Energy-from-Waste

Research Project Summary Report

A summary of the key information, analysis, conclusions and rationale of the assessment of the potential for development of an Energy-from-Waste facility in Southern Alberta.

IN SUPPORT OF:

Southern Alberta Energy-From-Waste Alliance
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1.0 Introduction

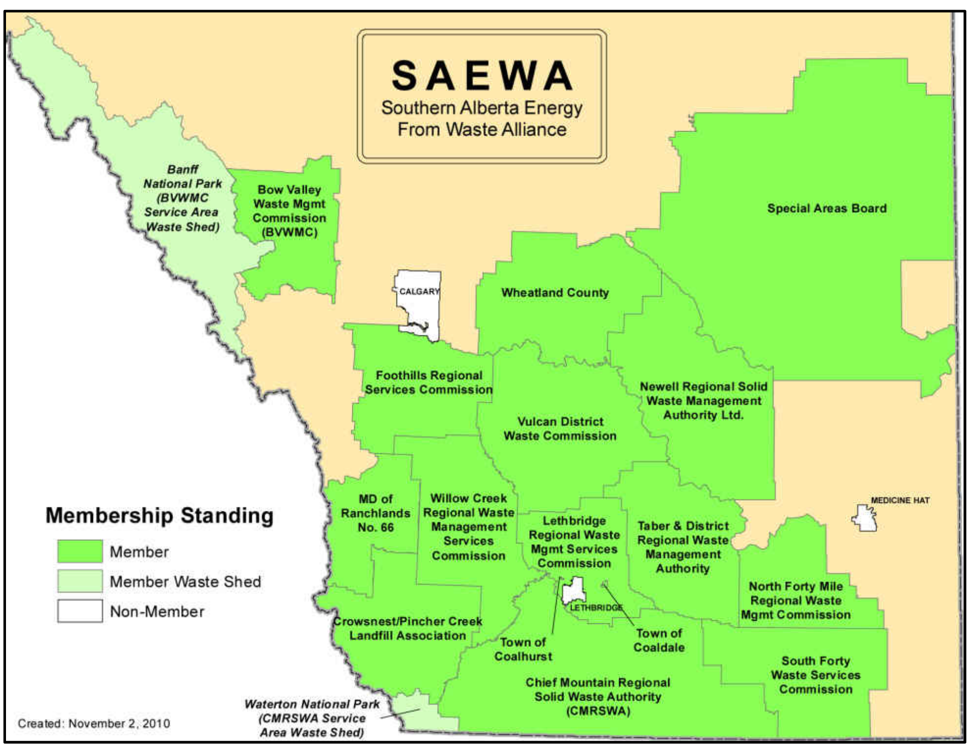
The Southern Alberta Energy-from-Waste Alliance (SAEWA) is a coalition of waste management jurisdictions committed to researching and recommending for implementation, technological applications for recovering EFW materials, and reducing reliance on landfills.

The membership of SAEWA consists of 16 waste authorities listed below and shown on Figure 1:

- Bow Valley Waste Management Commission
- Foothills Regional Services Commission
- MD of Ranchlands No. 66
- Crowsnest/Pincher Creek Landfill Association
- Willow Creek Regional Waste Management Services Commission
- Wheatland County
- Vulcan District Waste Commission
- Lethbridge Regional Waste Management Services Commission
- Town of Coalhurst
- Town of Coaldale
- Chief Mountain Regional Solid Waste Authority
- Newell Regional Solid Waste Management Authority
- Taber & district Regional Waste Management Authority
- North Forty Mile Regional Waste Management Commission
- South Forty Waste Services Commission
- Special Areas Board (Big Country)

Figure 1 provides a geographic perspective of the SAEWA membership.

Figure 1 - SAEWA Membership



2.0 Assessment Tasks

In July 2010, with the assistance of a grant from Rural Alberta Development Fund, the consulting team led by HDR was retained to assist SAEWA in further exploring the opportunities to develop an Energy-from-Waste (EFW) facility in Southern Alberta. This research project consists of four (4) phases, each with a series of tasks as follows:

Phase 1

The completion of Phase 1 activities resulted in the identification of waste quantities potentially available to be managed, the size of the facility required to manage these materials; and identification of technologies capable of managing the quantity and composition of available waste streams including anaerobic digestion, refuse derived fuel (RDF) processing and combustion, mass burn combustion, gasification and plasma arc gasification.

Phase 2

The Phase 2 analysis concluded that no further consideration should be given to anaerobic digestion technology due to limited applicability, limited energy recovery potential and regulatory and operational challenges. The completion of Phase 2 activities resulted in the identification of waste collection, transportation and handling implications with associated siting opportunities; heat recovery and cogeneration options, including potential market/siting opportunities; an additional level of detail with respect to the environmental implications (including transportation impacts from Task 3), and the facility permitting and siting requirements. A future project development schedule was outlined.

Phase 3

Phase 3 builds upon information developed in the preceding project tasks. The completion of Phase 3 activities will result in the identification of the financial and socio/economic implications of moving forward with the development of a facility(ies) and required supporting infrastructure.

Phase 4

The completion of Phase 4 has resulted in the assembly of this summary report and consolidation of all previous documents into the technical appendices attached to this document.

The following sections summarize the results of the above research project phases.

2.1 Waste Generation Rates and Facility Sizing

The baseline waste streams in Southern Alberta have been identified and categorized by source as follows:

- Municipal Solid Waste (MSW) from SAEWA members;
- MSW from non-SAEWA members; and
- Other waste sources within, or within close proximity to, Southern Alberta.

Waste Generation

Table 1 summarizes the waste disposal quantities from each of the SAEWA members. These figures represent an average disposal rate for the past three to four years, depending on the records that were submitted by the SAEWA waste authorities.

Table 1 - Average Annual MSW Disposal Rates from SAEWA Members

SAEWA Waste Authorities	Residential MSW (tonnes/ year)	ICI Solid Waste[1] (tonnes/year)	C&D Waste [1] (tonnes/ year)	Total tonnes/ year)	Current Method Of Management
Bow Valley Waste Management Commission	11,400		12,000	**23,400**	Transfer MSW to Calgary LF and C&D to local LF
Foothills Regional SC	30,100		6,800	**36,900**	Local LF disposal
MD of Ranchlands No. 66	20			**20**	Transfer to Foothills LF
Crowsnest/Pincher Creek LFA	10,500	700	5,100	**16,300**	Local LF disposal
Willow Creek Regional WMSC	3,700		2,900	**6,600**	Local landfill disposal
Wheatland County	1,410			**1,410**	Transfer to Drumheller LF
Vulcan District WC	5,700			**5,700**	Transfer to Lethbridge LF
Lethbridge Regional WMSC	2,200		50,000	**52,200**	Transfer to Lethbridge LF
Town of Coalhurst	550			**550**	Transfer to Lethbridge LF
Town of Coaldale	3,000			**3,000**	Transfer to Lethbridge LF
Chief Mountain Regional SWMA	10,300			**10,300**	Local LF disposal plus transfer to Lethbridge LF
Newell Regional SMWA	12,700	6,500	2,950	**22,150**	Local LF disposal
Taber & district Regional WMA	6,300			**6,300**	Transfer to neighbouring LFs
North Forty Mile Regional WMC	1,500			**1,500**	Local LF disposal
South Forty WSC	1,480			**1,480**	Transfer to North Forty Mile LF
Special Areas Board (Big Country)	9,040			**9,040**	Local LF disposal
TOTAL	**109,900**	**7,200**	**79,750**	**196,850**	

Notes: (1) Where separate volumes are known. Where blank, these categories are included with the residential quantities.

The largest cities in Southern Alberta are not SAEWA members. These cities include Calgary, Lethbridge and Medicine Hat. These cities operate their own landfills, and their average disposal rates are summarized in Table 2 below.

Table 2 - Summary of MSW Disposed from Non-SAEWA Members

Non-SAEWA Members	MSW Disposed (tonnes/year)
City of Calgary	710,000*
City of Lethbridge	110,000*
City of Medicine Hat	56,000
Drumheller Regional Landfill	30,000
RDEK (Fernie, Sparwood and Elkford)	8,000
Town of Strathmore	5,300
TOTAL	**919,300**

** The waste quantities from SAEWA members managed at the above non-SAEWA facilities have been removed to prevent the potential for double-counting of waste quantities.*

Other waste sources that were quantified and considered as potential contributors to a future EFW facility include:

- ICI sector wastes
- Agricultural sector wastes
- Municipal wastewater treatment biosolids
- Contaminated soils
- Combustible oilfield wastes
- Railway ties
- Specified risk materials (rendering wastes potentially associated with bovine spongiform encephalopathy)

The following presents a breakdown of wastes evaluated as being potentially available to be directed to a future EFW facility in Southern Alberta.

Table 3 - Summary of Total and Available Waste Quantities

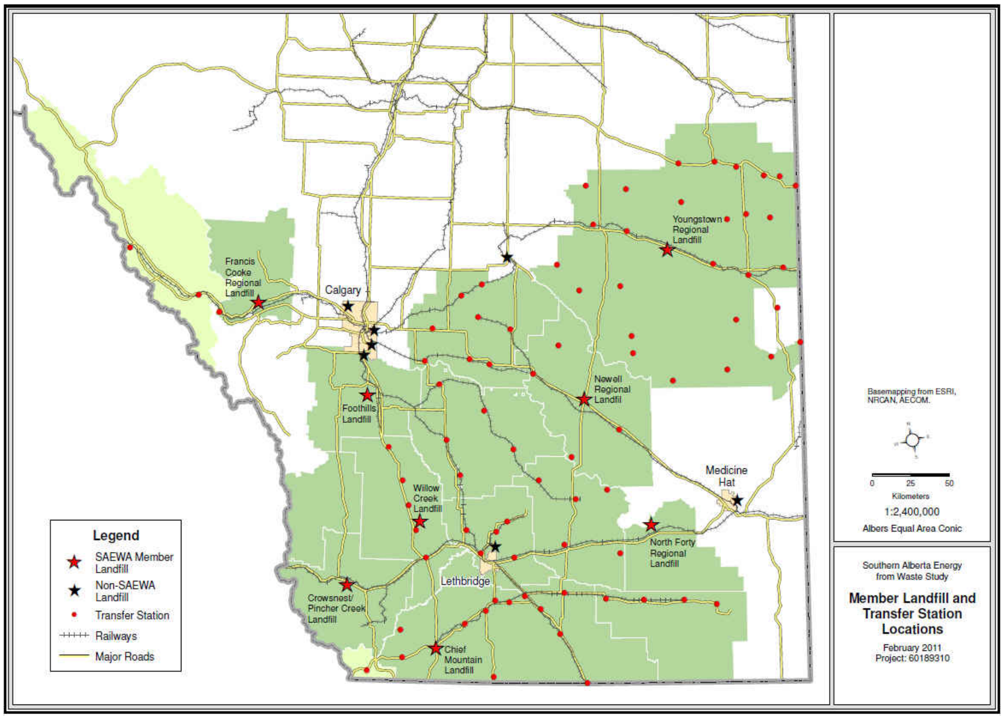
Waste Stream	Total Waste Quantities (Tonnes/year)	Potentially Available Waste for SAEWA (Tonnes/year)
MSW from SAEWA Members	196,850	196,850
MSW from Non-SAEWA Members	919,300	13,300
Other Waste Sources:		
ICI Sector Waste	290,000*	0**
Agricultural Waste	0***	0
Biosolids	22,232	1,232
Contaminated Soils	66,500	0
Combustible Oilfield Waste	2,500	2,500
Railway Ties	124,650	124,650
Specified Risk Materials - MBM	27,500	27,500
TOTAL	**1,649,532**	**366,032**

**Only includes quantities destined to the BFI landfill*
*** These cannot be defined at this time, and would likely only be available on the basis of lower tipping fees and transportation costs. This represents quantities that go to non-SAEWA member landfills or private landfills.*
****Included in "MSW from SAEWA" members category*

Waste Management Facilities and Infrastructure

Information regarding existing waste management systems and programs in Southern Alberta was collected and assessed. Figure 2 shows the location of the primary waste management infrastructure components.

Figure 2 - Map of Southern Alberta Landfills and Transfer Stations



The tipping fees for disposal of waste in the SAEWA communities range from $30 per tonne to $95 per tonne, and have a median rate of $55 per tonne, excluding transportation costs.

Waste Variability and Facility Sizing

Quantities of waste sent for disposal in SAEWA vary seasonally, typically following the pattern shown on Figure 3.

Figure 3 - Graph of Average Seasonal Variations in Disposal.

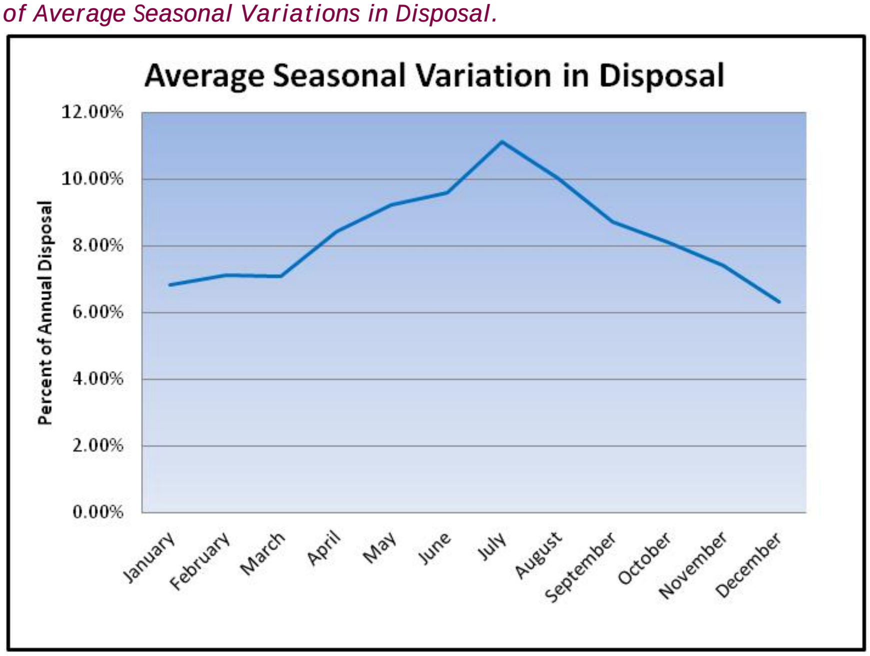
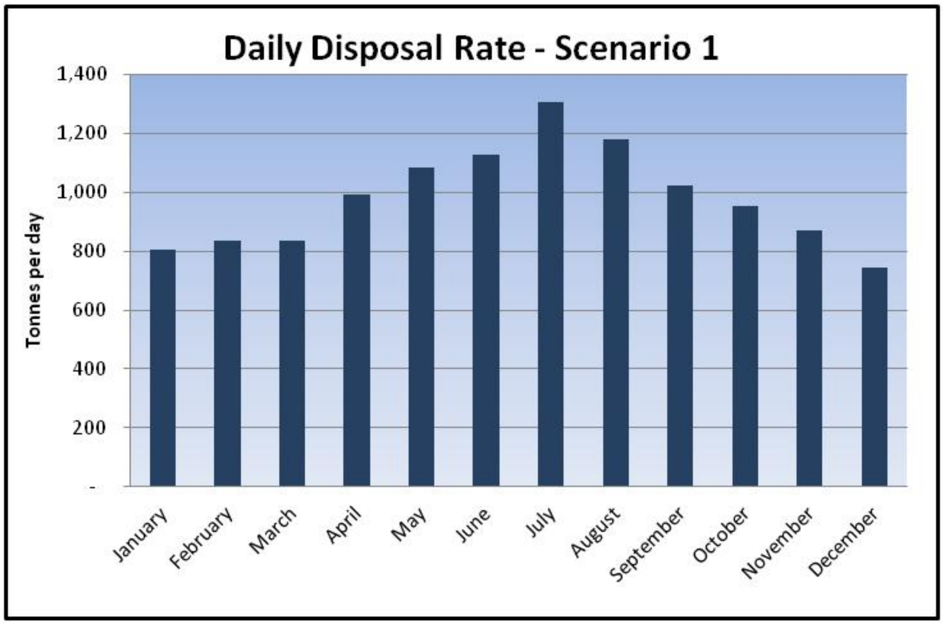
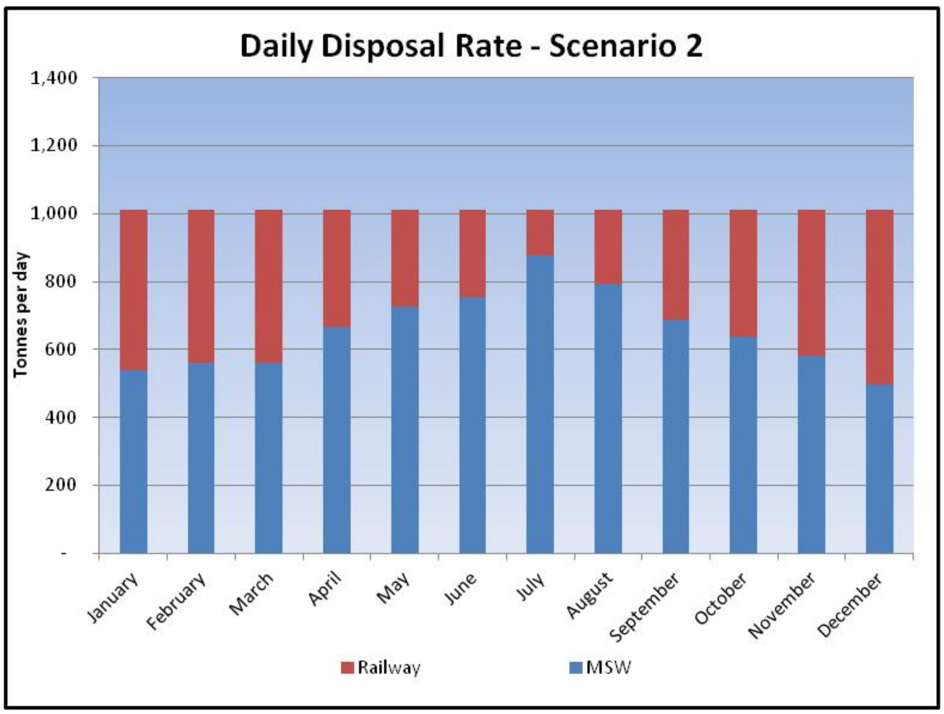


Figure 4 - Daily Disposal Rate with a Constant Flow of non-MSW material



Facility sizing takes into account both seasonal and daily variations in disposal rates as shown on Figure 4. Figure 5 illustrates how railway ties could be used to supplement the feedstock to attain a constant target EFW processing rate of approximately 1,000 tonnes/day.

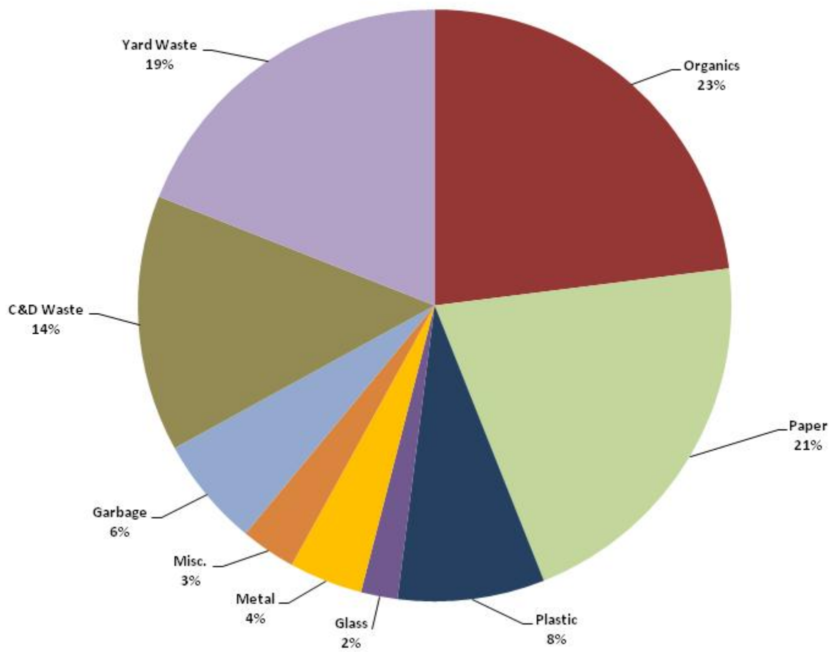
Figure 5 - Daily Disposal Rate with a Top up of Railway Ties to Balance Waste Flows



Waste Composition and Energy Content

Alberta Environment has compiled information on the typical waste composition for smaller towns in Alberta as shown on **Error! Not a valid bookmark self-reference.**.

Figure 6 - Typical Waste Composition for Small Towns in Alberta



Taking this typical 'mix' into consideration and accounting for the types of materials from other waste sources as identified previously, the following waste composition profiles were developed for the two scenarios referred to above on Figure 4 and Figure 5.

Table 4 - Composition of Waste Streams

	Scenario 1	Scenario 2 (Summer)	Scenario 2 (Winter)
Organics	13%	15%	11%
Paper	12%	14%	10%
Plastic	4%	5%	4%
Glass	1%	1%	1%
Metal	2%	3%	2%
Misc.	2%	2%	1%
Garbage	3%	4%	3%
C&D Waste	8%	9%	7%
Yard Waste	11%	12%	9%
Biosolids	1%	1%	1%
SRM - MBM	7%	7%	7%
Railway Ties	37%	27%	45%

As shown in Scenario 2, the waste composition changes significantly between the summer and winter months due to the inclusion of railways ties to adjust for seasonal variations and maintain a constant EFW processing rate.

Information from reliable literature sources was consulted to for estimates of energy content of the various waste constituents and the average heating values for the waste stream anticipated for an Southern Alberta EFW facility were estimated as follows:

- Scenario 1: 14,447 KJ/Kg
- Scenario 2 (summer): 13,970 KJ/Kg
- Scenario 2 (winter): 14,954 KJ/Kg

Waste Diversion

Most communities in SAEWA are relatively small, and waste diversion programs consist primarily of voluntary drop off depots rather than curbside recycling collection. For programs of this nature, maximum residential waste diversion rates experienced is likely to be in the 15 to 20% range.

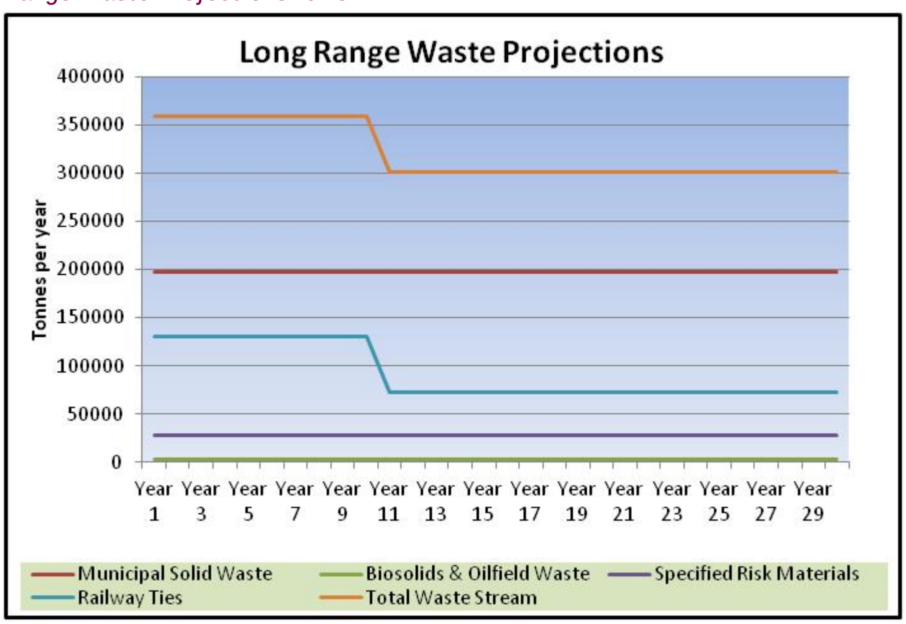
Future waste reduction, reuse and recycling initiatives, along with Extended Producer Responsibility (EPR) and more stringent packaging laws are important considerations when sizing a future EFW facility. The effectiveness of these programs will in part reduce the need for expansion of an EFW facility in the future, but will not in the foreseeable future result in a shortage of waste to be managed.

It is important to note that the types of EFW facilities being considered have the ability to increase waste diversion through the recovery of recyclable materials either through front-end processing and/or through the recovery of metals (ferrous and non-ferrous) from the ash/char produced by the facility. It is also a well documented fact that when sized properly, EFW facilities do not compete with waste diversion efforts, but rather provide another option for additional materials recovery. When looking to other jurisdictions, it is well documented that municipalities with EFW facilities to manage residual waste, also have the highest waste diversion rates.

Long Range Projections

Numerous factors that can influence waste disposal rates, capacities and needs were evaluated in the study. Although there will be a slight population growth in Southern Alberta, it is expected that any increase in MSW generation will be offset by new waste diversion initiatives. Waste disposal rates are expected to remain consistent throughout the planning period as shown on Figure 7.

Figure 7 - Long Range Waste Projections for SAEWA



An evaluation of waste variations, alternative disposal options, external influencing factors and risks concluded that the waste tonnage realistically available to a Southern Alberta EFW facility over the long term is approximately 365,000 tonnes per year, corresponding to the anticipated facility size of roughly 1,000 tonnes per day. This is a conservative estimate based on current understanding of the factors considered and should be periodically reviewed to account for changing conditions.

2.2 Technology Review

The review of combustion technologies covers not only thermal technologies, but also assesses chemical and biological processes evaluating proven, new, and emerging technologies in terms of their potential to process all or a portion of the potentially available waste stream. The technologies reviewed included: some that have been implemented successfully; technologies that have been tried but failed to handle an MSW stream on a commercial scale; and, those that are currently considered theoretical. The following technologies are evaluated in this study:

- Anaerobic digestion
- Mechanical biological treatment (MBT)
- Refuse-derived fuel (RDF) with stoker firing
- RDF with fluidized bed combustion
- Mass-burn combustion
- Catalytic depolymerization
- Hydrolysis
- Pyrolysis
- Gasification
- Plasma arc gasification

The important considerations in the evaluation of these technologies included:

- Assessing the current stage of development;
- Environmental and emission considerations;
- Potential risks; and,
- The applicability of the technology to the anticipated waste stream.

State of Development

The state of development of the technologies varied widely. Two of the technologies, mass burn combustion and RDF processing and combustion, were considered commercially proven with extensive experience throughout North America and Europe. Both gasification and plasma arc gasification have limited commercial operation, with facilities primarily located in Japan. There are a very limited number of small pyrolysis facilities operating in the world. Anaerobic digestion is proven for select portions of the waste stream and could provide a suitable alternative. Catalytic depolymerization and hydrolysis have no known commercially operating examples using MSW as a feedstock.

Based on the current state of development of the technologies, the report recommends removing catalytic depolymerization and hydrolysis from further consideration in the research project given their lack of demonstrated ability to manage the available waste streams. The other technologies identified, have been used in other places on similar waste streams and should therefore be carried forward for further consideration.

Environmental and Emission Considerations

There were not appreciable environmental differences between the technologies. The most significant concern for most technologies is air emissions which can be effectively addressed with modern air pollution control equipment. Water discharges can be avoided through the use of design concepts that limit water usage, reuse water within the facility and employ technology to enable zero discharge.

Potential Risks

Ranking the technologies with respect to risk resulted in three groups: Anaerobic digestion, mass burn combustion and RDF processing and combustion present limited risks; Gasification and plasma arc gasification present higher economic risks; and, Catalytic depolymerization, pyrolysis and hydrolysis presented the highest risks.

Suitability to the Waste Stream

All but three the technologies considered would be suitable for the entire waste stream. Catalytic depolymerization and hydrolysis were not considered suitable for the waste stream. Anaerobic digestion was considered suitable only for the specified risk materials (SRM) and parts of the MSW waste stream.

Conclusions

Based on the review completed, the following technologies were recommended for further analysis:

- Anaerobic digestion (limited feedstock);
- RDF processing and combustion;
- Mass Burn Combustion;
- Gasification; and,
- Plasma Arc Gasification.

2.3 Waste Collection Transportation and Handling

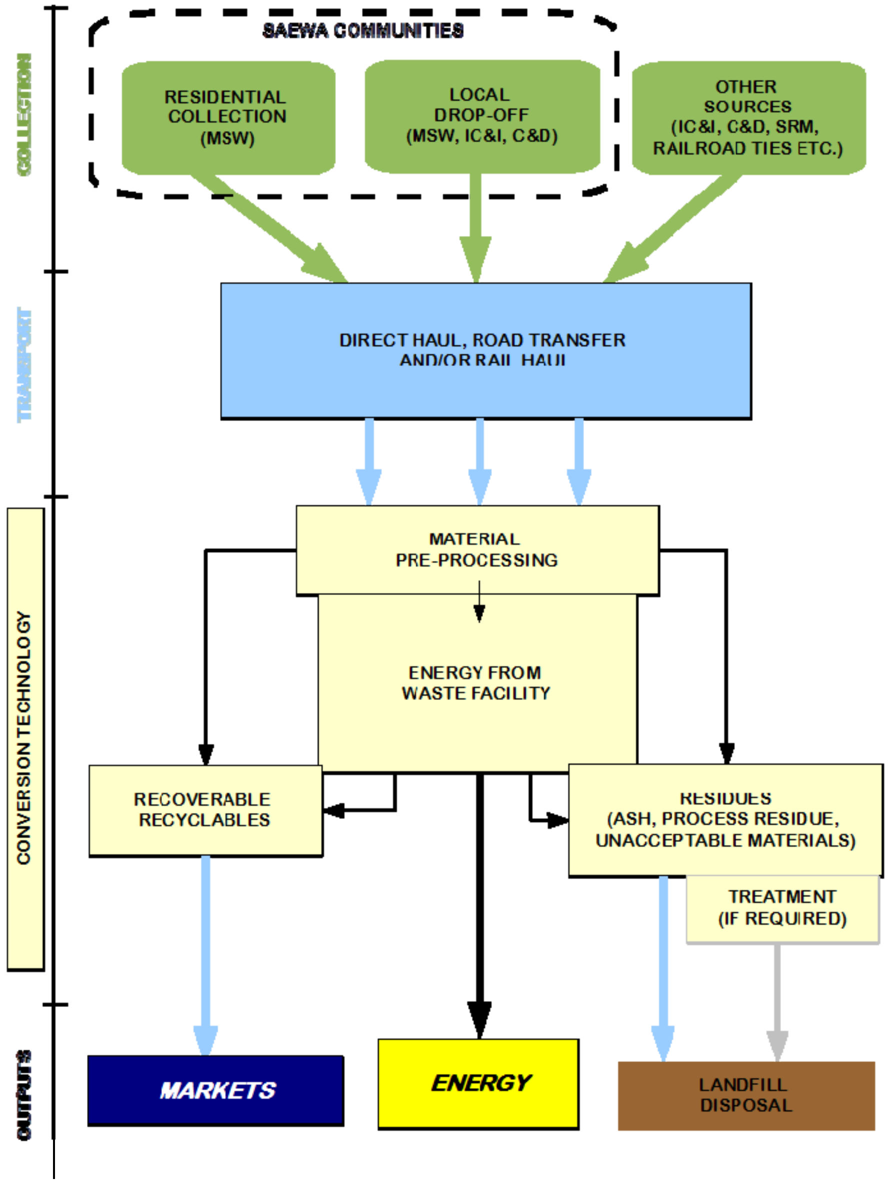
Each of the SAEWA member organizations runs local waste management programs and systems which balance community-specific needs and constraints to reflect the service delivery choices and preferences of the residents.

This assessment primarily focuses on the efficient and cost-effective transport and handling of the residual waste materials, once received from the local community-based collection programs.

This task provides an assessment of the waste transport framework, including the current baseline system and the potential implications/changes that will be required to implement a regional EFW facility.

Figure 8 presents an overview schematic of the various material collection and transport steps anticipated for a potential SAEWA EFW based system.

Figure 8 - Schematic of Material Handling for EFW System

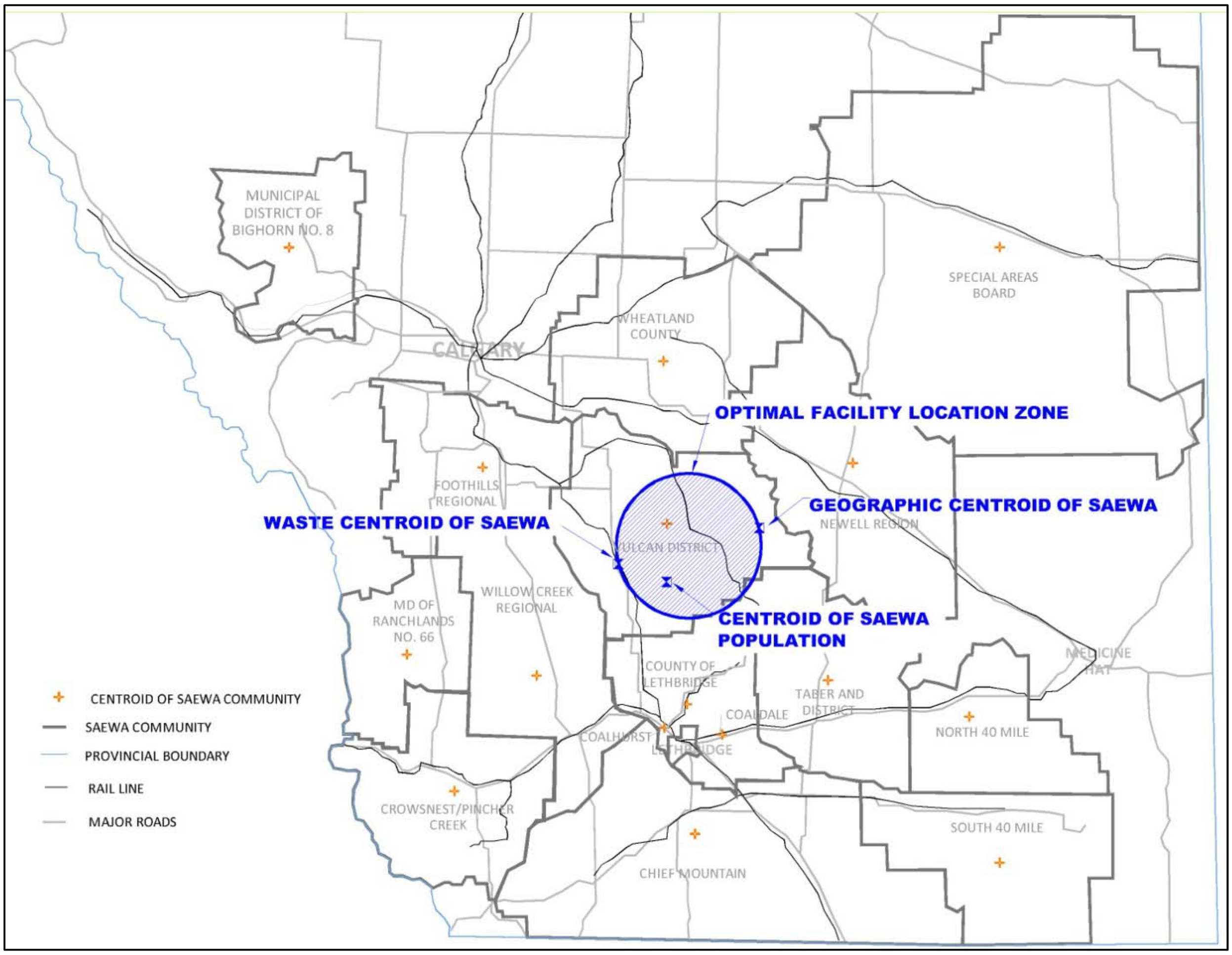


Results of the Collection, Transportation and Handling Review

The following summarizes the major findings of the analysis:

1. Waste generation in the SAEWA member communities is widely distributed over a large area.
2. From the perspective of waste transport efficiency, the optimal zone for siting an EFW facility is in close proximity to the waste centroid for the SAEWA as shown on Figure 9 generally within the central and southern portions of the Vulcan Waste District.

Figure 9 - Optimal Facilty Siting Zone (Waste Transport Basis)



Notes:

1. Geographic centroid = the physical location of the mean centre of an area
2. Waste centroid = the physical location of the mean centre of waste distribution for an area
3. Population = the physical location of the mean centre of population distribution for an area

3. Special handling requirements are required to allow acceptance of railroad ties, bio-solids and SRM at an EFW facility, however it is expected that measures can be incorporated to address these matters.
   a. Railroad ties will require preprocessing for size reduction (i.e. shredding).
   b. For use in combustion applications, bio-solids will require a maximum 3 % moisture content, grinding and introduction into the combustion unit as a segregated supplementary fuel.
   c. Specific permits are required for transport, handling and disposal of SRM.
      i. For use in combustion applications, SRM must be isolated and handled separately from non-SRM materials.
      ii. For use in non-combustion applications, SRM must be isolated and handled separately from non-SRM materials and any products or outputs containing SRM must be transported, handled, distributed and used in accordance with federal regulatory restrictions.

4. The break point between cost effective direct haul by packer truck and transfer trailers is approximately 80 km, round trip.
    a. Packer trucks can be used for cost effective waste haul within approximately 40 km of the EFW facility.
    b. For local collection systems that are more than 80 kilometres from the location of potential EFW facility, transfer stations should generally be used and located as close as possible to the waste generation weighted-centroid of each individual collection area.
5. Waste rail haul for a potential EFW facility may be cost effective for aggregated waste quantities greater than 30,000 tonnes/year, if capital costs can be contained and attractive rail haul rates are available.
6. Material recovery and recycling opportunities are available for each EFW conversion technology to improve the overall sustainability profile of the project. Capitalization these opportunities requires inclusion of a marketing function in the project implementation business plan.
7. Clarification of ash management regulatory requirements is necessary.

2.4 Energy Recovery Options

The sustainability of EFW is derived from using residual waste as a resource for generation of electrical power, heat energy and/or syngas fuel, thereby conserving other natural resources. Generation efficiency and marketability of the various forms of energy are key factors influencing the technical suitability and financial feasibility of each of the technologies being considered. The review of energy recovery options included an assessment of:

- The potential for energy recovery from waste in the SAEWA area using anaerobic digestion, refuse derived fuel processing and combustion, mass burn combustion, gasification and plasma arc gasification;
- EFW facility sizing and operational characteristics for processing the planned waste streams;
- Conversion efficiencies, generation rates and energy delivery infrastructure associated with each of the above technologies; and,
- Review of potential markets for the recovered energy.

Potential Energy Recovery

For each of the technologies being considered, the potential to recover energy from the following waste streams was evaluated:

Table 5 - Potentially Available Waste Streams

Waste Stream	Potentially Available Waste for SAEWA (Tonnes/year)
MSW from SAEWA Members	196,850
MSW from Non-SAEWA Members	13,300
Other Waste Sources:	
ICI Sector Waste	0
Agricultural Waste	0
Biosolids	1,232
Contaminated Soils	0
Combustible Oilfield Waste	2,500
Railway Ties	124,650
Specified Risk Materials	27,500
TOTAL	**366,032**

With the exception of anaerobic digestion, each of the remaining technologies is capable of processing the entire waste stream to generate energy. Anaerobic digestion technology is applicable exclusively to the Specified Risk Materials (SRM), subject to compliance with stringent regulatory requirements governing handling and transport of SRM and SRM containing by-products.

The following summarizes the facility sizing for each EFW technology:

Table 6 - Facility Sizing

Technology	Suitable Waste Stream	Potentially Available Waste (Tonnes/year)	Required Processing System Size (Tonnes/hr)	Required Facility Size (Tonnes/day)
Anaerobic digestion	Specified Risk Materials	27,500	N/A	90
RDF processing and combustion	Entire Waste Stream	366,032	80	1,180
Mass Burn Combustion	Entire Waste Stream	366,032	N/A	1,180
Gasification	Entire Waste Stream	366,032	80	1,180
Plasma Arc Gasification	Entire Waste Stream	366,032	80	1,180

Anaerobic digestion technology has the potential to generate approximately 1.5 MW or 12,161 MWh/yr of electrical power from biogas derived from SRM. Because anaerobic digestion has limited applicability to only a portion of SAEWA's potential waste stream, further consideration is not given to this technology.

Generation of electrical power is a key benefit resulting from all of the technologies being considered. Production of heat energy in combination with electrical power generation is often referred to as combined heat and power (CHP) or cogeneration.

The following summarizes the energy generation characteristics and capabilities associated with each of the remaining technologies under consideration:

Table 7 - Energy Generation Characteristics

Technology	Electrical Production Efficiency Range	Electrical Production (MW)	Potential Steam (1000's kg/hr)	Calorific Value (kJ/kg)	Electrical Production (MW)
RDF processing and combustion	17.4% to 21.0%	34.5 – 41.5	160 – 200	14,500	34.5 – 41.5
Mass Burn Combustion	19.0% to 23.0%	37.6 – 45.4	180 – 220	14,500	37.6 – 45.4
Gasification	13.0% to 19.0%	25.6 – 37.6	120 – 180	14,500	25.6 – 37.6
Plasma Arc Gasification	5.9% to 13.1%	11.7 – 25.9	55 – 125	14,500	11.7 – 25.9

Recovery and use of steam heat requires transport of steam via a pipeline from the EFW facility to the steam consumer. Analysis of the economics of steam export conclude that a suitable steam consumer would ideally be located within approximately 12 kilometres of the EFW facility to be financially viable.

Energy Markets

The following list the energy outputs and key market characteristics associated with each of the technology options under consideration.

Table 8 - Energy Output and Key Market Characteristics

	Energy Outputs		
	Electricity	*Heat*	*Gas Fuel*
Technologies			
RDF Processing and Combustion	✔	✔	
Mass Burn Combustion	✔	✔	
Gasfication	✔	✔	⊙
Plasma Arc Gasification	✔	✔	⊙
Key Market Characteristics (Non-financial)			
Access Mechanism	Grid	Pipeline	Pipeline
Nature of Market	Widespread	Local	Local or Widespread
Demand Variability Risk	Stable	High	High or Stable
Market Security Risk	Reliable	Customer Specific	Variable
Primary Barriers	Administrative	Geographic Opportunity	Product Quality

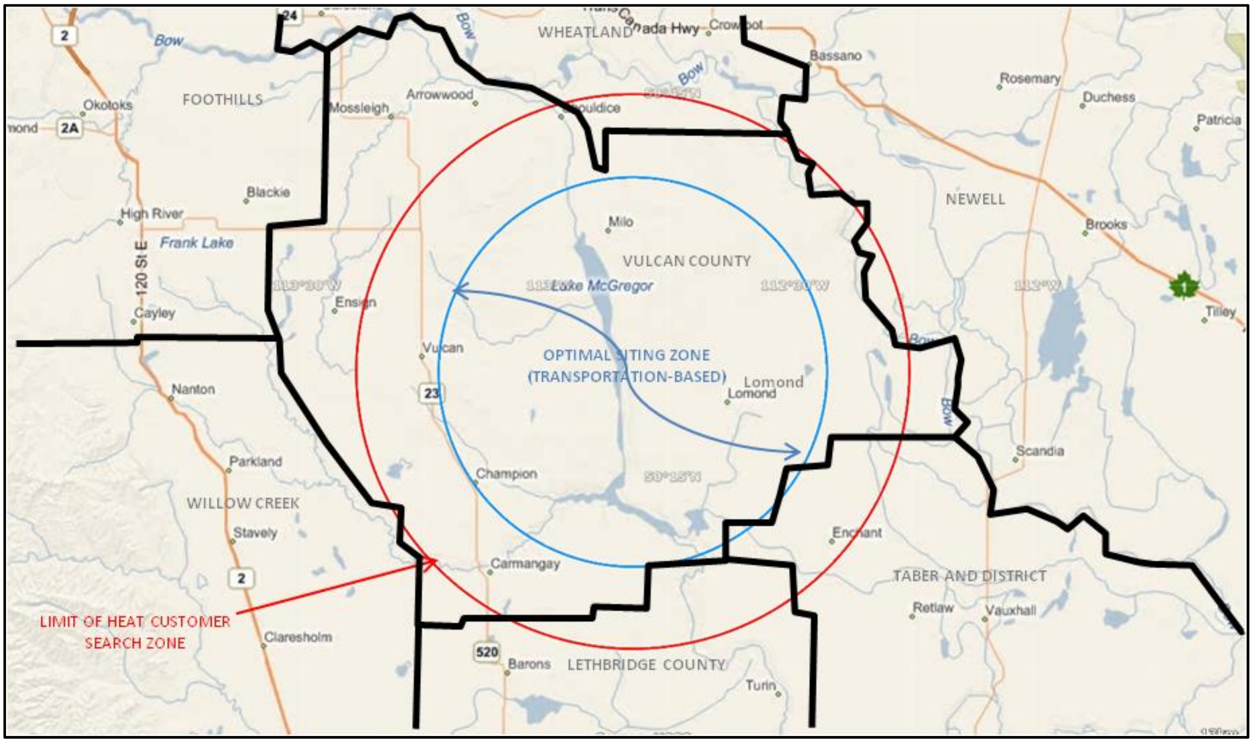
Note: ✔ represents a primary output. ⊙ represents an alternative output.

The widespread and reliable market for electrical power in Alberta provides an attractive and low risk potential source of revenue for all of the EFW technologies being considered. The power system is run by the Alberta Electric System Operator (AESO) and administered by Energy Alberta and the Alberta Utilities Commission. Pricing for electrical power is established by the rules of the power system with premium pricing credits available to certain types of renewable and alternative power. Accessibility to the electrical power market is dependent on meeting the technical requirements for connection to the power grid, which is universally present throughout the SAEWA.

Each of the combustion technologies being considered provides the opportunity to recover marketable heat energy in the form of steam. The marketability of steam heat is primarily a matter of geographic opportunity resulting in consumer(s) with compatible heat demand within about 12 kilometers of EFW facility.

The following shows the optimal facility location zone based on transportation considerations and the search zone for a heat energy customer.

Figure 10 - Optimal Facility Location Zone (Transportation Based)



A flexible approach to facility siting should be applied that also allows case-by-case consideration and evaluation of other siting and heat customer opportunities that may exist beyond these defined zones.

Where markets of sufficient size exist or can be established, EFW facilities can serve as the hub of a district energy system providing heat to a cluster of energy consumers. The presence of established infrastructure and markets for heat energy could influence the feasibility of an EFW system.

A review of the business/industrial profile of the study area suggests there may be some potential for businesses in the area to become heat energy customers of an EFW facility. Identification of existing potential heat energy customers can most effectively be included in evaluation of surrounding land uses as part of consideration of candidate siting opportunities and by issuing a proactive solicitation of requests for expression of interest from potential heat energy customers.

An overall development plan and business case analysis can provide information necessary to support decision-making for consideration of implementing EFW as a cornerstone supplier of heat energy to a new district energy system.

A range of uses for syngas derived from MSW has not yet been commercially demonstrated. Given this, direct export of syngas to an end-user or commercial gas pipeline are considered only as potential alternatives to the primary opportunities for electricity generation and steam export.

Results of the Heat Recovery/Cogeneration Review

The following summarizes the major findings of the analysis:

1. With the exception of anaerobic digestion of SRM, all of the technologies being considered have the capability to generate electricity and heat energy from processing of SAEWA's planned waste streams.

    a. Due to its limited applicability to only a small portion of SAEWA's planned waste streams, anaerobic digestion will not be evaluated further.
2. Generation of electrical power is considered to be the primary mode of energy recovery for an SAEWA EFW facility.
3. Recovery of steam heat as a secondary mode is applicable to all of the remaining technologies under consideration and increases the overall energy recovery efficiency of EFW.
4. Mass burn technology offers the highest energy conversion efficiency.
5. The market for electrical power from EFW is generally accessible and can provide a reliable, stable source of revenue.
6. Marketing of steam heat offers the potential to provide existing and new businesses with energy savings to assist economic development while also creating an important additional revenue stream to enhance the financial feasibility of EFW.
    a. Markets for steam are less certain than for electrical power and are primarily dependent on the presence of a compatible steam consumer in relatively close proximity to the EFW facility.
    b. Integration of an EFW facility into an existing district energy system may provide access to steam consumers while avoiding costs for new steam export infrastructure.
    c. Identification of existing potential heat energy customers can most effectively be included in evaluation of surrounding land uses as part of consideration of candidate siting opportunities and by issuance of a proactive solicitation of requests for expression of interest from potential heat energy customers.
    d. An overall development plan and business case analysis can provide information necessary to support decision-making for consideration of implementing EFW as a cornerstone supplier of heat energy to a new district energy system.
7. Proximity to existing and potential heat energy markets should be included as an important evaluation criterion in the site selection process.

2.5 Air Emissions, Greenhouse Gases and Control Options

EFW facilities equipped with modern air pollution control systems are capable of meeting stringent air emission criteria to protect air quality. Regulations and air emissions criteria for EFW facilities vary by jurisdiction. In order to meet emission criteria, air pollution control systems are designed to suit the combustion technology utilized and the characteristics of the anticipated waste stream.

Anaerobic digestion is being given no further consideration in this evaluation due to the limited applicability of this EFW technology to only a small portion of SAEWA's potential waste stream.

The review of air emissions, greenhouse gases and control options includes assessment of:

- Emission standards for EFW systems in the US, Europe, other parts of Canada and the standards anticipated for the SAEWA facility.
- The primary flue gas emissions from the combustion processes.
- Anticipated greenhouse gas emissions from an EFW facility and estimated greenhouse gas reductions (i.e. greenhouse gas offsets) for EFW in comparison to landfill disposal of waste.
- Key emission rates in comparison with conventional power generation technologies.

Emission Criteria and Air Pollution Controls

The following summarizes established emission limits for Alberta, Ontario, Europe and the US:

Table 9 - International Air Emission Limits

Pollutant	Units	Alberta [2]	Ontario, A7 Guidelines (Rev 3/13/09) [1]	EU Directive 2000/76/EC [1]	US EPA 40 CFR 60 [1]
Particulate Matter	mg/Rm^3	50	14	9	14
Sulfur Dioxide (SO2)	mg/Rm^3	450	56	46	55
Hydrogen Chloride (HCl)	mg/Rm^3	75	27	9	26
Hydrogen Flouride (HF)	mg/Rm^3	N/A	N/A	1	N/A
Nitrogen Oxides (NOx)	mg/Rm^3	400	198	183	198
Carbon Monoxide (CO)	mg/Rm^3	57	40	46	40
Mercury (Hg)	µg/Rm^3	20	20	46	35
Cadmium (Cd)	µg/Rm^3	N/A	7	N/A	7
Lead (Pb)	µg/Rm^3	N/A	60	N/A	98
Cd + Ti	mg/Rm^3	N/A	N/A	46	N/A
Sum (Sb, As, Pb, Cr, Co, Cu, Mn,)	mg/Rm^3	N/A	N/A	452	N/A
Dioxins/Furans (ITEQ) [3]	pg/Rm^3	80	32	92	100
Organic Matter (as Methane)	mg/Rm^3	N/A	N/A	N/A	N/A

Notes: N/A = Not Applicable.
1. All concentrations are corrected to 11% O2 at 25oC, 101.1 kPa.
2. Government of Alberta Environmental Code of Practice for Energy Recovery, Table 14-2.
3. U.S. EPA requires that facilities report Total Dioxin/Furan Emissions vs iTEQ values. The iTEQ was estimated by dividing the total emissions by a factor of 50.

Comparison of emission limits from various jurisdictions suggests that standard air pollution control systems similar to those in use at many EFW facilities throughout North America should be capable of meeting the Alberta emission limits.

Alberta Environment has indicated that project-specific emission criteria will be established reflecting the Canadian Council of Ministers of the Environment Canada-wide Standard for incinerators, as endorsed by Alberta Environment through the Minister.

Emission characteristics and air pollution control technologies for mass burn systems are similar to those associated with combustion of refuse derived fuel. Combustion of syngas to produce electricity is expected to have common emission characteristics and air pollution control requirements whether produced from gasification or plasma arc gasification.

The following lists primary pollutants of concern, emission limits as established in Alberta's Code of Practice for Energy Recovery and the air pollution control technologies anticipated to meet the criteria:

Table 10 - Alberta Air Emission Limits

Air Emission Concern	Alberta Air Emission Limit[1] (mg/Rm3)	Anticipated Control Technology
Particulate Matter	50	Fabric Filter
NOx	400	SNCR
CO	57	Good Combustion
SO2	450	Dry Scrubber
HCL	75	Dry Scrubber
Dioxins and Furans	8E-08	Carbon Injection
Mercury	0.02	Carbon Injection
NOx (Syngas Combustion)	N/A	SCR

Notes:
N/A = Not Applicable.
1. Government of Alberta Environmental Code of Practice for Energy Recovery, Table 14-2.

Greenhouse Gas Emissions

An inventory of greenhouse gas emissions was developed for each technology option being evaluated, and compared to landfill disposal as a baseline.

Table 11 - Greenhouse Gas Implications

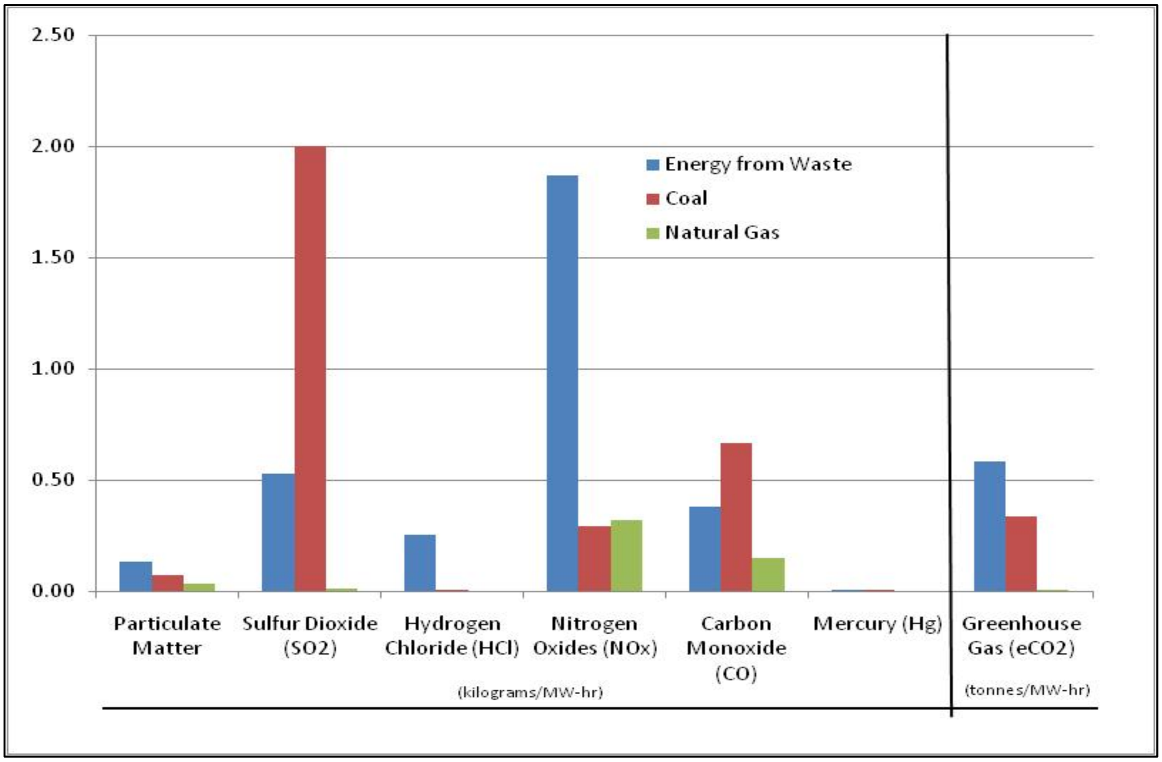
Summary of Estimated GHG Annual Emissions	Refuse Derived Fuel with Combustion	Mass Burn Combustion	Gasification	Plasma Arc Gasification	Landfill
Disposal (MTCO2/yr)	7,030	0	7,030	7,030	58,587
Combustion (MTCO2/yr)	84,140	78,116	84,140	84,140	0
Transportation (MTCO2/yr)	2,483	2,456	2,483	2,474	1,635
Facility Fuel Usage (MTCO2/yr)	244	228	244	238	532
Electrical Purchase and Sales (MTCO2/yr)	-92,276	-104,265	-76,894	-45,650	0
Ferrous & Non FerrousRecovery (MTCO2/yr)	-31,906	-31,906	-31,906	-31,906	0
Net GHG Estimated Emissions (MTCO2E/yr)	**-30,300**	**-55,400**	**-14,900**	**16,300**	**60,800**
GHG Emissions Reduction Relative to the Landfill (MTCO2E/yr)	91,100	116,200	75,700	44,500	-
Percent Reduction	150%	191%	125%	73%	-

The analysis shows that all EFW technologies evaluated achieve substantial reductions of GHG emissions in comparison to landfill disposal of the same quantity of waste. Mass burn offers the greatest GHG emissions reduction performance of the options being considered. This is primarily due to the higher energy efficiency that mass burn technology is able to achieve, resulting in a greater electricity production creating greater GHG emission offsets.

Emissions from Other Power Generation

The following shows a comparison of key emissions from EFW, coal, and natural gas fired power plants in terms of tonnes of emissions per MW•hr of power produced.

Figure 11 - Power Generation Emissions Comparison



Notes:

EFW emissions based on USEPA emission limits.
EFW plant based on mass burn facility.
Coal plant based on typical modern plant using USEPA emission limits.
Natural gas based on simple cycle plant using USEPA emission limits.

The main objective for EFW facilities is to reduce the amount of waste that would otherwise need to be disposed in a landfill while production of power is a secondary, beneficial by-product. Thus comparisons to conventional power generation are deceptive due to the lower energy density of MSW as a fuel and the consequently lower power production from an EFW plant. This results in higher unit emission rates (i.e. mass/per MW•hr) for some compounds, when compared to coal or natural gas power plants as shown.

Results of the Review of Air Emissions, Greenhouse Gases and Control Options

The following summarizes the major findings of the analysis:

1. Since it is applicable to only a small portion of SAEWA's potential waste stream anaerobic digestion should be given no further consideration in this feasibility assessment.
2. The remaining EFW technologies under consideration (RDF processing and combustion, mass burn combustion, gasification and plasma arc gasification), when equipped with modern air pollution controls are all capable of meeting stringent regulatory air emission criteria as required to protect air quality.

3. The Environmental Code of Practice for Energy Recovery lists emission criteria for mass burn facilities in Alberta. Additional clarification is required regarding the specific approval requirements that Alberta Environment would require for an SAEWA EFW facility. Project specific emission limits would be specified in the Approval issued by Alberta Environment.
4. All of the EFW technologies considered offer considerable greenhouse gas emission reductions in comparison to landfill disposal of waste. Mass burn technology offers the greatest greenhouse gas emission reductions of the technologies evaluated.
5. For many parameters, emissions per unit of power generation (i.e. kg/MW•hr) are lower for conventional power generating technologies consuming fossil fuels, in comparison to EFW making use of municipal solid waste as a resource. This is primarily due to the nature of the more homogenous fuels, energy efficiency and overall greater quantity of power produced using conventional technologies.

2.6 Permitting, Siting and Schedule Considerations

Waste management is a highly regulated industry with federal, provincial and municipal requirements applicable to various aspects and stages of most undertakings. EFW projects also encompass many of the regulatory aspects governing the energy industry. Implementation of any waste management project requires a systematic and comprehensive site selection process to: support sound decision-making, achieve compatibility of the project with the community and surrounding area, identify and mitigate potential impacts and establish a foundation for long-term success of the project. Stakeholder engagement and consultation is a key element of this process. Implementation of an EFW project is a complex process that can take several years and requires careful coordination.

The review of permitting, siting and schedule considerations included assessment of:

- Permitting requirements associated with implementation of EFW in southern Alberta;
- A process to guide identification, screening, evaluation and selection of a suitable site for an EFW facility within one of the SAEWA member communities;
- Needs for stakeholder engagement and consultation in the site selection process; and,
- A preliminary program and timetable for implementation of EFW.

Permitting Requirements

The following lists the primary regulatory instruments and approvals that are, or may be applicable to development of an EFW facility in Alberta:

- Federal:
  - Canadian Environmental Assessment Act
  - Fisheries Act
  - Aeronautics Act (i.e. Airport Zoning Regulations)
  - Requirements of the Canadian Food Inspection Agency (management of specified risk materials)
- Provincial:
  - Alberta Environmental Protection and Enhancement Act
    - Activities Designation Regulation
    - Approvals and Registrations Regulation
    - Substance Release Regulation
    - Waste Control Regulation

        - Code of Practice for Energy Recovery
        - The Alberta User Guide for Waste Managers
    - Climate Change and Emissions Management Act
        - Specified Gas Emitters Regulation
        - Specified Gas Reporting Regulation
        - Renewable Fuels Standard Regulation
    - Electric Utilities Act
        - Requirements of the Alberta Utilities Commission
        - Requirements of the Alberta Electric System Operator
    - The Water Act
        - Storm Drainage System Registration
    - The Alberta Land Stewardship Act
        - Regional Land Use Plans
            - South Saskatchewan Regional Plan (Currently under consultation)
            - Red Deer Regional Plan (Future)
    - The Alberta Fire Code

- Municipal:
    - Municipal Development Plans
    - Structure Area Plans
    - Zoning by-laws
    - Plumbing/Water and Sewer Connection permit
    - Building permit
    - Occupancy permit
    - Heating permit (steam)
    - Electrical permit

The preceding list is not necessarily comprehensive and illustrates the potential complexity associated with development of a project of this nature.

There are a number of clarifications required from Provincial regulators to better understand specific expectations with respect to the approvals processes, application of aspects of the regulations and definition of certain criteria. Discussions with the appropriate Provincial representatives would aid in clarifying these issues.

Siting and Stakeholder Consultation

Site selection is a decision-making process involving: information gathering and synthesis, review and input by engaged stakeholders and analysis of the results. A step-wise outline of the major elements of a generalized site selection process includes:

Step 1 - Definition of Site Characteristics, Evaluation Criteria and Priorities

Step 2 - Identification of Candidate Sites

Step 3 - Evaluation of Candidate Sites

Step 3 A - Detailed Investigations, Review and Confirmation of the Preferred Site (Optional)

Step 4 - Preparation and Recommendation of Development Concept for Preferred Site

Modifications to this generalized process may be required based on discussions with Alberta Environment.

Stakeholder consultation is an important component of planning and decision-making processes for projects with potential environmental and/or social impacts. A detailed stakeholder consultation plan should be developed prior to commencement of the site selection process. The following lists several of the key principles for effective and constructive stakeholder consultations:

- Inclusive
- Early
- Open
- On-going
- Collaborative
- Meaningful

Preliminary Project Implementation Schedule

The following summarizes a preliminary implementation program and timetable based on experience on similar EFW projects in other jurisdictions:

Table 12 - Preliminary Project Implementation Schedule

Project Implementation Activity	Estimated Timing
Establish Formal SAEWA Partnership	October 2011 to March 2012
Site Selection	March 2012 to September 2012
Procurement:	
Request for Proposal	September 2012 to February 2013
Receive Proposals	February 2013 to August 2013
Evaluation and Negotiation	August 2013 to January 2014
Permits and Approvals:	
Prepare and Submit Applications	August 2013 to December 2013
Regulatory Review and Approval	December 2013 to April 2014
Notice to Proceed	April 2014
Design Build:	
Detailed Design	April 2014 to October 2015
Construction:	
Site Works	November 2014 to May 2015
Facility Works	May 2015 to May 2017
Commissioning & Start-up	May 2017 to September 2017
Commencement of Operations	September 2017

This preliminary project implementation schedule is based on a number of assumptions regarding methods, sequencing and durations of tasks and is therefore subject to change as the project progresses.

Results of Assessment of Permitting, Siting and Future Project Schedule

The following summarizes the major findings of the analysis:

1. Similar to most other jurisdictions, permitting of EFW in Alberta is a complex undertaking potentially involving many different regulatory agencies and requiring several permit application submissions.
2. Additional information and clarification of a number of regulatory issues is required prior to proceeding to implementation. It is recommended that pre-approval consultation discussions with the regulatory representatives be held prior to proceeding with implementation.

3. A systematic approach to site selection should be followed that complies with the requirements of Alberta Environment and includes proactive stakeholder engagement and consultation as a primary element.
4. A preliminary program and timetable for project implementation has been prepared involving: initial establishment of a project ownership and governance partnership, site selection, permitting, procurement, design and construction. It is anticipated that this program will span a period of 5 to 6 years. Opportunities for improvement on this timeline may be realized as the project progresses.

2.7 Capital and Operating Costs

Achieving sustainability is generally accepted as establishment and maintaining a balance of the interests of:

- The Environment;
- Society or the Community; and,
- Economy.

Economic sustainability can be considered as the achievement of equity between the sum total of all life cycle costs and financial contributions to an undertaking. Assessment and comparison of the EFW options under consideration in accordance with these principles forms the basis of the analysis in this report.

Assessment of capital and operating costs was performed to:

- Build upon work completed in previous reports regarding waste supply, available technologies, transportation and waste handling, energy and material recovery opportunities, emissions and control systems, approvals and future implementation/development needs for an EFW undertaking;
- Assess the financial implications of undertaking an EFW option taking into account:
    - A life cycle economic framework for analysis
    - Capital and operating costs based on comparable industry examples
    - Revenue generation potential in Southern Alberta including both electrical power sales and marketing of recovered recyclables
    - Establish an equivalent landfill-based financial model as a frame of reference for examination of the EFW options
    - Express financial results in terms of net unit life cycle costs ($/tonne) for waste management to provide a common basis for comparison
- Identify and assess other indirect community economic implications of undertaking EFW
- Consider and summarize key environmental implications of the EFW options under consideration

Results of Assessment of Capital and Operating Costs

Financial models were developed for a hypothetical landfill scenario and the four EFW options under consideration in accordance with the following set of assumptions:

Table 13 - Financial Evaluation Assumptions

	Base Case	Energy From Waste Based Systems			
	Landfill System	RDF and Combustion	Mass Burn Combustion	Gasification	Plasma Arc Gasification
Waste available (tonne/year)	366,032				
Nominal facility size	366,032 (tonne/yr)	1,000 (tonne/day)	1,000 (tonne/day)	1,000 (tonne/day)	1,000 (tonne/day)
Capacity factor (%)	100	90	90	75	70
Waste disposed or processed (tonne/year)	366,032	328,500	328,500	273,750	255,500
Lifespan capacity (tonnes)	11 M	16.4 M	16.4 M	13.6 M	12.8 M
Facility operating lifespan (years)	30	50	50	50	50
Contaminating lifespan (years)	50	0	0	0	0
Electricity revenue ($/MW•hr)	NA	80.00[1]	80.00[1]	77.00[2]	77.00[2]
Ferrous metals recovery ($/tonne)	NA	50	50	50	50
Non-ferrous metals Recovery ($/tonne)	NA	750	750	750	750
Potential heat recovery ($/1000kg steam)	NA	8.24	8.24	8.24	8.24

NA = not applicable

Capital, operating and revenue estimates were prepared for each of the four EFW options and the landfill comparison scenario. These estimates made use of recent information from other relevant projects, similar in nature to the scenarios and options being considered. It is important to note that these financial models are presented to provide a reasonable basis for comparison of the scenarios and options under consideration. These models should not be interpreted as optimized or business models or business cases for any of the options.

The following summarizes the results of the financial life cycle assessment:

Table 14 - Estimated Life Cycle Costs

	Base Case	Energy From Waste Based Systems			
	Landfill System	RDF and Combustion	Mass Burn Combustion	Gasification	Plasma Arc Gasification
Total Waste Disposed (tonnes)	*11,000,000*	*16,425,000*	*16,425,000*	*13,687,500*	*12,775,000*
Operating Lifespan (years)	*30*	*50*	*50*	*50*	*50*
Lifecycle Expenditures					
Capital	$266,717,000	$476,889,000	$464,039,000	$468,714,000	$429,354,000
Operating	$763,333,950	$1,664,446,100	$1,356,937,500	$1,272,689,600	$1,414,693,400
Total Expenditures	$1,030,050,950	$2,141,335,100	$1,820,976,500	$1,741,403,600	$1,844,047,400
Gross Lifecycle Unit Cost ($/tonne)	94	130	111	127	144
Lifecycle Revenues					
Electricity Sales	0	$709,560,000	$791,028,000	$500,620,313	$314,776,000
Sale of Recyclables	0	$63,657,500	$63,646,875	$53,039,063	$49,503,125
Total Revenue	0	$773,217,500	$854,674,875	$553,659,375	$364,279,125
Residual Asset Value	0	$25,000,000	$25,000,000	$25,000,000	$25,000,000
Net Lifecycle Cost	$1,030,050,950	$1,343,117,600	$941,301,625	$1,162,744,225	$1,454,768,275
Net Lifecycle Unit Cost ($/tonne)	**94**	**82**	**57**	**85**	**114**

From this financial assessment, the following key observations and conclusions arise:

- Mass burn EFW offers the lowest net life cycle unit cost
- On average, net life cycle unit costs for the EFW options are comparable or lower than the net life cycle unit costs for landfill
- Relative to the landfill comparison scenario, the higher capital and operating costs for EFW options are offset to varying degrees by revenue from sale of power and recovered recyclables
- The life cycle costs of landfilling are considered low-end estimates
- Similarly, the life cycle revenues for EFW scenarios are also considered low-end estimates

Community Factors

Development of an EFW facility of the size under consideration would result in creation of roughly 200 full-time construction jobs spanning a period of roughly four years. Over the long-term, roughly 30 to 40 permanent positions would be created associated with operation of the facility. Additional indirect employment and business opportunities would be expected to result from provision of materials and services to the facility, as well as “spin-off” employment and opportunities associated with the temporary and permanent workforce increases.

Studies have indicated that there is no long-term negative impact on sale-ability or property values in the vicinity of EFW facilities. In a situation where district energy can be implemented, property values may even increase due to attraction of energy consuming industries and potential increased development pressures.

Some EFW facilities have been developed to fill a role as a community amenity incorporating features such as advanced architectural treatments, educational and conference/visitor centres, cultural venues, and other complementary functions.

Environmental Life Cycle Considerations

Environmental performance considerations such as energy generation, emissions/greenhouse gases and waste diversion all represent key non-financial factors to take into account in decision making.

The following summarizes several of the key environmental performance indicators for the EFW options under consideration.

Table 15 - Environmental Life Cycle Considerations

Life Cycle Parameters	*RDF and Combustion*	*Mass Burn*	*Gasification*	*Plasma Arc Gasification*
Electricity Production (kW•h)	8,869,500,000	9,887,850,000	6,501,562,500	4,088,000,000
Additional Recyclables Recovered (tonnes)	468,150	468,113	390,094	364,088
Greenhouse Gas Emission Reductions* (tonnes)	4,555,000	5,810,000	3,785,000	2,225,000

* Relative to landfill.

3.0 Primary Findings

The following lists several of the major findings of this research project:

Waste Supply:

- It is conservatively estimated that approximately 365,000 tonnes per year of residual solid waste would be realistically available to a Southern Alberta EFW facility over the long term. This corresponds to an anticipated facility size of roughly 1,000 tonnes per day.
- The anticipated waste stream would be made up primarily of SAEWA municipal solid wastes, scrap railway ties and smaller amounts of other wastes and would be expected to have overall energy content in the range of roughly 13,970 to 14,954 KJ/Kg.

Conversion Technologies & Energy Recovery:

- Of the ten energy conversion technology options initially identified and evaluated, the study concluded that the following four technologies are all capable of processing the anticipated waste stream:
  - RDF processing and combustion;
  - mass burn combustion;
  - gasification; and,
  - plasma arc gasification.
- These four technologies were compared to a further level of detail.
- Due to energy generating efficiencies and market characteristics, production of electrical power is considered the primary energy recovery mode for a SAEWA EFW facility, with recovery of additional heat energy considered an attractive secondary energy option.
  - Proximity to existing and potential heat energy markets is an important evaluation criterion in site selection.
- All four of the EFW technologies compared have the capability to generate electricity and heat energy from processing SAEWA's anticipated waste stream.
  - Mass burn combustion offers the highest energy conversion efficiency.

Emissions and Controls:

- All four of the EFW technologies compared, when equipped with modern air pollution controls, are all capable of meeting stringent regulatory air emission criteria as required to protect air quality.
- All four of the EFW technologies compared offer considerable greenhouse gas emission reductions (i.e. 2.2 to 5.8 M tonnes of eCO_2) relative to landfill disposal of waste.
  - Mass burn technology offers the greatest greenhouse gas emission reductions of the technologies evaluated.

Waste Transport:

- From the perspective of overall waste transport costs, the optimal zone for siting an EFW facility to serve the SAEWA membership would generally lie within the central and southern portions of the Vulcan Waste District. Transfer stations, aggregation of waste and rail haul all offer the potential for efficiencies and savings on transport of waste to a central EFW facility.
  - There are numerous other factors to consider in selection of a preferred site.

Permitting, Siting and Implementation:

- Permitting and approvals for an EFW facility is a complex and lengthy undertaking. Many different federal, provincial and municipal regulatory requirements must be met.
- Siting is an important aspect of development of an EFW facility including proactive stakeholder engagement and consultation as a primary element.

- A project implementation timetable would conservatively be expected to span a period of 5 to 6 years and involve: initial establishment of a project ownership and governance partnership, site selection, permitting, procurement, facility design and construction.

Financial Considerations:

- Gross capital and operating expenditures for all EFW options are higher than for landfilling on a per tonne of waste processed/disposed basis.
    - These higher expenditures for EFW options are offset to varying degrees by revenue from sale of power and recovered recyclables.
- The net life cycle unit costs for the EFW options are comparable or lower than the net life cycle unit costs for landfill.
    - Mass burn combustion offers the lowest net life cycle unit cost of all scenarios compared.