IRM Technology Gap Analysis

Capital Regional District

Advanced Integrated Resource Management (IRM) Project

August 25, 2017

1. Introduction

On June 28, 2017 the Integrated Resource Management Advisory Committee (IRMAC) recommended to the CRD Environmental Services Committee that five key deliverables be prepared and delivered for the September IRMAC meeting, based on the staff report entitled the Advanced Integrated Resource Management, Next Steps and the presentation that was provided regarding the IRM Road Map. These recommendations were approved by the Environmental Services Committee on June 28th, 2017 and subsequently by the CRD Board. One of these five key deliverables is the completion of a Gap Analysis to addressing the evaluation of the broader array of technologies and feedstock combinations, as required in the provincial approval of the Core Area Liquid Waste Management Plan, Amendment No. 11.

The following provides a Gap Analysis regarding technologies and potential feedstock. This Gap Analysis identifies the full spectrum of possible technologies that could be considered by the CRD and considers the application of these technologies to the potential feedstock combinations considered by the CRD. This preliminary Gap Analysis reflects the outcome of the IRM RFEOI as reported in the detailed analysis of the RFEOI results provided to the IRMAC on June 28, 2017 as well as the outcome of the Jurisdictional Review both of which are key components supporting the assessment of the full spectrum of approaches to beneficially reuse biosolids. As the responses to the RFEOI did not reflect the full spectrum of possible IRM technologies that are available, additional resources were used to supplement this information including: other reports prepared on behalf of the CRD such as the *Gasification Technologies – Characterization of Waste Resources in the Capital Region (September 2016)*, studies provided previously as information to the CRD including the *City of Sydney Advanced Waste Treatment Master Plan (March 2014)*, and reports prepared by HDR that have been developed in the course of undertaking similar studies on behalf of other jurisdictions in North America such as the *Oregon Metro, Long Term Waste Management Options Study (March 2015)*. A selected list of references is provided at the end of this document.

This Gap Analysis should be considered as an initial document that would be refined as further work is undertaken over the course of the next few months as set out in the recommended CRD IRM Project Plan Outline (discussed in the separate report to the IRMAC) regarding the approach for technology selection and development of feedstock assumptions for the RFQ. The assessment of the full spectrum of beneficial uses and integrated resource management options in the IRM Project Plan, would be comprised of this Technology and Feedstock Gap Analysis along with the additional work undertaken regarding the approach for technology selection and development of feedstock assumptions, information gathered during the proposed IRM facility tours as set out in the IRM Facility Tour Plan and the outcome of the IRM RFQ process.

2. IRM Technology Gap Analysis

The Detailed Analysis of Responses to RFEOI No. 16-1894 (Detailed Analysis) was presented to the IRMAC on June 28, 2017. An overview of the technologies offered by the RFEOI respondents and the subject liquid and solid waste streams was summarized in Table 6.1 of the Detailed Analysis. Generally there was good representation of technologies suitable for managing the full spectrum of the CRD solid and liquid waste streams, however not all known technologies were reflected in the RFEOI submissions. In addition, no one technology indicated in the RFEOI submissions offered a complete IRM solution for managing all of the solid and liquid waste feedstock identified by the CRD. Some submissions indicated interest in processing a sub-set of the

CRD materials. Others indicated the use of a combination of technologies in order to manage all potential feedstock.

The RFEOI responses generally can be categorized within specific technology groups that could be applied to manage solid and liquid waste streams in an integrated resource management process as noted in Table 1 below. Table 1 also notes specific technologies that were not represented within the RFEOI responses.

Table 1 Overview of Technologies Represented and Not Represented in the RFEOI Responses

Technology Classification	Technology	Represented in the RFEOI Responses (by Company name)	Not Represented in the RFEOI Responses
Mechanical	Mechanical Sorting	Anaergia, APD, ECS, ICC Group, Pivotal, Redwave, Veolia, Walker, WTT	
	Autoclave/Steam Classification		Not represented
Biological	Composting	ECS, Redwave, Veolia, Walker, WTT	
	Anaerobic Digestion Dry or High solids	Anaergia, Redwave, WTT	
	Anaerobic Digestion using wet (low solids) or WWTP	Veolia, Walker	
Thermal	Gasification	Pivotal, ICC Group	Not all gasification technologies represented
	Electro-Thermal Gasification	APD	
	Pyrolysis		Not represented
	Waste to Fuel (Fischer-Tropsch)		Not represented
	Combustion (WTE, EFW, Mass Burn)		Not represented
	Refuse Derived Fuel (also pelleting or briquetting)	Anaergia, ICC, Pivotal, Redwave, WTT	
Chemical	Thermal and Chemical Hydrolysis		Not represented
	Catalytic and Thermal Depolymerization		Not represented
Other	Nutrient Recovery	Ostara	

Assessing the technologies represented in the RFEOI submissions indicates that:

1. In regards to mechanical processing, the RFEOI submissions addressed the current range of sorting technologies applied to mechanically process MSW and other solid waste materials, including some newer technologies that are currently being successfully applied to extract the organic fraction of the waste stream from other materials. The submissions did not include emerging technologies such as autoclave/steam classification.

2. In regards to biological processing, the RFEOI submissions addressed the current range of aerobic composting processes as well as the range of anaerobic digestion (AD) processes (dry stackable, high solids and wet AD) that are being successfully applied to process and recover value from the organic fraction of the solid waste stream as well as to process biosolids (and/or sewage sludge).

3. In regards to thermal processing, the RFEOI submissions addressed a few specific gasification technologies that can be applied to recover energy from the solid waste stream. However, a number of current thermal technologies were not represented including combustion and some types of gasification (e.g. plasma gasification) as well as some emerging technologies.

4. There are a few emerging chemical processing technologies that were also not reflected in the RFEOI submissions.

The mechanical, biological and thermal technologies represented in the RFEOI submissions were discussed in detail within the *Detailed Analysis of Responses to RFEOI No. 16-1894*. Those IRM technologies not represented in the RFEOI responses are discussed further in Section 2.1.

The full spectrum of technologies capable of specifically managing biosolids and/or sewage sludge were not represented in the RFEOI responses. The RFEOI responses focused primarily on those technologies that could manage biosolids as part of an IRM solution (per Table 1), with one technology focused on managing a sub-set of the biosolids stream (recovery of nutrients from dewatering liquid). A separate *Beneficial Reuse of Biosolids Jurisdictional Review* was prepared for the CRD in June 2017 to present examples of how other jurisdictions produce and use Class A biosolids. The well-established and emerging technologies represented in that report include those technologies that address biosolids management in a separate stream, as well as those that can address biosolids in an IRM approach with other materials. A brief summary of the outcome of that separate study is provided in Section 2.2 for reference, specifically noting those technologies that were identified which could contribute to an IRM solution.

2.1 Discussion Regarding Other IRM Technologies

The following text discusses the thermal technologies that were not represented in the RFEOI submissions. In each case a brief overview of the technology is provided as well as a summary table indicating key parameters regarding the technology.

2.1.1 Autoclave/Steam Classification

Autoclaving is classified as a "mechanical" process that uses heat and pressure in a mechanical rotating cylinder to separate the cellulosic material from other portions of the municipal solid waste stream. The basic Autoclave technology has been in use for sterilization of hospital wastes and equipment and other related applications for many years.

Autoclaving addresses only a portion of the waste stream, namely the cellulose-fiber-containing portion, which is usually 40% to 60% of the total MSW input stream. This technology can accept mixed MSW which contains a large organic fraction to be used as a "front-end" to many of other technologies. The Autoclave process has the potential for a 40% to 60% reduction in waste volume with the cellulose recovery having the potential to be used as feedstock for paper production, fuel, ethanol production feedstock, compost feedstock; or digester feedstock for methane production.

Autoclaves are large rotating vessels that have steam injected and kept at a certain temperature and pressure over a 2 to 4 hour period to convert the MSW. A trommel screen is usually utilized after autoclaving to separate out the various mixes of fibrous organic materials produced from autoclaving and other materials (i.e., fine organics stream, bulky organics stream, and overs, such as inorganic materials, and recyclables such as glass, metals and plastics). If the goal for the autoclaving technology is recovery for paper production, because the fibers are of such a mixed grade, the main product that can be produced is a lower-grade cardboard.

Autoclaves are currently operating in batch mode accepting from approximately 1 to 25 tons per batch (2-3 hour). The Salinas Valley Solid Waste Authority employed an autoclave pilot study for several years at their Crazy Horse Landfill in Salinas California. The study was partly funded by grants to explore cellulosic fuel development.

There are no large-scale commercial Autoclave facilities operating in North America that use a purely mixed MSW stream as a feedstock. All of the demonstration projects have been completed on a fairly small scale (less than 300 tpd) on different feedstocks besides MSW. No known commercial operation exists at this time in the U.S. or elsewhere for processing MSW.

Benefits include the diversion of materials from landfill, the production of a cellulose product valuable for many uses as described above. The environmental risks of Autoclaving are not known. Water consumption and wastewater generation for this technology is unknown at this time.

SUMMARY Autoclave/Steam Classification
Technology Classification: Mechanical
Current Technology Providers: There are dozens of medical autoclave providers but no waste processing providers at commercial levels. CR3 developed the Salinas Valley demonstration facility.
General Description of Processing Technology (overview): Cycled steam pressurization in rotating vessel followed by screening to separate inert materials (metals, glass, etc) from the cellulose (paper products) for further refinement. Autoclave technology is commonplace in the medical field to sterilize medical instruments. This is a preprocessing technology that could separate cellulose for a variety of other technologies such as RDF, Waste to fuel, AD, etc.
Inputs (acceptable feedstock composition): Mixed waste material containing paper, paperboard, cardboard, etc.
Size (range of existing facility sizes): Currently small scale-batch type facilities operating at 2 to five tons per hour.
Environmental Implications (air, noise, water, GHG emissions): This is a preprocessing system to prepare and extract cellulose for a variety of other processes such as RDF, waste to fuel, etc.
Products / Materials / Energy Recovered: recyclables (metals, glass, some plastics), cellulose as a feedstock for further refinement or as a feedstock for other processes.
Status: New and Emerging. There have been some demonstration applications completed using mixed municipal solid waste and other select waste streams; however, there has been no widespread commercial application of this technology.
Reference Facility(ies):
Representative Existing Facilities: Salinas Valley Solid Waste Authority: pilot research project.[1]

2.1.2 Thermal and Chemical Hydrolysis

Hydrolysis is a multi-step process to eventually produce a fuel-grade ethanol solution from the cellulose fractions in municipal solid waste (paper, food waste, yard waste).Hydrolysis is a multi-step process that includes four major steps: Pre-treatment; Hydrolysis; Fermentation; and Distillation. For MSW the pre-treatment step would include separation of the feedstock stream as necessary to remove any inorganic/inert materials (glass, plastic, metal, etc.) from the organic materials (yard waste, paper, etc.). Feedstock materials that are appropriate for hydrolysis/fermentation of the cellulosic components of MSW include wood, green waste and paper. Wastewater treatment plant operators may also apply a form of hydrolysis (Thermal Hydrolysis) to increase the biogas generation from their anaerobic digesters and improve the de-waterability of the sludge.

Pre-processing of the incoming waste stream for this technology involves separating the cellulose fraction of the municipal solid waste. This can be accomplished by a variety of methods including air classification, screening, and manual sorting. The remaining organic material is shredded to reduce size and produce a more homogenous feedstock.

The feedstock is placed into a reactor. Next, the feedstock reacts with a strong acid (e.g. sulfuric acid) to produce sugars. After that, these sugars are fermented to produce an organic alcohol. This alcohol is then distilled to produce a fuel-grade ethanol solution. The by-products from this process are carbon dioxide (from the

[1] Oregon Metro Solid Waste Plan Phase 3 Final Report, March 2015. HDR.

fermentation step), gypsum (from the hydrolysis step) and lignin (non-cellulose material from the hydrolysis step). Since the acid acts only as a catalyst, it can be extracted and recycled back into the process.

The process of chemical Hydrolysis is well established for some organic feedstocks, such as in the conversion of wood to paper pulp, but has only been applied to MSW-derived organics on a conceptual basis, or limited to laboratory- or pilot-scale. There has been no widespread commercial application of this technology using MSW as a feedstock in North America or abroad.

SUMMARY Thermal and Chemical Hydrolysis
Technology Classification: Chemical
Current Technology Providers: Cambi (biosolids), BioRefinex (organic waste), Lystek (biosolids), BlueFire Renewables (biomass)
General Description of Processing Technology (overview): Pressure and heat are applied, similar to pressure cooking, resulting in sugars that can be digested using anaerobic digestion or refined using other processes. This process is seen as a pretreatment system to enhance anaerobic digestion of biosolids but could have other applications in the waste industry.
Inputs (acceptable feedstock composition): Currently biosolids but could be relevant to other materials containing cellulose (paper, paperboard, cardboard) and organics (meats, fats, feedlot mortality, etc.)
Size (range of existing facility sizes): This is an emerging industry in the waste field so the scale of facilities are generally small but its application to other industries (pulp/paper and petroleum) is larger and more common.
Environmental Implications (air, noise, water, GHG emissions): This is a preprocessing system to enhance anaerobic digestion of biosolids but could be applicable to processing meats, fats, etc.
Products / Materials / Energy Recovered: Petroleum like by-products.
Status: New and Emerging. There have been some demonstration and pilot-scale applications completed using mixed municipal solid waste and other select waste streams; however, there has been no widespread commercial application of this technology.
Reference Facility(ies)
Representative Existing Facilities: This technology is used in the biosolids processing field but is still in research and development. There are no known facilities operating on solid waste streams. [2]

2.1.3 Catalytic and Thermal Depolymerization

In catalytic or thermal depolymerization, the plastics, synthetic-fibre components and water in the municipal solid waste feedstock react with a catalyst under non-atmospheric pressure and temperatures to produce a crude oil. This crude oil can then be distilled to produce a synthetic gasoline or fuel-grade diesel. This process is somewhat similar to that used at an oil refinery to convert crude oil into usable products, including the use of distillation to segregate the desired hydrocarbon liquids (such as diesel fuel). Typical feedstocks proposed for depolymerization are plastics, waste oils, grease, and offal (i.e., processed animal soft tissue). Technology vendors representing this technology indicate that it can theoretically use MSW and biomass as feedstocks. This has not been shown as

[2] Niagara Region – Assessment of Alternative Waste Management Technologies, Technical Memo No. 2, January 2014, HDR.

feasible except at extremely small scale. There are two depolymerization methods that can be used to convert organic materials into fuel: thermal and catalytic.

Thermal Depolymerization

Thermal depolymerization utilizes temperature (temperature ranges from 1,000° to 1,400° Fairenheit) and pressure to crack the large hydrocarbon molecules within the feedstock. Once the hydrocarbon molecules are broken into shorter chains, additional refining steps are required to convert the molecules into oil. The high temperature and additional refining steps in the thermal process require the input of a significant amount of energy, as compared to the catalytic depolymerization approach. The energy balance data for thermal depolymerization of waste-derived organic materials are lacking with regard to commercial scale processing.

Catalytic Depolymerization

The catalytic depolymerization process uses lower temperatures (ranging from 500° to 700°F) and lower pressures than thermal depolymerization. In order to achieve adequate product yields and qualities at the lower temperatures and pressures, a catalyst is employed to aid in the process of breaking down or cracking the large molecules efficiently. Zeolite, silica-alumina, and bauxite are common types of catalysts used in the process. In a catalytic depolymerization process, the plastics, synthetic-fiber components and water in the feedstock react with a catalyst under non-atmospheric pressure and temperatures to produce a crude oil. This crude oil can then be distilled to produce a synthetic gasoline or fuel-grade diesel.

There are four major steps in a catalytic depolymerization process: Pre-processing, Process Fluid Upgrading, Catalytic Reaction, and Separation and Distillation. The Pre-processing step is where the feedstock is removed of contaminants and is sized. This process typically requires processing to produce a much smaller particle size with less contamination. The next step in the process is preparing this feedstock. The feedstock is mixed with water and a carrier oil (hydraulic oil) to create a sludge-type material. This sludge is sent through a catalytic turbine where the catalytic reaction under high temperature and pressure produces light oil. The light oil is then distilled to separate the synthetic gasoline or diesel oil. This catalytic depolymerization process is somewhat similar to that used at an oil refinery to convert crude oil into usable products. This technology is reportedly most effective with processing a waste stream with high plastics content and may not be suitable for a mixed MSW stream. The need for a high-plastics-content feedstock also limits the size of the facility.

There are no large-scale commercial Depolymerization facilities operating in North America that use a purely mixed MSW stream as a feedstock. There are some facilities in Europe and one in Mexico that utilize this or a similar process to convert waste plastics, waste oils, and other select feedstocks. One vendor claims to have a commercial-scale facility in Spain that has been in operation using MSW since late 2009; however operating data (including feedstock used) could not be obtained. Catalytic De-polymerization has been proposed in some locations for select portions of the waste stream with concentrated plastics content. It might be most effectively applied at a very large plastics manufacturing facility or similar industry that can become the source of the feedstock. Because such arrangements are very rare, limited interest in this technology has developed.

Benefits include the diversion of plastic and oil waste from landfill, the production of an oil or fuel product that can be used as fuel. Environmental risks are not well defined. Catalytic cracking could emit some hydrocarbons from the process. There could also be some other risks resulting from the handling of the catalysts or solvents and related compounds that might be required for the process. Water and wastewater use is also not known.

SUMMARY Thermal and Catalytic de-polymerization
Technology Classification: Chemical
Current Technology Providers: None processing waste feedstock material
General Description of Processing Technology (overview): A thermally or catalytically enhanced thermo-chemical process under pressure and the absence of oxygen to break long-chain polymers composed of hydrogen, oxygen, and carbon into shorter chains of petroleum-like feedstock (referred to as a 'light crude oil'). Thermal de-polymerization occurs in higher ranges of temperature (1,000 to 1,400 F) compared to catalytic that employ a catalyst and can occur at lower temperatures (500 to 700 F).
Inputs (acceptable feedstock composition): Materials containing cellulose (paper, paperboard, cardboard) but also organics (meats, fats, feedlot mortality, etc.)
Scalability (range of existing facility sizes): This is an emerging industry in the waste field so the scale of facilities are generally small but its application to other industries (pulp/paper and petroleum) is larger and more common.
Environmental Implications (air, noise, water, GHG emissions): Insufficient information is available regarding potential for emissions.
Products / Materials / Energy Recovered: Petroleum like by-products.
Status: New and Emerging. There have been some applications using fractions of MSW and one reported commercial scale facility using MSW; however, there has been no widespread commercial application of this technology.[3]
Reference Facility(ies)
Representative Existing Facilities: This technology is used in the petroleum industry as a part of the oil distillation process. There are no known facilities currently operating on solid waste streams.

2.1.4 Waste-to-Fuel Technology

Waste-to-Fuel could be categorized as a type of gasification process however, due to its unique byproducts, we are including this discussion to clarify the process.

There are several proposed methodologies to convert MSW into fuels. The first step in the most prevalent MSW-to-fuel technologies requires the use of a process to generate a syngas, typically a thermal conversion process such as gasification. The syngas is then cleaned to remove impurities (tars, hydrocarbons, contaminants, etc.). The next step involves a Fischer-Tropsch (FT) process which is the key component required to convert gas to a liquid synthetic fuel. The FT process is defined as a collection of chemical reactions that converts a mixture of carbon monoxide and hydrogen into liquid long chain hydrocarbons. The chemical reactions produce a variety of hydrocarbon molecules with the more useful reactions producing alkanes. Most of the alkanes produced tend to be straight-chain molecules, suitable as diesel fuel. Use of the proper catalyst in the FT process is essential to garner the highest quality fuel while not deteriorating the catalyst. There are many forms of catalyst including

[3] Niagara Region – Assessment of Alternative Waste Management Technologies, Technical Memo No. 2, January 2014, HDR.

cobalt and ferrous based. Issues associated with using syngas from MSW gasification in the FT process include the contaminants in MSW syngas and low ratios of H_2 to CO. This FT process is usually followed by a hydro-cracking process. Hydro-cracking is required to break up the long-chain hydrocarbons into liquid fuels. The very long-chained hydrocarbons are waxes, which are solid at room temperature. Therefore, for production of liquid transportation fuels it is usually necessary to crack some of the FT products. Subsequent stages than can be applied as part of waste to fuels processes include: methanol synthesis; mixed alcohol synthesis; or syngas fermentation. Each process features different reaction pressures and temperatures, require different syngas composition, and use different catalysts.

Feedstock preparation, gasification, syngas clean-up and fuel synthesis are commercially viable at some scale using select feedstock materials such as biomass, coal or petroleum based materials. However, when using mixed waste streams as a feedstock, these systems as a whole are still in the demonstration or early commercialization stages. INEOS constructed the Indian River BioEnergy Center in Vero Beach, Florida and began processing biomass in anticipation of producing cellulosic ethanol at a commercial scale in late 2013. However, this facility encountered operational difficulties and ceased operation. The Enerkem facility in Edmonton Alberta, has constructed a waste to fuels facility as part of Edmonton's integrated waste management facility. Enerkem states that it will handle up to 100,000 metric tpy of carbon rich feedstock when operating at full capacity. The fuel feed for the Enerkem facility is produced through processing of various streams of materials recovered from the other facilities that form the full waste management complex for the city, processing both MSW and biosolids. Benefits include the potential production of an ethanol based fuel. Drawbacks include air emissions impacts associated with the thermal gasification and syngas conditioning process and the potential for only being able to produce fuel from a biomass only feedstock. In addition, there are solid and liquid wastes associated with this technology.

SUMMARY Waste to Fuel
Technology Classification: Thermal
Current Technology Providers: Enerkem
General Description of Processing Technology (overview): Feedstock preparation (screening, shredding), followed by gasification, syngas clean-up and fuel synthesis are commercially viable at some scale using select feedstock materials such as biomass, coal or petroleum based materials.
Inputs (acceptable feedstock composition): Woody biomass, and cellulosic material.
Size (range of existing facility sizes): Up to 100,000 tpy reported capacity for Enerkem facility in Edmonton.
Environmental Implications (air, noise, water, GHG emissions): The possibilities of significant environmental if this technology is developed fully. Environmental implications include air emissions from gasification.
Products / Materials / Energy Recovered: Petroleum like based fuels.
Status: Transitioning to Commercial Scale. Two commercial sized facilities have been developed, one of which is closed (Inneos). In general terms, this technology is developing from pilot to commercial scale but is more common for materials such as biomass, coal or petroleum based materials.[4]
Reference Facility(ies)
Representative Existing Facilities: Enerkem, Edmonton AB; Inneos, Florida - formerly operating but currently closed.

[4] Oregon Metro Solid Waste Plan Phase 3 Final Report, March 2015. HDR.

2.1.5 Pyrolysis

Pyrolysis is an emerging technology in MSW and biosolids management that has been found to minimize air emissions, while generating syngas that can be converted to energy and biochar, a soil amendment.

Pyrolysis is a thermal process where carbonaceous materials (waste materials such as woody wastes but also paper, food, sewage sludge or biosolids) are exposed to heat while being starved of oxygen, usually in the presence of a catalyst to enhance the process. The process results in the material degrading into a gaseous form called syngas that is then refined to remove impurities, synthetic oil obtained from the cooling of combustible vapours and an ash or biochar containing remaining carbon and inert materials. The ash or a biochar produced can be disposed of in landfills or potentially used as soil amendment. Pyrolysis is most commonly used on separated organic materials that allow for the recovered char to be used as a soil amendment.

Some high-temperature gasification facilities for MSW may employ a form of pyrolysis as part of the overall system, but not as the primary technology. For example the Chiba City Thermoselect High Temperature Reactor process combines slow pyrolysis with high-temperature gasification and ash melting.[5] Other demonstration facilities for MSW or components of MSW have been developed in jurisdictions outside North America.

While there are few examples of biosolid pyrolysis projects in North America, there is recognition that biosolids can serve as a renewable energy source to offset energy requirements at waste treatment facilities. Pyrolysis projects, such as those being investigated by the Bay Area Biosolids to Energy Coalition are aiming to provide viable, year-long alternatives to land application programs that go beyond biosolids-to-energy goals by also seeking to recycle biochar back into the environment. There are few pyrolysis projects at a demonstration or commercial scale applying pyrolysis to MSW or pre-processed MSW streams. A few large scale facilities in the US were not able to successfully operate (Baltimore, San Diego). A small German facility did operate for many years from the mid-1980s. Agilyx has a demonstration facility in Oregon which has applied pyrolysis to plastic waste.

SUMMARY Pyrolysis
Technology Classification: Thermal
Current Technology Providers: Agilyx, Mitsui; Compact Power; PKA; Thide Environmental; WasteGen UK; International Environmental Solutions (IES); SMUDA Technologies (plastics only); Utah Valley Energy.
General Description of Processing Technology (overview): Pyrolysis could be described as a form of gasification but employs a catalyst to enhance the process. Like gasification, pyrolysis is a thermal process where carbonaceous materials (waste materials such as woody wastes but also organics such as paper, food, sewage sludge or biosolids) are exposed to very high heat while being starved of oxygen. The process results in the material degrading into a gaseous form called syngas that is then refined to remove impurities.
Inputs (acceptable feedstock composition): Woody biomass, and cellulosic material (paper products, biosolids)

[5] City of Sidney, Advanced Waste Treatment Master Plan (March 2014)

SUMMARY Pyrolysis
Size (range of existing facility sizes): There are no known facilities operating. Facilities in the range of 4,000 to 36,000 tpy are reportedly under development.
Environmental Implications (air, noise, water, GHG emissions): Air emissions from waste conversion systems employing pyrolysis are primarily those discharged from the energy recovery device, which, for example, could be an internal combustion engine-generator set or a steam boiler.
Products / Materials / Energy Recovered: Syngas materials for further refinement into fuels, biochar.
Status: New and Emerging. Several projects employing a pyrolysis process have been developed over the years to treat MSW or specific feedstock materials typically found in MSW. Some of the facilities have processed MSW at the pilot-scale and at the demonstration-scale; however, none have been developed to a commercial scale in the United States.
Reference Facility(ies)
Representative Existing Facilities: No operating commercial facilites, some bench / research scale facilities.

2.1.6 Gasification Technologies

The gasification technologies represented in the RFEOI submissions included:

a) conventional gasification proposed by ICC, with the feedstock being Refuse Derived Fuel from pre-processing the MSW stream mixed with dried digestate from AD of organic materials; and
b) a form of advanced gasification proposed by Pivotal, including fast internally circulating fluidized bed (FICFB) gasification or circledraft technology with the feedstock being biomass sorted via manual and mechanical processing.

Another gasification technology which was not represented in the RFEOI submissions is Plasma Arc Gasification (or Plasma Gasification) which alternatively may be referred to as High temperature Gasification with ash melting/vitrification depending on its application.

Plasma Arc gasification has been used for a range of industrial disposal applications for mostly homogenous waste streams such as gasification of hazardous waste, auto shredder residues and other materials for some time. It has only been within the last 10 to 15 years that application of this technology to MSW or pre-processed MSW has been undertaken. Plasma arc technology uses carbon electrodes to produce a very-high temperatures arc ranging between 3,000 and 8,000 degrees celcius that "vaporizes" the feedstock. This creates a high temperature ionized gas (or "Plasma"). The heat of the plasma breaks down the feedstock to basic elemental compounds. The syngas created can be combusted and heat recovered in a HRSG or the syngas can be cleaned and combusted directly in an engine or gas turbine to produce energy and/or thermal energy. Inorganic material in the feedstock is melted to form a slag material. MSW should be pre-processed to remove bulky materials and inerts, while homogenizing the feedstock. Syngas clean-up systems and/or air pollution control systems are required to control emissions. There have been demonstration facilities using MSW in North America including the Plasco facility in Ottawa (now decommissioned), Alter NRG in Madison Pennsylvania, and PyroGenesis which has a demonstration unit on an airforce base in Florida.

Commercial operations of facilities in Japan include facilities that use mostly industrial waste or materials with high energy content. Many of the facilities in Japan are referred to as plasma direct melting reactors, with their primary focus being to melt the ash remaining after gasification, in order to render the ash inert. One large facility intended to gasify MSW and recover energy had been proposed to be built in the Tees Valley in the UK, however, this project was cancelled. A smaller facility is under development near Birmingham, UK.

SUMMARY Plasma Gasification
Technology Classification: Thermal
Current Technology Providers: Alter NRG, Advanced Plasma Power, Thermoselect, Ebara, PyroGenesis
General Description of Processing Technology (overview): Plasma arc gasification uses electrical energy and extremely high temperatures (3,000 to 8,000°C) (5432 to 14,432 °F) to break down the organic portion of the waste into its elemental compounds and produce a syngas. Some plasma arc technologies use pure oxygen in the waste conversion process to improve the quality of the syngas. Once cleaned, the syngas can be combusted directly in an internal combustion engine, gas turbine, or for liquid fuel synthesis. Inorganic materials in the municipal solid waste are melted and then cooled and hardened to form a slag material which encapsulates pollutants.
Inputs (acceptable feedstock composition): High BTU Industrial Waste, Pre-processed MSW
Size (range of existing facility sizes): Modular units constructed at a pilot scale up to 100 tpd. There are larger units in development.
Environmental Implications (air, noise, water, GHG emissions): Similar to conventional gasification, the air emissions from plasma gasification systems are primarily discharged from the energy recovery device. The treatment of syngas produced from the plasma technology processing municipal solid waste for use in energy conversion equipment and emission control of syngas constituents has limited operating history. Solid residues from plasma gasification are in the form of a glass-like vitrified slag, which is claimed to be inert.
Products / Materials / Energy Recovered: Syngas, chemical by-products, vitrified slag.
Status: Emerging in regards to MSW applications outside of Japan. Have been used for commercial scale operations in Japan primarily for industrial materials.
Reference Facility(ies)
Representative Existing Facilities: Ebara Aomori facility in Japan, Thermoselect Chiba City Recycling Centre in Japan, Alter NRG Mihama-Mikata facility in Japan.[6][7]

2.1.7 Combustion and Energy from Waste (WTE, EfW or Mass Burn)

Combustion, (also waste-to-energy or energy-from-waste or mass burn) is a thermal process where carbonaceous materials (MSW, waste materials such as woody wastes but also paper, plastic, food, sewage sludge or biosolids) are exposed to very high heat with high levels of oxygen (burning). The exhaust from the burning process is treated through a series of emission control systems to remove particulates, dioxins, furans, sulfur and other pollutants. Heat from the process is used to produce steam and hot water which are used to produce electricity using a steam turbine. Steam or hot water from the system can also be used for heating

[6] Oregon Metro Solid Waste Plan Phase 3 Final Report, March 2015. HDR.
[7] City of Sidney, Advanced Waste Treatment Master Plan (March 2014)

purposes such as district heating schemes. Water used in the power generation process is recirculated through the system.

Combustion is thought by some as less environmentally friendly processing due to concerns regarding air emissions, and generation of an ash product which is most commonly landfilled. Recently, however, combustion is being viewed as a more attractive process by some jurisdictions as technical and process improvements have become available, such as more efficient heat recovery and power generation and significant improvements in air pollution control systems. Ash treatment and recovery systems have also been developed to recover solid materials from ash for beneficial use. EfW is the most common form of waste treatment in much of Europe, where many advancements have been made in the design and operation of the combustion units and air pollution control systems[8]. Modern combustion systems are being designed to achieve strict emission limits while also being energy efficient [9]. The most recent EfW facility in Canada was developed in the Regional Municipality of Durham, to process 125,000 tpy of residual waste (remaining after diversion) from the Regional Municipalities of Durham and York. This facility was commissioned in 2015 and is in full operation.

SUMMARY Combustion (Waste to Energy, Energy from Waste)
Current Technology Providers: Covanta, Babcock and Wilcox, Veolia
General Description of Processing Technology (overview): Waste to Energy and Energy from Waste facilites burn feedstock, using the heat to produce steam to power turbines to produce electricity. Often heat energy is recovered for industrial or district heating purposes.
Inputs (acceptable feedstock composition): MSW, biosolids
Scalability (range of existing facility sizes): Existing WTE facilities range from as small as 50 tons per day to over 1,000 tons per day.
Environmental Implications (air, noise, water, GHG emissions): The scientific community is mixed as to the environmental benefits of this technology. Although most of Europe embraces WTE as superior to landfilling, the US scientific community has concerns regarding air emissions, the resulting ash and water use.
Products / Materials / Energy Recovered: Electricity, commercial (high pressure) steam, district heat, metals, ash.
Reference Facility(ies)
Representative Existing Facilities: There are 82 operating facilities in the US. The nearest WTE facility is the Burnaby facility in BC. Newest Canadian facility is in Durham Region, ON.

[8] Waste to Energy, A Technical Review of Municipal Solid Waste Thermal Treatment Practices, prepared for the BC MOE, Stantec Ltd. (March 2011)
[9] World Energy Council, World Energy Resources, Waste to Energy (2016)

2.1 Beneficial Reuse of Biosolids Jurisdictional Review, Summary of Biosolids Management Technologies

This jurisdictional review identified a series of well-established biosolids management facilities and programs, as well as a series of emerging technologies with more limited use as of the time the review was completed. The report discussed examples of the techniques used by other jurisdictions across BC, which would fall under the BC Organic Material Recycling Regulations (OMRR) and across other jurisdictions with differing regulations. The technologies identified in the jurisdictional review are outlined in Table 2.

Table 2 Summary of Technologies Represented in the Biosolids Jurisdictional Review

Emerging Technologies	Number of Jurisdictions Cited in Review	Status of Technology/Facilities	End Product Produced
Biogas Utilization – Fuel	2	Operational	natural gas vehicle fuel / renewable natural gas
Thermal Hydrolysis	1	Design	Biogas, Class B Biosolids
Biological Hydrolysis	1	Operational	Biogas, Class A Biosolids
Biodiesel Production	1	Operational	Biodiesel, Class A and B Bisolids
Gasification	3	Operational / Pilot	Syngas, Ash/Biochar
Pyrolysis	2	Evaluation/Construction	Pygas, Biochar
Fluidized Bed Combustion	1	Operational	Heat & Steam to Energy, Ash

Established Class A Biosolids Management Technologies	Number of Jurisdictions Cited in Review	Percentage of Class A Biosolids Produced (Directed to System)	Beneficial Reuse of Biosolids
Anaerobic Digestion (Thermophilic, Mesophilic)	2	80 / 30	Application as fertilizer, range of uses including forest fertilization
Aerated Static Pile Composting	3	100 / 2	Application as compost, range of uses
RDF Lime-pasteurization	1	5	Application as Fertilizer, range of uses

Co-composting with Organic Waste	1	80	Compost, range of uses
N-Viro Alkaline Stablization / Lime Stabilization	4	50/75/100	Application as fertilizer, range of uses, biodiesel production
Covered Aerobic Static Pile Composting	1	100	Application as fertilizer, range of uses
Thermal Drying	2	100	Agriculture, cement kiln fuel

The emerging technologies identified in the jurisdictional review are much the same as those identified in Section 2.1 of this gap analysis, and generally can be applied to other solid waste feedstock as well as liquid waste streams.

The established biosolids management technologies, with the exceptions of RDF Lime-pasteurization and Alkaline or Lime Stabilization can also be applied to other solid waste feedstock and are represented in the technologies as identified in the CRD IRM RFEOI submissions.

The facilities and investigations represented in the jurisdictional review focused only on technologies/facilities in current or proposed use in North America. There are other facilities outside of North America that have applied other advanced technologies to successfully process biosolids. For example, in Balingen Germany there is a gasification facility that has been successfully expanded including a biosolids drying component and expansion of the gasification unit in 2011. This facility has been used to process biosolids imported from Alaska on a trial basis. A similar demonstration facility was developed in Mannheim Germany.

3. IRM Feedstock Analysis and Feedstock Combinations

The CRD has identified the following feedstock materials as being potentially available for an IRM solution:

1. 35,000 tonnes per year of Class A biosolids;
2. 120,000 to 135,000 tonnes per year of general municipal refuse;
3. 8,000 to 12,500 tonnes per year of controlled waste (including screenings and sludge from existing wastewater plants);
4. 15,000 to 20,000 tonnes per year of source separated household organics (kitchen scraps and compostable paper, not including yard and garden wastes); and,
5. 15,000 to 18,000 tonnes per year of yard and garden wastes.

In addition, the CRD has also maintained the option that the IRM facility could also accept up to 50% of the raw sewage sludge generated in the CRD, ranging up to 55,429 kg-TS/day (Peak 10-day year McLoughlin Residual Solids load).

As noted in the CRD IRM Facility Tour Plan (report under separate cover to the IRMAC), there are few facilities that currently process all of the potential solid and liquid waste feedstock of interest to the CRD. It is likely that an IRM solution would require co-location or a combination of technologies to address the full spectrum of CRD materials.

Table 3 presents a matrix of technologies and material streams that are currently being used in commercial operating facilities, to assist in understanding how the technologies could be applied to the CRD solid and liquid waste streams. In most cases, the feedstock processed by a commercial operation reflects whether there is a viable business case for directing that type of feedstock for processing, considering factors such as the operating and capital cost range for the technology and the market value for materials and/or energy that could be recovered. For example, it would be difficult to make a business case to direct low energy value waste streams to a thermal technology. It may be theoretically possible to process a type of feedstock with the technology, however the information gathered to-date for the IRM project does not indicate any commercial applications. Where a technology is not applicable at all due to the nature of the material stream, NA is indicated.

Table 3 Matrix of IRM Technologies and Potential Feedstock

Technology	Biosolids	Sewage Sludge	Municipal Solid Waste (MSW)	Source Separated Organics (SSO)	Leaf and Yard Waste (LYW)	Controlled Waste
Mechanical Sorting	NA	NA	Yes	Yes	NA	NA
Autoclave / Steam Classification	NA	NA	Yes	Yes	NA	NA
Composting	Yes	Yes	Organic Fraction Only	Yes	Yes	Organic Material Only
Dry or High Solids Anaerobic Digestion	Yes	Yes	Organic Fraction Only	Yes	Yes	Organic Material Only
Wet Anaerobic Digestion	Yes	Yes	Organic Fraction Only	Yes	Yes	Organic Material Only
Gasification	Yes, dried	Yes, dried	RDF recovered from mechanical sorting	No	No	No
Electro-thermal Gasification	No	No	No	No	No	No
Pyrolysis	No	No	Organic Fraction Only	No	No	No
Waste to Fuel	Yes, pre-processed with MSW	No	Organic Fraction Only	No	No	No
Combustion	Yes	Yes	Yes	No	No	Yes

Technology	Biosolids	Sewage Sludge	Municipal Solid Waste (MSW)	Source Separated Organics (SSO)	Leaf and Yard Waste (LYW)	Controlled Waste
Refuse Derived Fuel	Yes, dried	Yes, dried	High Btu fraction following mechanical sorting	No	No	Yes, pre-processed and/or dried materials
Thermal and Chemical Hydrolysis	Yes	Yes	Yes, Cellulosic materials only	No	No	No
Catalytic and Thermal Depolymerization	Yes	Yes	Yes, Cellulosic/ Organic materials only	No	No	No
Nutrient Recovery	Yes	No	No	No	No	No
Lime Pasteurization	Yes	Yes	No	No	No	No
Lime Stabilization	Yes	Yes	No	No	No	No

Table 3 clearly demonstrates that no one technology is capable on its own, of processing all of the CRD Solid and Liquid waste streams. At minimum, some form of pre-processing is required to select for the appropriate constituents feedstock to allow for efficient operation of the technology. For example this could come in the form of mechanical sorting of the MSW stream to select for the high energy fraction (paper, plastic), organic fraction (paper, food waste) or cellulosic fraction (paper, wood).

In addition, material streams like Source Separated Organics and Leaf & Yard waste, are not commonly directed to many of the technologies, as usually they are directed to a sub-set of these technologies (composting or AD) which can potentially be more cost effective and recover compost or soil amendments for beneficial use.

For a CRD IRM solution to be successful, it will require consideration of the appropriate combination of technologies and the appropriate combination of feedstock materials, considering:

a) The properties of the feedstock materials (chemical composition, heating value, moisture content etc.);
b) The quantities of the feedstock materials considering the quantities required to achieve economies of scale as well as the availability of these materials considering flows of materials that are controlled by and that are not controlled by the CRD;
c) Requirements for amendments and other supplemental materials (e.g. woody amendment materials);
d) The range of beneficial materials that can be recovered, and the markets for these materials;
e) The economic implications associated with applying specific technologies to this feedstock.

Each of these points is discussed in greater detail below.

In regards to the properties of the feedstock materials, the CRD commissioned a report completed in September 2016 by TWE, the *Gasification Technologies, Characterization of Waste Resources in the Capital*, to assess the properties of the CRD MSW stream (composition, energy content, biomass fraction, renewable energy content and biogenic carbon content), in order to understand the energy recovery potential of these materials. This analysis was based upon a waste composition study undertaken for the CRD in 2009/2010. While this study provides a basis for understanding the general properties of the MSW stream and the potential applicability of primarily thermal technologies to MSW, it has some limitations given:

a) There have been changes to the waste programs in the CRD since the 2009/2010 waste composition study was undertaken, particularly with the food scrap ban, which would shift the compositional analysis, potentially reducing moisture content and increasing the energy value of the MSW stream.
b) This analysis did not address the composition of the other solid waste streams, nor the liquid waste stream.
c) The composition of the MSW stream and other solid waste streams could be expected to shift over time as a result of programs implemented by the CRD and member jurisdictions, and to reflect changes in waste generation rates based on changes in the marketplace.

Further analysis of the solid and liquid waste stream will be required to support the IRM Project Plan including the IRM procurement process, as outlined in the IRM Project Plan outline. Predictions regarding the change in generation rates and composition of the solid material streams would be supported by the CRD Solid Waste Management Plan (SWMP).

As reported by CRD Staff at the June 28, 2017 IRMAC meeting, of the total waste materials generated in the CRD estimated as approximately 208,000 tonnes per year combined, the CRD has control over approximately one third, including only 30% of the source separated organics stream and 15% of the MSW stream while controlling 100% of the yard waste stream and biosolids related streams. In order to achieve reasonable economies of scale for the majority of the IRM technologies identified, a larger portion of the MSW and/or source separated organics streams would be required. This could be achieved either through some form of regulatory control (flow control), or through functional competition of an IRM solution in comparison to other waste management facilities through market forces. The ability of an IRM solution to present a competitive solution cannot be determined until the IRM RFQ and Preliminary Business Case are completed as set out in the IRM Project Plan outline.

The same can be said regarding the need for supplemental materials, as these range significantly depending on the type of IRM processing technology. Processes like composting for example, may require bulking agent (woody materials) to achieve the appropriate carbon/nitrogen ratios and porosity for aerobic composting. Anaerobic Digestion processes may be improved or supplemented by clean, high energy commercial food waste streams. Many of the emerging technologies identified by respondents to the RFEOI indicated requirements for woody/cellulosic materials to supplement those found in the MSW stream. The IRM RFQ process would further determine, based on the responses and technologies identified, if there would be a need for the CRD or the respondents to source supplemental materials in order to implement an IRM solution. The preliminary Business Case would need to analyze the current market value of any supplemental materials and the issues that could arise in sourcing/securing these material streams.

The combination of appropriate IRM feedstocks, needs to consider the range of beneficial materials that could be recovered and the market value of these materials. Overall, when considering the range of products (materials and energy) that could be recovered, it helps to think of the solid and liquid waste streams, not as 'waste' but as various forms of resources, some of which have a higher value and some that have a lesser value depending on the market. The decision for example as to whether it is reasonable to direct yard and garden waste to a dry anaerobic digestion facility or to a composting facility (along with other CRD waste streams) should reflect the ability to generate biogas from this material, and the value of that biogas to the value of the compost product should this material continue to be composted. The decision on whether the MSW stream should be mechanically processed to recover recyclable materials and/or an organic fraction for further processing and/or a solid recovered fuel, should reflect whether the effort to recover these materials is worth it based on the market for the final products. The IRM RFQ process will assist in this determination, along with the preliminary Business Case which will need to examine local market conditions.

As the IRM Project Plan proceeds, the economic implications associated with an IRM solution will need to be addressed. This would be addressed by the development of a preliminary Business Case based on the outcome of the RFQ and a final Business Case based on the outcome of the RFP. The Business Case for the project would consider:

a) Current and projected market values for recovered materials and/or energy as discussed above;
b) The assessment of project risks and evaluation of service delivery models, as generally direct capital and operating costs increase as the amount of risk allocated to the contractor increases. Risk allocation is reflected in the service delivery model chosen, with Design Build contracts allocating the most risk to the CRD and Design Build Finance Own Operate contracts allocating the most risk to the contractor;
c) Competitive market conditions in the surrounding area for solid waste processing. Essentially directing specific feedstock to an CRD IRM solution would be more economically viable if it is cost competitive with any other facilities that could process or dispose of the same materials (also considering haul costs);
d) The direct capital and operating cost for the technology or combinations of technologies that are identified by the respondents in the IRM procurement process. This would be identified generally as an outcome of the IRM RFQ, and specifically as an outcome of the IRM RFP process.

Ultimately, the decision regarding appropriate IRM feedstock combinations needs to be supported by the next steps in the IRM Project Plan.

4. Systems Integration

The IRM project is dependent upon and needs to be integrated with the plans and existing systems associated with the management of the CRD's solid and liquid waste stream. Decisions made during the IRM process, will affect the CALWMP and SWMP planning and implementation processes, and vice versa. This is discussed within the IRM Project Plan Outline.

For example, the outcome of the CALWMP RFP for a Residual Treatment Facility will determine the quantity and composition of the biosolids stream that could be directed to an IRM solution. The timing of implementation of an IRM solution, will impact upon the requirements for short-term biosolids storage. In addition, there may be opportunities for integrating resource recovery for an IRM solution and the RTF, for example the implementation of technologies capable of recovering nutrients from the liquid fraction remaining after biosolids dewatering or use of biogas from the RTF to dry biosolids for IRM applications.

The existing solid waste management system and the changes that could result based on the SWMP process, will have an effect on the quantity and composition of solid material streams that could be directed to an IRM solution. They also represent opportunities for co-management or co-marketing of materials. For example biogas generated through anaerobic digestion of organics could be co-managed/co-marketed with landfill gas (LFG) and the availability of shared infrastructure and higher combined gas flows could improve the viability of both IRM and landfill related biogas recovery infrastructure.

Decisions regarding the technology or combination of technologies that would comprise an IRM solution, and the feedstock that would be directed to an IRM solution, must be integrated with the other concurrent IRM planning processes, and consider the effect on the CRDs overall liquid and solid waste management systems.

5. Conclusions and Next Steps

Generally with one exception, the range of established technologies capable of managing the CRD solid waste streams were represented in the CRD IRM RFEOI submissions. The one exception relates to WTE/EfW technology which is an established waste management practice in many jurisdictions. The technologies that were not captured in the RFEOI process, consist largely of emerging thermal technologies with few pilot or representative facilities of any scale currently in operation. The technologies identified in the RFEOI submissions also captured the range of established technologies identified in the separate biosolids jurisdictional review, and are capable of managing the range of solid and liquid IRM materials including Class A biosolids and/or sewage sludge. The emerging technologies identified in the biosolids jurisdictional review include many of the same emerging technologies identified in this Gap analysis.

It is clear based on the review of the technologies presented in the RFEOI submissions, the analysis of additional technologies not captured in the RFEOI process and the technologies identified in the jurisdictional review, that there is not one single technology applied at an operating facility that has managed the full range of IRM solid and liquid feedstock. It is anticipated that further steps in the IRM Project Plan, including the proposed RFQ process, will identify a viable sub-set of technologies that would be applicable to both the solid and liquid CRD waste streams that could be developed for the CRD by qualified companies. A successful IRM solution is most likely to consist of a combination of technologies at a single facility, or a combination of facilities, integrated into the CRD’s overall system for solid and liquid waste management.

For a CRD IRM solution to be successful, it will require consideration of the appropriate combination of technologies and the appropriate combination of feedstock materials, considering:

a) The properties of the feedstock materials (chemical composition, heating value, moisture content etc.), which will be supported by the CRD Solid Waste Management Plan (SWMP).
b) The quantities of the feedstock materials considering the quantities required to achieve economies of scale as well as the availability of these materials considering flows of materials that are controlled by

and that are not controlled by the CRD. Economies of scale could be achieved either through some form of regulatory control (flow control), or through functional competition of an IRM solution in comparison to other waste management facilities through market forces. Flow control would be addressed through the assessment of policy/project implications in the SWMP.

c) Requirements for amendments and other supplemental materials (e.g. woody amendment materials). The IRM RFQ process would determine, based on the responses and technologies identified, if there would be a need for the CRD or the respondents to source supplemental materials in order to implement an IRM solution. The preliminary Business Case would need to analyze the current market value of any supplemental materials and the issues that could arise in sourcing/securing these material streams.
d) The range of beneficial materials that can be recovered, and the markets for these materials. The outcome of the IRM Facility Tour and IRM RFQ process will assist in this determination, along with the preliminary Business Case which will need to examine local market conditions.
e) The economic implications associated with applying specific technologies to this feedstock. . This would be addressed by the development of a preliminary Business Case based on the outcome of the RFQ and a final Business Case based on the outcome of the RFP

There is a real potential that the outcome of the initial steps of the IRM Project Plan, including the RFPQ and Preliminary Business Case, may indicate that either a phased solution or a multi-facility approach may be identified as more feasible approaches to implement an advanced IRM solution for the CRD. For example, it may be made clear that initially the focus of an IRM facility should be the management of biosolids and a smaller subset of other CRD materials, with the option that over time either a facility expansion or an additional facility could be developed to manage other CRD materials. A phased approach could be developed by the same or a different entity. Alternatively, it may become apparent that the most feasible IRM solution may include more than one facility at the outset, developed by different entities, managing separate CRD material streams.

Decisions regarding the technology or combination of technologies that would comprise an IRM solution, and the feedstock that would be directed to an IRM solution, must be integrated with the other concurrent IRM planning processes, and consider the effect on the CRDs overall liquid and solid waste management systems.

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