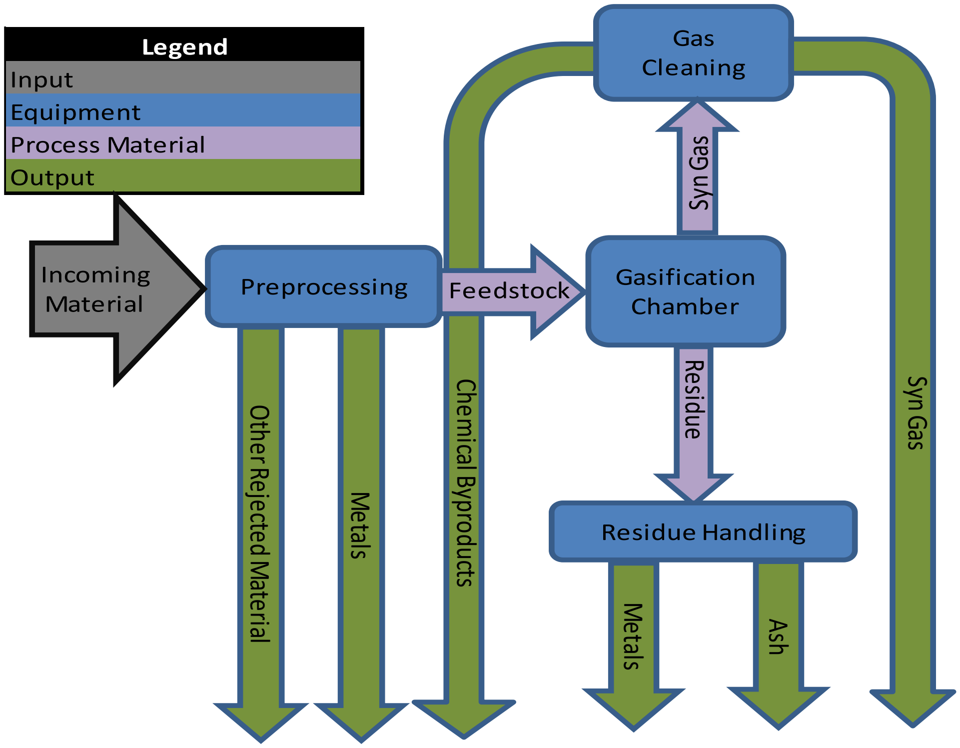
Mass Burn Incineration	
	• L'incinérateur de la Ville de Québec – Quebec City, Quebec; • L'incinérateur de Lévis – Lévis, Quebec; and, • PEI Energy Systems – Charlottetown, Prince Edward Island.
Target Material / Feedstock	Municipal solid waste, including hazardous wastes. Minimal pre-processing is required.
Outputs	Generated electricity and/or steam, metals. Waste outputs include bottom ash, fly ash, and carbon dioxide.
Regulatory Considerations	Thermal treatment of waste requires Environmental Screening process, or potentially an Individual EA, under the *Environmental Assessment Act.* An EA was undertaken for the Durham-York Energy Centre (DYEC), which was a 6-year process from 2005-2010. MECP approval timeframe once the EA was submitted was approximately 14 months. Environmental Compliance Approval required for both a Waste Disposal Site and for Air from the MECP. The ECA for the DYEC was approved in approximately 6 months following submission. https://swana.org/Portals/0/Awards/2018/Winners/Excellence2018-WtE-gold.pdf
Capital and Operating Cost Range	Depending on facility size and negotiated rates for energy sales, the net value of the energy recovered is estimated to range between \$140 to \$150/tonne of material processed. The Durham-York Energy Center cost \$255 million (2016) to construct the facility and \$29 million for the Environmental Assessment, permitting and approvals, site servicing, consulting fees and economic development activities in the host community of Clarington. The gross annual operating costs are approximately \$14.7 million (2010 dollars).

Mass Burn Incineration	
Revenue Opportunity / Cost Savings	Revenue opportunity for the recovered energy from the process. It is reported that the Durham-York Energy Center generates revenue in the order of $8.5 million annually from the sale of electricity, and $550,000 annually from the sale of recovered metals. https://www.durhamyorkwaste.ca/FAQ/FAQ.aspx
Risks and Benefits	**Risks** • Must comply with stringent environmental monitoring and mitigation plans, regulations, standards and guidelines; • Reliability of technology, maintaining consistent facility operation; • Public opposition of incineration facilities is common; • Lengthy and uncertain approvals process; • Requires stable energy market; • Hazardous waste and fly ash disposal costs; and, • Typically requires a put or pay agreement with the municipality on the hook to meet these requirements. **Benefits** • Reduces landfill airspace consumption rate and extends the life of landfill; and, • Reduced land requirements compared to landfill.
GHG Impacts	Anticipated Reduction in GHGs • Potential for net GHG emissions reductions due to avoided GHG emissions associated with the generation of electricity which offsets (avoids) emissions from electricity generation sources (depends on electricity mix) and Avoided steel

Mass Burn Incineration	
	manufacture from steel recovery at WTE facilities from combusted materials.
Potential Environmental Impacts and Benefits	● Air pollution control systems must be used to ensure mass burn system complies with emission and environmental requirements; ● Recovery of energy and materials; ● The reduction of landfill airspace used for disposal; ● Renewable resource could displace fossil fuels currently being used in market; and, ● Reduction of single use plastics and plastic waste entering landfills.
Potential Known Health Impacts	● Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

10.2 Gasification

Gasification	
Approach / Technology Type(s)	Gasification involves converting solid or liquid carbon-based wastes into gas form at high temperature without combustion. Technology types include - updraft fixed bed; downdraft fixed bed; bubbling fluidized bed; circulating fluidized bed; entrained flow.
Description	Gasification is a process that converts solid organic material under controlled conditions of partial oxidation into fuel gases and other by-products. The process can be used during the production of chemicals such as methanol and liquid fuels, in addition to producing fuel gases for direct conversion into energy. Partial oxidation is achieved by utilizing less oxygen than required for complete combustion of the material. Heating temperatures range from 750 to 1,650 degrees Celsius. The fuel gas that is produced is known as syngas. Syngas primarily consists of carbon monoxide, hydrogen, methane, and other hydrocarbons. In some gasification processes, carbon dioxide and nitrogen gas can also be produced. Concentrations of the gases depend heavily on the composition of the organic material used for process and the operating conditions of the process. City of Ottawa - Summary of Waste Technologies and Approaches (Updated) Technical Memorandum, HDR, 2014. Accelerating Circular Supply Chains for Plastics: A Landscape of Transformational Technologies That Stop Plastic Waste, Keep Materials in Play and Grow Markets, Closed Loop Partners, 2019. Life Cycle Inventory of 100 percent Postconsumer HDPE and PET Recycled Resin from Postconsumer Containers and Packaging (Revised Final Report), Franklin Associates, 2011.

Gasification	
	
Status	Emerging for municipal solid waste, proven for biomass (i.e., organic agricultural and industrial wastes, sewage sludge, vegetation waste)
Availability	Gasification has been used successfully for select feedstock (e.g., wood and biomass). There has been mixed success and failure using municipal solid waste. Pilot projects and test facilities have not been successful for differing reasons, including not being able to achieve energy efficiency and become economically viable, unable to maintain continuous uptime, and issues related to environmental emissions or spills. There are currently several operating facilities in Japan and some select pilot facilities in North America designed to use MSW feedstock.

Gasification	
Examples / Case Studies	There are currently few waste gasification plants in operation around the world. There is a biomass gasification plant in operation in Svenljunga, Sweden which has operated since 2008 and produces 14 MW of power. No commercial plants that gasify or pyrolyze Municipal Solid Waste (MSW) are operating in the United States today. Although gasification/pyrolysis plants using MSW as a feedstock were operated in the 1970s and 1980s, these facilities experienced many technical problems and failed to achieve acceptable technical or economic performance and were eventually shut down. Some examples of these earlier project failures include Baltimore, MD and Bridgeport, CT. More recent examples of failed attempts to use high temperature gasification technologies using MSW as a feedstock include Plasco in Ottawa, Ontario, Canada and AlterNRG in Tees Valley, United Kingdom. **Edmonton, AB** - The Alberta Biofuels Facility in Edmonton is currently using a gasification/pyrolysis technology to convert non-recyclable and non-compostable MSW feedstock into methanol and ethanol via Fischer-Tropsch reactions (a chemical process to convert carbon monoxide into liquid hydrocarbons). The technology provider, Enerkem, claims the plant has achieved commercial operation, but has not produced any detailed operating or performance data to date. https://enerkem.com/facilities/enerkem-alberta-biofuels/. Other gasification technologies have developed pilot and demonstration facilities that may be using some fraction of MSW as a feedstock, but no data has been made available. Gasification technologies are used in Japan and on a smaller scale in Europe using some fraction of MSW as a feedstock.
Target Material / Feedstock	Pre-processing is required to prepare a uniform feedstock source (e.g., RDF) from municipal solid waste. Feedstock consists of wastes containing high carbon content, such as plastics, agricultural

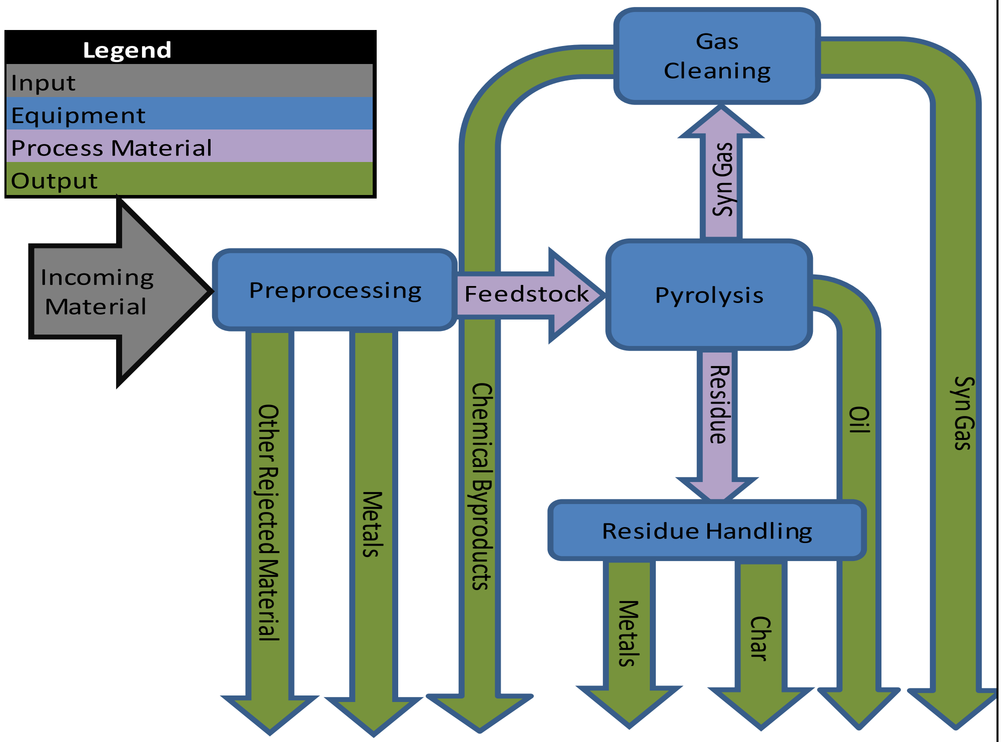
Gasification	
	residues, wood wastes, sewage sludge, and mixed waste of these materials.
Outputs	Electricity and/or heat; metals (ferrous, aluminum); ethanol/biofuels (depending on process). Waste outputs for the process include carbon dioxide and ash residuals.
Regulatory Considerations	Thermal treatment facilities require Environmental Screening, or potentially an Individual EA, under the *Environmental Assessment Act.* Time to complete is unknown but is expected to be lengthy (5+ years). Environmental Compliance Approval for a Waste Disposal Site and for Air. Approvals could be shorter with the completion of an EA. Land use planning (e.g. Official Plan, Zoning, Site Plan) approvals would be required for a new facility, depending on the site.
Capital and Operating Cost Range	Enerkem's facility's capital costs for construction were approximately $100 million (2013). Operating costs are not publicly available.
Revenue Opportunity / Cost Savings	Revenue opportunity for the recovered fuel gas from the process. Depending on the facility size and process, as well as on the quality of the feedstock, the net revenue for the fuel gas can range from approximately $175 to $190 per tonne processed. Enerkem also claims that operating a plant in a municipality can generate $65 million per year in net economic benefits; however, no further details to substantiate this claim are publicly available.
Risks and Benefits	**Risks** ● Must comply with stringent environmental monitoring and mitigation plans, regulations, standards and guidelines;

Gasification	
	● Reliability of technology, Plasma gasification had been piloted unsuccessfully by a private company in Ottawa; ● Lengthy and uncertain approvals process; and, ● Feedstock requirements including caloric value of the waste, moisture content, homogeneous nature, can be difficult to provide and maintain. **Benefits** ● Benefits relate to higher waste capacity of the landfill and delayed need to locate new landfill capacity; and, ● Reduced land requirements compared to landfill.
GHG Impacts	Anticipated Reduction in GHGs ● The process generates biofuels, displacing some need for fossil fuels.
Potential Environmental Impacts and Benefits	● Air pollution control systems must be used to ensure gasification system complies with emission and environmental requirements; ● Process generates wastewater from the syngas clean-up and air pollution which need to be managed; ● Recovery of energy and materials (e.g., ferrous and aluminum material); ● Reduction of landfill airspace used for disposal; ● Renewed resource could displace fossil fuels currently being used in market; and, ● Reduction of single use plastics and plastic waste entering landfills.
Potential Known Health Impacts	● Health impacts are typically considered and addressed through the technology evaluation process and/or technology

Gasification	
	vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

10.3 Pyrolysis

Pyrolysis	
Approach / Technology Type(s)	Pyrolysis involves heating municipal solid waste in an oxygen-free environment to produce a combustible gaseous or liquid product and a carbon char residue. Technology types include - auger-type; rotary kiln; updraft and downdraft fixed bed; bubbling and circulating fluidized bed.
Description	Pyrolysis is a chemical process in which organic materials are decomposed by high temperatures in the absence of oxygen. The decomposed materials are converted to gas, liquid, and solid fuels. Pyrolysis is similar to the process of gasification, but the process generally takes place at slightly lower temperatures. Syngas can be used as fuel for boilers, internal combustion units, or turbines, provided that the produced gas is clean enough and of sufficient quality. The feedstock for pyrolysis largely dictates whether the process will produce a good enough product to make the operation viable, the higher the content of organic materials the better. City of Ottawa - Summary of Waste Technologies and Approaches (Updated) Technical Memorandum, HDR, 2014. Accelerating Circular Supply Chains for Plastics: A Landscape of Transformational Technologies That Stop Plastic Waste, Keep Materials in Play and Grow Markets, Closed Loop Partners, 2019. Life Cycle Inventory of 100 percent Postconsumer HDPE and PET Recycled Resin from Postconsumer Containers and Packaging (Revised Final Report), Franklin Associates, 2011.

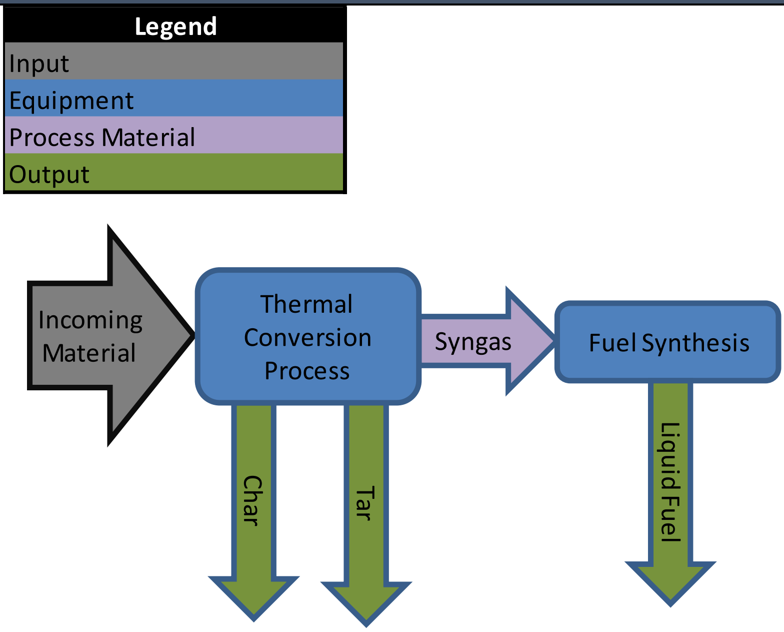
<table>
<tr><th colspan="2">Pyrolysis</th></tr>
<tr><td></td><td>
</td></tr>
<tr><td>Status</td><td>Pilot.</td></tr>
<tr><td>Availability</td><td>Some facilities in North America have processed municipal solid waste at a comparative pilot-scale; however, no facilities are currently operating on a commercial scale. Reportedly, there are some commercial-scale facilities in operation in Europe and Japan; however, the feedstock for these facilities is unclear and there is no further information publicly available.</td></tr>
<tr><td>Examples / Case Studies</td><td>See the above examples of gasification/pyrolysis in Section 10.2.</td></tr>
<tr><td>Target Material / Feedstock</td><td>Pre-processing of municipal solid waste to segregate organics is required to prepare a uniform feedstock source (e.g., RDF).</td></tr>
</table>

Pyrolysis	
Outputs	Electricity and/or heat; metals; pyrolytic oil; ethanol and other biofuels. Waste outputs include carbon char residue and carbon dioxide.
Regulatory Considerations	Thermal treatment facilities require Environmental Screening, or potentially an Individual EA, under the *Environmental Assessment Act.* Time to complete is unknown but is expected to be lengthy (5+ years). Environmental Compliance Approval for a Waste Disposal Site and for Air. Approvals could be shorter with the completion of an EA. Land use planning (e.g. Official Plan, Zoning, Site Plan) approvals would be required for a new facility, depending on the site.
Capital and Operating Cost Range	Costs are dependent on the facility size and negotiated rate for energy sales.
Revenue Opportunity / Cost Savings	Revenue opportunity from the recovered fuel gas.
Risks and Benefits	**Risks** • Must comply with stringent environmental monitoring and mitigation plans, regulations, standards and guidelines; • Reliability of technology is still being tested, and is not yet commercially available; and, • Lengthy and uncertain approvals process. **Benefits** • Benefits relate to higher waste capacity of the landfill and delayed need to locate new landfill capacity.; and,

Pyrolysis	
	● Reduced land requirements compared to landfill.
GHG Impacts	Anticipated Reduction in GHGs ● The process generates fuels, displacing some need for fossil fuels.
Potential Environmental Impacts and Benefits	● Air pollution control systems must be used to ensure pyrolysis system complies with emission and environmental requirements; ● Process generates wastewater from the syngas clean-up and air pollution which need to be managed; ● Recovery of energy and metals; ● Reduction of landfill airspace used for disposal; ● Renewed resource could displace fossil fuels currently being used in market; and, ● Reduction of single use plastics and plastic waste entering landfills.
Potential Known Health Impacts	● Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

10.4 Waste to Liquid Fuel

Waste to Liquid Fuels	
Approach / Technology Type(s)	Generation of liquid fuels from biomass (carbon-rich wastes) and organic wastes. Technology types include Fischer-Tropsch synthesis; methanol synthesis; mixed alcohol synthesis; syngas fermentation.
Description	Liquid fuels can be generated from biomass and organic wastes by undergoing three stages of processing. Non-recyclable waste can be processed into Refuse Derived Fuels (RDF). Using gasification, a thermal conversion process is used to generate syngas from the RDF. This syngas is cleaned to remove tar and other impurities and it is then combined with a chemical catalyst to undergo a series of chemical reactions to convert the syngas into a liquid fuel source. One of four types of chemical catalyst processes can be used to synthesize the syngas into a liquid fuel. These processes include Fischer-Tropsch synthesis, methanol synthesis, mixed alcohol synthesis, or syngas fermentation. Each process utilizes different reaction pressures and temperatures, requires different syngas compositions, and uses different catalysts. City of Ottawa - Summary of Waste Technologies and Approaches (Updated) Technical Memorandum, HDR, 2014.

Waste to Liquid Fuels	
	
Status	Pilot
Availability	The component systems that comprise this technology, including those used for feedstock preparation, gasification, and methanol synthesis, are viable on a commercial scale. However, the combination of these individual technologies in a single system using mixed waste streams and municipal solid waste as a feedstock has not been demonstrated commercially.
Examples / Case Studies	**City of Edmonton, AB** - The first commercial facility in Canada was constructed in Edmonton in 2013 and was designed to convert approximately 180,000 tonnes of non-recyclable waste into 100,000 tonnes of RDF; which can then be processed into approximately 38 million litres of biofuel. Enerkem has a 25-year agreement with the City of Edmonton to supply 100,000 tonnes per year residual waste. The City of Edmonton is responsible for supplying the RDF to Enerkem; the RDF is made from non-recyclable and non-compostable residual

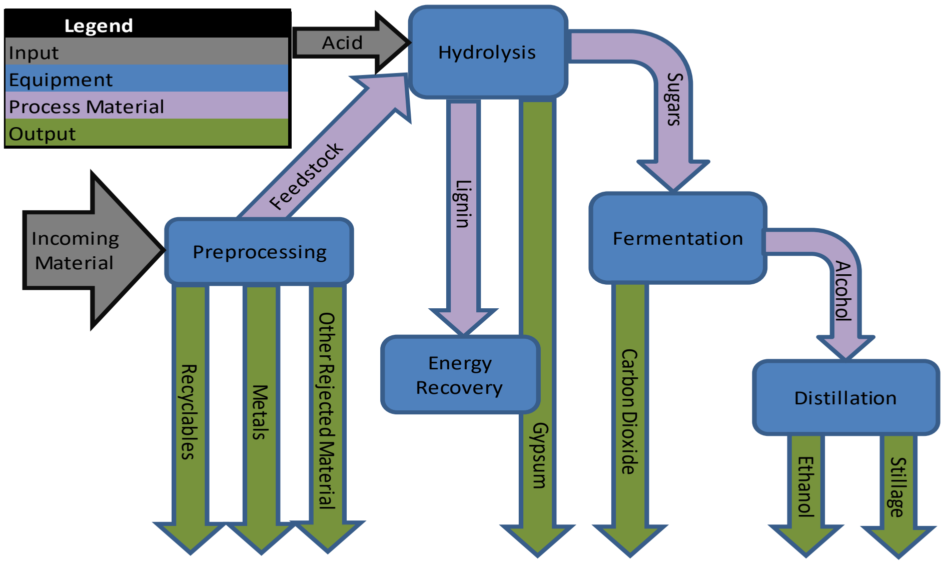
Waste to Liquid Fuels	
	material. The RDF is fed into the gasification system where it is then processed into syngas. The syngas is then used to produce methanol. https://www.edmonton.ca/programs_services/documents/PDF/Fact_Sheet_June_2014.pdf https://edmontonjournal.com/business/local-business/five-minutes-from-trash-to-ethanol-edmontons-long-delayed-enerkem-plant-explained **Montreal, QC -** In August 2019, Montreal announced its plans to build a biomethanation plant (a method of processing organic matter through fermentation without oxygen) that will process municipal organic waste and produce RNG. The plant will process 60,000 tonnes of organic waste a year and produce enough RNG to power approximately 3,600 homes. The estimated cost for design and construction of the facility is almost $130 million, plus five years' of operating costs which is estimated at approximately $37 million. http://biomassmagazine.com/articles/15005/biomethanation-plant-begins-operations-in-quebec
Target Material/ Feedstock	Pre-processing of municipal solid waste to segregate organic waste is required to prepare a uniform feedstock source (e.g., RDF).
Outputs	Diesel; gasoline; naphtha; ethanol; methanol; Compressed Natural Gas (CNG), other organic alcohols, metals (ferrous, aluminum), chars and tars.
Regulatory Considerations	Thermal treatment facilities require Environmental Screening, or potentially an Individual EA, under the *Environmental Assessment Act.* Time to complete is unknown but is expected to be lengthy (5+ years). Environmental Compliance Approval for a Waste Disposal Site and for Air. Approvals could be shorter with the completion of an EA.

Waste to Liquid Fuels	
	Land use planning (e.g. Official Plan, Zoning, Site Plan) approvals would be required for a new facility, depending on the site.
Capital and Operating Cost Range	Enerkem's facility capital costs for construction were approximately $100 million (2013).
Revenue Opportunity / Cost Savings	There is a revenue opportunity for the sale of the RDF and fuel products. No public, reliable information is available for cost savings opportunity.
Risks and Benefits	**Risks** ● Must comply with stringent environmental monitoring and mitigation plans, regulations, standards and guidelines; ● Reliability of technology is still being tested; and, ● Lengthy and uncertain approvals process. **Benefits** ● Benefits relate to extended waste capacity of the landfill and delayed need to locate new landfill capacity; and, ● Reduced land requirements compared to landfill.
GHG Impacts	Anticipated Reduction in GHGs ● Less organic material disposed in landfills.
Potential Environmental Impacts and Benefits	● Odour management likely necessary; ● No emissions data is currently available; ● Recovery of energy and materials; ● Reduction in landfill airspace used for disposal ● Renewed resource could displace fossil fuels currently being used in market; and,

Waste to Liquid Fuels	
	● Reduction of single use plastics and plastic waste entering landfills.
Potential Known Health Impacts	● Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

10.5 Hydrolysis

Hydrolysis	
Approach / Technology Type(s)	Hydrolysis is a chemical reaction in which the organic fraction of the waste material is used to synthesize glucose and/or other simple sugars that can then be fermented or digested to manufacture other products (e.g., ethanol).
Description	In processes used to chemically hydrolyze municipal solid waste or other organic feedstocks, an acid or enzyme is used as a catalyst to break down the complex structures of the material structures contained in the feedstock (e.g., paper, food waste, and yard waste) into simpler compounds like glucose and other sugars. Microorganisms and enzymes can then ferment the sugars, under appropriately controlled conditions, into ethanol, or process them using an anaerobic digestion system into methane-rich biogas. City of Ottawa - Summary of Waste Technologies and Approaches (Updated) Technical Memorandum, HDR, 2014. Accelerating Circular Supply Chains for Plastics: A Landscape of Transformational Technologies That Stop Plastic Waste, Keep Materials in Play and Grow Markets, Closed Loop Partners, 2019.

Hydrolysis	
	
Status	Pilot for MSW, emerging for modifying wood fibres
Availability	The process of chemical hydrolysis is well established for select organic feedstocks (e.g., wood to paper pulp), but the process has only been utilized for municipal solid waste-derived organic matter on a preliminary/conceptual basis. There has been a limited number of laboratory and/or pilot-scale testing done for the application of hydrolysis for municipal solid waste.
Examples / Case Studies	The majority of hydrolysis plants have been installed in Europe, with a few facilities in North America. In Oslo, Norway a 50,000 tonnes/year facility has been operating since 2012 and provides liquid fuel to the Oslo public transport system. There is a commercial-scale biomass demonstration facility in Spain. This facility uses wheat and barley straw as a feedstock. There is also currently a pilot plant operating in Nebraska.

Hydrolysis	
	https://www.cambi.com/references/plants/europe/norway/oslo-romerike-biogas-plant/
Target Material / Feedstock	This technology works on organic wastes, so segregation of these wastes is required to prepare a uniform feedstock from municipal solid waste.
Outputs	Ethanol, biogas, agricultural fertilizer.
Regulatory Considerations	Thermal treatment facilities require Environmental Screening, or potentially an Individual EA, under the *Environmental Assessment Act.* Environmental Compliance Approval for a Waste Disposal Site and for Air from the MECP. Approvals could be shorter with the completion of an EA. A long approval time (>2 yrs) is expected due to the facility complexity. Land use planning (e.g. Official Plan, Zoning, Site Plan) approvals would be required for a new facility, depending on the site.
Capital and Operating Cost Range	Information not publicly available.
Revenue Opportunity / Cost Savings	Revenue opportunity for ethanol and/or biogas.
Risks and Benefits	**Risks** ● Reliability of technology for municipal solid waste is still being tested, and is not yet commercially available; and, ● Lengthy and uncertain approvals process.

Hydrolysis	
	Benefits ● Higher waste capacity of the landfill and delayed need to locate new landfill capacity; and, ● Revenue opportunity from production of liquid fuels.
GHG Impacts	Anticipated Reduction in GHGs ● The process generates biogas or renewable natural gas, displacing some need for fossil fuels.
Potential Environmental Impacts and Benefits	● Odour management likely necessary; ● Limited emissions data is currently available; ● Recovery of energy; ● Production of ethanol; ● Reduction in landfill airspace required for disposal; and, ● Renewed resource could displace fossil fuels currently being used in market.
Potential Known Health Impacts	● Health impacts are typically considered and addressed through the technology evaluation process and/or technology vendor procurement process, which could include a Human Health and Environmental Risk Assessment as part of the EA process prior to issuance of the ECA.

10.6 Landfill Mining

Landfill Mining	
Approach / Technology Type(s)	Landfill mining consists of excavating previously landfilled waste and is typically used to recover soils, gain landfill capacity, redevelop the property and/or mitigate environmental impacts.

Landfill Mining	
	Landfill reclamation can be used following landfill mining to re-engineer the landfill site with improved compaction and cover placement.
Description	Landfill mining refers to the process of excavating previously landfilled waste to recover valuable recyclable materials and/or space. This is a complicated process and its economic feasibility is based on the expected content of the landfill and/or reducing long-term liabilities and recovered airspace. Reducing long-term liabilities can be related to re-disposal of previously improperly landfilled waste or re-engineering of the landfill base with a more robust base liner system. Landfill mining is only considered or completed when its benefits outweigh the associated high costs, and odour and health and safety concerns. The process typically is completed according to the following sequence: ● Planning - Prepare health and safety plan, air quality plan, odour mitigation plan, dust and erosion and sediment control plan, leachate control plan; ● Site preparation - Strip and stockpile existing soil cover; ● Waste excavation and pre-separation - separate out large materials that may damage screening equipment and large recyclable materials; ● Waste screening - Screening process used to separate fines (soil) from residual materials. Recovered residual materials can then be recycled or reused as appropriate. Separated soil material could be reused as daily cover material for the landfill; ● Fines - Haul fines to active face for use as daily/intermediate cover or stockpile; and,

Landfill Mining	
	• Compaction and cover - Haul residual materials to active face to be re-landfilled. https://www.canadianconsultingengineer.com/features/reclamation-re-engineering/
Status	Proven.
Availability	Suitability of landfill mining is site-specific.
Examples/Case Studies	**Barrie, ON** – In 2008 the City of Barrie's municipal solid waste landfill was anticipated to close by 2017. An updated landfill design was developed to involve mining of waste in the western two-thirds of the landfill to address environmental compliance. Between 2009 and 2015 approximately 44 percent of the total licensed landfill volume was excavated (1.6 million m^3). Based on 2017 annual waste disposal rates and population growth predictions the total lifespan of the landfill was calculated to extend to 2035 (18-year gain). The gain is largely due to re-use of fines as daily cover, greater density of compaction and reductions in waste disposal rates since the project began. Dillon Consulting Limited (2017), Waste Connections of Canada, Landfill Mining Assessment Report, Ridge Landfill Expansion EA, June 2018 **Durham Region, ON** – In 2018 Durham Region began a landfill mining pilot project at the former Blackstock landfill site. The pilot project was conducted between October 2018 and January 2019 and recovered approximately 98 tonnes of scrap metal, and 500 tires. The Region is assessing costs and benefits, and developing lessons learned from the pilot study, but the initial assessment is that the pilot was a success.

Landfill Mining	
	https://www.durhamregion.com/news-story/9212866-durham-unearths-tonnes-of-waste-from-old-blackstock-dump-through-landfill-mining-project/ **City of Ottawa, ON** – The Trail Waste Facility Landfill conducted a pilot program to mine landfilled waste as part of the optimization / expansion project in the early 2000s. The pilot program was undertaken in Stage 1 as part of the environmental assessment process to expand the landfill in order to confirm: ● Landfill net volume gain; ● Recovered material types and quantities; ● Odour effects and mitigation; ● Health and safety issues; ● Leachate production with removal of landfill cap; and, ● Review of the most effective processing equipment
Target Material / Feedstock	Soil for daily or intermediate cover or valuable recyclable material, landfill airspace.
Outputs	Soil, valuable recyclable material, landfill air space, redevelopment of the property for a new use.
Regulatory Considerations	Environmental Compliance Approval from the MECP. Approval timing to amend an ECA is unknown and will depend on the complexity of the changes being proposed. An EA would be required if the landfill mining excavation would increase by more than 100,000 m^3 the amount of waste that could be deposited at the site without any increase in the total waste disposal volume. Timing for approvals is unknown and unpredictable depending on the level of community interest.

Landfill Mining	
Capital and Operating Cost Range	Landfill mining has high cost implications that include: ● Construction costs from waste excavation and pre-separation, waste screening, and re-landfilling; ● Costs related to managing nuisances such as litter, odour and dust at the mining area; ● Costs related to managing surface water, landfill gas and leachate at the mining area; and, ● Potential costs from Municipal Hazardous waste disposal. A review of the costs associated with three landfill mining projects (City's Trail Waste Facility Landfill pilot project, Barrie, Blue Mountains) indicate the range in costs (excluding liner or leachate collection system) is from $10 to $35 per cubic metre.
Revenue Opportunity / Cost Savings	● Potential revenue from increased landfill airspace and landfill lifespan. Four reviewed projects in Ontario had airspace recovery rates ranging from 20 percent to 60 percent; ● Potential to reduce closure costs due to improved re-engineering and re-landfilling practices; ● Potential to reduce costs related to importing soil for daily/intermediate cover; and, ● Potential revenue from recovered valuable recyclable materials; however, contamination of materials is likely.
Risks and Benefits	**Risks** ● Health and safety concerns from exposure to landfill gas, unknown waste materials and/or leachate; ● Potential for increased nuisances (odour, litter, dust) for site neighbours during mining process;

Landfill Mining	
	• Unknown waste conditions may result in a low rate of material recovery (i.e., mining cost exceeds value of recovered airspace or material). Recovery rates are dependent on a number of parameters (e.g., waste density, soil type, filling practices); and, • Presence of certain materials (e.g., wires and industrial fabrics) may slow down reclamation process. **Benefits** • Potential remediation of groundwater impacts (e.g., from unlined sites or sites with existing groundwater impacts); • Reduction of potential environmental liabilities as a risk management strategy, for example, improperly disposed of wastes or an unlined portion of a landfill; • Gain landfill capacity; • Opportunity to address soil shortages for future landfill operations; and, • Reclamation of other materials, such as tires for internal road construction.
GHG Impacts	Anticipated Increase in GHGs • Given the requirement to expose and handle previously buried waste, a short-term increase in release of GHG at the landfill mining area is likely; and, • A short-term increase in GHG emissions are also expected from more vehicular activity during the mining period.
Potential Environmental Impacts and Benefits	• Creates a risk of contaminants (e.g., fly plastics, leachate spill), escaping to the environment; • Potential to mitigate groundwater impacts due to unfavourable hydrogeological conditions, such as high

Landfill Mining	
	permeability soils at landfill base or high groundwater levels; and, ● Potential to improve environmental controls if landfill reclamation is sought.
Potential Known Health Impacts	● Potential safety risk for workers conducting excavation from exposure to landfill gas, Municipal Hazardous waste (especially if no records on materials deposited exist), or leachate (saturated waste or perched leachate); and, ● Potential for health and safety risks from increased dust and airborne contaminant levels.

10.7 Summary of Recovery Technologies

The following table summarizes the technology researched, the potential applicable material stream and the potential customers the technology could be applied to.

Technology	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
Mass Burn Incineration	Garbage	X	X	X	X	X
Gasification	Garbage	X	X	X	X	X
Pyrolysis	Garbage	X	X	X	X	X
Waste to Liquid Fuels	Garbage	X	X	X	X	X
Hydrolysis	Garbage	X	X	X	X	X
Landfill Mining	Garbage	X	X	X	X	X

11 Landfill Disposal Technologies

This section reviews various landfill disposal technologies that can be used as an alternative to or in combination with traditional landfilling. Reviewed technologies include: bioreactor, stabilized landfill, biocell, and landfill optimization.

The intent of this section is to provide a high–level overview of technology types and approaches, availability and status, approval requirements, costs and revenue, potential environmental impacts and benefits and potential known health impacts. Further details will be researched in Phase 2 of the development of the SWMP, including further identification of approval requirements, as applicable. It is assumed that any waste management facility developed must meet all conditions required as part of any necessary approvals at that time (e.g. Environmental Compliance Approval) which have been established to ensure protection of public health.

The City of Ottawa owns and operates the Trail Waste Facility Landfill, located in south Nepean. Operational since 1980, the Trail Waste Facility Landfill accepts residential and commercial municipal solid non-hazardous waste, C&D waste, yard waste, recyclable materials and asbestos. The landfill is an engineered landfill, considered state of the art and uses composite liners, plastic caps, and leachate and gas collection systems to mitigate impacts on the environment. Leachate recirculation was used in the past at Trail Waste Facility Landfill to increase organic waste biodegradation, reduce the contaminating lifespan of the landfill and increase the settlement of the solid waste.

The City has also been using photogrammetry to measure soil stockpiles and to regrade the closed landfill areas due to settlement. The two compactors used at the landfill have a full Global Navigation Satellite System (GNSS) for the purpose of determining real time machine location, grade control, compaction and mapping capability, in centimeter accuracy for the XYZ coordinates and relating this data to system final surfaces or alternate surfaces in use by the compactor vehicles. The system also helps reduce fuel consumption and enables staff to construct specific landfill cells to promote gas collection and reduce odours.

The landfill has an expected closure date of 2041 and may have limited options for further expansion. A pilot program was undertaken in the early 2000s on landfill mining as part of the Expansion/Optimization Environmental Assessment for the Trail Waste Facility Landfill. In 2005, approval was granted for both a vertical expansion of Stages 1 through 4, and a horizontal expansion into Stage 5. Further expansion of the Trail Waste Facility Landfill could also be considered to increase disposal capacity in the future. Alternative disposal options, including engineered landfill, will be identified and evaluated in Phase 2 of the SWMP.

The following three tables present research on landfill disposal technologies which includes bioreactors, biocells and landfill optimization.

11.1 Bioreactor

Bioreactor	
Approach / Technology Type(s)	Bioreactors are designed to enhance and accelerate the degradation of landfilled materials through biological processes (bacteria). Leachate is typically collected and recirculated back into the landfill. Bioreactors can be designed as aerobic reactors (which rely on oxygen to sustain bacteria), anaerobic reactors (which rely on a low oxygen environment to sustain bacteria), and hybrid reactors which employ both types of bacteria.
Description	All bioreactors have a lined cell and recirculate leachate and/or liquids such as stormwater, wastewater, or wastewater sludges through the waste pile to promote biological breakdown of the waste. Maintaining an optimum moisture content within the waste material is critical for operation of bioreactors. For aerobic bioreactors, air is injected into the landfill through vertical or horizontal wells to maintain aerobic conditions. For anaerobic bioreactors, a Landfill Gas (LFG) recovery system is installed to collect biogas and generate power. All bioreactors accelerate waste decomposition to: stabilize the waste, realize the benefits of additional waste capacity faster than a traditional landfill, and reduce landfill gas emissions. A bioreactor consists of the following components: composite liner, leachate collection and recirculation system, liquid injection system, gas collection and/or air injection system, intermediate covers and final cover. https://www.epa.gov/landfills/bioreactor-landfills
Status	Demonstration/pilot
Availability	Recommended for new sites in the design phase as specific infrastructure is more easily integrated during early stages of site development. Leachate recirculation system and other injection systems are easier to install during landfill construction. For

Bioreactor	
	anaerobic and hybrid bioreactors, landfill gas (LFG) collection systems that can accommodate high LFG generation rates and oxygen induced conditions are required also. Limited number of pilot and research projects in North America.
Examples/Case Studies	**Trail Waste Facility Landfill, Ottawa, ON** – At the Trail Waste Facility Landfill a pilot was conducted where leachate was recirculated in a small area for a short period of time. The following observations were made: ● Increase in odour emissions, which necessitated the installation of an active gas-recovery system; and, ● Recovery of approximately 20 to 30 percent of disposal capacity due to enhanced settlement of the waste as a result of leachate recirculati **Buncombe County Solid Waste Management Facility, North Carolina** – The Buncombe County Soil Waste Management Facility opened in 1997 and operates as a bioreactor. The landfill has a 38 ha footprint and is being developed with 10 disposal cells constructed sequentially as landfilling progresses. Goals of the bioreactor landfill include acceleration of waste decomposition and reaching a stabilized condition while the landfill is still active, reducing landfill gas emissions, realizing additional waste capacity during landfill development thereby reducing the need for new landfills. https://bioreactor.buncombecounty.org/
Target Material / Feedstock	Municipal solid waste and wastes with a high organic content.
Outputs	Landfill gas/biogas and landfill airspace.

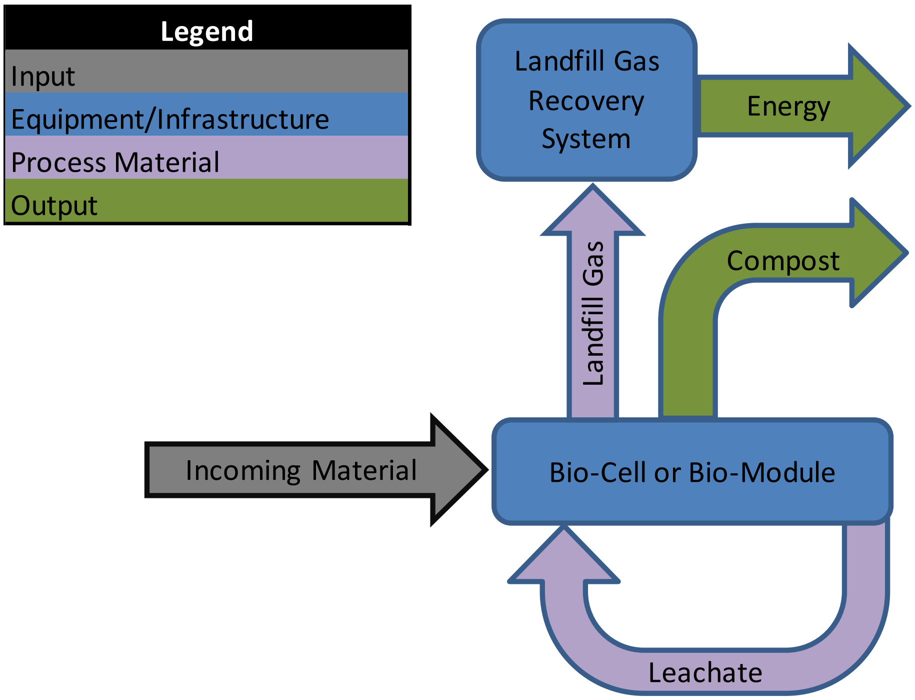
Bioreactor	
Regulatory Considerations	Environmental Compliance Approval from the MECP. Approval timing to amend an ECA is unknown and will depend on the complexity of the changes being proposed.
Capital and Operating Cost Range	Net lifecycle costs including capital, operating and closure/post-closure care range considerably depending on the type of bioreactor, scale of the site, and local site conditions.
Revenue Opportunity / Cost Savings	Greater LFG generation and recovery rates may relate to cost savings if used for energy production.
Risks and Benefits	**Risks** • Potential for odours; and, • Physical instability of waste mass due to higher moisture content required in waste. **Benefits** • Decomposition and waste stabilization occurs in a shorter period of time compared to traditional landfills; • Large amount of organics can be processed at low cost; • For anaerobic bioreactors, LFG is generated at a higher rate and at an earlier stage compared to traditional landfills. This increases the potential for gas utilization and minimizes risk and cost of maintaining and expanding system over a longer time period; • Recirculation stabilizes leachate faster, reducing treatment and disposal risks and costs; • Shorter contaminating lifespan has potential to reduce closure and post-closure care and costs;

Bioreactor	
	- For anaerobic bioreactors potential to generate energy if gas is collected; - Recovery of airspace due to a reduction in volume of the waste pile; and, - Revenue from recovered resources (compost or refuse derived fuel).
GHG Impacts	Anticipated Reduction in GHGs - Reduces GHG emissions from rapid generation and collection of landfill gas for anaerobic bioreactors. For aerobic bioreactors, carbon dioxide gas is produced instead of methane which has less global warming potential than methane; and, - A potential increase or reduction in GHG if LFG for generating power, depending on the type of bioreactor used.
Potential Environmental Impacts and Benefits	- Potential for environmental impacts if pumping and collections systems fail, such as increased gas emissions and leachate management due to recirculation; - Environmental impacts associated with traditional landfills, such as seeps; - Potential for higher odours compared to traditional landfills; - Potential to reduce landfill gas emissions; - LFG can be used to generate power in place of fossil fuels; - Leachate is recirculated reducing potential for surface water contamination; and, - Reuse of cell infrastructure and land.
Potential Known Health Impacts	For aerobic bioreactors, high temperatures and increased oxygen content within the waste increases the risk of landfill fires; and,

Bioreactor	
	● Minimal to no health impacts.

11.2 Biocell

Biocell	
Approach / Technology Type(s)	Landfill biocell combines a number of technologies including anaerobic bioreactor, air injection, leachate recirculation system, LFG recovery and utilization system, air pumping equipment, computerized monitoring system, and base and surface liners. Biocells differ from bioreactors in that there is always both anaerobic and aerobic phases, and air space is recovered through mining of residuals.
Description	The biocell is an approach similar to the bioreactor that places waste with high organic content into a lined cell and is kept moist with leachate recirculation. A biocell operates in three stages: ● The initial stage is an anaerobic phase to enhance gas production. Relies on recirculation of leachate or addition of liquids; ● The second stage is an aerobic phase to balance the organic matter to create compost-like material or material that can be further processed into refuse derived fuel. Relies on recirculation of leachate or addition of liquids and air injection; and, ● In the third stage, the biocell is mined to recover resources (metal material and reusable soil) and airspace. The cycle can be repeated. A biocell consists of the following components: composite liner, leachate collection and removal system, liquid injection system, gas collection and air injection system, intermediate covers and final cover.

Biocell	
	Conestoga-Rovers & Associates (2011), British Columbia Ministry of Environment, Technologies and Best Management Practices for Reducing GHG Emissions from Landfills Guidelines.
	
Status	Emerging, Pilot (City of Calgary)
Availability	Recommended for new sites in the design phase as specific infrastructure is more easily integrated during early stages of site development. Requires LFG systems that can accommodate high LFG generation rates and oxygen induced conditions. Limited number of projects in North America; however, is gaining popularity as research progresses.

Biocell	
Examples / Case Studies	**Calgary, AB** - The City of Calgary's pilot Landfill BioCell was constructed using 65,000 tonnes of waste and is currently operating in the first stage. Hettiarachchi, Hiroshan & Hunte, Carlos & Hettiaratchi, Joseph & Meegoda, Jay. (2012). The City of Calgary Biocell Landfill: Data Collection and Settlement Predictions Using a Multiphase Model. Advances in Geotechnical Engineering. 4202-4211.
Target Material / Feedstock	Municipal solid waste with high organic content; wastewater biosolids.
Outputs	Recyclable materials, materials for landfill disposal, compost-like material, refuse derived fuel (require further processing), landfill airspace.
Regulatory Considerations	Environmental Compliance Approval from the MECP. Approval timing to amend an ECA is unknown and will depend on the complexity of the changes being proposed,
Capital and Operating Cost Range	Initial infrastructure capital and operational costs are high compared to traditional landfilling given additional infrastructure. Expected to have higher initial operation and monitoring costs, but less monitoring costs expected during closure/post-closure.
Revenue Opportunity / Cost Savings	Revenue can be generated from recovered resources (compost or refuse derived fuel). Greater LFG generation and recovery rates may relate to cost savings if used for energy production.
Risks and Benefits	**Risks** ● Requires municipal solid waste with high organic content; ● Potential for adverse impacts if pumping and collections systems fail, such as increased odours;

Biocell	
	● Additional technologies needed to separate out residual materials recovered during final phase; ● Physical instability of waste mass; and, ● Relatively new technology; quality of final residual products unknown. **Benefits** ● Decomposition and waste stabilization occurs in a shorter period of time than traditional landfills; ● Large amount of organics can be processed at once; ● LFG is generated at a higher rate and at an earlier stage. This increases the potential for gas utilization and minimizes risk and cost of maintaining and expanding system over a longer time period; ● Recirculation stabilizes leachate faster, reducing treatment and disposal risks and costs; ● Shorter contaminating lifespan has potential to reduce closure and post-closure care and costs; ● Potential to generate energy if gas is collected during anaerobic stage; ● Recovery of airspace; and, ● Revenue from recovered resources (compost or refuse derived fuel).
GHG Impacts	Anticipated Reduction in GHGs ● Reduces GHG emissions from rapid generation and collection of landfill gas during anaerobic conditions. During the aerobic stage, carbon dioxide gas is produced instead of methane which has less global warming potential than methane; and,

Biocell	
	• A potential reduction in GHGs if LFG used for generating biogas that can be used for RNG, heating and/or electricity production.
Potential Environmental Impacts and Benefits	• Potential for environmental impacts if pumping and collections systems fail, such as increased gas emissions; • Environmental impacts associated with traditional landfills still possible, such as seeps; • Potential to reduce landfill gas emissions; • LFG can be used to generate power in place of fossil fuels; • Reduction in leachate generation time may reduce long-term groundwater contamination potential; • Leachate is recirculated reducing potential for surface water contamination; • Resource recovery of materials that would typically be buried; and, • Reuse of cell infrastructure and land.
Potential Known Health Impacts	• Safety risks exist for the landfill gas system during the aerobic stage. High temperatures and increased oxygen content within the waste increases the risk of landfill fires; and, • In general, minimal to no health impacts.

11.3 Landfill Optimization Approaches

Landfill Optimization Approaches	
Approach / Technology Type(s)	Landfill optimization consists of making changes to an existing landfill to enhance the operations of the landfill, review landfill equipment for optimizations and improvements, adjust to a changing climate, and to increase the volume of waste that can be deposited through changes in the configuration of the mound.
Description	Landfill optimization approaches involve a review of the current operations and configuration of a landfill and assessing what the benefits would be to enhance operations, maximize the amount of waste landfilled within existing approved contours, and modify final contours, including the final height of the landfill, in order to increase airspace for depositing waste. Dillon Consulting Limited (2019), Waste Connections of Canada, Attachment 5: Alternative Methods Comparative Evaluation Tables, Draft Ridge Landfill Environmental Assessment Report, July 2019
Status	Proven
Availability	Many modern landfills go through a review of potential optimizations at some point during operation. The Trail Road Waste Facility went through an optimization process to develop final contours as the existing contours provided in the EA were insufficient for design operations. This resulted in additional airspace though some of the design options have yet to be implemented (i.e., gable west end of Stage 4 and eastern corner of Stage 5). Two optimization projects were completed in 2016, a Waste Limit and Final Contour Review by Dillon Consulting and an Airspace Optimization Review by JL Richards, to provide a more detailed surface design for Stages 2, 3, and 4.

Landfill Optimization Approaches	
Examples/Case Studies	**Halton Waste Management Site, Region of Halton, ON** – The Region is currently preparing a solid waste management strategy. As part of the Short Term options, the Region considered the following measures that would optimize landfill operations, increase the remaining capacity and extend the site life of the landfill: leachate recirculation to increase settlement, use of GPS system to upgrade equipment operations, implement an evapotranspiration final cover to increase water storage capacity, implement pollinator habitats at closed landfill cells, purchase a shredding/baling system to reduce waste volumes prior to final disposal and develop a fill sequence plan for current and future cells to optimize landfill space. Dillon Consulting Limited, Regional Municipality of Halton, Short Term Solid Waste Management Strategy, April 2018 **Fredericton Region Solid Waste, NB** – Fredericton's landfill became the first landfill in Atlantic Canada to bale solid waste. Baling involves garbage being placed in a large compactor which compresses the waste into rectangular cubes. Baling reduces the environmental impact of leachate, keeps the site clean by reducing and preventing blowing litter; and helps extend the lifespan of the landfill. One bale weighs approximately 1,500 kg. Once a bale is produced, it's taken to the landfill site and placed in a cell. About 120,000 bales can fit in one cell. Bales are added to cells daily and covered with clean gravel. When the cell is full, it is covered with one metre of clay. About 30 centimetres of topsoil is spread over the clay and seeded. The end result is a grass field sloped to aid in runoff. http://frswc.ca/operations/
Target Material / Feedstock	Municipal solid waste.

Landfill Optimization Approaches	
Outputs	Additional landfill capacity through optimization or expansion.
Regulatory Considerations	Environmental Compliance Approval from the MECP for optimization approaches within existing approved landfill volume contours. Approval timing to amend an ECA is unknown and will depend on the complexity of the changes being proposed, An EA approval would be required for any increase in the total waste disposal volume. Timing for approvals is unknown and unpredictable depending on the level of community interest.
Capital and Operating Cost Range	Net lifecycle capital costs range considerably depending on the type and extent of optimizations and work required to reconfigure the landfill. Operating costs typically only marginally increase.
Revenue Opportunity / Cost Savings	• Potential revenue from increased capacity within existing approved airspace; and, • Potential to reduce closure costs due to improved re-engineering and re-landfilling practices.
Risks and Benefits	**Risks** • Healthy and safety concerns from exposure to landfill gas, unknown waste materials and/or leachate if old areas of the landfill are reopened and exposed; • Potential for marginal increased nuisances (odour, litter, dust) for site neighbours due to higher volume of waste landfilled; and, • EA process for landfill expansion is complex and takes many years until approval is received. **Benefits** • Gain landfill capacity; and,

Landfill Optimization Approaches	
	● Ability to improve operations to adapt to a changing climate.
GHG Impacts	Anticipated Increase in GHGs ● The anticipated GHG emissions per unit of waste does not change compared to pre-landfill optimization, however GHG impacts are marginally higher due to the greater volume of waste deposited.
Potential Environmental Impacts and Benefits	● Environmental impacts are marginally higher due to higher volume of waste deposited; and, ● Benefits relate to higher waste capacity of the landfill and delayed need to locate new landfill capacity.
Potential Known Health Impacts	● EA would identify potential health impacts associated with expansion; and, ● Minimal to no known health impacts from optimizing within approved contours.

11.4 Summary of Landfill Disposal Technologies

The following table summarizes the technology and/or approach researched, the potential applicable material stream and the potential customers the technology and/or approach could be applied to.

	Applicable Material Streams	Curbside Residential	Multi-Residential	Parks and Public Spaces	City Facilities	Partner Programs
Bioreactor	Garbage, Organics	X	X	X	X	X
Biocell	Garbage, Organics	X	X	X	X	X
Landfill Optimization Approaches	Garbage	X	X	X	X	X

12 Next Steps

This Technical Memorandum presents a high-level review of waste management technologies and approaches to waste management for consideration by the City as part of the options identification in future tasks.

The technologies and approaches range from proven to emerging and could apply to various waste streams and sectors served by the City. The information provided in this Technical Memorandum helps set the tone for where the SWMP could go and provides a range of options for consideration.

As part of Phase 2, a more detailed analysis specific to Ottawa will be undertaken. This will include consideration of the type of waste the City manages currently, and in the future based on proposed changes to Ontario regulations. It will also consider future trends in population, housing, and waste generation/composition. A list of options for consideration will be developed and evaluated using a set of criteria developed in collaboration with the City and that reflect feedback from stakeholders. Ultimately, options will be identified for the various customers served by the City for the short, mid and long term planning period that meet Ottawa's unique needs.