New and Emerging Residual Waste Management Technologies Update

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Executive Summary

The Regional District of Nanaimo (RDN) and Cowichan Valley Regional District (CVRD) retained Gartner Lee Limited to conduct a preliminary review of new and emerging residual waste management technologies. The primary objective of this review was to determine if any of these technologies might have some applicability to the regional districts in the foreseeable future and thus help direct resources for future consideration of residual waste management options.

It should be noted that this study is only a preliminary review of technologies based on readily available information and not an exhaustive, technical review or feasibility analysis. The research entailed reviewing existing reports, particularly those done for Canadian local governments, web research and phone interviews.

Residual waste processing technologies can be grouped into four major types: physical, biological, chemical and thermal. The review considered the status, costs, advantages and disadvantages of each of these types of technologies. Although residual waste management systems often engage more than one technology such that a system may include a mechanical process to start with, a biological process as the next phase and apply the remaining residuals to a thermal process, each type of technology was reviewed independently. All of the technologies generate some residuals that ultimately require landfilling. The need for landfills is not eliminated by any new and emerging technology.

Most of the technologies reviewed are considered technically viable for managing residual MSW, having been proven at least at a commercial demonstration scale, in Europe, Japan or North America. However, most of these technologies have not been economically proven in a North American context, as commercial scale facilities have not been established on the continent, or, having been established, have generally failed for financial reasons. This means that there is a significant lack of relevant information regarding real costs and benefits of these new and emerging technologies, which in turn increases the risks associated with adoption. Table 1.1 illustrates the technical and economic status of technologies reviewed. The economically proven technologies, material recovery facilities, refuse derived fuel processes, municipal solid waste composting and incineration, generally do not fall into the category of new and emerging technologies, but are of interest due to their capabilities for managing residual wastes.

Table 1-1 Technical and Economic Status

Technology	Technical Viability	Economic Viability in North America
Material Recovery Facilities (MRF)	√	√
Refuse Derived Fuel (RDF)	√	√
Steam	X	X
Aerobic MSW Composting	√	√
Anaerobic Digestion	√	X
Fermentation (Ethanol Production)	X	X
Chemical	X	X
Incineration/Waste-to-Energy	√	√
Gasification	√	X
Pyrolysis	√	X

The availability and quality of relevant cost data varied depending on the type of technology reviewed. Recent Canadian reports on requests for expressions of interest (REOI) provided some insight, as did comments from individuals directly responsible for, or involved in, MSW technology analysis and implementation. Generally, new and emerging approaches for residual MSW management are capital intensive and expensive to operate compared to conventional landfills, with costs ranging from $70 to $217 per tonne. How transferable these costs are to the RDN and CVRD and how comparable they are to direct landfilling is not known since:

- costs are affected by economies of scale;
- cost of landfilling does not typically recognize full cost accounting; and
- cost estimates for technologies are only a component cost of a residual waste management system and not a whole system cost.

The various types of technologies reviewed varied considerably in terms of their advantages and disadvantages. Generally, many of these technologies can provide significant value in terms of the amount of waste diverted from landfill. Some have the added advantage of maximizing the recovery of marketable recyclables, whereas others have the added advantage of maximizing energy recovery and power generation potential. Where intermediate or unconventional primary products are produced, including Class B compost, RDF, steam, syngas and bio-oil, challenges arise regarding marketability. This issue may translate into a disadvantage depending on the context, and if so, will affect economic viability and costs.

Although the review was not conclusive regarding the viability of residual waste processing, the research process unveiled that there is a significant amount of local government level analysis of options underway in regions across Canada, including Halifax, Toronto, York, Niagara and Edmonton. The California Integrated Waste Management Board is also currently involved in a review of conversion technologies for MSW.

The review indicates that there may be some promise for residual waste processing in the future. The feasibility will be based on available waste quantities, the change in composition, and depending on the technology, energy markets. Hence, some continued work in this vein is recommended; specifically:

- Continue to monitor the development of the technologies that have proven to be technically viable, including refuse derived fuel, anaerobic digestion, waste-to-energy, gasification and pyrolysis.
- Keep abreast of municipal activities in Canada related to residual waste management such as those occurring in Edmonton, Niagara, York and Toronto. As pilot projects and RFP processes are completed, relevant cost information will be become available.
- Continue to monitor the work currently underway in California relating to thermal conversion technologies.
- Consider residual waste processing technologies in the context of the RDN and CVRD's whole waste management systems, as a given technology may or may not be beneficial to the current solid waste management planning direction. All of the implications of adopting a residual waste technology should be assessed before adoption.

Pending developments in these residual waste processing technologies, our findings suggest that traditional diversion activities may be the preferred option for the RDN for next few years. A conventional but aggressive waste reduction strategy could aim to divert up to 70% of the solid waste stream through maximizing organics recovery in a source-separation based program, as well as enhancing materials recovery and recycling initiatives.

1. Introduction

The Regional District of Nanaimo (RDN) and Cowichan Valley Regional District (CVRD) retained Gartner Lee Limited to conduct a preliminary review of new and emerging residual waste management technologies. The primary objective of this review was to determine if any of these technologies might have some applicability to them in the foreseeable future.

There have been many articles in North American trade journals about residual waste technologies in recent years indicating that research and progress is underway for further reducing the amount of waste going to landfill. This review was to determine if, in fact, progress has been made, to establish if any specific technology has proved out and is being adopted in other North American jurisdictions, and what technologies have been determined to be non-viable.

It should be noted that this study is only a preliminary review of technologies based on readily available information and not an exhaustive, technical review or feasibility analysis. The research focused on residual waste processing technologies and did not consider enhancements to waste diversion initiatives (e.g., improvements to the recycling collection program) or landfill space maximization opportunities.

Figure 1-1 Residual Waste at the RDN Regional Landfill

The research entailed reviewing existing reports, particularly those done for Canadian local governments, web research, and phone interviews with individuals who have been and are closely involved in the review of residual waste technologies. Much of the focus of the research was on southern Ontario, as this area of Canada has been avidly searching for solutions for their residual waste volumes. However, experience in other parts of Canada, the US, Europe and Japan was also included in the research process.

2. Background Information

Often, the viability of a certain technology is dependent on the type of waste stream (e.g., municipal, industrial, agricultural, etc.), the quantity of waste available and the composition of the waste stream. This section of the report looks at the potential quantity of residual waste, the current composition of the waste stream and policies/programs that may impact upon both the quantity and the composition.

2.1 Waste Quantities

Many residual waste processing technologies have been developed to address the large waste volumes generated in major urban centres. Because of the large volumes, certain economies of scale can be achieved. On a relative basis, the current quantity of residual waste generated in the RDN (60,000 tonnes per year) and CVRD (26,000 tonnes per year) is not large, making it economically challenging to consider many available waste management technologies. However, combining the volumes may make some technologies more viable. There is also the potential for involving waste from other nearby jurisdictions, such as the Capital Regional District (CRD). By including the CRD's residual waste (144,000 tonnes per year), the quantity of residual waste is increased to over 200,000 tonnes per year, such that the quantities are more in line with the quantity generated by a major urban centre.

Table 2-1 Residual Waste Projections (with current waste diversion rate)

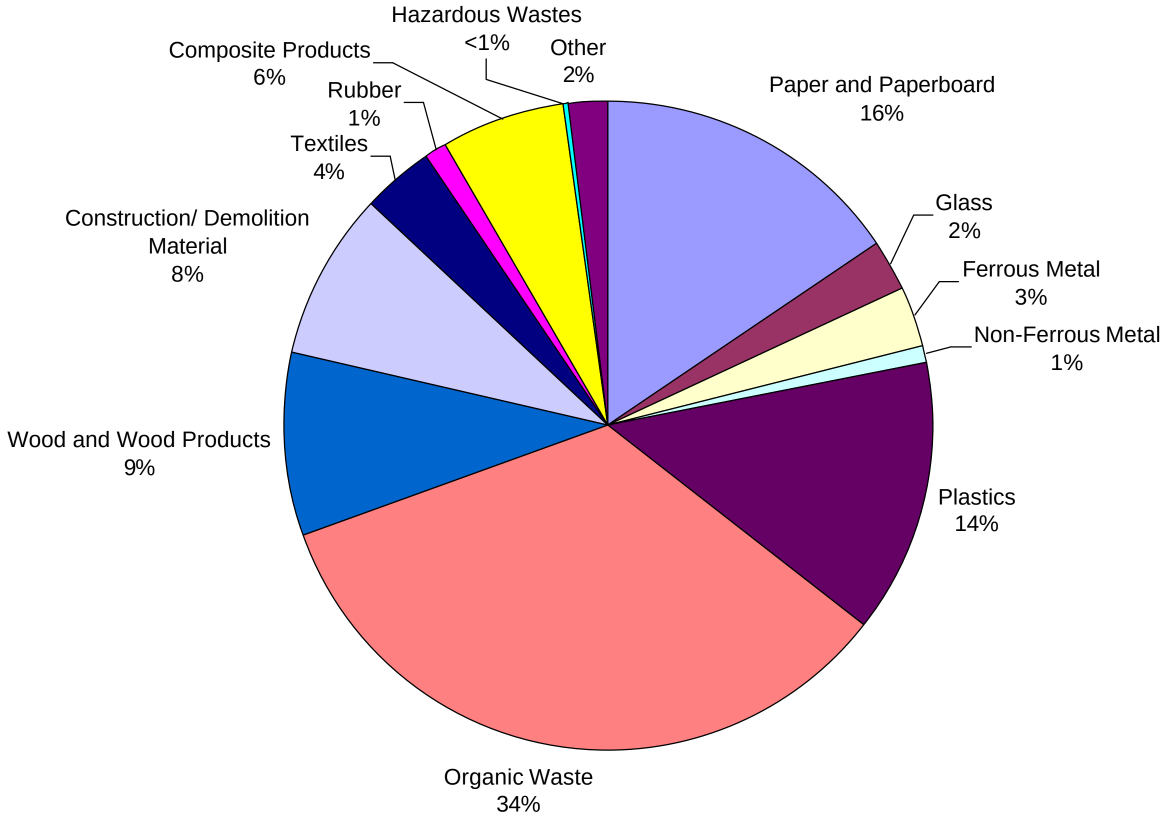
	RDN	CVRD	RDN + CVRD	Tonnes Per Day	CRD	Total	Tonnes Per Day
2003	60,000	26,000	86,000	235	144,000	230,000	630
2013	73,140	31,694	104,834	287	175,535	280,369	768
2023	89,157	38,635	127,791	350	213,976	341,768	936

The quantity of residual waste is expected to increase as the population grows. Table 2-1 provides a very rough projection of the growth of the residual waste if no additional waste diversion is achieved and the population in the area grows by 2% per year for the next 20 years.

2.2 Waste Composition

The composition of the RDN and CVRD waste stream is estimated based upon a 2001 waste composition study conducted in the Capital Regional District.[1] The CRD has similar solid waste management policies and programs, landfill tipping fees and climate to the RDN and CVRD, hence the data from their study provides a good indication of the composition of the waste disposed. The composition, shown in Figure 2-1, indicates that the largest components disposed, by weight, are organic waste (34%), paper products (16%), plastic (14%), construction/demolition waste (8%) and wood (9%).

Figure 2-1 Estimated Waste Composition



The composition is particularly important for those technologies that target a specific segment of the residual waste stream. For example, some technologies such as composting and ethanol production take advantage of the organic portion of the waste stream, and the thermal technologies target the combustible components of the waste, such as plastic, paper and wood.

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[1] Sperling Hansen Associates, 2002.

2.3 Policy Initiatives

There are a number of policy initiatives in place in the RDN and the CVRD that are likely to decrease the quantity of residual waste available from those shown in Table 2-1 and affect the composition of the waste stream. These are:

- Disposal bans: Current and anticipated disposal bans on organic waste and construction wood waste will impact on both the volume and composition of waste.
- Tipping fees: With tipping fees in both regional districts approaching $100/tonne, commercial waste generators have a definite incentive to reduce their waste generation. In addition, if tipping fees increase in the future, the potential of some residual waste management technologies becomes more economically attractive.
- Waste stream management licensing: One of the objectives of the upcoming licensing system is to provide a “secure” environment for the recycling and composting industry to invest. If additional diversion activities take place as a result of licensing, both the composition and volumes will be impacted.
- Zero waste: The adoption of the “zero waste” target suggests a continual drive to reduce the volume of residual waste.
- Product stewardship: Future product stewardship programs (at a provincial or national level) could serve to further reduce the volume of waste and will likely reduce its potential toxicity, particularly as electronic waste programs come into effect.

3. Technology Review

The residual waste processing technologies can be grouped into four major categories: physical, biological, chemical and thermal. For each category of technology, the following is provided in this section:

- a brief description of the process;
- status of the technology’s development (bench, pilot, full-scale) and where there is experience with the technology;
- costs, based upon experience elsewhere or vendor claims (if available);
- advantages and disadvantages of the technology, including its diversion potential (if known).

Residual waste management systems can engage more than one technology such that a system may include a mechanical process to start with, a biological process as the next phase and apply the remaining residuals to a thermal process. The potential linkages of one technology to another are noted in the process descriptions. These multi-process systems have significant diversion potential, but the combined costs of these systems is unknown and therefore not provided.

3.1 Physical Processes

For the purposes of this report, physical processes are primarily designed to separate components of the mixed residual waste stream into utilizable and non-utilizable materials streams. The process may also involve additional pre-treatment of a segregated materials stream to make it more suitable for a designated utilization. Some of these types of processes may function as stand alone strategies for further diverting and reducing the amount of waste destined for disposal. They may also comprise part of an integrated technological solution for managing residual MSW, as is the case with some advanced thermal technology processes. Three types of physical processes are reviewed in this section:

- Materials Recovery Facilities;
- Refuse Derived Fuel Production; and
- Steam Processing for Material Recovery.

3.1.1 Materials Recovery Facility (“Dirty MRF”) Processes

Process

Materials Recovery Facilities (MRFs) provide an intermediary or pretreatment approach involving the manual and mechanical separation of an MSW feedstock into recyclable and non-recyclable materials streams. “Clean” MRF processes provide this sorting and processing function for clean, dry, commingled recyclable materials (excluding putrescibles and green wastes) derived from source segregated collection programs. “Dirty” MRF processes provide this sorting function for mixed MSW feedstocks (including putrescibles and green wastes). This section will provide further information on MRFs that process residual waste.

Generally, MRFs may be tooled to exclusively recover dry recyclables, with the wet residue and non-recyclables destined for landfill or as feedstock for incinerators/advanced thermal treatment processes. In this type of system, the recovery rates are, at best, 50 per cent. However, the process may also, or primarily, be tooled to recover the organic fraction for subsequent processing. Organics may be recovered for use as a feedstock in aerobic or anaerobic composting systems. If the organic fraction is ultimately suitable for utilization as soil amendment, then the diversion potential of the system may be as high as 70 to 80 per cent.

MRF processes typically involve a number of stages, including removal and processing of large bulky items, manual and automated sorting of recyclables and organics, and organics screening, where applicable. Bagged waste may be opened manually, or mechanically using trommel screens with knives. Typical MRF equipment used to recover marketable recyclables includes conveyors, screens, magnetic and eddy current separators, shredders, crushers and bailers.

Status

MRFs are not a new and emerging technology. There have been facilities operating at a commercial scale in North America for a number of years.

Costs

No cost information was available[2].

Advantages

- potential for high diversion rate, if both dry recyclables and compostable materials are recovered;
- no changes required to existing MSW residual collection structure; and
- potential displacement of virgin material demand due to recovery of recyclables.

Disadvantages

- high level of contamination of potentially recyclable streams; and
- lower revenue potential from recyclables due to low value and reduced quantities of recyclables recovered.

3.1.2 Refuse Derived Fuel (RDF) Production

Process

This is a type of pre-treatment approach involving the separation of MSW into combustible and non-combustible materials streams. The combustible stream, which includes plastics, wood, paper and organics, is typically shredded, dried and processed into pellets, fibre or fluff suitable for use as a fuel in subsequent processes. Typical applications include cement kilns, coal power plants, paper mills, and biomass power plants. Non-combustible materials include recyclables such as ferrous and non-ferrous metals and glass. A key distinction in terms of the types of RDF production processes available concerns how the particulate waste is dried to make it suitable for utilization as a fuel. Mechanical drying involves the application of an external heat source; biological drying ("bio-mechanical treatment") involves partial aerobic composting. In both cases, the drying process results in a stabilized, dry material suitable for subsequent separation into combustible and non-combustible materials streams.

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[2] Cost information specific to MRF systems was not found in the literature reviewed during the course of this study.

Status

RDF technologies are well developed, with plants operating on a commercial scale in Europe and North America for five or more years. In terms of capacity, these types of systems can be scaled from very small (10,000 tonnes per year (tpy)) to very large (200,000 tpy or more).

Costs

No cost information was available.[3]

Advantages

- diversion potential is claimed to be moderate to high (80-90%), depending on the availability of markets for the RDF;
- RDF technologies produce a fuel that has a higher, and more consistent, caloric value than that which can be produced by a dirty MRF, making it more marketable; and
- potential displacement of fossil fuel demand due to recovery of combustibles.

Disadvantages

- uncertainty of finding markets for RDF; and
- existing power generation facilities may require retrofitting to utilize RDF.

3.1.3 Steam Processing for Material Recovery

Process

This is an emerging pre-treatment process involving the use of steam pressure to sterilize a mixed waste feedstock, resulting in the production of clean recyclables as well as biomass suitable for composting, RDF production, or feedstock for paper manufacturing. In essence, this approach is a variation of autoclaving used for sterilizing and reducing biomedical wastes, adapted for application to an MSW feedstock. Typical MRF equipment such as conveyors, screens, magnetic separators and eddy current separators are integrated into the process to facilitate recovery of marketable recyclables. The primary input material, mixed MSW, requires minimal pre-processing, notably the removal of bulky items. The feedstock is fed into a steam pressure vessel that cooks the waste such that it breaks down into organic and inorganic fractions, and is also sterilized. These materials streams are subsequently sorted and separated in the MRF process.

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[3] Cost information specific to RDF systems was not found in the literature reviewed during the course of this study.

Status

This type of technology is in the pilot stage in North America and elsewhere, with one commercial scale, demonstration plant, part of an MSW gasification system, being commissioned in Australia. As such, costs and diversion potential are unknown.

Costs

No cost information was available.

Advantages

- proven on non-MSW applications;
- waste is sterilized;
- steam strips labels and glue from containers, enhancing recyclability;
- potential high volume reduction of the biomass fraction; and
- potential displacement of virgin material and fossil fuel demands due to recovery of recyclables and combustibles.

Disadvantages

- no commercially operating facilities at present.

3.2 Biological Technologies

The biological process-based technologies target the organic fraction of the waste stream, which generally forms the largest portion of residual waste stream. In the RDN and CVRD, the organic portion of the waste stream is roughly 55 per cent of the waste stream at present. This percentage is expected to decrease as source-separated composting expands in the area.

There are three types of biological technologies:

- MSW composting;
- anaerobic digestion; and
- ethanol fermentation.

The marketable end product from biological processes is generally compost or fuel. Which process is selected is generally dependent on local market conditions – that is, whether the market outlook is more favourable for energy or compost.

3.2.1 Aerobic Composting (MSW Composting)

Process[4]

MSW (municipal solid waste) composting is the processing and controlled decomposition of largely unsorted residual waste. End products include compost, a recyclable fraction consisting mostly of metals and the non-compostable/non-recyclable portion which must be landfilled or could be feedstock for a refuse-derived fuel process. MSW composting facilities typically have a pre- or post-processing component that is used to recover recyclables, eliminate bulky wastes (e.g., couches, carpets) and to eliminate hazardous materials. This processing component is effectively similar to a dirty MRF.

There is a variety of MSW composting technology vendors, with varying configurations of their processes; however they all operate in an enclosed environment (in-vessel) and use the following steps:

Pre-processing

> Incoming solid waste is deposited on a tipping floor for initial screening. Oversized items such as pallets, mattresses and fishing nets are segregated for separate handling. In some systems, the screened MSW is then processed through a system of trommels, magnetic separators and other mechanized and manual sorting equipment. This processing is used to remove contaminants, recover recyclables and provide initial size classification. Large materials can be rejected while smaller materials are passed through as a composting feedstock.

Digestion

> “Digestion” is the initial mixing and biological activation of the composting feedstock. Several vendors (e.g., Bedminster) use large rotating tubes with internal baffles. The drums resemble cement kilns and are placed on a slight angle to assist with material migration from one end to the other. Material resides in the digestion tubes for two to three days. During that period, additional liquid and nitrogen can be added to achieve the preferred composting mix. Some facilities omit a separate digestion step in favor of an enhanced feedstock preparation stage in the active composting phase.

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[4] This process description is largely taken from a technical memo on MSW composting provided to the RDN by Sound Resource Management in 1999. The process of MSW composting has not changed since that memo was written.

Figure 3-1 Conporec's MSW Composting Facility in Tracy, Quebec

Active Composting

Active composting is the intensive aeration and turning phase, which takes between three and four weeks. Active composting can occur in channelized, open floor or box/drum systems. Channelized facilities typically have multiple 2-3 metre wide concrete channels 50-100 metres long. A mechanized turner is mounted on top of the channel walls. The turner periodically traverses each channel, mixing and aerating materials as it travels down each channel. The Envirowaste facility in Abbotsford is an example of a channelized facility. Open floor systems feature a 1-2 metre thick layer of compost feedstock spread across an aerated floor. An overhead-mounted turner traverses the floor to mix and aerate materials. The Ebara facility in Lunenberg, N.S. is an example of this technology. A box or drum-based system is loaded and then sealed for the entire active composting cycle, with air and liquid added as needed. The West Coast Waste Diversion facility in Cobble Hill is an example of an enclosed box system and the International Composting facility at Duke Point in an example of an enclosed drum system. All systems feature forced aeration with varying degrees of process control as well as an odour control system for treating off-gasses.

Curing

After compost feedstock is removed from the active composting stage, it requires additional curing to produce a mature and stable product. Curing is often done outdoors in either static (unturned) piles or in aerated windrows. The final curing can take two to three months, depending on the efficiency of the active composting process and the degree of attention given to the curing process.

Screening and Marketing

> The level of screening to remove remaining bits of plastic and other inert contaminants will depend on the anticipated end use of the compost. Because of the nature of residual waste, the quality of the compost is typically lower than compost made from source-separated organic waste and usually meets "Class B" compost quality standards. In BC, Class B compost requires a land application plan be prepared for every property where the compost will be applied, making the use of the compost onerous and marketing it into the commercial market impossible. Consequently, Class B compost is often used as landfill cover or is landfilled as a "biostabilized" material as is done in Halifax, Nova Scotia.

Status

There are several operating MSW composting facilities in the US and two in Canada (Edmonton, Alberta and Tracy, Quebec). Although these facilities are operating successfully, proposals to build MSW composting facilities in BC have not come to fruition, in part due to the cost and in part due to the challenge of finding an appropriate end-use for the compost product. Halifax, Nova Scotia has a biostabilization facility, which is essentially a MSW composting facility, to meet Nova Scotia's ban on organic waste to landfills.

Cost

In 1999, the RDN received proposals for an MSW composting facility which provided prices between $70 and $99/tonne, however these prices were not rigorously reviewed as the technology was rejected in favour of source-separated composting. The Edmonton facility, which receives 180,000 tonnes of MSW per year, cost $100 million to build and has an operating cost of $65 per tonne.[5] These costs do not include the cost to landfill or further process the waste or end products that cannot be marketed.

Advantages

- MSW composting has significant diversion potential. Since the whole residual waste stream is composted, all organics in the residual waste stream are captured and many recyclables can be recovered in the front-end and back-end screening processes.
  - It is estimated that if the compost can be marketed, 60% of the residual waste stream could be diverted.
  - The City of Edmonton has achieved a 70% diversion rate of their residential waste through a combination of a residential recycling program and composting of the residual waste.[6]
  - If the compost was to be landfilled, a diversion of 30- 40% could be achieved through volume reduction and removal of recyclables.

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[5] Telephone conversation with Bud Latta, the Director of Engineering, Processing and Disposal for the City's Waste Management Branch in 2002.

[6] Edmonton's composting facility targets only residential waste. ICI waste is not received at the facility.

  - If RDF is produced with the waste screened out of the compost, the diversion rate could surpass 70%.
- The public generally is positive towards technologies that involve composting or some form thereof.

Disadvantages

- Because the whole residual waste stream is composted (with some initial screening to remove large, non-compostable items such as televisions and tires), the quality of the compost is lower than composting facilities that use source-separated organics. Marketing of Class B in BC will be very difficult.
- This type of facility may compete directly with source-separated recycling and composting programs.

3.2.2 Anaerobic Digestion

Process[7]

Anaerobic digestion (AD) is the biological conversion of organic materials in the absence of oxygen. The process is carried out in a controlled environment by anaerobic micro-organisms that convert carbon-containing compounds to biogas, which is a gas primarily consisting of methane and carbon dioxide, with trace amounts of other gases. The material remaining is a partially stabilized organic material that can be used as a soil amendment after stabilization through composting.

Key components of an anaerobic digestion process are:

- Initial removal of large and unsuitable items;
- Recyclable materials recovery and removal of contaminants via mechanical preprocessing;
- Anaerobic digestion process;
- Collection and utilization of biogas (the biogas is collected from the tank and directed to energy utilization equipment, where it is burned to produce electricity and/or steam)
- Post-digestion separation of liquids and solids;
- Composting of solid digestate; and
- Treatment and disposal of wastewater.

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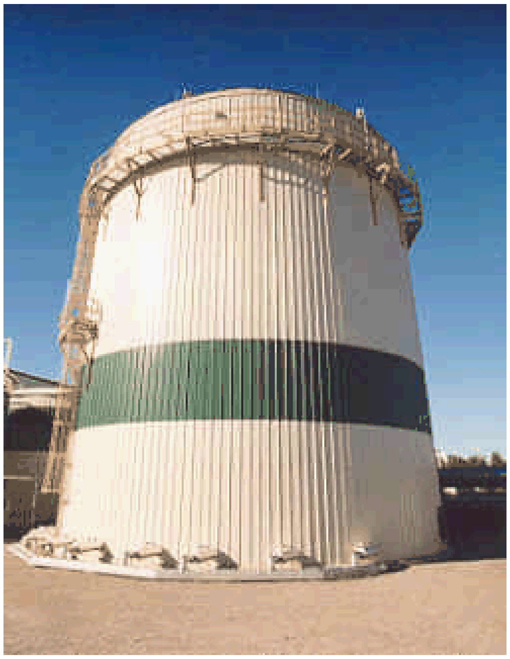
[7] Process description largely taken from “Technologies Review Reference Manual” done for the Greater Toronto Area Working Group by MacViro and Earth Tech, December 2003.

Figure 3-2 Anaerobic Digester



Following digestion, the digested material may be dewatered and subjected to further separation steps before being composted and cured, or fed to a thermal process. The composting stage is required for pathogen kill, for volume reduction through moisture loss, and for aerobic conversion of organic carbon that was not converted during the anaerobic phase. The composting stage may be followed by screening of the compost, which generates a waste stream of oversized and non-organic particles that is generally landfilled.

Biogas production from facilities in Europe is generally reported in the range of 75-150 m^3 of biogas per tonne of waste digested (this varies with different facilities, composition of the waste, etc.). Biogas has a lower heat value in the range of 20,000 kJ/m^3 and, therefore, at an electrical conversion efficiency of 35%, anaerobic digestion of one tonne of waste could produce approximately 150 to 300 kWh of electricity.

Status

Anaerobic digestion facilities are viable in Europe, where prices for green electricity are up to three times as high as the prices in Ontario, and landfill tip fees are multiples of North American tip fees. European AD facilities are also supported by legislation requiring organic waste to be processed before disposal starting in 2005. The absence of these economic and policy “drivers” in North America make AD less viable here than in Europe.

There is some experience with anaerobic composting in Ontario. An AD facility called Canada Composting Inc. opened north of Toronto but went bankrupt and is no longer operational.[8] Other proposed facilities in southern Ontario such as SUBBOR did not reach start-up phase before closing down. The City of Toronto built a 25,000 tonnes per year pilot facility but chose to operate the facility using source-separated organics. The facility has experienced technical difficulties but is currently operational. The City has been unable to sell the biogas and currently flares it instead. The digestate is brought to a windrow composting facility to be made into compost. The compost produced is Class A due to the feedstocks to the AD being source-separated organics. The City has suggested that the costs of operating this facility do not make AD attractive as a residual waste processing technology.[9]

Cost

The cost of an anaerobic composting facility for residual waste in North America is not known at this time. The City of Toronto is not willing to share cost information on their pilot composting facility at this time due to an on-going competitive process for alternative residual waste management processes. Costs will be largely dependent on the value of the energy (which can likely be sold as “green” energy) and the availability of energy users.

Advantages

- Unlike aerobic composting, anaerobic digestion is a net producer of energy. Biogas produced by anaerobic digestion is burned in a boiler or generator to recover heat and/or electricity. Typically, a portion of the heat and power are used for the process, with the balance being sold to the grid. The net power output to the grid may be in the range of 100 kWh - 200 kWh or less per tonne processed, as energy in the form of biogas can be recovered only from the biodegradable components of the waste. This is lower than the 500 kWh per tonne typical of thermal technologies.
- In addition to biogas, anaerobic composting processes can also generate recyclables and Class B compost.
- Diversion potential ranges from 40% if digestate is landfilled, to 60% if another use can be found for the digestate (e.g., compost, RDF).
- The public generally is positive towards technologies that involve composting or some form thereof.

Disadvantages

- Economic viability questionable under current energy prices.
- The compost produced will likely be Class B and can probably only be used as landfill cover.
- There have been some historic issues with odour generated at AD plants in Ontario which may make siting a facility problematic.

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[8] This facility has been recently purchased by International Paper Industries. However, IPI’s plans for the facility are unknown at time of writing.

[9] Telephone conversation with City of Toronto staff involved with the AD pilot and the review of alternative residual waste technologies.

- As the quantity of organics in the waste stream decreases due to source-separated composting operations coming on-line, AD will become less viable.

3.2.3 Ethanol Fermentation

Process[10]

Ethanol fermentation is a process in which organic material is converted by microorganisms to simpler compounds, such as sugars. These compounds are then fermented by yeast to produce ethanol and carbon dioxide. The ethanol is then purified and/or mixed with petroleum to produce vehicle-grade fuel. The process generally includes the following components:

- initial screening of large and unwanted materials;
- mechanical processing to remove recyclables and other contaminants;
- initial hydrolysis process which produces a slurry and results in the conversion to simpler compounds;
- fermentation of organics;
- post-fermentation purification to produce ethanol;
- gasification of solid residuals to provide heat may be done, although landfill of residuals is most likely; and
- treatment and disposal of wastewater.

Status

This technology is well-proven using grain as feedstock. Using MSW to produce ethanol has only been done on a bench and pilot scale.

Cost

No cost information available. There is no experience with this technology on a municipal scale.

Advantages

- End product is fuel grade ethanol which has an established market.
- Diversion may be similar to other biological processing options (MSW composting and AD). If thermal treatment of residuals is conducted, there is the potential for significant diversion.

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[10] Process description largely taken from “Technologies Review Reference Manual” done for the Greater Toronto Area Working Group by MacViro and Earth Tech, December 2003.

Disadvantages

- Unproven technology for use as a residual waste management.
- Significant wastewater is generated that will require appropriate treatment and discharge capacity.

3.3 Chemical Technologies

In a 2003 Request for Expressions of Interest for residual waste processing technologies for the City of Toronto, some submissions were received that apply chemical technologies to the challenge of residual waste management.

Process

The “chemical” submissions combine chemical additives to physical processes to produce energy or construction materials. The submissions included:

- hydrogen reforming and catalytic conversion to produce syngas then ethanol; and
- physical process and chemical additives to produce construction panels.

In general, all of these processes included these components:

- screening to remove recyclables and bulky items;
- creation of gas, liquid and/or solid to be processed;
- sterilization or cleaning of output product;
- residue disposal; and
- emissions and wastewater treatment.

Status

All of these technologies are at a bench or pilot scale in their development.

Cost

Because these processes are in the early stages of development, their costs at a municipal scale are unknown.

Advantages

- potentially marketable energy and construction materials.

Disadvantages

- unproven technologies;
- limited information available so that there is a high level of technical risk;
- unproven market; and
- unknown diversion potential.

3.4 Thermal Technologies

For the purposes of this report, thermal technologies include conventional incineration and waste-to-energy technologies and more recent developments typically characterized as advanced thermal treatments (ATT).

3.4.1 Incineration/Waste-to-Energy

Overview

MSW incineration is a technically and commercially well-established approach for managing residual MSW in North America and Europe. Incineration is a process that involves the complete degradation or combustion of carbon-based material in MSW through the application of heat in an oxygen rich environment. Ash residue, including bottom ash and fly ash, inert materials, metals and flue gases are the principal residual waste streams. Excess heat is also produced, and may be recovered if the process is configured as a waste-to-energy facility.

The majority of mass burn and fluidized bed incineration facilities currently operating in North America, Europe and Japan are designed to recover excess heat energy generated during combustion. These waste-to-energy facilities use the excess heat to produce steam, which in turn may be used directly in this form as a heat or energy source (e.g., distributed to municipal heating systems), or converted to electricity by means of steam turbine generators. Steam generated electricity can be utilized in-plant as well as being sold to local electricity grids. Some MSW incinerators, such as the GVRD’s waste-to-energy facility in Burnaby, BC, co-generate steam and electricity.

Incineration Processes

Mass burn incineration is the predominant thermal technology in use today for managing residual MSW. This type of process is designed to combust unsegregated MSW feedstock as it is received, with minimal pre-processing.

Large-scale mass burn facilities may range in capacity from 100 to 3,000 tonnes per day[11], and may include two or more, single-stage combustion units. In the typical configuration, the feedstock is continuously fed into a moving grate system that conveys the waste through the combustion chamber. Air is supplied above and below the grate to facilitate combustion. Burned residues, deposited on the bottom of the grate, are recovered for recycling or disposal. Flue gases are passed through a cleaning phase in order to neutralize or removed contaminants that are released or produced during combustion. Contaminants of concern associated with mass burn incineration typically include metals, organics such as dioxins and furans, acid gases, particulate matter, nitrogen oxide, and other substances, such as carbon monoxide. Cleaned flue gas is released to the environment via a stack. The resulting fly ash is typically treated as a hazardous waste unless it has been further processed to stabilize metals.

Modular mass burn systems have also been developed to address smaller scale capacity requirements (e.g., <400 tonnes per day). These types of facilities are often pre-fabricated, and can be assembled on-site in modules scaled to meet the existing capacity requirements. They may vary from large-scale processes in a number of ways. For example, they may employ two or more combustion chambers, have batch feed rather than continuous feed systems, and use different air pollution control technologies, among other things. The smaller scale and modular aspects of this approach typically imply lower costs than single stage, mass burn facilities.

Fluidized bed combustion technologies have emerged as an alternative to mass burn incineration of MSW. Widely used in Japan and increasingly used in Europe, this type of technology replaces the mass burn moving grate system with a bed of inert particles, such as sand or limestone. The bed is heated and air is blown through the particles, causing the bed to partially fluidize, which in turn facilitates consistent temperatures throughout the combustion chamber. The main types of fluidized bed technologies include bubbling and circulating bed processes. These differ primarily in terms of air flow and bed material. These processes significantly increase the efficiency of combustion, which in turn reduces the production of air emissions and residuals. Energy recovery is also increased. Unlike mass burn processes, this type of technology typically requires a pre-processed MSW feedstock, including size reduction, drying and removal of glass and metal. Refuse derived fuel is a typical feedstock for such systems.

Status

MSW incineration utilizing waste-to-energy technologies is economically mature. In terms of air emissions, optimized combustion practices and innovations in air pollution control technologies required by legislation have increased the capability for compliance with existing air emissions standards in North America, and in Europe, where the standards are significantly more stringent. Locally, the GVRD waste-to-energy facility reports ongoing compliance with site-specific air emissions standards, including particulate matter, sulphur dioxide, hydrogen fluoride, hydrogen chloride, total hydrocarbons, metals, mercury, cadmium, lead, nitrogen oxides and carbon monoxide.

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[11] At present, the RDN generates 165 tonnes per day, the CVRD generates 70 tonnes per day, and combined the two regional districts generate 235 tonnes per day.

Costs

The most relevant information on costs of incineration technologies is associated with the recently completed Regional Niagara *Long Term Disposal Study* (September 2003) and the City of Edmonton *Study of Gasification/Pyrolysis of MSW Residuals* (January 2004). The Niagara study reported preliminary costs of $115 – $180 per tonne of waste managed, including assumed revenues, for a large-scale (> 400 tonnes/day) mass burn incinerator, based on responses from three proponents. The study also reported preliminary costs of $70-$90 per tonne managed, including assumed revenues, for a smaller-scale modular facility, based on four submissions. The Edmonton study reported preliminary "break even" tipping fees based on information provided by two proponents of fluidized bed technologies. The break even tipping fee includes capital and operating costs after revenue from the sale of power, but excludes profits. In one case, for a facility with a capacity of 72,740 tonnes per year, the break even tipping fee was estimated to be $132/tonne. In the second case, for a facility with a capacity of 110,000 tonnes per year, the break even tipping fee was estimated to be $75/tonne.

Advantages

- most proven of thermal conversion technologies;
- potential for energy recovery and electricity generation; and
- conserves landfill space.

Disadvantages

- capital intensive, with long term payback schedule;
- potential conflict with waste reduction policies and programs;
- high potential for public opposition
- steam must be used on-site or locally
- less efficient than other thermal technologies at energy recovery
- contaminants formed by process, extensive pollution control technologies required; and
- fly ash management required.

3.4.2 Advanced Thermal Treatment

Overview

Conventional incineration processes for residual MSW are designed to result in the complete combustion of carbon-based inputs. Heat energy is a byproduct that may be recovered through the integration of waste-to-energy systems that produce steam and steam generated electricity. In contrast, advanced thermal treatment (ATT) processes are designed to convert, through partial combustion or thermal degradation, the carbon-based solids in MSW into energy-rich primary products, notably hydrocarbon gases (syngas) and hydrocarbon liquids (bio-oils). These primary products have the potential, depending on technical and economic factors, to be further processed into a range of marketable products, such as electricity, hydrogen, fuel alcohol and chemicals.

Gasification Processes

Gasification, invented in the 1800s to convert coal to gas, is not a new technology per se; however, interest in its application to MSW has emerged only in the past two decades in the context of disposal capacity shortages and energy crises.

Gasification is the conversion of the carbon-based, high-energy fraction of MSW from the solid to the gaseous state. In the gaseous state, the energy is more readily available for use in power generation, and the constituents of the gas may be recovered as chemicals. The primary gasification process is characterized by the partial combustion of MSW at a high temperature in a reactor, with combustion facilitated through the application of air, oxygen or steam. The resulting chemical reactions produce synthesis gas (syngas), as well as char, an inert solid byproduct, and possibly some liquids. Gasification processes are typically optimized to produce a syngas product consisting primarily of carbon monoxide and hydrogen gas, with lesser amounts of carbon dioxide, water and nitrogen.

Figure 3-3 Thermoselect high temperature gasification/vitrification facility, Karlsruhe, Germany

As a primary product, syngas is a “dirty gas”, containing contaminants of concern with respect to air emissions and gas utilization. Dioxins and furans are considered to be less of a problem in ATT approaches compared to conventional incineration. However, other contaminants, including some heavy metals (mercury, cadmium and arsine[12]), acidic gases and particulates may require mitigation. As a

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[12] Arsine is a poisonous hydride of arsenic.

result, emissions control technologies are typically integrated into the system, with the type of control – flue gas scrubbing and/or specialized syngas cleaning – dependent on how the syngas will be utilized.

With respect to utilization, dirty syngas can be combusted in a secondary combustion chamber, producing hot flue gas that, in turn, can be transformed into steam in a boiler and subsequently used to generate heat and electricity. In this case the utilization pathways are typical of conventional waste-to-energy facilities. Cleaned syngas can be used in gas engines and turbines for the production of electricity – a more efficient means of generating electricity than the use of steam turbine engines – and it can be used as an industrial fuel. Cleaned, it has an energy value of 1/3rd that of natural gas.

In terms of specific gasification processes, there are a number of types of gasifiers on the market or under development that are of relevance to MSW management. Notably fixed bed, fluidized bed, high temperature and plasma arc gasification processes have emerged as technologies with real or potential value for residuals management. These types of processes vary in terms of feedstock pre-processing requirements, reactor temperatures, gas clean-up requirements, and byproduct management, among other things. Of note in terms of these differences is that high temperature and plasma arc gasification processes have the added potential of converting glass and metal byproducts to a vitrified slag that can be utilized as construction aggregate.

Pyrolysis Processes

Unlike incineration and gasification, pyrolysis, also known as "thermolysis", does not involve combustion. Instead, the carbon-based fraction of MSW is decomposed into chemical constituents through the application of an external heat source (400 to 800ºC, or higher) to an environment characterized by the absence of oxygen. The heat is typically applied to the walls of the reaction chamber into which the MSW is fed. In the primary reaction process, gas, liquid and char are always produced, with greater quantities of liquid (bio-oil) or syngas produced depending on process-related factors such as temperature and exposure time. Bio-oil has the potential to be further refined for use as a liquid fuel or

Figure 3-4 Wastegen Pyrolysis Plant Kiln, Burgau, Germany

chemical feedstock. However, this strategy has seen little development due to economic factors. Some types of systems combine pyrolysis with gasification, such that the bio-oil produced in the pyrolysis phase is subsequently fed into a gasification chamber to produce syngas. Syngas may be cleaned and utilized following the same types of processes used in gasification systems.

Status

Over 80 types of gasification and pyrolysis processes are currently being marketed in various countries, although only a limited number have been applied to MSW. Generally, while some of these technologies are operating at a commercial scale in Europe and Japan, there are no commercial scale plants operating in North America. As Table 3-1 indicates, there are two pilot scale plants operating in Canada, both located in Quebec.

Table 3-1 Gasification Projects

Technology Type	Status	Examples
Fixed bed gasification	Pre-bench to demonstration scale	55,000 tpy demonstration plant commissioned (Australia)
Fluidized bed gasification	Pre-bench to commercial scale, no commercial scale operations in NA	25,000 – 150,000 tpy facilities (Spain, Japan) 5000 tpy pilot plant in Sherbrooke, Quebec
High temperature gasification	Pre-bench to commercial scale, no commercial scale operations in NA	35,000 – 225,000 tpy plants (Germany, Japan)
Plasma arc gasification	Pre-bench scale to commercial scale, no commercial scale operations in NA	Commercial scale plants (Japan) Pilot scale plant in Montreal, Quebec
Pyrolysis	Pre-bench scale to commercial scale, no commercial scale operations in NA	25,000 – 225,000 tpy plants (Germany, Japan)

Costs

The most relevant information on costs of ATT technologies is associated with the recently completed Regional Niagara *Long Term Disposal Study* (September 2003) and the City of Edmonton *Study of Gasification/Pyrolysis of MSW Residuals* (January 2004). In the Niagara study, proponents of gasification and pyrolysis systems submitted preliminary costs ranging from $143 - $217 per tonne for a 75,000 tpy plant, to $79 - $135 p/t for a 300,000 tpy plant. The Edmonton study reported preliminary "break even" tipping fees based on information provided by four proponents. The tipping fees ranged from $78/tonne for a 120,000 tpy gasification plant to be designed by Canadian owned Enerkem to $157/tonne for a 132,000 tpy pyrolysis and gasification plant to be designed by Swiss owned Thermoselect.

Advantages

- high diversion potential (claims of 70 – 90%), depending on whether char is vitrified and can be utilized as construction aggregate;

- more potential scope and flexibility than conventional incineration/waste-to-energy due to diverse energy recovery pathways;
- potential for high efficiency energy recovery through gas turbines;
- potential reductions in dioxin/furan and NOx emissions compared to incineration;
- lower GHG emissions compared to incineration;
- conserves landfill space;
- reduced potential for public opposition, compared to incineration; and
- better suited to small and medium scale applications.

Disadvantages

- technology is not proven yet in Canada;
- may be viewed as high risk by banks, politicians;
- capital intensive, with long term payback schedule;
- potential conflict with waste reduction policies and programs; and
- extensive pre-processing (e.g., RDF) may be required.

4. Conclusion

The primary objective of this preliminary review was to determine if any new and emerging technologies for managing residual MSW might have some applicability to the RDN and CVRD in the next five to ten years. The review focused on four types of approaches, including physical, biological, chemical and thermal approaches, and considered their status, costs, advantages and disadvantages, to the extent possible based on available information.

Technical and Economic Status

Most of the technologies reviewed are considered technically viable for managing residual MSW, having been proven at least at a commercial demonstration scale, in Europe, Japan or North America. However, most of these technologies have not been economically proven in a North American context, as commercial scale facilities have not been established on the continent, or, having been established, have failed for financial or economic reasons. This means that there is a significant lack of relevant information regarding real costs and benefits of these new and emerging technologies, which in turn increases the risks associated with adoption. Table 4.1 illustrates the technical and economic status of technologies reviewed.

The economically proven technologies, MRFs, RDF processes, MSW composting and incineration, generally do not fall into the category of new and emerging technologies, but are of interest due to their capabilities for managing residual wastes.

Table 4-1 Technical and Economic Status

Technology	Technical Viability	Economic Viability in North America
MRF	√	√
RDF	√	√
Steam	X	X
Aerobic MSW Composting	√	√
Anaerobic Digestion	√	X
Fermentation (Ethanol Production)	X	X
Chemical	X	X
Incineration/Waste-to-Energy	√	√
Gasification	√	X
Pyrolysis	√	X

Costs

The availability and quality of relevant cost data varied depending on the type of technology reviewed. Recent Canadian reports on requests for expressions of interest (REOI) provided some insight, as did comments from individuals directly responsible for, or involved in, MSW technology analysis and implementation. Generally, new and emerging approaches for residual MSW management are capital intensive and expensive to operate compared to conventional landfills. Costs may be affected by economies of scale, as well as by full cost accounting criteria, including whether there remains a need for a landfill to manage residual wastes. In all cases, the need for landfilling was not eliminated by the adoption of a residual waste processing technology. As such, cost estimates for technologies should be regarded as a component cost of a residual waste management system and not considered a whole system cost. Table 4.2 summarizes cost estimates from Canadian reports on requests for expressions of interest (REOI).

Table 4-2 Cost Estimates from Canadian REOI Reports

Technology	Estimates from Canadian REOI Reports
Aerobic MSW Composting	$70-99/tonne
Incineration/Waste-to-Energy	$70-180/tonne
Gasification/Pyrolysis	$78-217/tonne

Advantages and Disadvantages

The various types of technologies reviewed varied considerably in terms of their advantages and disadvantages. Generally, many of these technologies will provide significant value in terms of the amount of waste diverted from landfill. Some have the added advantage of maximizing the recovery of marketable recyclables, whereas others have the added advantage of maximizing energy recovery and power generation potential. Where intermediate or unconventional primary products are produced, including Class B compost, RDF, steam, syngas and bio-oil, challenges may arise regarding marketability. This issue may translate into a disadvantage depending on the context, and if so, will affect economic viability and costs.

Summary

Although the review was not conclusive regarding the viability of residual waste processing, the research process unveiled that there is a significant amount of local government level analysis of options underway in regions across Canada, including Halifax, Toronto, York, Niagara and Edmonton. The California Integrated Waste Management Board is also currently involved in a review of conversion technologies for MSW. Pending developments in these jurisdictions, our findings suggest that traditional diversion activities may be the preferred option for the RDN and CVRD for next few years. A conventional but aggressive waste reduction strategy could aim to divert up to 70 per cent of the whole waste stream through maximizing organics recovery in a source-separation based program, as well as enhancing materials recovery and recycling initiatives.

4.1 Next Steps

The review indicates that there may be some promise for residual waste processing in the future. The feasibility will be based on available waste quantities, the change in composition, and most likely, energy markets. Hence, some continued work in this vein is recommended:

- Continue to monitor the development of the technologies that have proven to be technically viable, including refuse derived fuel, anaerobic digestion, waste-to-energy, gasification and pyrolysis.
- Keep abreast of municipal activities in Canada related to residual waste management such as those occurring in Edmonton, Niagara, York and Toronto. As pilot projects and RFP processes are completed, relevant cost information will be become available.
- Continue to monitor the work currently underway in California relating to thermal conversion technologies.
- Consider residual waste processing technologies in the context of the RDN and CVRD’s whole waste management systems, as a given technology may or may not be beneficial to the current solid waste management planning direction. All of the implications of adopting a residual waste technology should be assessed before adoption.