Environment

Regional District of Nanaimo, Cowichan Valley Regional District and Capital Regional District

Tri-Regional District Solid Waste Study

Prepared by:

AECOM
3292 Production Way, Floor 4 604 444 6400 tel
Burnaby, BC, Canada V5A 4R4 604 294 8597 fax
www.aecom.com

Project Number:

60156649

Date:

May 2011

Statement of Qualifications and Limitations

The attached Report (the "Report") has been prepared by AECOM Canada Ltd. ("Consultant") for the benefit of the client ("Client") in accordance with the agreement between Consultant and Client, including the scope of work detailed therein (the "Agreement").

The information, data, recommendations and conclusions contained in the Report (collectively, the "Information"):

- is subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the "Limitations")
- represents Consultant's professional judgement in light of the Limitations and industry standards for the preparation of similar reports
- may be based on information provided to Consultant which has not been independently verified
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued
- must be read as a whole and sections thereof should not be read out of such context
- was prepared for the specific purposes described in the Report and the Agreement
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time

Consultant shall be entitled to rely upon the accuracy and completeness of information that was provided to it and has no obligation to update such information. Consultant accepts no responsibility for any events or circumstances that may have occurred since the date on which the Report was prepared and, in the case of subsurface, environmental or geotechnical conditions, is not responsible for any variability in such conditions, geographically or over time.

Consultant agrees that the Report represents its professional judgement as described above and that the Information has been prepared for the specific purpose and use described in the Report and the Agreement, but Consultant makes no other representations, or any guarantees or warranties whatsoever, whether express or implied, with respect to the Report, the Information or any part thereof.

The Report is to be treated as confidential and may not be used or relied upon by third parties, except:

- as agreed in writing by Consultant and Client
- as required by law
- for use by governmental reviewing agencies

Consultant accepts no responsibility, and denies any liability whatsoever, to parties other than Client who may obtain access to the Report or the Information for any injury, loss or damage suffered by such parties arising from their use of, reliance upon, or decisions or actions based on the Report or any of the Information ("improper use of the Report"), except to the extent those parties have obtained the prior written consent of Consultant to use and rely upon the Report and the Information. Any damages arising from improper use of the Report or parts thereof shall be borne by the party making such use.

This Statement of Qualifications and Limitations is attached to and forms part of the Report and any use of the Report is subject to the terms hereof.

AECOM
3292 Production Way, Floor 4
Burnaby, BC, Canada V5A 4R4
www.aecom.com
604 444 6400 tel
604 294 8597 fax

May 20, 2011

Dennis Trudeau
General Manager of Transportation & Solid Waste Services
Regional District of Nanaimo
6300 Hammond Bay Road
Nanaimo, BC V9T 6N2

Dear Dennis:

Project No: 60156649

Regarding: Tri-Regional District Solid Waste Study

We are pleased to present the report of the Tri-Regional District Solid Waste study for the combined regions of Nanaimo, Cowichan Valley and Capital Region. The report has been completed in accordance with comments received.

A copy of this report has simultaneously been sent to the CRD and CVRD. It has been a pleasure working with you and your colleagues and we thank you for the confidence placed in our team.

Sincerely,
AECOM Canada Ltd.

Wilbert Yang, P.Eng.
Senior Environmental Planner, Waste Services

WY:gc

CC: CRD, Larisa Hutcheson
CVRD, Bob McDonald

Distribution List

# of Hard Copies	PDF Required	Association / Company Name
	1	RDN
	1	CRD
	1	CVRD
	1	AECOM

AECOM Signatures

Report Prepared By:

Wilbert Yang, P.Eng.
Senior Environmental Planner

Report Reviewed By:

Konrad Fichtner, P.Eng.
Senior Environmental Consultant

Report Reviewed By:

Robert C. Dickin, M.Sc., P.Geo.
Senior Hydrogeologist - Environment

Executive Summary

AECOM has assessed thermal treatment technologies for municipal solid waste (MSW) on behalf of three regional districts located in the southern portion of Vancouver Island (Tri-Regional District Solid Waste Study). This is an extension of two previous studies on the same subject conducted in 2006 for the Regional District of Nanaimo (RDN) and in 2008 for the RDN combined with the Cowichan Valley Regional District (CVRD).

This Tri-Regional District Study builds on the previous studies and now includes the Capital Regional District (CRD). In the expanded study, technologies are again reviewed in light of the larger volume of feedstock available and for the potential to accept dried biosolids as additional fuel. Four sites are reviewed, one in each of the participating regions and one in Gold River, BC. Costs are assessed as well as greenhouse gas implications.

Combining the solid waste that is expected to be generated in the CRD, CVRD and RDN after organics management and recycling have been maximized, still leaves about 225,000 tonnes per year that need to be treated and/or disposed. Waste-to-energy (WTE) technologies could conceivably treat about 200,000 tonnes per year and extract the remaining energy from this waste.

Technologies were assessed for 200,000 tonnes per year of feedstock, including biosolids. The technologies considered for further review and analysis were:

- mass burn;
- gasification; and
- plasma gasification.

Mass burn was confirmed as the most proven, reliable and lowest cost technology and the de-facto world standard for energy recovery from waste. A single WTE facility would have adequate economies of scale to employ mass-burn technology; however, it is still not at an optimum size from a pricing perspective, which would be about 3 times larger. The out of region WTE facility being offered in Gold River does fall into a desirable economy of scale range because it plans to accept waste from other regions. However, there is additional cost involved in getting the waste to Gold River.

Gasification and plasma gasification offer some process and environmental advantages, such as being able to make alternate fuels for combustion elsewhere or for use in vehicles, or by achieving higher overall electrical efficiencies. There is a greater technical and financial risk with gasification and plasma gasification than with mass burn, but select reference facilities are available in Japan, although none in Europe or North America. Gasification and plasma gasification could be included as options in a future selection processes.

Four siting options were reviewed as set in the scope of work:

- CRD – A site in the CRD;
- CVRD –Centroid of CVRD;
- RDN – A site in the RDN; and
- Out of region – private facility in Gold River.

These were used for demonstration and comparison only; this study was not conducted for the purpose of choosing a site. For each of the example sites, transportation options were analysed for costs, fuel usage and GHG emissions.

The site that is closest to where most of the waste is generated (i.e. in the CRD) offers the lowest transportation costs. Direct haul, transfer haul, rail haul and barging (for Gold River only) were considered. Transfer haul is the lowest cost option for all locations. It also offers the lowest fuel usage, lowest GHG emissions and most flexibility for backhauling.

New transfer stations would be needed in all scenarios. If a WTE facility were built in the CRD, a new transfer station would be required in the Nanaimo area. If the WTE facility is located in RDN, then the CRD would require a new transfer station. If the waste goes to an out of region facility at Gold River, then both Nanaimo and CRD require new transfer stations. Existing transfer stations would continue to operate, except if the WTE facility were to be located in CVRD, in which case the local transfer station would be needed only for recycling and stewardship programs. If barging to Gold River is preferred, a special transfer station at the water front in the CRD would be required.

There is a fairly large variation in unit costs for the different technologies:

- mass burn would cost $84 to $98 per tonne (the latter without district heat);
- gasification to ethanol would be $136 per tonne;
- plasma gasification to electricity and district heat would be about $152 to $155 per tonne; and
- private facility mass burn in Gold River is estimated at $42 per tonne.

When transportation costs are incorporated, total unit costs are similar for all sites using the same technology. For example; mass burn costs range from $111 (Gold River) to $119 (CRD), with CVRD at $116 and RDN at $115 per tonne. A table presenting the different technology and transportation costs for the various technologies is shown below.

Option	Description	Capital Costs $ Million	Facility Cap and Operations $/T	Transportation Costs $/T	Total Costs $/T
1	**WTE in CRD**				
1a	Mass burn	$209 M	$98	$21	$119
1b	Gasification	$323 M	$136	$21	$156
1c	Plasma gasification	$292 M	$155	$21	$176
2	**WTE at CVRD**				
2a	Mass burn	$209 M	$84	$31	$116
2b	Gasification	$323 M	$136	$31	$167
2c	Plasma gasification	$292 M	$152	$31	$183
3	**WTE at RDN**				
3a	Mass burn	$209 M	$84	$30	$115
3b	Gasification	$323 M	$136	$30	$166
3c	Plasma gasification	$292 M	$152	$30	$182
4	**WTE at Gold River**				
	Mass burn	N/A	$42	$68	$111

It should also be noted that the CRD options analysis was undertaken with no potential for district heating. If a site with district heating opportunities was realized, the total unit cost could be reduced from $119 to $105 per tonne. This would make this option the most economical.

Small changes in capital costs, transportation costs, and energy recovery efficiency and markets can easily change the order of preference. Therefore, the selection of a site within the regions will depend more on other factors, such as:

- political and social preference/desire to host a facility by the community;
- availability of land under appropriate zoning;
- good transportation access;
- preferred form of energy recovery (electricity or fuel);
- ability to utilize district heat in the surrounding area; and
- minimizing transportation costs and GHG emissions.

Greater refinement of costs will require either a detailed study with actual technology selection, preliminary design and site selection, or a public proposal/tender process, or a combination of both.

The out-of-region WTE facility at Gold River benefits from greater economies of scale and thus can offer a substantially lower tipping fee than a constructed in-region facility. However, current calculations show that most of the lower tipping fee will be offset by higher transportation costs. For this option, further discussions with the proponent on how to optimize barging are recommended. These are contingent on the project proceeding based on the proponent having other key waste supply agreements in place.

If the advantages of gasification and or plasma gasification are appealing, it will be necessary to decide what level of risk is acceptable to the three regions. Should the regions wish to pursue these technologies instead of mass burn, then it is recommended to confirm technology viability through further research and site visits of commercially operating plants before including them in a public selection process.

If in-region mass burn is seriously being considered, it is recommended that the three regional districts continue to cooperate in order to maintain the currently studied economies of scale. This would likely not be necessary if waste is shipped out of region to a private facility.

If an in-region WTE facility is preferred, it is recommended to give preference to a site in the RDN, since it offers the greatest potential for district heat. This is only essential in the case of combined heat and power technologies are selected. If ethanol production is preferred, then the CRD offers the preferred location due to lower transportation costs and should be considered.

Biosolids, provided they are dried adequately, should be welcomed as additional fuel, since they increase the biogenic portion in the feedstock and improve the overall GHG balance.

The GHG emissions and respective off-sets were compiled to assess the net GHG emissions for each option. These include a local landfill option, nine local WTE options and one out of region WTE option in Gold River, BC. The chart below summarizes the GHG emissions and the star on each bar graph represents the net GHG emission. In general, GHG emissions are lower with WTE than landfilling. GHG emissions are lowest where the waste is gasified and converted into fuels that offset fossil based fuels such as natural gas or diesel fuel. Both conventional and plasma gasification are capable of this, although in our example plasma gasification was, for comparative purposes, shown producing electricity and heat.

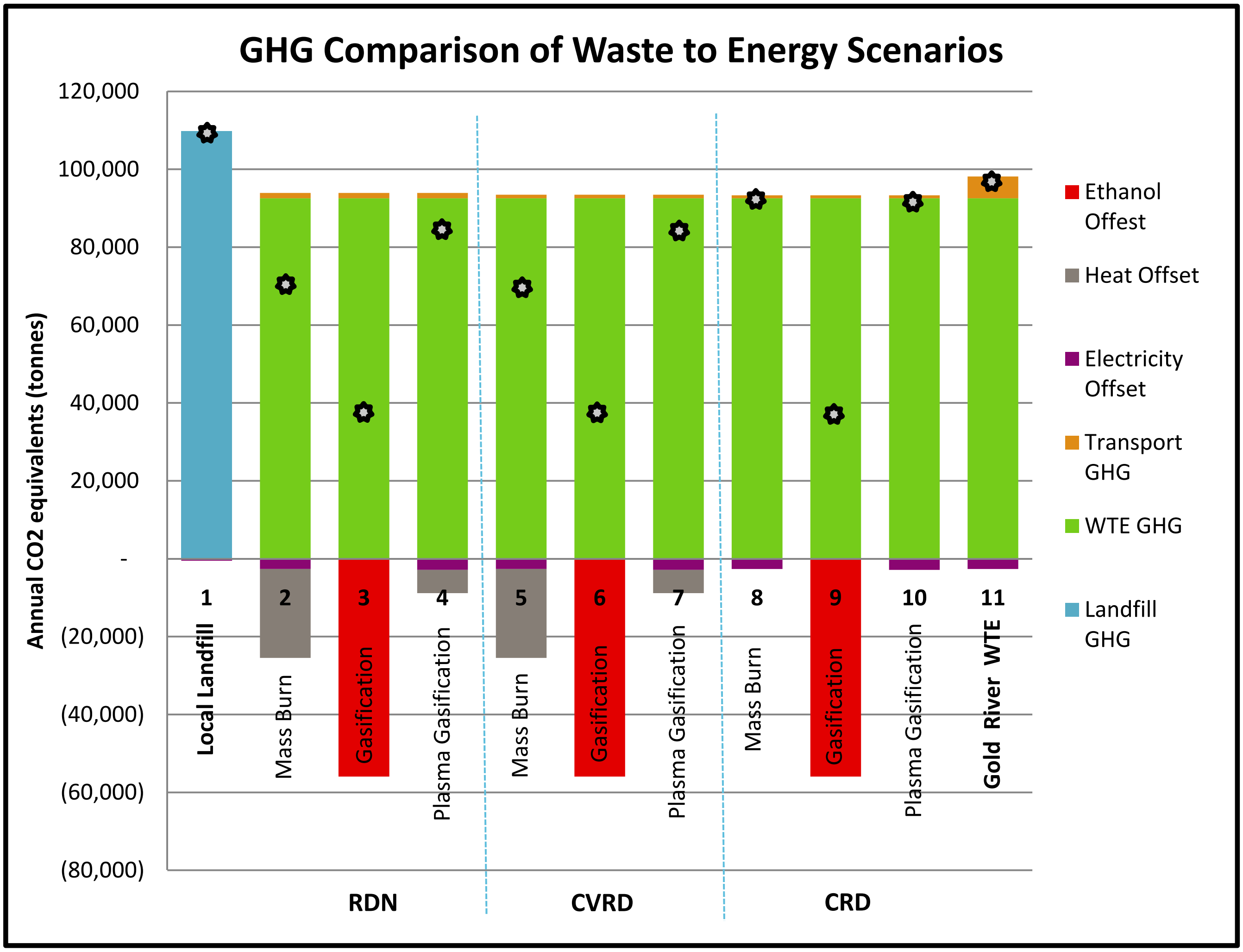

GHG Comparison of Waste to Energy Scenarios
120,000
100,000
80,000
60,000
40,000
20,000
-
(20,000)
(40,000)
(60,000)
(80,000)
Annual CO2 equivalents (tonnes)
1 Local Landfill
2 Mass Burn
3 Gasification
4 Plasma Gasification
5 Mass Burn
6 Gasification
7 Plasma Gasification
8 Mass Burn
9 Gasification
10 Plasma Gasification
11 Gold River WTE
RDN
CVRD
CRD
Ethanol Offest
Heat Offset
Electricity Offset
Transport GHG
WTE GHG
Landfill GHG

Table of Contents

List of Figures

List of Tables

Appendices

1. Introduction

AECOM has assessed thermal treatment technologies for municipal solid waste (MSW) on behalf of three regional districts located in the southern portion of Vancouver Island (Tri-Regional District Solid Waste Study). This is an extension of two previous studies on the same subject conducted in 2006 for the Regional District of Nanaimo (RDN) and in 2008 for the RDN combined with the Cowichan Valley Regional District (CVRD).

This Tri-Regional District Study builds on the previous studies and now includes the Capital Regional District (CRD). In the expanded study, technologies are again reviewed in light of the larger volume of feedstock available and for the potential to accept dried biosolids as additional fuel. Four sites are reviewed, one in each of the participating regions and one in Gold River, BC. Costs are assessed as well as greenhouse gas implications. Information from this study will help local governments make informed and defensible decisions on how to set the direction for solid waste treatment and disposal in the future.

1.1 Background

In 2008 AECOM (formerly Gartner Lee Limited) assessed thermal treatment technologies for MSW on behalf of the Regional District of Nanaimo (RDN) and the Cowichan Valley Regional District. This was a follow-up to a 2006 study for the RDN only and expanded the scope to include Cowichan Valley waste. In this study, traditional and new and emerging technologies were reviewed to determine their maturity and potential cost of implementation for the study area, with the purpose of extracting energy in the form of electricity and heat and extending the life of the RDN landfill.

For the CVRD which has no landfill and high disposal costs, the thermal treatment cost was competitive with long haul disposal. For the RDN which owns and operates its own landfill, thermal treatment costs are considerably higher than current landfill disposal costs; however, thermal treatment would extend the life of the landfill by twenty years. Nevertheless, the residual waste quantities from RDN and CVRD are not sufficient for a thermal process to be economically feasible without bringing in waste from other regions, or exporting the waste to a larger facility outside the region.

The advantages of thermal processing include reducing waste volumes thereby extending landfill life, recovering energy from waste, reducing GHG emissions, additional metal recycling and favourable processing costs if and when higher economies of scale can be achieved.

It was concluded that the greater volumes of waste from combining both regional districts did improve economics, but not adequately to compete with landfilling. Emerging technologies had not yet reached a maturity level acceptable to the risk criteria established for the study. It was recommended to monitor technology developments and costs every five years. It was further recommended to explore and consider working with private sector waste-to-energy firms offering the service outside of the study region.

Opportunities to include waste from other regions presented themselves when the Capital Regional District (CRD) started evaluating management options for organic waste. The purpose of that study was to identify a variety of technologies and options for processing source separated food organics from the solid waste stream and to compare them with options for managing biosolids from the liquid waste stream. Because a number of the scenarios that were evaluated included waste-to-energy as a disposal option for non-food and non-recyclable residuals, a solid waste study shared among the three regional districts was initiated to compare transportation, cost, GHG and landfill life implications for establishing a common waste-to-energy facility on southern Vancouver Island.

1.2 Project Approach

The study is based on recent and projected waste quantities that are provided by the regional districts. The waste quantities are projected over 30 years and take into account the planned diversion and organic programs in addition to volume estimates for biosolids. A baseline year was selected to analyze and compare the possible scenarios.

The transportation analysis is based on four possible locations for the waste-to-energy facility, one in each of the three regional districts and one outside the study area in Gold River, BC. Existing and new transfer facilities are assessed based on their capability to process future waste quantities, and capital and operating costs. The transportation assessment uses the quantities from the baseline year and compares transportation options (including direct haul, long haul, and rail haul) to determine fuel consumption, cost and GHG emissions. Barging is also assessed for the Gold River alternative.

Thermal technologies are evaluated based on the feedstock volumes from all three regions with the exception of the facility in Gold River, BC. Following a technology review process, the analysis examines one appropriate conventional technology in addition to looking at a gasification process and one using plasma gasification. Based on information in the public domain and typical industry values, the feasibility analysis estimates capital and operating costs, potential revenue from energy sales (steam, electricity, district heating and alternate fuels), and GHG generation.

2. Waste Quantities

2.1 Solid Waste Quantities

In 2009, the regional districts reported the following disposal rates in tonnes. As shown in the Table 1 below, the disposal rate for the three regional districts equates to 246,929 tonnes. The disposal per capita rates were calculated using the existing population for the regional districts.

Table 1. Disposal Rate for the Three Regional Districts

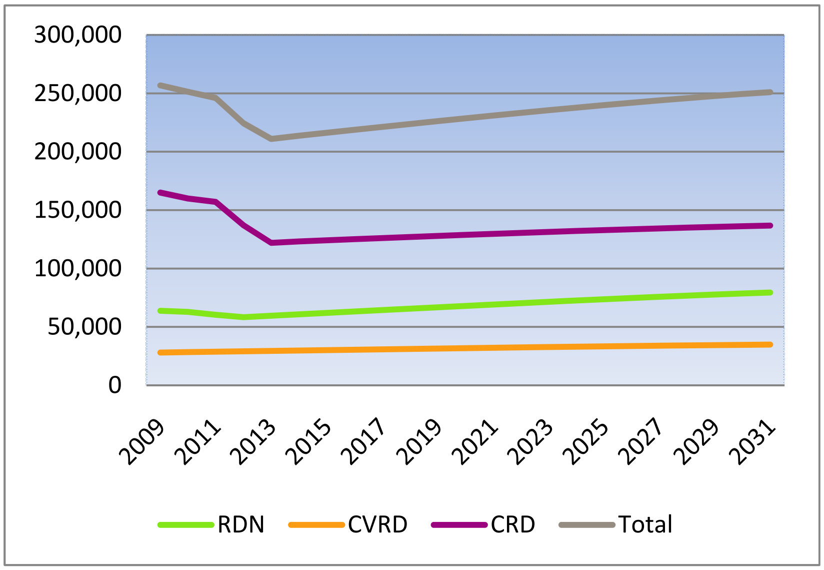
	RDN	CVRD	CRD	Total
2009 Disposal (tonnes)	63,529	27, 984	155,000	246,929
Disposal Per Capita (t/capita)	0.43	0.34	0.42	0.41

Over the next three years, the three regional districts have and will continue to ramp up organic waste diversion programs. The messaging that will be included to promote these programs should enhance existing recycling programs in addition to new Extended Producer Responsibility (EPR) programs and material disposal bans that will play a large role in decreasing per capita disposal rates. The regional districts have targeted the following disposal rates per capita.

- 0.36 t/c for RDN by 2012,
- 0.34 t/c for CVRD by 2013, and
- 0.32 t/c for CRD by 2013.

Population projections for the regional districts and the per capita disposal rates were used to project solid waste disposal demand. Figure 1 illustrates the estimated disposal rates over time. This suggests the required solid waste processing capacity for treatment and disposal will be between 210,000 and 250,000 tonnes per year. The waste-to-energy capacity used for planning purposes will be lower than the total expected volumes to allow for additional recycling and reduction efforts, as well as seasonal and economic fluctuations.

Figure 1. Solid Waste Disposal Projections



2.2 Biosolid Quantities

Biosolids from the liquid waste stream are identified as additional feedstock for the waste-to-energy facility. There are over twenty (20) wastewater treatment plants that are operated by the regional districts that vary in size from small neighbourhood facilities to large facilities that service several municipalities. The estimated biosolids disposal rates are estimated below.

	RDN	CVRD	CRD	Total
Biosolid Disposal (tonnes)	4,600	n/a	5,840	10,440

It is estimated that biosolids will add an additional 10,440 tonnes of material that the waste-to-energy would need to process. Population growth in the three regional districts is estimated to grow by 30% to 50% in the next 30 years. This suggests that biosolids disposal can increase to 15,000 tonnes per year by 2031.

2.3 Solid Waste Facilities and Waste Flows

The existing solid waste facilities in the Tri-Regional District study are summarized in Table 2 below.

Table 2. Existing Solid Waste Facilities

RDN	CVRD	CRD
Nanaimo Landfill – regional disposal site	Bings Creek Transfer Station (Duncan) – 100 tonnes per day facility that loads long-haul trailers.	Hartland Landfill – regional disposal site
Church Road Transfer Station (Parksville) – waste transferred to Nanaimo Landfill	Meade Creek Depot (Lake Cowichan) – waste residuals transferred to Bings Creek TS	
	Peerless Road Depot (Ladysmith) – waste residuals transferred to Bings Creek TS	

For RDN, waste is collected and delivered to one of two facilities, Nanaimo Landfill or Church Road Transfer Station (CRTS). Waste from CRTS is transferred to Nanaimo Landfill for final disposal. Of the 84,000 tonnes of waste that the RDN disposes each year, approximately 75% is directly hauled to Nanaimo Landfill and 25% is received at CRTS.

The CVRD waste is disposed at an out of region landfill in South Central Washington. Waste that is collected from residential or commercial sources is delivered to one of three facilities. The two smaller facilities (Meade Creek and Peerless Road Depots) transfer their waste to Bings Creek Transfer Station. This transfer station is the main transfer station that loads long-haul trailers to be disposed of at the South Central Washington Landfill. Of the 27,000 tonnes per year of waste that is collected in the regional district, 95% is received at Bings Creek, 1.5% at Meade Creek in Lake Cowichan and 3.5% at Peerless Road in Ladysmith.

In the CRD, the majority of the waste is directly hauled and disposed of at the Hartland Landfill. There are privately operated ICI transfer stations near the City of Victoria that transfer and dispose of their waste at the Hartland Landfill.

2.4 Solid Waste Disposal Costs

The waste disposal rates for each of the regional districts vary and depend on the system that is available to them. The two regional districts (RDN and CRD) that own and operate their own disposal system have lower tipping fees than the regional district that exports their waste outside the region. Table 3 below summarizes the tipping fees for the three regional districts. These tipping fees take into consideration other waste diversion programs.

Table 3. Existing Disposal Cost Summary

	RDN	CVRD	CRD
Tipping Fee	$107.00 /tonne	$135.00 /tonne	$100.00 /tonne
Land Disposal Cost	$50 /tonne	$115 /tonne	$37.00 /tonne

The disposal costs represent the actual cost for operating the disposal facilities which are considerably lower than the tipping fees. The tipping fees include waste diversion services such as operation of the recycling depots, public education and curb-side recycling programs (CVRD also uses some tax requisition to assist with financing of waste diversion). For the purpose of this report, it is the disposal costs that are relevant because thermal processing would impact the cost of disposal and would also add to potential revenue opportunities.

3. Transportation Analysis

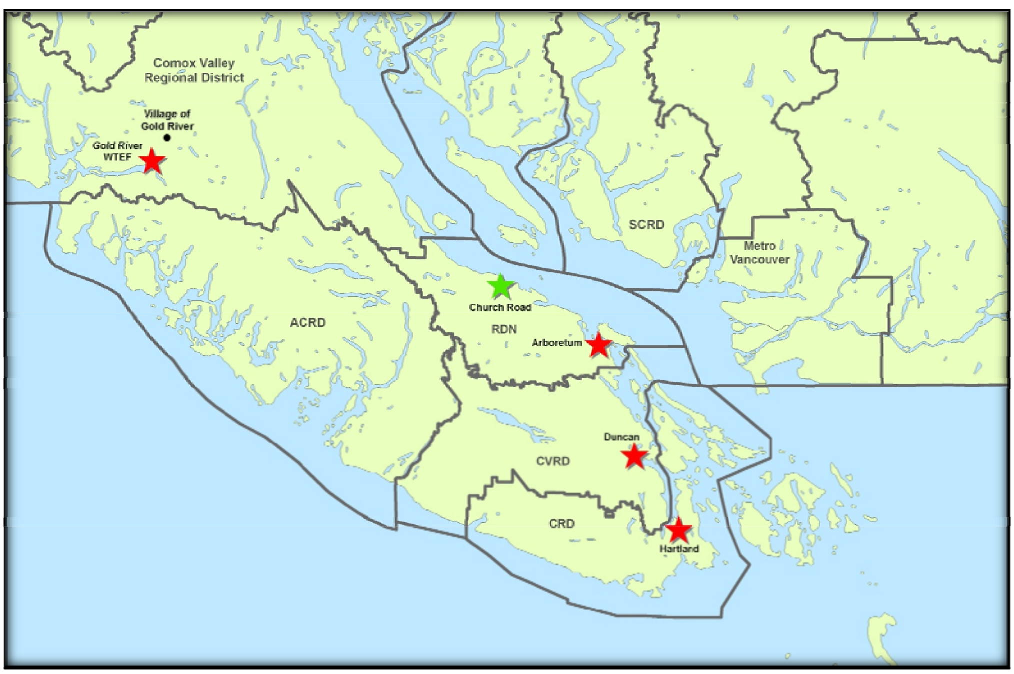
The transportation analysis examines the many different scenarios for transporting waste to the potential Waste-to-Energy (WTE) sites. The objective of this analysis is to determine the logistics of each transportation scenario and to compare each scenario. Topics that have been selected for comparison include:

- fuel consumption;
- GHG emissions;
- transfer facilities;
- backhaul opportunities; and
- transportation costs.

3.1 Facility Scenarios

Four potential WTE sites are identified in Figure 2 below. There is one site in each of the participating regional districts and one site outside the study area in Gold River, BC. The RDN site is a hypothetical location and would represent the most northerly of the in-region sites. The CRD site is hypothetical location that is assumed to be in the vicinity of the Hartland Landfill for simplicity and for calculation reasons. The CRD site is also a hypothetical and would represent the centroid for the three regional districts. The Gold River site is a proposed WTE site by the private sector. The proponent is hoping to accept waste from Metro Vancouver (following a public tender) and has expressed interest in accepting waste from communities on Vancouver Island as well.

Figure 2. Map of Potential Sites for a WTE Facility



3.1.1 Scenario 1 – RDN WTE

The RDN site would likely be located in the vicinity of the Nanaimo-Regional Landfill. Local RDN waste that normally goes to the landfill, including waste transferred from the Church Road Transfer Station, could be direct to this site.

Waste from the CVRD would be transported to this site via the existing network of transfer stations in the CVRD. The CRD would have to build a transfer station, to bring its wastes to this site.

3.1.2 Scenario 2 – CVRD WTE

The CVRD site represents the centroid of the three regional districts. The majority of the waste from the CVRD could be delivered directly to this site, possibly making the Bings Creek Transfer Station redundant. Waste from RDN and CRD would have to be transported to this site. For the RDN, the existing Church Road transfer station would continue to be used, and a new transfer station would need to be built to handle all of the materials that come to the landfill. The CRD would need to construct a transfer station for all of the waste currently going to the Hartland Landfill.

3.1.3 Scenario 3 – CRD WTE

Waste from the CRD would be directly hauled to this site. Waste from RDN and CVRD would be transported to this location. Transfer station facilities that are required for this scenario include the existing Church Road and Bings Creek transfer stations and a new transfer station in RDN, potentially near the existing landfill.

3.1.4 Scenario 4 – Gold River WTE

The Gold River WTE site has been proposed and permitted by the private sector. It is vying for Metro Vancouver waste as well as Island waste so that it can achieve economies of scale that make it highly competitive with landfilling or other WTE initiatives. Waste from the three regional districts could be transported to the Gold River site. Transfer stations that are required for this scenario includes the existing Church Road and Bings Creek transfer stations and two new transfer stations; one for RDN and one for CRD. For this scenario, a barging option was included as part of the transportation analysis.

3.1.5 Distance and Travel Summary

The transportation analysis is dependent on the how far waste needs to travel and the time required to travel that distance. This information was obtained using Mapquest and was to calculate fuel consumption and truck and driver costs. The distance and travel times between potential sites are summarized in Table 4 below. For study purposes, it has been assumed that any new transfer station in RDN would be located near the landfill, and in CRD it would be located at the Hartland Landfill. This is an assumption for comparative analysis only and not a designation of sites, which would have to be determined in a separate study when the concept of a centralized WTE facility is more advanced.

Table 4. Summary of Distance and Travel Times between Potential Sites

Site Scenario	Distance	Travel Time
Regional District of Nanaimo		
Church Rd. TS to RDN site	53 km	40 minutes
Bings Creek TS to RDN site	53 km	42 minutes
Hartland Landfill to RDN site	118 km	103 minutes
Cowichan Valley Regional District		
Church Rd TS to CVRD site	88 km	68 minutes
RDN TS to CVRD site	53 km	42 minutes
Hartland Landfill to CVRD site	60 km	56 minutes
Capital Regional District		
Church Rd TS to CRD site	148 km	124 minutes
RDN TS to CRD site	118 km	103 minutes
Bings Creek TS to CRD site	60 km	56 minutes
Gold River WTE Facility		
Church Rd. TS to Gold River WTE site	222 km	151 minutes
RDN TS to Gold River WTE site	275 km	191 minutes
Bings Creek TS to Gold River WTE site	310 km	219 minutes
Hartland Landfill to Gold River WTE site	370 km	275 minutes

3.2 Transportation Scenarios

The transportation options that were assessed include (1) direct haul using collection vehicles, (2) transfer haul using tractor trailers, and (3) rail haul. For the Gold River WTE scenario, a barge haul option was included as part of the assessment.

The transportation analysis focuses on the transportation logistics after the point from where it would normally go (i.e., transfer station or disposal site) to the potential WTE sites. For instance, CRD waste is collected and disposed at the Hartland Landfill. If a WTE facility were located in RDN or CVRD, the transportation analysis would begin from the Hartland Landfill and end at the WTE site. The waste collection aspects are not expected to change and are therefore not included in the analysis.

3.2.1 Direct Haul

Direct haul involves utilizing collection vehicles to transport the waste to one of the potential WTE sites. The benefit of this option is that no transfer station and waste reloading activity would be required. Factors to consider are collection vehicles typically carry loads that are four to six tonnes and fuel efficiency that is in the order of 0.7 km/L.

3.2.2 Transfer Haul

Transfer haul involves reloading waste from collection vehicles into larger tractor trailers units and hauling that waste to the potential WTE site. This transportation option requires transfer stations, front end loaders and labour to reload waste into tractor trailer units. Although there is a cost to transferring waste from smaller vehicles to a larger one, tractor trailers have a larger capacity (27 tonnes per load), better fuel efficiency (2.1 km/L) and require fewer trips.

3.2.3 Rail Haul

Rail haul is a transportation option that large communities, such as Seattle, Los Angeles and New York, use to transport waste considerable distances (typically in excess of 400 km). This method involves the following:

- transporting waste in intermodal containers (27 tonnes per container);
- loading of intermodal containers at transfer stations;
- intermodal yards at each end of the railway system;
- short hauls that move containers from transfer stations to intermodal yards and from intermodal yards to the disposal sites;
- railway agreements so that railcars are moved between intermodal yards; and
- return process that returns the empty containers back to the originating transfer stations.

The railway system on Vancouver Island is managed by Southern Railway of Vancouver Island (SRVI) and runs between the Cities of Victoria and Courtney. There is also a section that runs between the Parksville and Port Alberni. SRVI is a bulk railway company that primarily moves goods on and off the island. As part of that service, SRVI also moves railcars up and down the island. Most of the commercial railway service on Vancouver Island is between Cowichan Valley and Nanaimo.

The rail haul analysis for this study is limited to Nanaimo and Victoria waste. Because the Bings Creek transfer station is approximately 53 km and 60 km away from either the RDN or CRD sites, it is not practical to rail haul the CVRD's waste. Waste from the Church Road Transfer Station would be transferred either to the RDN transfer station or to the intermodal yard that rail hauls to the Victoria intermodal site.

Rail hauling waste to Gold River WTE is limited because the railroad tracks end at Courtenay, BC, resulting in a long transfer haul between Courtenay and Gold River. The distance between Courtenay and the Gold River WTE site is approximately 160 kilometres and the estimated travel time is 110 minutes. For this scenario, to minimize railway stops along the railway corridor, all of the waste from RDN (which includes waste from Church Road Transfer Station and RDN Transfer Station) would be transfer hauled directly to the Gold River WTE site. Only CRD and CVRD waste would be rail hauled from an intermodal yard located between Bings Creek TS and Hartland Landfill to an intermodal yard in Courtenay, BC. The rail haul unit cost is also adjusted to reflect the additional cost for fuel.

3.2.4 Barge Haul

The barge haul option is based on the transportation system that is being considered by the Gold River proponent for Metro Vancouver's solid waste. It is a network of four or five barges and three tugboats that run continuously between Gold River and Metro Vancouver. The barging system would be owned and operated by the proponent. Their model is a "drop and go" approach where at each of the loading and unloading points, one barge would be dropped off and the other would be taken away. Therefore at a waste loading facility, an empty barge would be dropped off and a loaded barge

would be picked up and taken to the WTE facility in Gold River. It takes a tugboat and barge approximately 33 hours to travel from Metro Vancouver to Gold River. According to the proponent, the barging system could accommodate a loading facility near the Victoria/Esquimalt shoreline.

This barging scenario requires waste to be baled in plastic. Similar to the Metro Vancouver proposal, a transfer facility with baling capabilities would be required to be located along the waterfront for loading purposes. The waste would be loaded onto a barge immediately after it is baled to minimize double handling. This is the preferred approach as it prevents having to store and backhaul empty waste containers and to avoid the additional weight of the container itself which can add four to five tonnes per container.

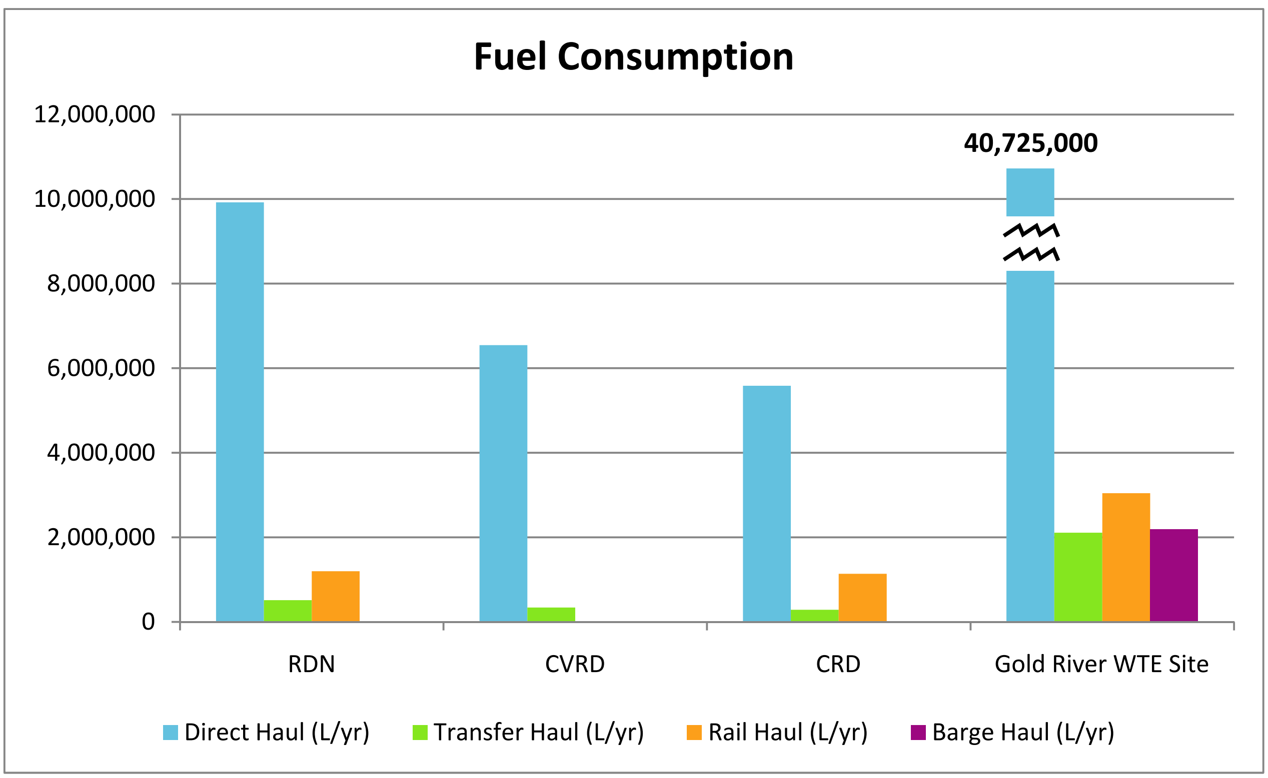
Barging waste in intermodal containers is not recommended as it increases the barging cost. The weight of the containers, handling to return the empty containers, storage space on the barge and loading facility, and loading of the empty containers on to trailers are considerations that would increase the cost.

Aspects that would be required to entertain this barging system are a waterfront loading facility in the southern point of Vancouver Island possibly along the Victoria/Esquimalt shoreline. This facility could replace the need to construct a transfer station on Hartland Landfill as waste collected from the CRD could be hauled directly to the barge loading facility. This facility would also need to be large enough such that RDN and CVRD waste could be transfer hauled to this facility for loading onto barges.

3.3 Fuel Consumption

Fuel consumption is a function of distance traveled, vehicle fuel efficiency and number of deliveries. Calculations for fuel consumption by facility and transportation scenario are included in Appendix A and summarized in Figure 3.

Figure 3. Graph Showing Fuel Consumption by Transportation Option and Destination



The direct haul option has the highest fuel consumption rate due primarily to poor fuel economy, smaller waste payloads of the waste collection vehicles and higher number of trips. While this was known at the beginning, the numbers have been left in the analysis for information and comparison only. The transfer haul option has significantly lower fuel consumption because the tractor trailer units have better fuel economy and larger payloads than waste collection vehicles.

Rail haul is optimized when the locomotive is hauling near its capacity. Train sets can haul between 12,000 and 18,000 tonnes per trip or a maximum of 120 to 140 railcars. For the waste from the three regional districts, the amount of waste that would be transported ranges from 250 to 600 tonnes per trip or five to ten railcars. The limited commercial rail hauling on Vancouver Island would also mean that trips between the three regional districts would likely be conducted alone. These considerations make this option inefficient as shown on the figure above.

In effect, the rail haul service would be an exclusive service for waste only. Therefore all of the fuel and time involved to move the train set up and down the southern portion of the island would contribute only to the waste being rail hauled. A locomotive's fuel consumption is about 750 litres per hour and each trip is estimated to take 2.5 hours. Therefore for a daily round trip, the fuel consumption would be approximately 3,750 litres per day. The number of railcars that would be pulled ranges from 5 to 10 railcars depending which RD the waste is coming from. The annual fuel consumption for the rail haul component only is nearly 1 M Litres of diesel per year. The rest of the fuel would be from the short hauls between the intermodal yard and the transfer stations and WTE facility, and the transfer haul from the CVRD.

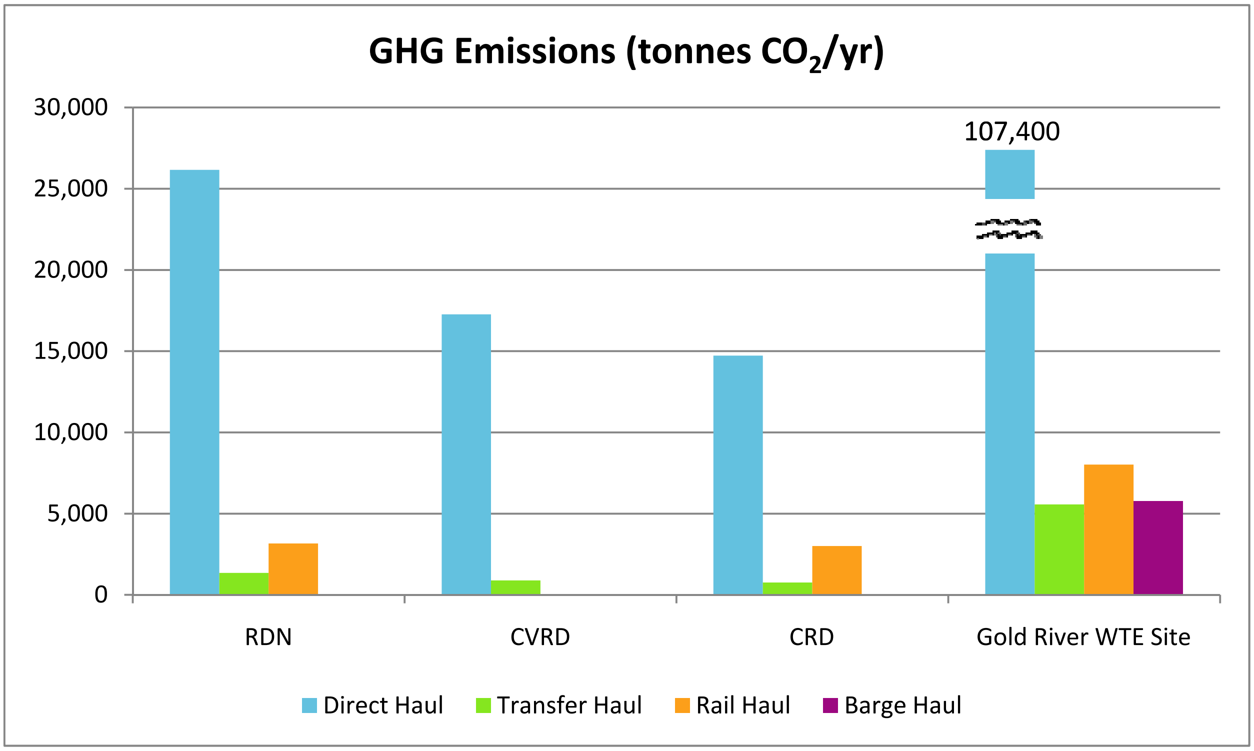
Transporting to Gold River's WTE facility is a completely different comparison. It is not within the boundaries of the three regional districts and is at least 300 km away from the centroid of the three regional districts. This additional distance is evident when comparing the amount of fuel being consumed. Generally, transporting waste to Gold River would increase the fuel consumption by four to seven times when comparing the transfer haul option and which RD the waste is coming from.

Barge hauling has concepts that are similar to rail hauling. Tugboats use diesel engines that are similar if not the same as those used in locomotives. Fuel consumption for each tugboat is also about 750 litres per hour. The travel time from the Victoria/Esquimalt loading facility to the Gold River WTE facility is about 24 hours (approx. 360 km away). The waste from the three RDs is also only part of a larger system thereby reducing the unit fuel consumption rate significantly. Because barge hauling depends on Metro Vancouver's waste, which accommodates about 70% of the waste being hauled, the overall fuel consumption for the three RDs is about 25% of the fuel consumption for the entire barging system. Because of these factors, barge hauling is almost equivalent to transfer hauling to Gold River.

3.4 GHG Emissions

GHG emissions were estimated based on transporting the waste to the potential WTE sites. These emissions are a function of the distance travelled and efficiency of the mode of transportation which results is the fuel consumed. The standards GHG emission rate for diesel fuel is 0.002637 tonnes CO_2 per litre. The GHG emissions for each of the scenarios are illustrated in Figure 4 below.

Figure 4. Summary of GHG Emissions for Each Site Scenario and Transportation Method



Similar to the Fuel Consumption chart, the transfer haul option has the lowest GHG emissions. Of the transfer haul options, having the WTE facility in the CRD area results in the least amount of fuel and GHG emissions. This is due to the least amount of waste requiring to be transported into the regional district.

3.5 Waste Transfer Facilities

The capital and operating costs for waste transfer facilities are important aspects for the transfer haul, rail haul and barge haul options. There are up to four locations for transfer stations, three locations for intermodal yards and one location for a barge loading facility. The subsections below discuss important considerations and estimated costs for the waste transfer facilities.

3.5.1 Transfer Stations

Transfer stations are required to reload waste from smaller and less efficient collection vehicles to larger and more fuel efficient tractor trailer units. Waste can be loaded into various lengths of trailers that range from 28 feet to 57 feet or intermodal containers that are typically 40 feet. The amount of waste that a tractor trailer unit or intermodal container holds is approximately 27 tonnes. Tandem units are able to hold 37 tonnes of waste. The number of transfer stations required depends on the location of the WTE facility and mode of transportation.

Up to four transfer stations are required to manage waste from the three regional districts. These include two existing transfer stations, Church Road Transfer Station (Parksville, BC) and Bings Creek Transfer Station (Duncan, BC), and two new facilities in the RDN and CRD.

The existing transfer stations do not appear to require significant capital upgrades. The processing capabilities of these two facilities should be sufficient to accommodate the 2030 solid waste projections. It may be prudent to allocate additional funds for possible facility upgrades and new assets such as tandem trailers with walking floors. A conservative estimate of $1.0 M is used to account for new trailers and possible facility upgrades. The unit operating cost for these smaller transfer stations is assumed to be $20 per tonne.

The solid waste projections for 2030 show that the RDN and CRD transfer stations should be designed to accommodate a minimum of 80,000 per year and 140,000 tonnes per year, respectively. The estimated capital costs for facilities of this size are $15 M and $20 M. These figures are based on construction costs for a transfer station in Metro Vancouver and appropriate cost escalations. The unit operating costs for facilities of this size are $10 to $15 per tonne, respectively.

A summary of capital and operating costs for the four transfer station facilities are included in Table 5 below.

Table 5. Transfer Station Capital and Operating Cost Summary

Transfer Station Facility	Waste Transferred (t/yr)	Average Daily Capacity (t/d)	Capital Cost ($)	Amortized Annual Capital Cost ($/yr)	Unit Operating Cost ($/t)	Unit Transfer Station Cost ($/t)
Church Road	20,000	100	$1.0 M	$80,000	20	23.9
RDN	42,062	150	$15 M	$1,200,000	15	43.1
Bings Creek	30,119	100	$1.0 M	$80,000	20	22.6
CRD	124,123	400	$20 M	$1,600,000	10	22.7

3.5.2 Rail Haul Facilities

In addition to the transfer stations, the rail hauling option also requires intermodal yards to load and unload intermodal containers onto flatbed railcars and trailer frames. Discussions with Southern Railway of Vancouver Island (SRVI) revealed that there are no intermodal yards between Nanaimo and Victoria, and that SRVI own no assets (i.e., flatbed railcars, intermodal property, and container loaders) that the three regional districts could use.

In order for this option to be pursued, the regional district would have to acquire at least three properties in close proximity to the railroad track for intermodal facilities, flatbed railcars, intermodal containers with trailers and two container loaders. Locations for intermodal yards are Victoria, Nanaimo and Courtenay, BC. These properties must also be large enough to store containers (up to 20) and to allow tractor trailers to manoeuvre to pick up and drop off containers. The minimum size for an intermodal yard is one hectare.

Costs for flatbed railcars, intermodal containers and container loaders were obtained from vendors. The number of components required depends on the location of the WTE facility and frequency of trips on the railway system. For this analysis, it is estimated that that the waste is rail hauled five times per week. The considerations for rail haul are summarized in Table 6 below.

Table 6. Rail Haul Considerations

WTE Site	Transfer Stations	Intermodal Yards	Intermodal Containers	Railcars	Container Loaders	Yard Operating Cost
RDN	CRTS BCTS CRD TS	Nanaimo Victoria	18	10	2	$200,000 per site
CRD	CRTS BCTS RDN TS	Nanaimo Victoria	10	5	2	$200,000 per site
Gold River	CRTS BCTS RDN TS CRD TS	Victoria/Duncan Courtenay	22	11	2	$200,000 per site

3.5.3 Barging Facility

The barging facility applies to transporting waste to the Gold River WTEF. This facility requires enough storage capacity to accommodate waste from the three regional districts (over 200,000 tonnes per year). Possible location for this facility is along the Victoria/Esquimalt shoreline. This barging facility could also act as a transfer station for CRD instead of building a transfer station on Hartland Landfill.

The other transfer stations required include CRTS, RDN TS and Bings Creek TS. Waste would be transferred from these locations using tractor trailers with walking floors and unloaded into a tipping area. Similar to the Metro Vancouver proposal, the waste would be baled and wrapped in plastic before being loaded onto the barge.

The capital cost for the barging facility on solid ground could range from $20-$25 M, not including property cost. Soft soil which is typical of shoreline properties may require significant foundation support such as piling to stabilize the structures. Operating cost should be similar to a transfer station of this size ($10/tonne). Loading the waste onto the barge has been estimated to be about $2 per tonne. The property would likely need to be at least four hectares is size.

3.6 Backhaul Opportunities

Backhauling is a means to optimize the transportation system so that vehicle and trailers are not moving around empty thereby consuming fuel, costing money and emitting GHG's. Metro Vancouver applies this principle when they transport waste to Cache Creek Landfill backhaul woodchips from the interior. This has significant savings on transportation cost which in turn lowers the allocated fuel consumption and GHG emissions for the waste disposed at Cache Creek. To realize backhaul opportunities, there must be the vehicle and flexibility that allows others to use this system. This section rates backhaul opportunities for the various transportations options and rates them based on high, moderate and low.

Intermodal Containers
40 feet container is 8 feet wide and 8.5-9.5 feet high. Volume is about 67.5 m^3.

Semi-Trailers
Range in is size from 28', 45', 48', 53' and 57' long and are 8' wide by 9' high. Volumes are about 2,016, 3,240, 3,456, 3,744 and 4,104 cubic feet, respectively.

3.6.1 Direct Haul

Direct haul uses waste collection vehicles to transport garbage. These vehicles are made to haul garbage, recyclables and organic waste such as food and yard waste. Commodities that could be transported in a collection vehicle cannot be fragile, since the compactor may crush the contents in the vehicle. In addition, loading materials into the collection vehicles can be challenging. From these perspectives, backhauling opportunities with waste collection vehicles are low.

3.6.2 Transfer Haul

Transfer haul uses tractor trailers to move waste from a transfer station to a WTE facility. The loading capacity is typically limited by the gross vehicle weight that the trailers are allowed to carry on the road. Trailers come in a number of sizes that range from 28 feet to 57 feet. Trailers can have open tops or walking floors that allow materials to be loaded and unloaded with relative ease. Tractor trailers have flexibility in where they can travel and can transport materials between the transfer station and the WTE facility. Therefore, the backhaul opportunities for the transfer haul option are high.

3.6.3 Rail Haul

Rail haul is limited by the railway system and the schedule it needs to follow. Intermodal containers are a standard 40 feet and can be loaded after waste is emptied. Utilizing rail haul system for back hauling is better suited for long distance transport. Therefore, the backhaul opportunities for the rail haul option are low to moderate.

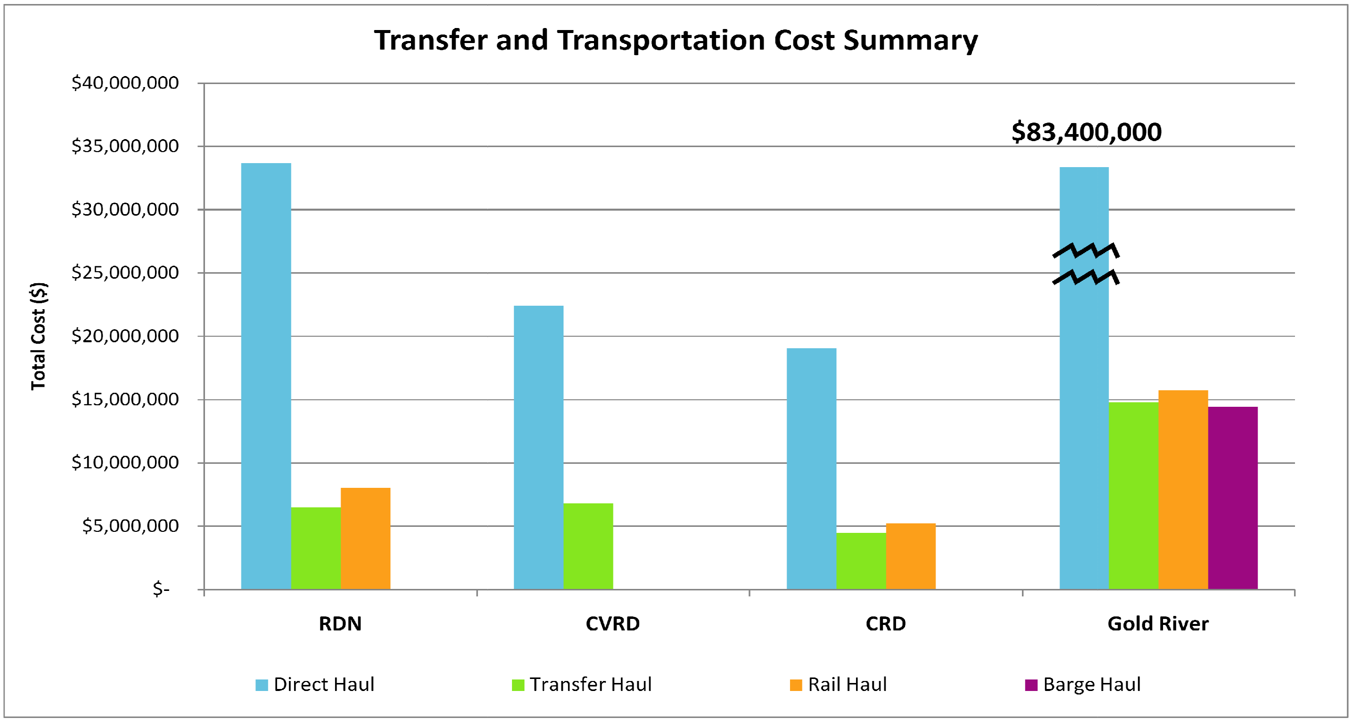
3.6.4 Barge Haul

Barge hauling system would be operated by Covanta. Their priority is to move waste to the Gold River WTEF. Utilizing bales means the barge will be empty when heading back to Metro Vancouver or the barge loading facility near Victoria/Esquimalt. This transportation system has the potential to transport forestry products from Gold River to Victoria or Vancouver. Other options to explore include backhauling ash from Gold River for disposal at the existing Hartland landfill. This could save Covanta the need to build an ash monofill and provide revenue for continued operations of the Hartland landfill. Therefore, the backhaul opportunities for the barge haul option are moderate to high.

3.7 Transportation Costs

Transportation costs were calculated based on a driver and truck cost of $100 per hour and fuel cost of $1.20 per litre diesel fuel. These rates are subject to change but are used to provide a realistic comparison of the transportation options. Figure 5 is a summary of the transfer and transportation costs for each location.

Figure 5. Summary of Transfer and Transportation Cost for Each Scenario



3.7.1 Direct Haul

Distances are such that direct haul using collection vehicle is not economical. The smaller loads and poorer fuel economy means there will be additional trips that add to fuel consumption and cost. The assumptions and calculations for the direct haul option are included in Appendix A.

The results of the direct haul option were rounded off to the nearest hundred. It also does not take into consideration the fleet size that would be required for the municipality or regional district.

Besides cost and fuel consumption, other considerations that make this option unfeasible include the following:

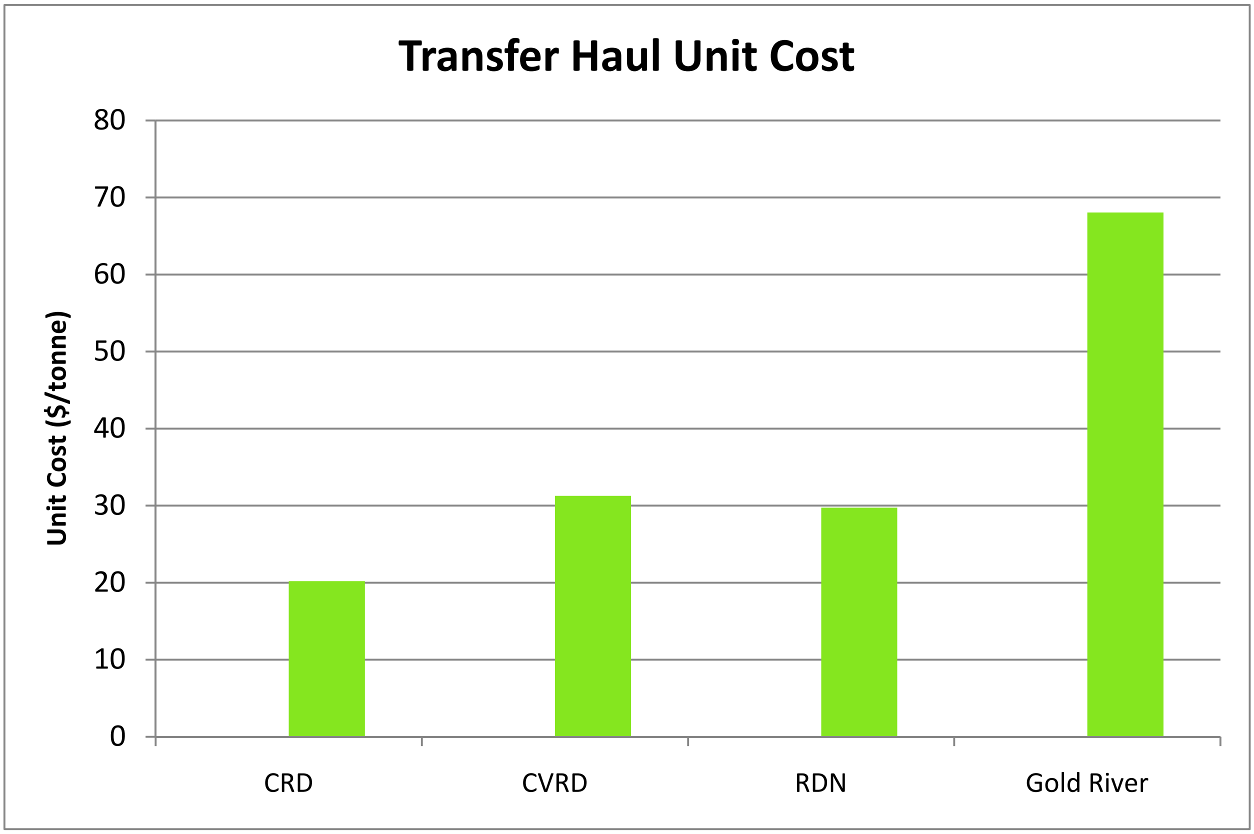
- longer lag times when collection vehicles are unable to collect waste travelling to unload waste;
- increases the wear and tear on collection vehicles; and
- need for larger vehicle fleet.

3.7.2 Transfer Haul

The transfer haul scenario represents the most economical option. The payloads are at least five times larger which means there will be four times fewer trips. In addition, the better fuel economy of the tractor trailers will further reduce fuel and fuel costs. The trade off with this transportation scenario is that transfer stations are required to reload the waste into the larger tractor trailer units. Even with the additional transfer activity, the transfer haul option is three to five times less costly than direct haul.

The comparison charts show that the least expensive transportation scenario is locating the WTE site in the regional district that generates the most waste. This lowers the transportation cost by having fewer trucks delivering waste and not having to build the largest transfer station of the three regional districts. Therefore, from a total cost perspective, the lowest cost option is locating the WTEF in the CRD area. From a unit cost comparison perspective, as shown in Figure 6 below, transporting to CVRD or the RDN adds about $10 per tonne and transporting to Gold River adds about $38 to $48 per tonne.

Figure 6. Comparison of Transfer Haul Unit Costs for Each WTE Site



Sending waste outside the three regional districts is an added cost. Gold River is approximately 300 km away from the centroid of the three regional districts which is a significant expense. 300 km means the tractor trailers would on average need to drive a whole day to deliver the waste and to drive back to the starting location. This option also requires that a transfer station would be required in each regional district. In short, the increased cost can be attributed to the extra transfer station, extra distance and extra travel time to transfer waste from the three regional districts to Gold River.

3.7.3 Rail Haul

Other rail haul and transfer haul comparison studies have shown that transfer hauling is typically more economical than rail haul when the travel distance is less than 400 km. This finding is consistent with the cost analysis for the Tri-Regional District study. This is especially the case because of the following:

- commercial rail system is very small and only railcars that would be pulled are the waste from the three regional districts;
- rail system is only pulling 5% of its capacity which means it is very far from running at an optimal level;

- separate intermodal yards would need to be established by the regional district at a significant cost as industrial land on Vancouver Island is at a premium (>$1 M/acre);
- having to load and unload intermodal containers at the intermodal yards is an extra cost; and
- maximum distance between the three regional districts is about 150 km which is not sufficient to make rail haul more economical than transfer haul.

Rail hauling to Gold River is also difficult because the tracks only go to Courtenay, BC and an additional 160 km of transfer haul is required to bring the waste to the Gold River WTE site. There are no economies to scale that would warrant utilizing the island's railway system.

3.7.4 Barge Haul

Barge haul is an option that seems comparable to transfer haul provided the three regional districts can utilize the system that was developed for Metro Vancouver. Without the economies of scale from Metro Vancouver's waste, the barging haul costs are estimated to increase by 10%-15%, which includes the cost of transferring and hauling waste from RDN and CVRD to the waterfront at CRD. Hauling by barge could be a viable transportation option provided the following are undertaken:

- Metro Vancouver needs a contract with the Gold River WTE facility;
- Covanta then needs to build the WTE facility;
- capacity needs to be available for the three regional districts;
- Covanta and three regional districts need to develop a contract;
- barge loading facility needs to be acquired/built in Victoria/Esquimalt;
- waste will be baled at the loading facility before loading onto the barge;
- plastic will wrap the garbage; and
- utilizing intermodal containers to deliver waste is not practical because of additional handling costs.

3.8 Transportation Analysis Summary

The transportation analysis shows that the three regional districts are close enough to one another that there are economical benefits to establishing a WTE facility within their geographic area. It also shows that the most economical approach is to locate a WTE facility in the regional district where most of the waste is generated. That way the additional transportation required is minimized and the need for a new large transfer station does not arise because the WTE facility would be located there.

Rail haul is not economical on Vancouver Island. The amount of waste being moved in only about 5% of the rail system's hauling capacity. Therefore, the benefits of hauling the waste by rail are not realized. Rail haul is also limited because there are no tracks between Courtney and Gold River.

Of the transportation options analyzed, the transfer haul option is by far the most economical and emits the least amount of GHG. It also allows for better flexibility and opportunities for backhauling commodities within the three regional districts.

Transporting waste to Gold River will have a noticeable increase in cost, fuel consumption and GHG emissions. That added cost must be balanced against the potentially lower tipping fees from a larger WTE facility at Gold River compared to a smaller facility built within the regions.

4. Thermal Technology Review

4.1 Previous Studies

Previous studies examined conventional direct combustion (mass burn and controlled air) and gasification/ pyrolysis/plasma technologies. The two studies that are referenced for this report are:

- Assessment of New Treatment Technologies; prepared for Regional District of Nanaimo and Cowichan Valley Regional District by Gartner Lee Ltd, December 2008.
- Management of Municipal Solid Waste in Metro Vancouver – A Comparative Analysis of Options for Management of Waste after recycling; prepared by AECOM in June 2009.

Both of these reports provide extensive analysis and references on the various types of technologies available to thermally recover the energy from municipal solid waste. A third report was recently prepared for the CRD and presented to CRD committees in draft form. It includes some updates to the above reports and this updated information is also used for this report.

For brevity, the content of these reports will not be repeated here. Table 7 provides a summary of key attributes of the various technologies under consideration. In the following subsections, each category is updated with the most recent information and advantages and disadvantages of this category of technology are presented.

Upon review, it was found that when excluding the pilot and bench scale conversion technologies that are still under development, the following categories emerge for further discussion and consideration:

- Conventional combustion with mass burn. This is the most proven technology with over 800 plants world wide.
- Gasification using Thermoselect technology. This is technically proven in Germany and Japan, provides an alternative to mass burn combustion, but is more costly.
- Plasma gasification, which has two operating plants in Japan (Alter NRG technology), and full scale demonstration facility in Canada (Plasco) which is not operating full time yet.

Table 7 provides a summary comparison of the thermal treatment technologies described in the referenced reports.

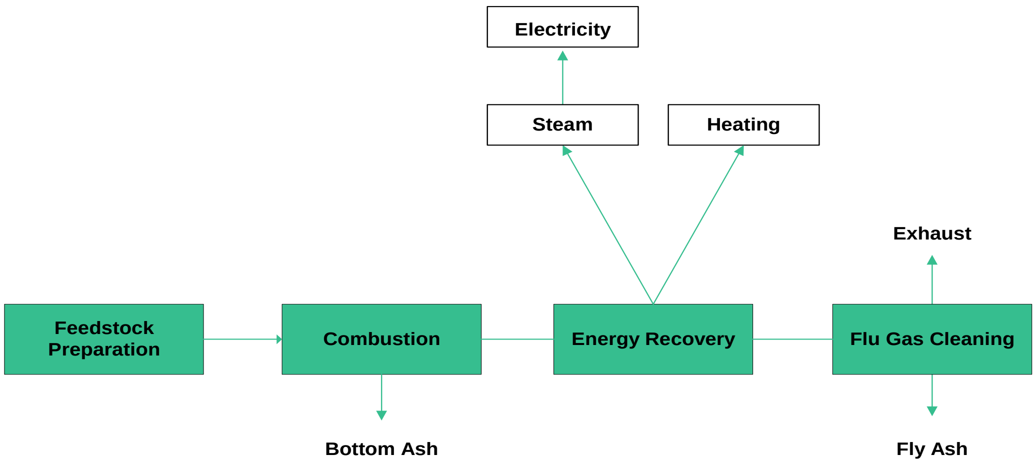
Table 7. Technology Summary

	Mass Burn	Controlled Air	Gasification	Pyrolysis	Plasma/Gasification
Vendor Names (examples only)	Von Roll, Martin, Keppel-Seghers	Consultech Systems, NCE Crawford Emcoteck	Thermoselect, Enerkem, Nexterra	WasteGen UK	Plasco, Alter NRG
Commercially Proven with North American Waste	Yes	Yes	No	No	No
Proven Processing Capacities	90Kt-1Mt/yr	30Kt-180Kt/yr	10Kt/yr-225Kt/yr	50Kt/yr	8Kt/yr-60Kt/yr (Alter NRG)
Waste Feedstock	Residential MSW Commercial waste Bulky waste Sewage sludge	Residential MSW Commercial waste Bulky waste Sewage sludge	Residential MSW Commercial waste Bulky waste Sewage sludge	Residential MSW Commercial waste Bulky waste Sewage sludge	Residential MSW Commercial waste Bulky waste Sewage sludge
Capital Cost	Moderate	Moderate	High	High	High
Operating Cost	Moderate	Moderate	High	High	High
Process Risk	Low	Low	Moderate	Moderate	Moderate
Carbon Footprint	Moderate	Moderate	Small, if fuels made	Moderate	Small, if fuels made
Meets Canadian Emission Criteria	Yes	Yes	Yes	Yes	Yes
Energy Recovery Efficiency (combined heat and power %)	25% electricity only. Over 90% with district heating	20% electricity only. Over 80% with district heating	25% conventional steam cycle. Over 40% with combined cycle operations Over 80% with district heating	Unknown, reference facility in Germany has low efficiency but built for demonstration only	25% conventional steam cycle. Over 40% with combined cycle operations Over 80% with district heating
Additional Processing	Minimal pre-processing	Minimal pre-processing	High degree of pre-processing to size and moisture specifications and recovery recyclable material	High degree of pre-processing to size and moisture specifications and recovery recyclable material	High degree of pre-processing to size and moisture specifications and recovery recyclable material
Residuals (% mass of incoming waste)	5% if bottom ash is recycled, otherwise >20%, including fly ash	5% if bottom ash is recycled, otherwise >20%, including fly ash	<1% if ash is vitrified, otherwise >20%	Unknown, but >30% if residue not treated	<1% if ash is vitrified, otherwise >20%
Level of Maturity/ Implementation	Highly mature. Hundreds of plants in operation in North America and Europe	Mature with 3 facilities in Canada (Brampton, Ont.; Charlottetown, PEI; and Wainright, Alta)	Thermoselect is mature with seven plants in Japan. 225 Kt/yr Thermoselect facility in Germany closed due to high operating costs. Other vendors not well proven	36Kt/yr plant operating in Burgau, Germany since 1987	Two facilities (similar to Alter NRG) operating in Japan (**Mihama-Mikata and** Utashinai) since 2002 and 2003, respectively.
Operational Complexity	Routine – Operational procedures well understood and established	Simple– Operational procedures well understood and established	Complex process – requires additional operational experience and maintenance skills	Complex process – requires additional operational experience and maintenance skills	Complex process – requires additional operational experience and maintenance skills. Special challenges from ultra high temperatures

4.2 Conventional Combustion Update

By conventional combustion we understand the direct firing of waste or “burning” under highly controlled conditions, with subsequent clean-up of flue gases. Conventional combustion includes the technologies called mass burn, fluidized bed, controlled air and rotary kiln. For smaller systems, batch technologies sometimes referred to as batch oxidation systems also fall into this category. The schematic in Figure 7 demonstrates the major components and process sequence in conventional combustion.

Figure 7. Schematic of Conventional Combustion



Following some form of feedstock preparation, the combustion process is used to release the heat, which is then converted to steam or hot water. The steam in turn can be converted to electricity or used in industrial processes. The gases, after the heat has been extracted, are then cleaned before being vented to the atmosphere. Two forms of ash come from the process: bottom ash from the actual burning of the feedstock, and fly ash from the flue gas cleaning process.

Most bottom ash from WTE facilities burning MSW can be landfilled, or processed for other uses. The only WTE plant operating in BC is located in Burnaby and is owned by Metro Vancouver. Bottom ash is used at the Vancouver landfill as daily cover and roadbed material. Fly ash, which is considered hazardous, is stabilized with cement and disposed at the Cache Creek landfill. Metal is recovered after the combustion process and is sold to a local metal recycler. The only other mass burn facility in Canada is in Quebec City. Controlled air systems are in operation in Peel, Ontario, in PEI and Wainwright, Alberta.

Air emissions from modern WTE facilities can meet the most stringent guidelines in existence anywhere in the world today. The study for Metro Vancouver includes extensive research into the potential emissions from WTE and also potential health effects. Regarding health effects, it is quoted from a 2004, United Kingdom Department for Environment, Food and Rural Affairs (DEFRA) comprehensive report on the potential for health effects associated with the management of MSW. Based on a review of over 600 publications, no link was discovered between living close to a modern thermal treatment facility and adverse health impacts, including cancer and respiratory problems. The study concluded that:

> *"If the operation of these facilities does have any effect on the health outcomes which have been investigated, any effect is very small – smaller than many other influences on these health outcomes."*

Furthermore, as part of the same study, the (UK) government's independent expert advisory Committee on the Carcinogenicity of Chemicals in Food, Consumer Products and the Environment concluded that:

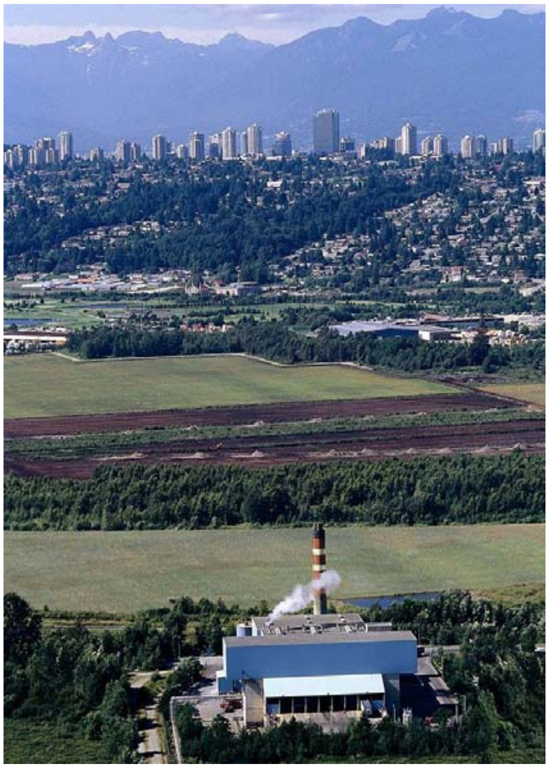
> *"any potential risk of cancer due to residency (for periods in excess of ten years) near to municipal solid waste incinerators was exceedingly low and probably not measurable by the most modern techniques."*

GHG emissions from combustion facilities will vary depending on the biogenic component of the waste stream. Whether a WTE facility is GHG neutral, positive or negative depends also on the offsets that can be achieved. In most parts of the world, where a portion of the electricity is generated by fossil fuels, WTE is generally in a GHG favourable position.

In BC, studies have shown that if WTE is used for the generation of electricity only, then the GHG balance is not so favourable. This is because our electricity in BC is mostly from hydro power, so there is a very low carbon density. Offsetting relatively low carbon electricity with WTE generated electricity has a negative effect on the carbon balance. However, if WTE is also used for district and industrial process heat (offsetting natural gas use), then WTE can be preferable to landfilling from a GHG perspective. It should be noted that recycling from a GHG perspective is in most cases preferable to both landfilling and WTE. When looking at GHG scenarios involving WTE (of the residuals that cannot be recycled), other factors such as transportation need to be taken into account.

A photo of a mass burn facility with a capacity of 280,000 tonnes per year is shown in Figure 8. This facility operates three separate lines that each process approximately 93,000 tonnes of waste per year.

Figure 8. Metro Vancouver Waste-to-Energy Facility



Conventional, direct fired combustion systems are the predominant technology chosen for the recovery of energy from municipal solid waste today. This is due to the technology's ability to handle the varying waste stream with little or no pre-processing, the simplicity of the process overall, the development and integration of sophisticated air pollution control systems and the overall thermal efficiency of the process. Conventional combustion technologies that lend themselves to the volumes and types of waste identified in this study are mass burn (predominantly) and to a lesser degree controlled air combustion. There have been no major technology changes since the referenced reports were issued, however thermal efficiencies and emissions are being continuously improved.

There is considerable technical and emotional debate about the advantages and risks of conventional combustion systems. Experience from the past, before modern emission standards and controls were in place, has caused waste incineration to receive a poor public perception. In Europe, modern WTE in conjunction with recycling is generally regarded as the most cost-effective and environmentally friendly method of managing waste without creating future liabilities and a legacy for future generations. In Europe, WTE is often employed as a means of reducing GHG compared to landfilling.

Advantages of conventional combustion systems:

- the technology for MSW it is well established worldwide. More than 36 million people in 29 countries dispose of their MSW at 800 waste-to-energy facilities;
- there are many examples of well-operated waste-to-energy facilities in the developed world. Modern WTE facilities have no significant impact on the environment and generally a positive greenhouse gas balance;
- conventional combustion is relatively simple and costs less to build and operate than most advanced systems, such as gasification and pyrolysis;
- other wastes, such as biosolids and biomedical materials can be destroyed; and
- the technology is reliable.

Disadvantages of conventional waste-to-energy systems:

- public perception and opposition can be significant when burning MSW or refuse derived fuel made from MSW;
- it does not represent an advanced form of energy recovery, but is rather one of the traditional technologies available,
- fly ash may be hazardous when combusting MSW, which requires some form of treatment or stabilization before disposal; and
- economies of scale suffer as the units get smaller, so that WTE is often uncompetitive with landfilling in smaller communities where the waste volumes are below 300,000 tonnes per year

4.2.1 Capital Costs vs. Annual Throughput

Costs are a function of size, and a report issued by the Municipal Waste Integration Council (MWIN) in 2007 provided the following graph (Figure 9) showing how economies of scale affect costs.

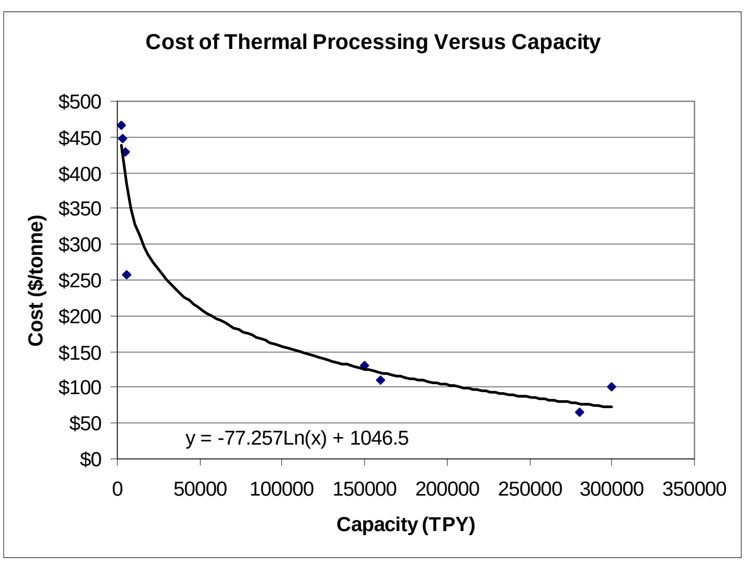


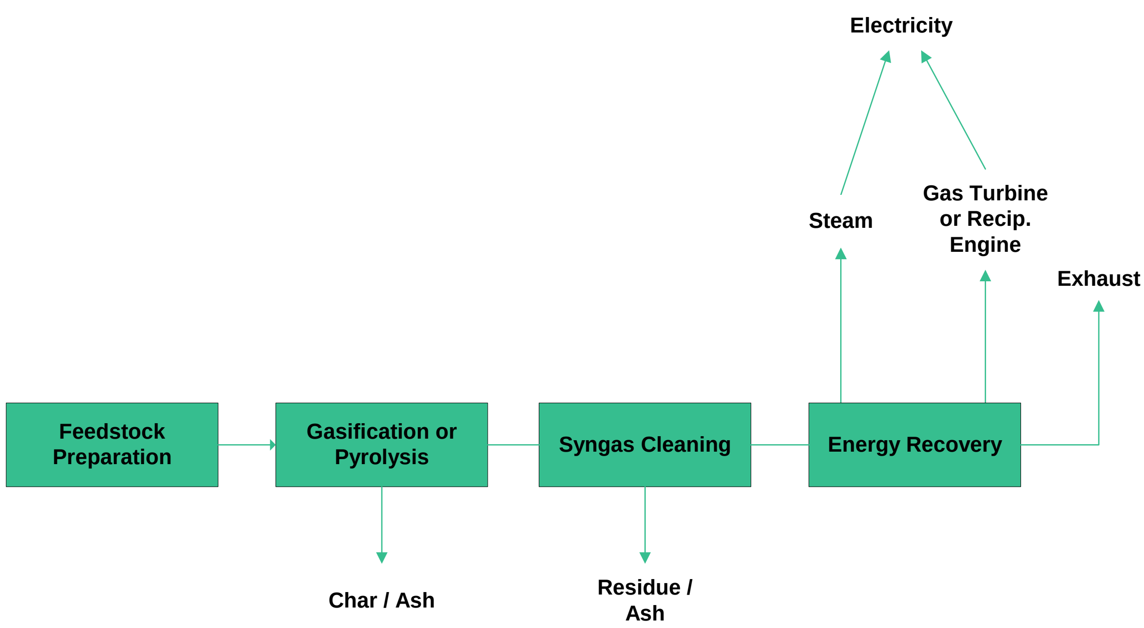
Figure 9. Incineration Costs as a Function of Annual Capacity (MWIN 2007)

Assuming that a WTE facility has a capacity of about 200,000 tonnes of waste throughput per year, then the cost would likely be above $100 per tonne (not including revenue from the sale of energy).

4.3 Gasification, Pyrolysis and Plasma Systems (Advanced Thermal Processes)

Pyrolysis and gasification, as well as ultra high temperature gasification using plasma are often called advanced thermal processes. After extensive pre-processing, thermal energy is used to create a synthetic gas (syngas) and char or bio-oil. Syngas is chemically cleaned before it is burned so that complex post combustion air pollution control is minimized, or not needed at all. Syngas and bio-oil can be upgraded as feedstock for other processes or burned to produce heat and/or power. Figure 10 illustrates a typical gasification or pyrolysis process.

Figure 10. Main Components of a Gasification or Pyrolysis System



The major differences between these so called "advanced" systems and conventional combustion systems are as follows:

Feedstock Preparation

For conventional combustion, especially mass burn, this is very simple and at most a coarse size reduction and removal of large undesirable items. For many advanced technologies, waste must be extensively prepared by shredding, drying and classifying. This adds to the cost and complexity of the system.

Gasification or Pyrolysis

In the advanced systems, energy is released by adding heat to the waste in the absence of oxygen (without allowing it to burn as in conventional combustion). This creates a synthetic gas, consisting of CO, some hydrogen, CO_2, nitrogen and contaminants. With gasification, there is still an ash, as with combustion, and with pyrolysis there is a carbon rich char that requires further processing. Heating the waste, if done by combustion, also creates some emissions which must be cleaned before being released to the atmosphere. Some plasma systems heat the waste using a plasma torch, which requires a large electrical input.

Syngas Cleaning

Syngas coming from the advanced technology is contaminated with tars, metals and particulates. If it is to be used in internal combustion engines or as a feedstock for other processes, it needs to be cleaned and purified. This is a chemical process that results in residues that need to be managed/disposed. Some processes, such as the Plasco technology, use hot plasma to clean the syngas of organic contaminants. If the syngas is well cleaned, then there is generally no or very little post combustion air pollution control needed (as in conventional combustion).

Energy Recovery

This is where advanced technologies convert the recovered gas into energy. If it is a thermal process, the gas is burned on-site to make electricity and heat in a reciprocating engine (similar to a landfill gas application), gas turbine, or it is made into a liquid fuel or pipeline quality gas that can be moved and burned elsewhere. In any case, the product will ultimately be burned (if there is to be energy recovery) which will produce GHG emissions, and other air emissions similar to what can be expected from natural gas combustion.

Advantages and disadvantages of advanced thermal processes are discussed in a recent Juniper publication that was prepared for Improvement and Efficiency South East, UK. Juniper Consultancy Services are a recognized leader in the assessment and evaluation of thermal technologies in solid waste management. This report was released in 2008 and is a public document. Advantages and disadvantages from previous studies and from the Juniper report are summarized below:

Advantages of Advanced Thermal Processes:

- Most of the basic technologies (gasification, pyrolysis) have been proven in industrial applications with specific materials.
- Potential for better lower carbon emissions than convention combustion through higher energy recovery efficiencies when using combined heat and power for electricity production.
- Potential to displace fossil fuels when using cleaned syngas as an intermediate in the manufacture of other fuels and chemicals.
- Syngas cleaning takes less space than flue gas cleaning in a conventional WTE plant.
- The recovered energy can be utilized/burned in a different location than where it was extracted.
- Advanced thermal processes have a better public image than conventional combustion and may be easier to site and to get public approvals.
- Module sizes are generally smaller than mass burn systems, so overall plant sizes can be smaller.

Disadvantages of Advanced Thermal Processes

- Few full scale technologies have been proven, and the only successful plants are operating in Japan.
- Technologies are generally more complex than mass burn, and costs are generally higher.
- Syngas cleaning to a level that enables combined cycle gas turbine applications is not well proven.
- Many technologies are only proven on a pilot or demonstration level in Europe.
- None of these technologies are currently commercially operating in North America.

4.4 Gasification Update

Gasification is the general term used to describe the process of partial combustion in which a fuel is combusted with a quantity of air that is deliberately set to be below what is required for complete combustion. It is an alternate technique to direct combustion for reducing the volume of MSW and for the recovery of energy. The process involves the partial combustion of carbonaceous fuel to generate a combustible syngas that can be burned at a later time (after cleaning) in an internal combustion engine, gas turbine, or boiler under excess-air conditions. The generated syngas has an energy content about one third that of natural gas if air is used as the oxidant. Use of pure oxygen can yield gases with higher energy content. Gasifiers have the potential to achieve low air pollution emissions with simplified air pollution control devices. The emissions can be comparable to or less than those from mass burn systems employing far more complex emission control systems. Gasification systems typically require homogeneous feedstock and therefore extensive front-end processing is generally required.

Gasifiers have been used since the 19^{th} century for coal and wood. By the early 1900s gasifier technology had advanced and was used on certain industrial waste streams to produce 'synthetic' natural gas fuel for stationary and portable internal combustion engines. Fuel shortages of World War II resulted in the further development of gasifier technology. However, with the return of relatively cheap and plentiful oil after the end of World War II, gasifier technology was no longer employed. In recent years, gasification technology has been developed for MSW as an alternative to conventional mass burn combustion.

Any solid material being combusted goes through a gasification stage. Some companies argue that if the gas is burned in a separate vessel, then it is a gasification system. However, the difference between a close coupled gasification system where the synthetic gas is immediately burned in a subsequent vessel, and an incineration facility where burning takes place in the same vessel, is minimal. For the purpose of this study, gasification will be defined as a process where the synthetic gas is cleaned and then used for some other process (which might be a chemical process for making methanol, or thermal process to make electricity in an internal combustion engine or gas turbine).

The syngas created by gasification can be used in many of the same ways as natural gas. Syngas can be burned in a conventional boiler to produce steam to drive a steam turbine generator to produce electricity. Cleaned syngas can also be used in:

- reciprocating engines to produce electricity and heat;
- combined cycle gas turbine power plants to produce electricity and heat; or
- fuel cells.

The efficiencies of gasification and pyrolysis when the syngas is converted to electricity using a steam boiler and turbine are up to 25%. This does not provide any advantage over mass burn systems, which typically reach up to 27% and can be optimized to achieve 30%. However, if the syngas is burned in a reciprocating engine, efficiencies increase to over 30% and in a combined cycle gas turbine, they can be as high as 40%. Since there is no known commercial scale applications of combined cycle gas turbines using syngas produced from MSW, or of ethanol produced from MSW, the actual efficiency of these systems is not known.

Gasification facilities are usually built with a fixed capacity. Module sizes range from less than 40,000 tonnes per year to about 100,000 tonnes per year. Due to their potential for smaller sized units, gasification facilities can be sited close to the feedstock source, i.e., decentralized applications. However, there are economies of scale to be achieved by building larger centralized facilities.

Companies such as Enerkem and Fulcrum BioEnergy are starting up new plants to produce ethanol from MSW however these techniques have yet to be proven over years of continuous operation. Enerkem claims that approximately 37.8 million litres (ten million gallons) of ethanol can be produced from 200,000 tonnes of MSW. Markets prices for ethanol are almost $2 per gallon which could possibly net $20 M/yr.

North American communities that are pursuing gasification technologies include:

- Edmonton, Alberta;
- City of Taunton, Massachusetts; and
- Pontotoc, Mississippi.

The projects mentioned above are planning to process the syngas into ethanol in addition to utilizing any thermal recovery. The Edmonton and Pontotoc projects are expected to be operational in 2011 and 2012, respectively.

Gasification – Conventional

There are few full-scale plants in continuous operation outside of Japan. A company named Energos claims to have eight gasification plants in operation in Norway and Germany. These are grate gasifiers that would be classified as controlled air combustion units in North America. The only true large scale commercially operating gasification plant in Europe was in Karlsruhe, Germany, using technology from a company called Thermoselect and there are seven plants with this technology operating in Japan.

The THERMOSELECT process converts mixed waste to clean synthetic gases and recoverable metals and minerals. High temperatures (2,000°C) and oxygen concentrations are used in the gasification stage. Subsequent rapid cooling is used to prevent formation/reformation of trace organic contaminants in the synthetic gas. A 225,000 tonnes per year “THERMOSELECT” plant in Karlsruhe, Germany was operated for some time but was recently shut down due to high costs compared to conventional mass burn WTE technology. The “THERMOSELECT” technology did not yield significant improvements in air emissions over state-of-the-art conventional incineration. In Japan, it does offer the benefit, at a significant cost premium – of vitrifying the residue char to meet Japanese ash standards.

The City of Taunton has chosen the Thermoselect process as the preferred technology for its energy recovery facility and estimates start-up sometime in 2014.

Plasma Arc Gasification

Plasma arc gasification processes use extremely high temperatures in an oxygen-starved environment to gasify waste into simple molecules. In essence, it is a conventional gasification system where the heat is supplied by a high temperature plasma field.

A thermal plasma field is created by directing an electric current through a low pressure gas stream, thereby creating a stream of plasma at temperatures from 5,000 to 15,000°C. The products of the process are slag and combustible gases.

Plasma arc technology is not new. Industrial applications include electric arc furnaces used in the steel industry and arc welding units used in the construction industry. Plasma technology is also used for treating hazardous waste. The technology involves relatively high capital and operating costs. However, because of extremely high operating temperatures and the resultant production of a vitrified inert ash that will not leach metals or other contaminants into the environment, plasma technology has environmental advantages in certain applications. The environmental advantages include the ‘ultimate destruction’ of highly problematic hazardous organic materials such as PCBs and complex stable volatile organic compounds.

In principle, plasma arc has the same attributes, advantages and disadvantages as conventional gasification, with the added benefit of much higher heat that destroys all organic contaminants and vitrifies the slag into a reusable aggregate-like substance. This aggregate would need to be ground into a marketable commodity and compete with traditional aggregates on price. The major disadvantages are the higher energy requirements to create and maintain the plasma, the heat losses associated with high heat conditions, and the technical complexity and material challenges that come from managing such high temperatures.

Despite considerable research into the application of plasma technology for MSW, the technology is still at the developmental stage. Currently, there are no commercial scale units managing MSW in North America or Europe, and only two plants in Japan. There are, however, a number of different patented plasma arc systems being proposed for the treatment of MSW and undergoing pilot tests. Two well known Canadian examples are Alter NRG, based in Calgary, Alberta, and Plasco in Ottawa. These are described briefly below.

Alter NRG

Alter NRG is selling a design based on using plasma technology from Westinghouse Plasma Corporation (WPC), an industry leader in the design and supply of plasma torch technology, which is now owned by Alter NRG. Their plasma torches have been in operation since 1989 and have logged over 500,000 hours of commercial use. Although this key component of plasma arc gasification is considered proven, the design, construction and operation of a solid waste facility that uses this technology has not been commercially applied in North America. There are currently two facilities have been operational in Japan since 2003. The specifics of these facilities are summarized below.

Location	Duty	Plant Capacity	Treatment Capacity	Start-up
Utashinai, Japan	Plasma gasification: - 50% MSW & - 50% auto shredder residue	180 tonnes per day	49,500 tonnes per year	2003
Mihama-Mikata, Japan	Plasma gasification: - 80% MSW & - 20% dried sewage sludge	22 tonnes per day	6,600 tonnes per year	2003

The first North American plasma arc gasification facility using Alter NRG's technology is being proposed in St. Lucie County, Florida. Geoplasma St. Lucie LLC was issued an air pollution permit from the Florida Department of Environmental Protection to build this facility on June 16, 2010. This plant will be designed to produce a gross 24 MW of power and process 622 tonnes per day (193,000 tonnes per year) of garbage, tires, metallurgical coke and other waste. Alter NRG is supplying the plasma torches and the plant is expected to be operational by 2013.

Plasco Process Description

Plasco Energy Corp. (Plasco) utilizes a more traditional approach to gasification. MSW is pre-selected and is fed into a gasification chamber where a portion is combusted to create the necessary heat for the gasification process to occur. Plasma torches are applied in the flue gas stream to clean up organic contaminants (also called syngas polishing) and in the slag area to create the vitrified residue. After passing through the plasma area, the syngas is cooled and passed through a cleaning system to remove metals, sulphur, and the remaining particulates. .

Plasco operates a demonstration facility in Ottawa with a permitted capacity of 27,000 tonnes per year. Plasco financed the construction and operation of the plant, and the City of Ottawa provided the site for the facility and is paying a tipping fee of $40/tonne. The facility is permitted to process up to 75 tonnes of MSW per day and ten tonnes per day of high carbon wastes (plastics 3-7 and tires). The high carbon wastes are added to reduce fluctuations in the energy content of MSW and to increase the heating value of the feedstock. The Plasco technology was designed primarily for mixed MSW, with the high temperatures of the plasma arc used to remove contaminants in the flu gas and vitrify the ash. Plasco is currently negotiating a contract for all of the residential waste with the City of Ottawa. Plasco is also in advanced stages of implementing a new facility in Red Deer, Alberta, which should be in construction later in 2011.

4.5 Pyrolysis Update

There are no known pyrolysis facilities that have been recently built for MSW in Europe or Japan, or planned in North America, with the exception of one facility in Germany, which creates a syngas that is fired without cleaning in an adjacent coal fired boiler for making electricity.

4.6 Summary

Conventional combustion technologies remain the benchmark for energy recovery with over 800 facilities worldwide. There are many examples of well-operated waste-to-energy facilities in the developed world, the closest being in Burnaby, BC. Modern WTE facilities are considered to have no significant impact on the environment and generally a positive greenhouse gas balance. Conventional combustion systems are relatively simple and cost less to build and operate than most advanced systems, and have been proven to extract energy from and destroy other wastes, such as biosolids and biomedical materials. Most importantly, the conventional combustion is reliable, proven, with many qualified firms offering equipment and services.

Advanced thermal technologies such as gasification and plasma arc gasification offer some advantages over conventional combustion. They have the ability to create an intermediary product, namely syngas, which can be used for the manufacturing of fuels and chemicals. If fuels are made, such as synthetic natural gas or ethanol, they will still be combusted with resulting GHG emissions, but they do not need to be combusted where they are made. Advanced thermal technologies also offer the promise of higher efficiency in the production of electricity, if syngas can be cleaned adequately for use in gas engines or in a combined cycle power plant, although the latter has yet to be proven.

The gasification technologies that are reasonably proven are generally more expensive than conventional combustion, and due to their limited application with MSW, carry a higher degree of technical and financial risk. This must be weighed against the environmental benefits that the technologies offer.

5. Financial Analysis

Facilities were sized according to the twenty year solid waste projections for the three regional districts in Section 2. The solid waste disposal rate for the baseline year (2015) is estimated to be 215,000 tonnes per year and that is expected to grow to 250,000 tonnes per year by 2030. Similarly, the biosolids generation rate is expected to grow from 10,000 to 15,000 tonnes per year by the year 2030. A reasonable annual processing capacity for a WTE facility is 225,000 tonnes per year. These estimates assume recycling and organics recovery programs will be implemented as planned.

In order to account for seasonal variations in the generation of waste, and to allow for even more aggressive and currently unscheduled additional recycling and waste reduction, it is suggested that the WTE facility be sized for not more than 200,000 tonnes per year. This would also enable the facility to continuously operate at 100% of capacity, which is necessary for efficient operation of most thermal technologies.

5.1 Facility Cost

Costs were developed based on information in the public domain. Since there are no known publications in North America that keep statistics on the cost of new WTE facilities, and no facilities have actually been built in the past 15 years, cost information must be obtained from a variety of sources. These include published reports and studies conducted by other engineering companies in North America, published tender results for WTE facilities where these are in planning, industry guides that are used internally by WTE developers when assessing WTE potential, and experience by AECOM staff from working in this field for many years. These numbers have been processed and modified for the proposed systems to be compared based on our professional judgment and experience.

The following assumptions were applied to each of the WTE technology options:

- amortization period 25 years;
- interest rate is 6%;
- electricity price is $100/MWh which is based on BC Hydro's last call for power plus the expectation of higher prices in future calls;
- Natural Gas rate is $6/GJ which is based on natural gas price forecasts submitted by BC Hydro in its most recent Long Term Acquisition Plan;
- district heating value is 70% of natural gas value which is based on heat generated by a WTE facility and can be sold to a district heating system;
- uptake of district heat is estimated at 90% of heat output of which 50% is conservatively taken up; and
- waste contains 11.5 GJ of energy per tonne.

5.1.1 Conventional Systems – Mass Burn

The most recent published cost estimates for a mass burn facility is for the proposed Durham-York WTE facility. The capital cost is estimated at $235M at the initial processing capacity of 140,000 tonnes per year (Phase 1). This facility is designed to be expandable to 250,000 tonnes per year (Phase 2) and to a final capacity of 400,000 tonnes per year (Phase 3). The utilities will be designed to accommodate the final processing capacity. Staff reports indicate that additional processing buildings and stack are not required until the facility is expanded to the final processing capacity.

Based on Durham-York's design approach, the capital costs were adjusted to reflect the 250,000 tonne per year capacity that is built into the proposed design. This equates to a unit capital cost of $1,044 per tonne of installed annual capacity.

Other aspects that have been reported by Durham-York include the following:

Operating Cost:	$14.7M/yr
Energy Generation:	667 kWh per tonne net (electricity) and 7.2 GJ per tonne (heat)
Facility Availability:	90%
Electricity Revenue:	$8.6 M
Metal Revenue:	$80 per tonne (based on MV WTE metals recovery rate)
Residuals (by wt):	21 percent of plant capacity

The capital cost, operating cost and energy revenues were estimated based on specifications for the Durham-York WTE facility. Table 8 below takes into consideration annualized costs, disposal cost and local electricity and potential district heating revenue.

Table 8. Mass Burn Capital and Operating Cost Estimate

Description			Comments
Plant Capacity	200,000	tonnes per year	
Chute to stack equipment with building	$208,888,889	$1,044	per tonne of installed capacity
Land costs	$0		Land already owned by District
Site work	$4,177,778	2%	of plant cost
Permits and approvals	$2,088,889	1%	of plant cost
Total capital cost	$215,155,556		
Assumed average cost of capital	6	6%	interest rate
Amortization period	25	25	years
Annual capital costs	$16,975,773		
Annual operation and maintenance costs	$13,040,000	$65.20	per tonne
Residue disposal (21% of feedstock)	$2,100,000	$50	per tonne
Revenue from steam sales			
Revenue from electrical energy	($12,006,000)	$100	per MWh (90% efficiency for electricity)
Revenue from district heating sales	($2,721,600)	$6	per GJ (assume 50% of heat sold)
Revenue from sale of metals	($500,000)	$80	Scrap metal price per tonne
Net annual cost	$16,888,173		
Cost per tonne	$84.44	$98.05	without district heating

The identified costs are without contingency and provision for profits. They also represent a conservative approach for estimating the capital cost for a waste-to-energy facility and the estimated tipping fees to balance costs (break-even tipping fees). These costs estimates are consistent with the cost estimates that were recently reported by Stantec, in a report entitled “Waste to Energy – A Technical Review of Municipal Solid Waste Thermal Treatment Practices”, dated August 27, 2010.

If district heat markets are not available, then the break-even tipping fee rises by about 15%.

5.1.2 Gasification System – Thermoselect

The City of Taunton, Massachusetts recently completed a Request for Proposal for alternative waste conversion technologies. The preferred proponent is Interstate Waste Technologies (IWT) that utilizes the Thermoselect process. The capital cost is estimated at $600 M with a processing capacity of 500,000 tonnes per year. The unit capital cost for this facility is calculated to be $1,205 per tonne. Revenue from this facility would come from the production and sale of 34 million gallons of ethanol per year.

There are no published costs for gasification systems, since there are no commercially operating gasification units in North America. The tender documents from Taunton, Massachusetts offers likely the most up to date capital cost figures. The Taunton facility is more than double the size for the three regional districts. It is reasonable that the unit capital cost would be about 30% higher ($1,566 per tonne of installed annual capacity) than the Taunton proposal.

Operating costs for a Thermoselect process are also documented in a City of Los Angeles’ Evaluation of Alternative Solid Waste Processing Technologies report. Operating costs ranged from $65 per tonne for a 340,000 tonne per year facility and $120 per tonne for a 90,000 tonne per year facility. The prorated operating cost for a 200,000 tonne per year facility is estimated to be $93 per tonne.

Energy revenue comes from ethanol. The Taunton proposal projects an ethanol production rate of 34 million gallons per year and 10 to 20% of that ethanol would likely be used to provide heat for the gasification process. For conservative purposes assume 80% of the ethanol produced is available for sale. This equates to 205 litres of ethanol per tonne of waste which is equivalent to 5.1 GJ per tonne.

The largest single use of ethanol is a fuel or fuel additive. The United States has used ethanol and gasoline blends (E85) up to 85% ethanol and 15% gasoline. The ethanol produced could be used to fuel the collection and transfer vehicles and the portion of ethanol used would not be subject to the carbon tax. The energy content of ethanol is approximately 60% that of diesel. Market rate for ethanol is approximately $0.529 per litre ($2 per gallon).

Other considerations include the following:

Facility Availability: 90%
Metal Revenue: $500 K
Residuals (by wt): 21% of plant capacity

Table 9 list the cost estimates for a gasification facility.

Table 9. Gasification Capital and Operating Cost Estimate

Description			Comments
Plant capacity	200,000	tonnes per year	
Chute to stack equipment with building	$313,207,573	$1,566	per tonne of installed capacity
Land costs	$0		Land already owned by District
Site work	$6,264,151	2%	of plant cost
Permits and approvals	$3,132,076	1%	of plant cost
Total capital cost	$322,603,801		
Assumed average cost of capital	6	6%	interest rate
Amortization period	25	25	years
Annual capital costs	$25,453,440		
Annual operation and maintenance costs	$18,645,069	$93	per tonne
Residue disposal (20% of feedstock)	$2,000,000	$50	per tonne
Revenue from ethanol production (~43.7 ML/yr)	($18,435,650)	$0.53	per litre
Revenue from electrical energy	$0	$0	per MWh (90% efficiency for electricity)
Revenue from district heating sales	$0	$0	per GJ (assume 50% of heat sold)
Revenue from sale of metals	($500,000)		
Net annual cost	$27,162,859		
Cost per tonne	$135.81		

These parameters have been selected because they are conservative. There is a reasonable chance that the market could respond with lower cost alternatives than are available in the literature, or that financial parameters might change. This is certainly the case with the market price for ethanol which fluctuates with gasoline prices.

5.1.3 Plasma Arc Gasification Systems – Alter NRG

There are no published costs for plasma arc gasification systems, since there are no commercially operating gasification units in North America. The City of Marion, Iowa, recently completed an economic feasibility study for a plasma arc gasification plant. The study examined and compared the capital and operating cost relative to a conventional mass burn WTE facility. The study findings include a capital cost that is 35.6% higher than a mass burn WTE facility and an operating cost that is $107 per tonne.

An ideal application for gasification technologies would be the use of the syngas as a natural gas (fossil fuel) substitute in a combined cycle power plant or reciprocating engines. These applications benefit from the high energy efficiencies which are in the order of 40% for reciprocating engines and over 50% for combined cycle gas plants. By comparison, mass burn is currently at 27% energy efficiency for a modern facility.

Combined cycle gas technology offers the highest energy recovery efficiency for electricity production, however, there are two factors which make it not suitable at this time: 1. The minimum practical size for combined cycle gas plants is in the 200 to 250 MW range, and the waste in the three regions is only enough for about one tenth of that; and 2. Gas turbines are extremely sensitive to contaminants in the gas, and there are no known facilities currently achieving the necessary level of gas cleaning from MSW derived syngas which are firing a gas turbine.

Reciprocating engines offer good efficiencies for electricity production and are less complex that steam cycles, which are necessary with mass burn technologies. Therefore, reciprocating engine technology has been chosen for this gasification option to demonstrate the potential of this technology. The City of Los Angeles Evaluation of Alternative Solid Waste Processing Technologies documents energy potential from syngas used to power a reciprocating engine to range from 838 to 875 kWh per tonne of MSW. For this financial analysis 850 kWh is used. There is also residual heat that can be used for district heating. Similar to the Mass Burn analysis, it is assumed that 50% of the heat can be taken up.

Option parameters are assumed as follows:

Energy Generation:	850 kWh per tonne (electricity) and 7.2 GJ per tonne (heat)
Facility Availability:	85%
Metal Revenue:	$500 K
Residuals (by wt):	2% of plant capacity for disposal; (vitrified slag used for construction purposes at zero cost and zero revenue)

Table 10 is a summary of a capital and operating cost for a plasma arc gasification facility.

Table 10. Plasma Arc Gasification Capital and Operating Cost Estimate

Description			Comments
Plant capacity	200,000	tonnes per year	
Chute to stack equipment with building	$283,253,333	$1,416	per tonne of installed capacity
Land costs	$0		Land already owned by District
Site work	$5,665,067	2%	of plant cost
Permits and approvals	$2,832,533	1%	of plant cost
Total capital cost	$291,750,933		
Assumed average cost of capital	6	6%	interest rate
Amortization period	25	25	years
Annual capital costs	$23,019,149		
Annual operation and maintenance costs	$21,350,821	$107	per tonne
Residue disposal (2% of feedstock)	$200,000	$50	per tonne
Revenue from syngas production		0	
Revenue (electricity) from reciprocating engines fueled by syngas	($13,005,000)	$100	per MWh (85% availability for reciprocating engine)
Revenue from district heating sales	($714,000)	$6	per GJ (assume 50% of heat is sold)
Revenue from sale of metals	($500,000)		
Net annual cost	$30,350,970		
Cost per tonne	$151.75	$155.32	without district heating

5.1.4 Gold River Waste-to-Energy Facility

The Gold River WTE facility is proposed to be built, operated and financed by Covanta Energy. This facility would be constructed after securing waste from Metro Vancouver or from other sources. The minimum quantity available from Metro Vancouver is 500,000 tonnes per year. The additional waste from the three regional districts would bring the total processing capacity to 700,000 tonnes per year.

Covanta plans to build a 750,000 tonne per year WTE facility for $500M. These capital costs are based on articles summarizing the Gold River project which are also consistent with another WTE project that Covanta is planning in the United Kingdom. Electricity will be the only source of revenue. Operating costs are expected to be $40 per tonne. Based on these published figures for the Gold River project, the break-even tip fee is calculated to be $42 per tonne. This break-even tip fee does not take into consideration any profit margin mark up.

5.2 Potential Energy Users

Each technology produces different products. These products may include syngas, steam, heat, electricity or ethanol. These products may be used by industries located in the vicinity of the WTE facility. Industrial users and their long term plans tend to adapt to economic conditions. Energy costs have risen significantly over the past several years, and are likely to keep rising. Interest in heat or steam recovered from waste is anticipated to grow as costs increase. The following subsections identify potential energy uses for each site.

5.2.1 RDN

The Harmac pulp mill is now owned and operated by Nanaimo Forest Products (a group of mill managers, workers, and three private investors) who was awarded possession in July 2008. The mill has been back in production since early 2009, with 300 employees. Nanaimo Forest Products president, Levi Sampson, expressed interest in opportunities that would enhance industrial activity in the area. Nanaimo Forest Products owns over 500 acres of industrial land in the surrounding area and would consider establishing a utility to supply steam, electricity, syngas and district heating. They are also exploring opportunities such as district heating for a proposed community development at Cable Bay, just south of the Harmac pulp mill.

Western Forest Products operates a sawmill just south of the Duke Point Ferry Terminal. That operation may expand as negotiations are underway to move Western Forest Products' Nanaimo sawmill to the Harmac site. Western Forest Products could potentially purchase electricity, heat and steam for the sawmill operation.

Nexen Chemicals produces sodium chlorate, which is used by pulp mills. Nexen purchases steam from the Harmac mill to produce sodium chlorate.

BC Hydro issues long term contracts to buy electricity that is incorporated into the grid. According to BC Hydro's last call for power, the estimated price for electricity is $100 per MWh.

5.2.2 CVRD

The majority of the residents in the CVRD reside around Duncan. The community is primarily residential with some light industrial and commercial operations. Opportunities for energy revenue include electricity sales to BC Hydro and potentially some residential district heating.

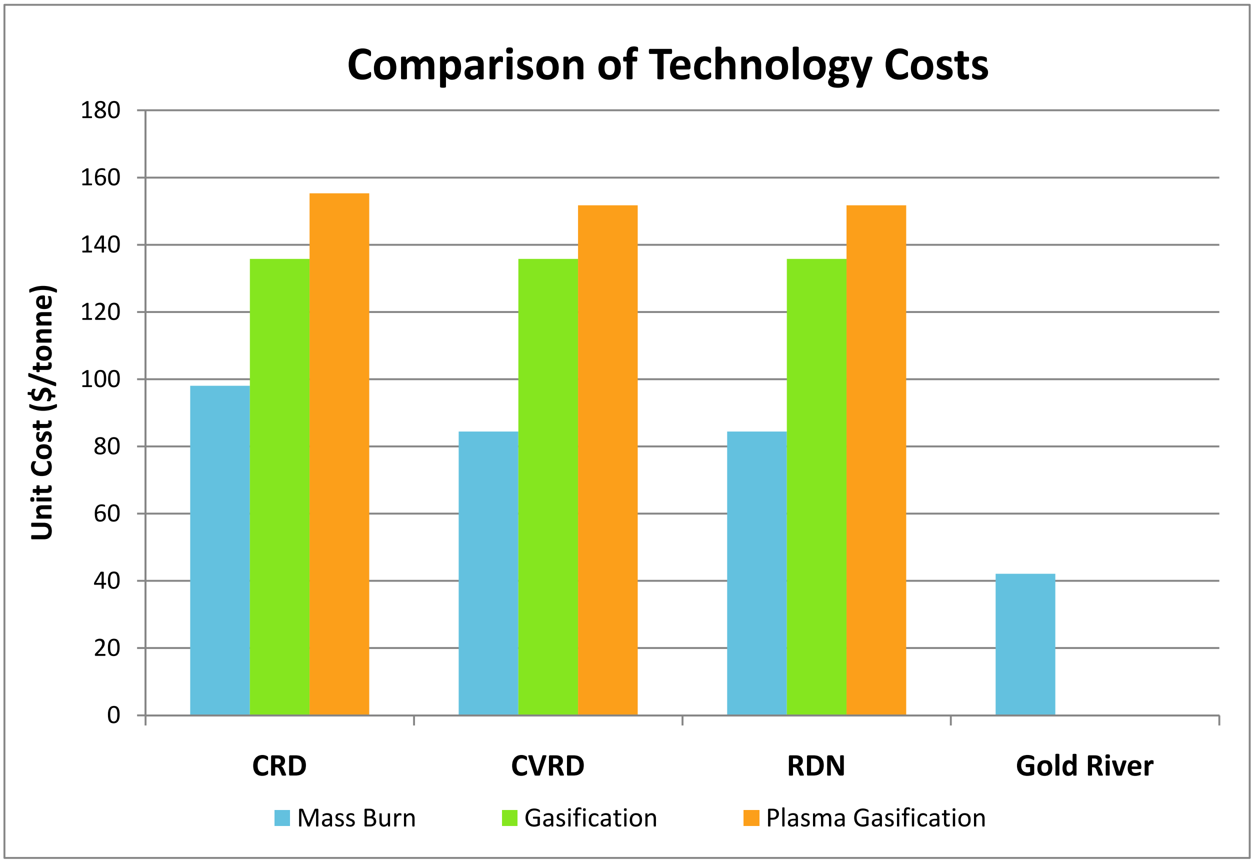
5.2.3 CRD

No specific site has been identified for a future waste-to-energy facility in the CRD. Sites throughout the region may offer a range from very limited to excellent opportunities for use of district heat and steam. To reflect a conservative analysis, the report considers having no users for heat and steam as a base case. Therefore, energy recovery opportunities would include electricity, which could be sold to BC Hydro, and fuel production such as ethanol, that would be produced from technologies that have that capability.

5.3 Financial Summary

The greatest difference in cost comes from the choice of technology, except for Option 4 (out of region mass burn), where economies of scale make a big difference. The actual technology cost between using mass burn, gasification and plasma gasification can be compared in Figure 11. These costs show net of revenue break even tipping fees, assuming 100% of the excess electricity generated can be sold, 100% of the ethanol can be sold, and 50% of the district heat energy can be sold (RDN and CVRD locations only). Having local markets for district heat helps economics from the revenue perspective.

Figure 11. Comparison of Technology Costs



The above analysis shows the basic costs and revenues for each technology. These must be combined with site specific factors, such as ability to sell heat at some locations, plus the cost to transport feedstock to the facilities. Together, these costs will indicate the actual break-even tipping fee required for a particular option.

Although this study only deals with four options, we need to consider the implications of technology and heat markets at each location. This effectively expands the number of options to ten. However, it also allows the assessment of technology and market implications. Costs are summarized in Table 11.

Table 11. Summary of Options

Option	Description	Capital Costs $Million	Facility Cap and Operations $/T	Transportation Costs $/T	Total Costs $/T
1	**WTE at CRD**				
1a	Mass burn	$209 M	$98.05	$20.57	$118.62
1b	Gasification	$323 M	$135.81	$20.57	$156.38
1c	Plasma gasification	$292 M	$155.32	$20.57	$175.89
2	**WTE at CVRD**				
2a	Mass burn	$209 M	$84.44	$31.45	$115.89
2b	Gasification	$323 M	$135.81	$31.45	$167.26
2c	Plasma gasification	$292 M	$151.75	$31.45	$183.20
3	**WTE at RDN**				
3a	Mass burn	$209 M	$84.44	$30.09	$114.53
3b	Gasification	$323 M	$135.81	$30.09	$165.90
3c	Plasma gasification	$292 M	$151.75	$30.09	$181.84
4	**WTE at Gold River**				
	Mass burn	N/A	$42.12	$68.42	$110.54

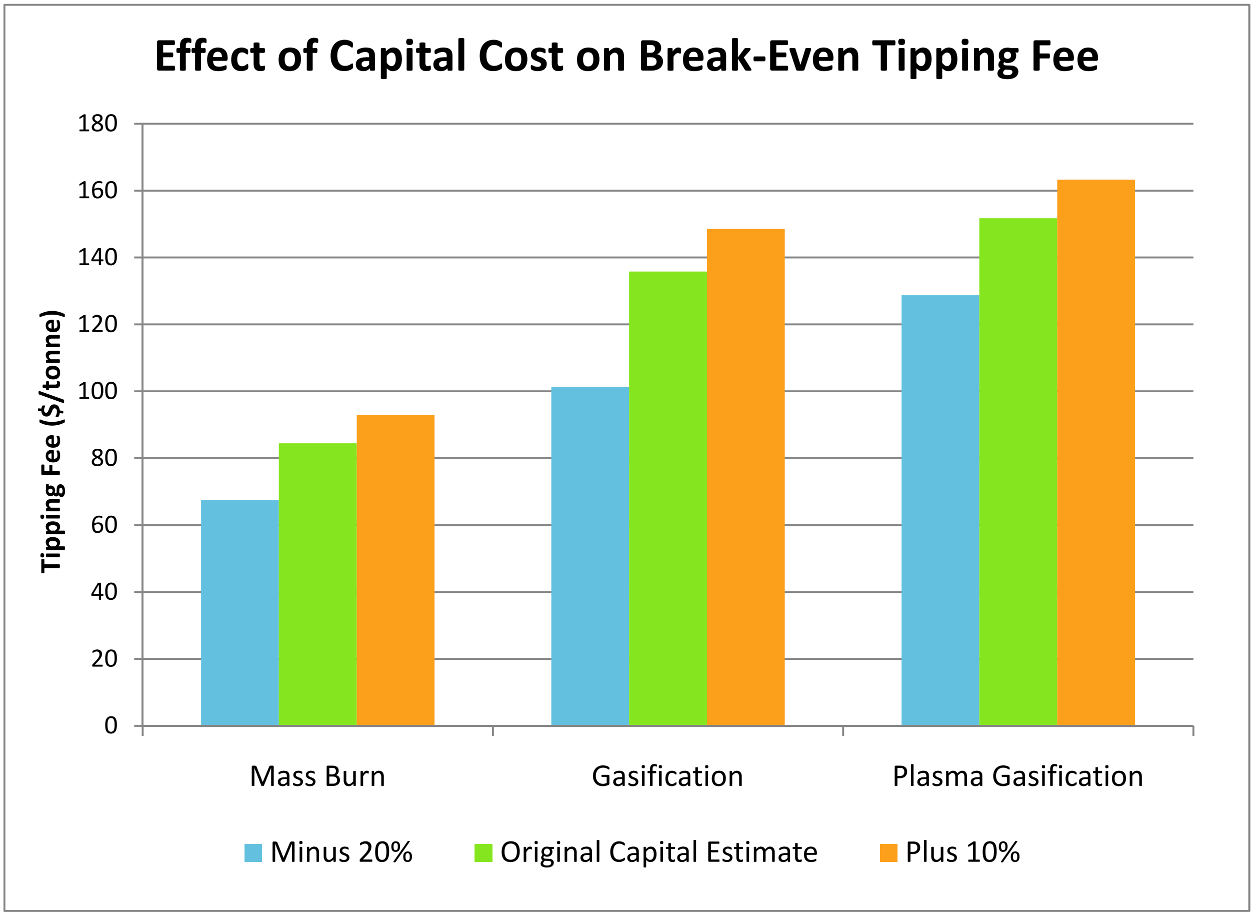
Transportation is the equalizing factor among the option locations. When the same technology is used, the difference after transportation is factored in, is less than 9% for mass burn (for example). This is well within the study's tolerance of cost estimating and could make any of the options attractive in a competitive situation. Further, small variances in the amount or cost of capital, revenues from sale of heat, or competitive transportation arrangements could change rankings and favour one option over another. These variances can only be determined through more advanced study, or proceeding with a tendering process.

For example, district heating revenue is conservatively estimated at 50% uptake for the RDN and CVRD sites. The potential heat and steam market at the RDN are very favourable and could reasonably achieve 80% uptake. This could lower the facility capital and operating unit cost by about $8, shifting the rating of the RDN site to a much more favourable position.

It should also be noted that the CRD options analysis was undertaken with no potential for district heating. If a site with district heating opportunities was realized, the total unit cost could be reduced from $118.62 to $105.01 per tonne. This would make this option the more economical than sending waste to Gold River.

One of the largest factors in overall feasibility is capital costs. To demonstrate the difference this makes, they were varied +10% and -20% for all of the scenarios. The results are shown in Figure 12 below.

Figure 12. Effect of Capital Costs on Break-Even Tipping Fees



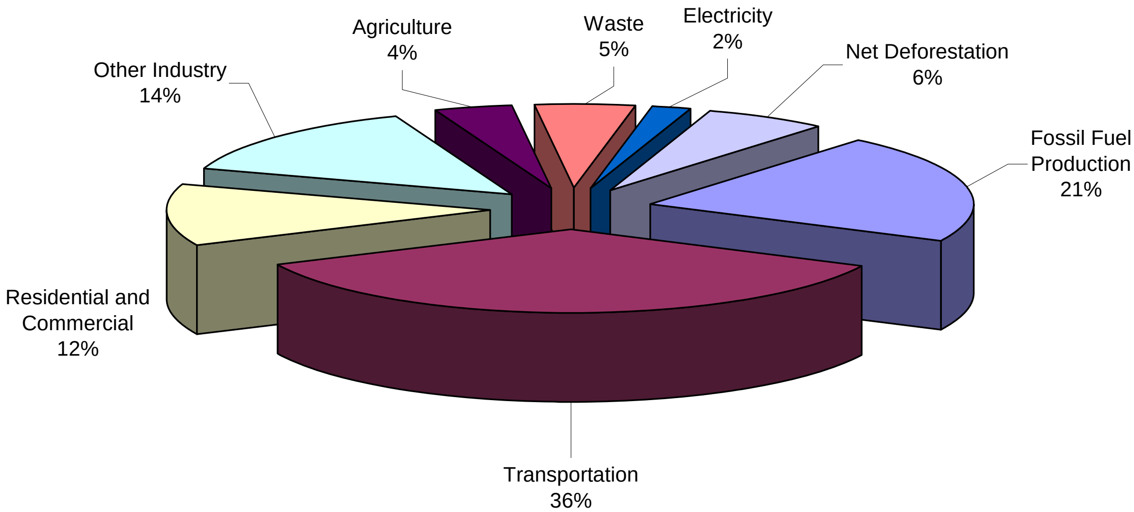
This comparison shows that with a 20% reduction in capital costs, plasma gasification could be less costly than conventional gasification (if no capital reduction can be achieved). The capital costs of gasification and plasma gasification would have to drop by much more than 20% in order to make them competitive with mass burn technology.

6. Greenhouse Gas Emissions

Waste management contributes to global climate change through the release of greenhouse gases (GHG). The most common GHG is carbon dioxide; emissions of all other GHG compounds are typically expressed in terms of carbon dioxide equivalents (CO_2e).

Provincially, the waste sector contributes 5% of the total GHG emissions. A breakdown of GHG emissions by sector for BC in 2006 is illustrated in Figure 13. Within the waste sector, 95% of the emissions are from landfills, with 2% from waste incineration and 3% from wastewater management. The statistics do not include the GHG resulting from the transportation of waste in these numbers.

Figure 13. Sectoral Breakdown of BC's GHG Emissions, 2006[1]



For the purposes of GHG inventories, it is important to distinguish between "fossil" and "biogenic" carbon in wastes. Fossil carbon is found in waste that is derived from fossil fuels (e.g., coal, oil, natural gas) that are processed into a variety of wastes (notably plastics). Biogenic carbon is in waste that has "recently" been alive (such as wood, paper, plants, food waste, rubber products). When conducting GHG inventories, the release of biogenic carbon to the atmosphere (as carbon dioxide) is not considered a GHG emission, because this carbon dioxide is simply returning to the atmosphere from where it was "recently" removed by the growth of organic matter. Biogenic waste can create a GHG emission if its treatment or disposal generates methane (for example in a landfill) or nitrous oxide (via combustion). These two gases are respectively 21 and 310 times more potent, than carbon dioxide. Therefore, the biogenic carbon is being returned to the atmosphere in a more potent form than it would have under natural conditions.

Emissions of carbon dioxide from the burning of biogenic waste are not included in the waste management section of a GHG inventory. Carbon dioxide from the burning of wastes of a fossil carbon origin is counted in the waste management portion of an inventory. It is therefore important to have an accurate estimate of the proportion of biogenic carbon in the waste stream so that estimates can be made about the climate-relevant emissions associated with thermal treatment. Methods are available to achieve this. Before a WTE facility is built, a waste analysis can accurately reveal the split between biogenic and fossil carbon. During WTE facility operation, there is instrumentation available that can measure the fossil portion of the emissions in real time. Generally, the biogenic portion of the municipal solid waste stream is in the 50 to 60% range, depending on the degree of organic material removal (i.e., kitchen wastes). If biosolids are added to the WTE feedstock, then that increases the biogenic portion.

GHG emissions originating in landfills are from the release of landfill gas (LFG) generated by the anaerobic decomposition of organic (i.e., biogenic) waste in landfills. LFG is primarily carbon dioxide and methane. As noted previously, methane has a higher global warming potential than carbon dioxide (21 times higher than CO2), and therefore is of great concern in MSW management. Landfills also have the potential to act as carbon "sinks", storing carbon underground rather than emitting it into the atmosphere. Only the fraction of the biogenic waste that does not decompose into carbon dioxide or methane is stored. Landfilling fossil-based carbon (e.g., plastic wastes) does not count as carbon storage, as that carbon has not "recently" been in the atmosphere.

---

[1] British Columbia. (2008). *BC Climate Action Plan.* Accessed August 8, 2008. *http://www.livesmartbc.ca/attachments/climateaction_plan_web.pdf.*

BC Climate Action Plan

The Province of BC is taking a leadership role in reducing emissions of greenhouse gases (GHG). The Province released a Climate Action Plan in June 2008, followed by a series of recommendations from the Climate Action Team in August 2008.

The Climate Action Plan outlines a series of initiatives that the provincial government commits to undertaking to reduce GHG emissions. The Plan also includes an overall reduction target of 33% for GHG emissions by 2020. A number of supporting pieces of legislation were also passed to enable the following actions to be achieved:

- implementation of a cap and trade system in conjunction with regional partners;
- implementation of a revenue-neutral carbon tax;
- adoption of vehicle emissions standards that will increase automobile fuel efficiency;
- regulation of LFG;
- development of more low-carbon energy generation projects;
- development of renewable forms of energy and decrease the carbon content of fuels;
- development of more sustainable, healthy communities; and
- low-carbon economic development.

The most relevant of these actions to waste management is the Landfill Gas Regulation, which was passed in December 2008.[2] The Regulation covers landfills that accept waste after January 1, 2009 and that have more than 100,000 tonnes of municipal solid waste in place, or that receive more than 10,000 tonnes of municipal solid waste per year.

Every landfill covered by the Regulation must complete a LFG generation assessment, based on the quantity of municipal solid waste received (historic and projected). Initial reports are due by January 1, 2011. If the assessment indicates that more than 1,000 tonnes of methane will be released, then a design plan for LFG management must be prepared for the site. The plan must be prepared within one year of the assessment and submitted to the Ministry of Environment. Once the design plan is approved by the Ministry of Environment, LFG management facilities and processes must be installed and implemented within four years of the approval. Landfill gas must be flared or used for a purpose that reduces the methane emissions by an amount equivalent to the reduction that would be achieved by flaring.

The recommendations from the Climate Action Team include interim CO_2 emissions reduction targets of 5-7% below 2007 levels by 2012, and 15-16% below 2007 levels by 2016. The recommendations also provide strategies related to a number of sectors, including solid waste, as noted at the beginning of this section. Although the strategy is not yet specified, the recommendation document mentions diverting organics from landfill, extended producer responsibility, expanded composting, and strict standards for air quality, energy efficiency for waste-to-energy facilities, and residuals management.

BC Energy Plan

The BC Energy Plan was released in February 2007. This plan notes that British Columbia is currently dependent on other jurisdictions to supply up to 10% of our electricity, and that forecasts from BC Hydro show that electricity

[2] British Columbia Ministry of Environment. (2008). *Landfill Gas Management Regulation.* Accessed January 5, 2009. http://www.env.gov.bc.ca/epd/codes/landfill_gas/pdf/lg-reg-12-08.pdf

demand may grow by up to 45% over the next 20 years. Within this context, the Plan sets a goal of achieving energy self-sufficiency by 2016.[3]

The new electricity generating capacity that will be required to meet the goal of energy self-sufficiency should comply with the following policies.[4]

- all new electricity generation projects will have zero net GHG emissions;
- zero net GHG emissions means that facilities that emit GHG will be required to purchase carbon offsets from other activities in British Columbia;
- zero GHG emissions means that the project itself must not generate any GHG emissions. This can be accomplished by sequestering (storing) carbon that is generated;
- clean or renewable resources include sources of energy that are constantly renewed by natural processes, such as water power, solar energy, wind energy, tidal energy, geothermal energy, geoexchange, wood residue energy, and energy from organic municipal waste;[5]
- zero net GHG emissions from existing thermal generation power plants by 2016;
- zero GHG emissions from coal thermal facilities;
- ensure clean or renewable electricity generation continues to account for at least 90% of total generation (Currently in BC, 90% of electricity is from clean or renewable resources); and
- no nuclear power.

Achieving these goals will be difficult, and implementation details have not yet been provided.

The plan further notes the potential for biomass to generate energy (bioenergy). Wood residue, agricultural waste, municipal solid waste and other biomass may be considered a carbon-neutral form of energy because the carbon dioxide released by the biomass when converted to energy is equivalent to the amount absorbed during its lifetime. This type of energy is considered firm, and the plan estimates the cost of additional biomass-based electricity capacity at $75 – $91/MWh.[6]

The BC Bioenergy Strategy is the supporting document to the BC Energy Plan.[7] This strategy provides detail on how municipal solid waste could potentially provide energy to BC. The case studies provided in the strategy focus on the capture and use of LFG (at Hartland Landfill , and at the Vancouver Landfill in Delta) and the WTE facility in Burnaby. The strategy earmarks municipal solid waste as a source of green energy with “endless potential”. The “next step” identified in the report is for the development of requirements for methane capture at landfills (which has been mandated under the recently enacted Landfill Gas Regulation).

It is our interpretation that the BC Bioenergy Strategy only considers the biogenic portion of the solid waste stream as having potential to generate green electricity. Therefore, any WTE system will need to determine what portion of the MSW is from fossil based sources and find carbon offsets for the electricity produced by this waste. In the case of district heating, this is fairly easy to do, since a lot of natural gas use would be displaced by the district heat, resulting in carbon credits. If Electricity only is produced, then carbon offsets may have to be purchased to make the

---

[3] British Columbia Ministry of Energy, Mines and Petroleum Resources. (2008). *The BC Energy Plan: A Vision for Clean Energy Leadership.* Accessed August 24, 2008. *http://www.energyplan.gov.bc.ca/*

[4] British Columbia Ministry of Energy, Mines and Petroleum Resources. (2008). *The BC Energy Plan: A Vision for Clean Energy Leadership.* Accessed August 24, 2008. *http://www.energyplan.gov.bc.ca/*

[5] British Columbia Ministry of Energy, Mines and Petroleum Resources. (2008). *The BC Energy Plan: A Vision for Clean Energy Leadership.* Accessed August 24, 2008. *http://www.energyplan.gov.bc.ca/*

[6] British Columbia Ministry of Energy, Mines and Petroleum Resources. (2008). *The BC Energy Plan: A Vision for Clean Energy Leadership.* Accessed August 24, 2008. *http://www.energyplan.gov.bc.ca/*

[7] British Columbia Ministry of Energy, Mines and Petroleum Resources. (2008). *BC Bioenergy Strategy Growing Our Natural Energy Advantage*. Accessed August 24, 2008. *http://www.energyplan.gov.bc.ca/bioenergy/*

electricity generation GHG neutral. This interpretation is only an opinion and needs to be verified with the Ministry of Environment in the case that WTE is pursued.

It should also be mentioned that WTE directly reduces GHG emissions from landfills by removing the source of the landfill gas emissions. This is taken into account in the GHG balances presented in this report; however it is not clear at this time how the MOE would calculate these GHG reductions.

Internationally, WTE is generally considered to be GHG neutral provided minimum electrical and heat recovery efficiencies are achieved. This differs in each jurisdiction depending on local conditions and legislation. In the USA for example, the federal EPA considers WTE to provide clean, renewable energy, and almost half of all US states do the same.

GHG Emissions from Tri-Regional District MSW

Waste management activities currently contribute about 5% to BC's GHG emissions, and un-captured landfill gas is by far the greatest source of GHG emissions coming from waste management activities. WTE can substantially reduce the amount of landfill gas produced.

As an energy producer, WTE will likely be judged on the amount of renewable energy it can produce, i.e., from biogenic carbon. If kitchen organics are removed and biosolids added to the WTE feedstock, then the biogenic portion can be expected to be in the 60% range. The carbon produced by making electricity from the fossil fuel portion of the waste stream may have to be offset by displacing natural gas use for heating or by buying carbon credits. A formal policy on this from the Provincial Government is not yet known and needs to be confirmed in the future.

The nature of GHG emissions from MSW is dependent on the carbon origin of the waste, i.e., carbon from fossil fuel origins versus carbon of biogenic origin. For WTE, the GHG emissions are related to the amount of fossil carbon in the waste from materials derived from geologic reserves of carbon like coal, natural gas, or petroleum, which is primarily found as plastics. For landfills, the GHG content is related to the amount of biogenic carbon from materials derived from "recently grown" biological sources, which includes paper, lumber, food scraps, and yard waste.

GHG Emissions from WTE

The GHG emissions from thermal process were estimated based on the amount of fossil and biogenic carbon in the MSW from waste composition studies and current total CO_2 emissions from Metro Vancouver's WTE facility.

Emissions from Metro Vancouver's WTE facility is determined through an analysis of the stack gas CO_2 content and the flow rates through each of the three lines. 2005 data waste used and indicated a total carbon dioxide emission rate of 1,157 kg per tonne of MSW. As indicated above, the biogenic portion of the waste is expected to be in the 60% range and the fossil carbon portion is estimated to be 40%. Therefore, the carbon dioxide emission for the fossil carbon portion of the MSW is 463 kg per tonne.

GHG Emissions from Landfilling

The anaerobic decomposition of organic matter generates landfill gas (LFG). LFG comprises of two greenhouse gases (methane and carbon dioxide). The rate and quantity of LFG generation is a function of many factors including the moisture content of the waste, the composition of the waste, the landfill conditions (pH, temperature, moisture content, compaction, etc.) and other factors. Evaluating the gas generation based on these factors is an on-going area of research.

For this study the LFG emissions were estimated using a computational model developed by the U.S. EPA called LandGEM (Landfill Gas Emissions Model) Version 3.02.[8] The LandGEM model is a spreadsheet-based tool that generates a forecast of LFG emissions based on inputs of waste deposition and defined model parameters.

There are two key parameters of the LandGEM model: k and L_0. The rate at which LFG is generated (i.e., the lag between waste deposition and gas generation) is described by k. The value of k does not affect the total amount of LFG estimated by the model, and is therefore not critical to the results of the greenhouse gas emission analysis since the objective is to determine the total quantity of methane and carbon dioxide generated from a tonne of MSW, and not the quantity generated in a specific year.

The second key parameter of this model is L_0, the methane gas generation potential. This parameter indicates the ultimate methane generation possible from the waste (units of methane production in m^3 per mass of waste). The U.S. EPA recommended figure for a traditional landfill in a wet region (such as on Vancouver Island) is 100 m^3 methane per tonne MSW. Based on the waste composition and previous studies for Metro Vancouver, an L_0 value of 98 m^3 of methane per tonne MSW was calculated and used in this study.

LFG is nominally composed of 50% methane and 50% carbon dioxide. There are many other contaminants associated with LFG and the LandGEM model includes standard concentrations of 48 other compounds. These have been included at their default concentrations.

To obtain an “apples to apples” comparison, we assumed that a new landfill with a disposal rate of 200,000 tonnes per year that commences operating in 2015 and operates for 25 years. If the existing two landfills were taken into consideration for this analysis, the GHG emission would be considerably higher (approximately 50% higher) primarily because of the previously deposited waste that is continuing to decompose.

It was also assumed that the new landfill would have a 75% LFG capture rate which is typical of newly designed bioreactor landfills. This is consistent with the recent environmental assessment completed for the proposed landfill at Logan Lake (or Highland Valley Copper) which predicts a 75% capture rate. The Vancouver Landfill has been modeled as achieving an average 75% average capture rate for LFG from now until closure. A recent study conducted by CH2M Hill on behalf of the City of Vancouver estimated a capture rate in the range of 65 to 90%.[9] A recent U.S. EPA report suggested 75% as an average value.[10] A 75% capture rate means that 25% of the LFG is not captured.

For this analysis, carbon storage in landfills is not included (i.e., carbon storage is set to 0 kg CO_2e per tonne of MSW), since even hard to decompose materials would be expected to undergo some degradation.[11] The US EPA is currently studying this issue, but has not yet officially recognized the potential for carbon storage. The IPCC’s 2006 Guidelines include carbon storage as an “informational item”, meaning that the data can be collected but does not form part of the inventory.[12]

---

8 U.S. EPA (2005). LandGEM Model V3.02, *posted to EPA software download site (http://www.epa.gov/ttn/catc/software) 5-12-05. Downloaded May 2006. User's Guide (EPA-600/R-05/047) downloaded May 2005.*

9 CH2M Hill. (2009). *Comparison of Greenhouse Gas Emissions from Waste-to-Energy Facilities and the Vancouver Landfill.* Prepared for the City of Vancouver.

10 Background Information Document for Updating AP42 Section 2.4 for Estimating Emissions from Municipal Solid Waste Landfills", EPA/600/R-08-116, September 2008 on page 7 (http://www.epa.gov/ttn/chief/ap42/ch02/draft/db02s04.pdf)

11 *Note that although fossil carbon in MSW is not released, this does not constitute a sequestration activity. Sequestration occurs when atmospheric carbon is removed from the atmosphere and kept from being released back into circulation. The creation of plastics and other MSW from fossil carbon has not removed carbon from the atmosphere; the carbon in these materials has been transported from one reserve (petroleum reservoir) to another (landfill).”*

12 Intergovernmental Panel on Climate Change (IPCC). (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, *Volume 5 – Waste, Chapter 2 – Waste Generation, Composition and Management Data.* Accessed August 26, 2008. *http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_2_Ch2_Waste_Data.pdf*

The expected change in future LFG generation due to the implementation of source segregated organics programs that reduce the quantity of gas generating putrescibles from entering the landfill has been accounted for in the calculations and estimates.

Captured LFG is assumed to be burned in an internal combustion engine (similar to that used at the Vancouver Landfill) to generate electricity. It is also assumed that the heat is not recovered. This analysis assumed best case conditions where 90% of the captured landfill gas is combusted in an internal combustion engine and 10% is flared. The GHG emissions rate for a 200,000 tonne per year landfill is calculated to be 549 kg CO_2 equivalents per tonne MSW.

GHG Emissions from Transportation

Transportation is not a substantial source of GHG emissions in any scenario. This is because the fossil fuel consumption for transportation is relatively low. Only the Gold River scenario has a notable GHG emission. The GHG emissions from the transportation of MSW are based on figures from the transportation analysis in Section 3. The GHG emission levels are also based on the transfer haul option and dependent on the location of the WTE facility.

Avoided Greenhouse Gas Emissions

In addition to calculating the direct GHG emissions resulting from landfilling or WTE, it is also necessary to account for emissions that are avoided elsewhere as a result of the energy that is recovered. Avoided greenhouse gas emissions represent energy outputs that displace or replace the need to use energy from coal, natural gas, oil, hydro or nuclear sources. The carbon dioxide emissions that are avoided vary depending on the type of energy being displaced and the local area. The GHG emission displacement by energy source is summarized in Table 12 below.

Table 12. Greenhouse Gas Emission Factors

Energy Source	Emission Factor	Units
Electricity (hydro-electric in BC)	0.022	Kg CO_2e per kWh
Heating (natural gas combustion)	50.3	Kg CO_2e per GJ
Ethanol combustion	1.66	Kg CO_2e per litre
Diesel combustion	2.73	Kg CO_2e per litre

The relatively low emission factor for electricity is based on the present GHG intensity of electricity generated in BC, which uses limited amounts of fossil fuel. In Alberta where electricity comes from coal fired power plants, the emission factor is much higher. The higher avoided GHG emissions come from the avoided emissions from district heating, which is assumed to offset a combination of natural gas fired boilers and electric heat. Ethanol can be utilized as a vehicle fuel and replace diesel. The energy content of ethanol is about 61% of diesel.

Summary of Greenhouse Gas Emissions

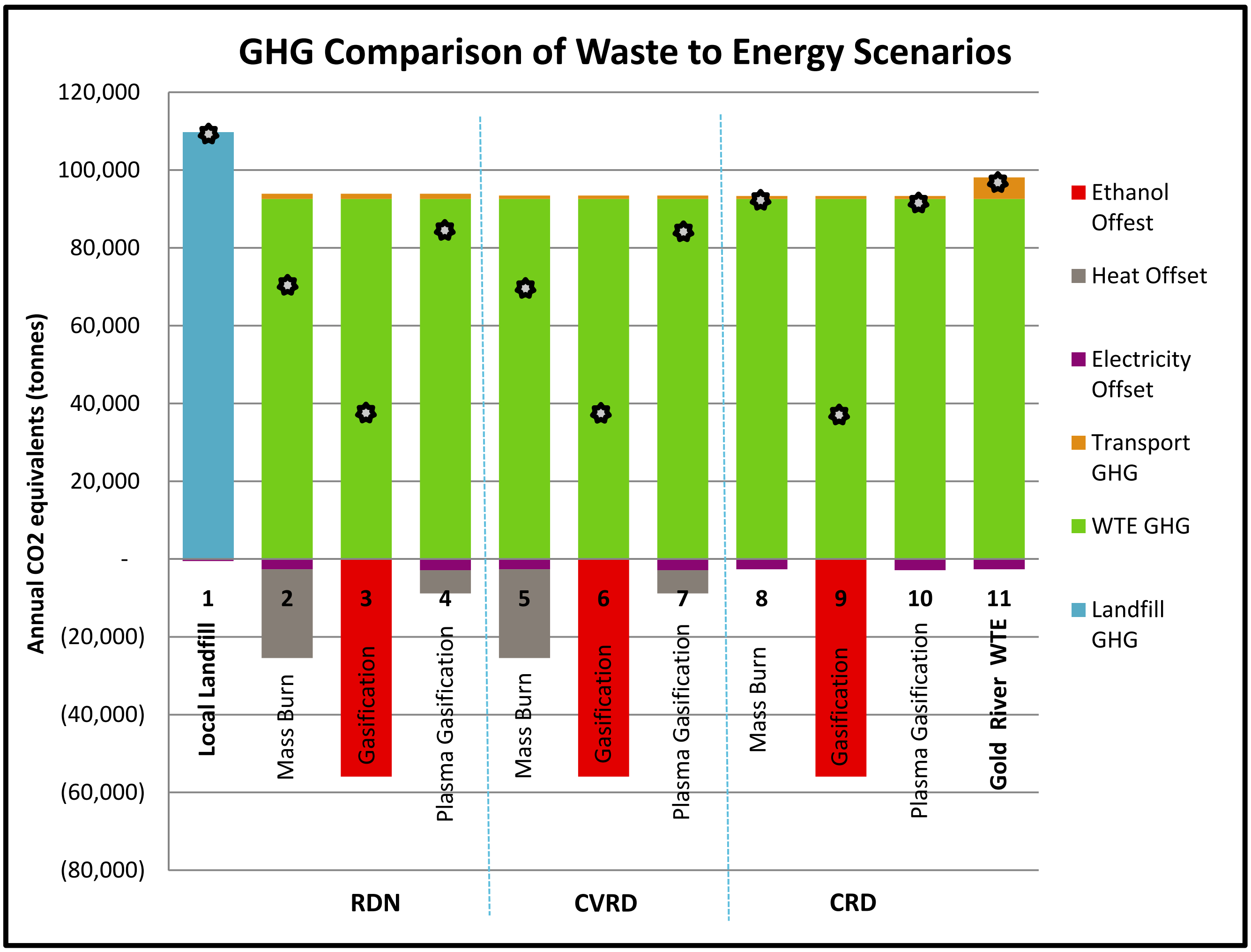
The GHG emissions and respective off-sets were compiled to assess the net GHG emission for each option. The options include a local landfill that has the same capacity as the proposed WTE facilities, nine local WTE options and one out of region WTE option in Gold River, BC. Figure 14 summarizes the GHG emissions and the star on each bar graph represents the net GHG emission. It should be noted that landfill gas captured for the local landfill scenario is utilized to generate electricity and is accounted for in the electricity off-set.

The conclusion is that landfilling, even with landfill gas recovery and utilization, produces more GHG than WTE. Under the WTE options, the technologies that generate fuels used to offset fossil based natural gas or diesel has the greatest benefits. BC's electricity has such a low carbon density that there are few carbon offsets that can be achieved from new electricity generation.

For this analysis, and to demonstrate a variance in the options, conventional gasification was shown as converting syngas to liquid fuel, and plasma gasification, due to its higher temperatures and claimed gas cleaning characteristics of the plasma, was shown producing electricity with a high efficiency. Plasma gasification systems are equally suitable for creating syngas that can be converted into fuel, thus they could achieve the same GHG levels as conventional gasification systems.

It should also be noted that the Gold River option is based on electricity production only. The proponent of the Gold River facility has indicated that there may be the possibility in the future of also providing steam to industrial users in the vicinity of the plant. If that becomes reality, then the GHG values for the Gold River option would improve, and likely be similar to the options that produce electricity and district using mass burn WTE.

Figure 14. GHG Emissions Scenarios



7. Summary and Conclusions

Combining the solid waste that is expected to be generated in the CRD, CVRD and RDN after organics and recycling have been maximized, leaves about 225,000 tonnes per year that need to be treated and/or disposed. WTE could conceivably treat about 200,000 tonnes per year and extract the energy from this waste.

Technologies were assessed for 200,000 tonnes per year of feedstock, including dried biosolids. The technologies considered for further review and analysis were:

- mass burn;
- gasification; and
- plasma gasification.

Four locations that could possibly host a WTE facility were also reviewed:

- CRD;
- CVRD;
- RDN; and
- out of region – private facility in Gold River.

A single WTE facility would have adequate economies of scale to employ the most proven combustion technology – mass burn. However, it is still not at an optimum size from a pricing perspective, which would be about three times larger. The out of region WTE facility being offered in Gold River falls into a desirable economy of scale range because it also plans to accept waste from other regions. However, there is additional cost involved in getting the waste to Gold River.

Mass burn is the technology that is most proven and can be used to generate electricity and supply district heat to potential users. It has been agreed that mass burn would provide electricity and district heat at the RDN and CVRD locations, otherwise only electricity at CRD and Gold River.

Gasification and plasma gasification offer alternate technologies that create a syngas that can be cleaned and used as raw material:

- combusted in reciprocating engines to achieve higher electrical efficiency, plus district heat where markets exist; and
- converted to ethanol and sold on the open market.

From a transportation perspective, the site closest to where most of the waste is generated (i.e., CRD area) offers the lowest transportation costs. Transfer haul is the lowest cost form of transporting waste for all options (compared to direct haul, rail haul, and barge transport). Transfer haul also has the lowest fuel consumption, produces the least GHG emissions and the most flexibility for backhauling. *Note: Barge haul numbers may change if more precise data becomes available after release of this draft report.*

New transfer stations would be needed for all scenarios, and this has been factored into the review. Existing transfer stations would continue to operate, except if the facility were to be located in Duncan, in which case the local transfer station would be needed only for recycling and stewardship programs.

There is a fairly large variation in unit costs for the different technologies. Break-even tipping fees for the thermal technologies and out of region option could be summarized in the following manner:

- mass burn $84 to $98 per tonne (the latter without district heat);
- gasification to ethanol $136 per tonne;

- plasma gasification to electricity and district heat $152 to $155 per tonne; and
- private mass burn facility in Gold River $42 per tonne.

When transportation costs are taken into consideration, the total unit costs are similar for all sites using the same technology. For example; mass burn costs range from $111 (Gold River) to $119 (CRD), with CVRD at $116 and RDN at $115 per tonne. Small changes in capital costs, transportation costs, energy recovery efficiency and markets can easily change the order of costs.

It should also be noted that locating a WTE in the CRD that has heat and steam recovery opportunities could reduce the total unit cost by $14 per tonne. At initial glance, this would make this option the lowest cost option at $105.

To determine the most suitable technology and location, it would be prudent to either conduct a very detailed study that selects technology, site and conducts conceptual designs and equipment selection, or a competitive process that refines capital costs, operating costs and revenues.

8. Recommendations

Mass burn is the proven technology and gasification is somewhat proven, but still carries some financial and technical risk with implementation. It will be necessary to decide what level of risk is acceptable to the three regions if the advantages of gasification and or plasma gasification are appealing. It is recommended to verify the appetite for risk, and to further research, review and to visit existing gasification and plasma gasification facilities operating commercially before including them in a public selection process.

If mass burn is seriously being considered, it is recommended that the three regional districts continue to cooperate to maintain the current economies of scale. This would likely not be necessary if waste is shipped out of region to a private facility.

Out of region WTE may, in a public competitive process, be very attractive. It should be considered that the out of region WTE facility will only be built if other sources of waste are available, i.e., the availability of this option is dependent on events out of the regions' control.

The out of region WTE option may also become more attractive financially if barging costs can be more closely defined. It is recommended to conduct further research in co-operation with the proponent into barging costs, understanding that this option is only viable if other contracts (i.e., with Metro Vancouver) are in place.

If an in-region WTE facility is preferred, it is recommended to give preference to a site that offers the greatest potential for district heat. This is essential in the case of combined heat and power technologies. If ethanol production is preferred (only possible with gasification or plasma gasification), then the CRD area offers the preferred location and should be considered.

Biosolids, provided they are dried adequately, should be considered as additional fuel, since it increases the biogenic content in the feedstock and improve the overall GHG balance.

AECOM

Appendix A

Transportation Analysis Calculations

Transportation Analysis Calculations

Evaluation of these transportation options:

Transportation Option	Transportation Description
Direct Haul	Use of collection truck to transport MSW to potential WTE sites (smaller loads, less fuel efficient and higher operating costs)
Transfer Haul	Use of tractor trailers to transport MSW from a central collection point (i.e., transfer station) to potential WTE sites
Rail Haul	Use of the railway system to transport MSW to a potential WTE site
Barge Haul	Use of a barging system to transport MSW to a potential WTE site

The road distances and travel times for each site scenario can be summarized in the following manner.

WTE Site Scenario	Distance	Travel Time
Regional District of Nanaimo		
Church Rd. TS to WTE site	53 km	40 minutes
Duncan to WTE site	53 km	42 minutes
CRD TS to WTE site	118 km	103 minutes
Cowichan Valley Regional District		
Church Rd TS to WTE site	88 km	68 minutes
RDN TS to WTE site	53 km	42 minutes
CRD TS to WTE site	60 km	56 minutes
Capital Regional District		
Church Rd TS to WTE site	148 km	124 minutes
RDN TS to WTE site	118 km	103 minutes
Bings Creek TS to WTE site	60 km	56 minutes
Gold River WTE Facility		
Church Rd. TS to Gold River WTE site	222 km	151 minutes
RDN TS to Gold River WTE site	275 km	191 minutes
Bings Creek TS to Gold River WTE site	310 km	219 minutes
CRD TS to Gold River WTE site	370 km	275 minutes

The railway system on Vancouver Island is managed by Southern Railway of Vancouver Island (SRVI) and runs between the Cities of Victoria and Courtney. There is also a section that runs between the Parksville and Port Alberni. The railway company's primarily business is to move goods on and off the island. As part of that service, SRVI also moves railcars up and down the island. Most of the commercial railway service on Vancouver Island is between Cowichan Valley and Nanaimo.

The barge haul option is based on the transportation system that the Gold River proponent is proposing for Metro Vancouver's solid waste. It is a network of barges and tugboats that run continuously between Gold River and Metro Vancouver. The barging system would be owned and operated by the Gold River proponent. It is approximately 360 km and takes a tugboat and barge approximately 24 hours to travel from the Victoria/Esquimalt shoreline to Gold River.

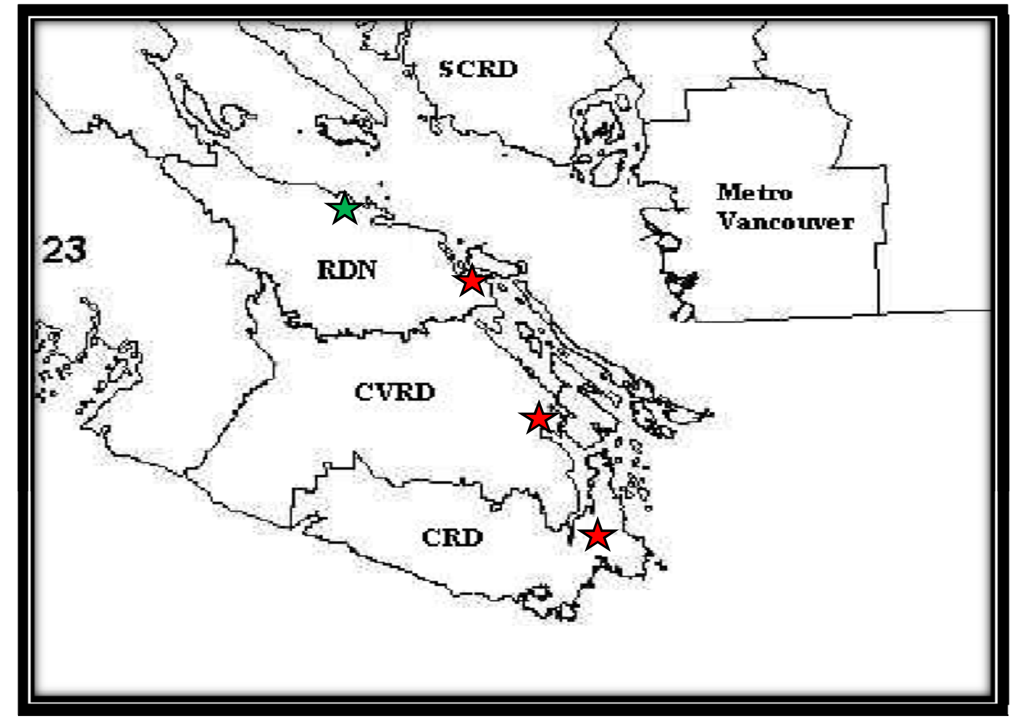
Direct Haul Analysis

Assumptions:

Collection routes not included in the transportation analysis.
Transportation analysis starts from where waste is typcially dropped off (i.e. TS or Landfill)
Vehicles used are deisel trucks and unit price for deisel is $1.20 per Litre
Collection trucks have an average load size of 5 tonnes per load
Average fuel economy of collection trucks is 0.7 km/L (~1.86 mpg)
Unit operating cost for a driver and collection truck is $100/hr
Waste transfer volumes to be provided by RD staff

Waste quantities collected from the local areas where potential site would be located is assumed to require no additional transporation.

Factors for Calculation		
Collection Truck Average Load Size:	5	tonnes/load
Unit Operating Cost (Truck and Driver):	$ 100.00	per hour
Collection Truck Fuel Economy:	0.7	km/L
Diesel Fuel Cost:	$ 1.20	per litre



	Distance (mi)	Distance (km)	Travel Time	Waste transferred (t/yr)	Truck Loads to travel (# truck/yr)	Fuel Use (L/yr)	Annual Operating cost (Truck and Driver)	Annual Fuel cost	Annual Fuel and Operating Cost ($/yr)	Transport cost per tonne	System Wide Unit Cost
Capital Regional District											
Duncan to Hartland Landfill	36.5 miles	61 km	56 minutes	30,119	6,024	1,046,986.04	$ 1,124,434.32	$ 1,256,383.24	$ 2,380,817.56	$ 79.05	
Nanaimo to Hartland Landfill	71 miles	118 km	103 minutes	42,062	8,412	2,844,188.69	$ 2,888,253.58	$ 3,413,026.43	$ 6,301,280.01	$ 149.81	
Church Rd TS to Hartland Landfill	89 miles	148 km	124 minutes	20,000	4,000	1,695,238.10	$ 1,653,333.33	$ 2,034,285.71	$ 3,687,619.05	$ 184.38	
TOTAL = Operating and Fuel Cost				92,181		5,586,412.82	$ 12,369,716.62	$ 6,703,695.39	$ 19,073,412.01	$ 206.91	$ 88.18
Cowichan Valley Regional District											
Church Rd TS to Duncan	53 miles	88 km	68 minutes	20,000	4,000	1,009,523.81	$ 906,666.67	$ 1,211,428.57	$ 2,118,095.24	$ 105.90	
Nanaimo to Duncan	32 miles	53 km	42 minutes	42,062	8,412	1,281,887.86	$ 1,177,734.47	$ 1,538,265.43	$ 2,715,999.90	$ 64.57	
Victoria to Duncan	36 miles	60 km	56 minutes	124,123	24,825	4,255,630.55	$ 4,633,908.83	$ 5,106,756.67	$ 9,740,665.49	$ 78.48	
TOTAL = Operating and Fuel Cost				186,185		6,547,042.22	$ 14,574,760.63	$ 7,856,450.67	$ 22,431,211.30	$ 120.48	$ 103.70
Regional District of Nanaimo											
Church Rd. TS to Duke Point	32 miles	53 km	40 minutes	20,000	4,000	609,523.81	$ 533,333.33	$ 731,428.57	$ 1,264,761.90	$ 63.24	
Victoria to Duke Point	71 miles	118 km	103 minutes	124,123	24,825	8,393,049.15	$ 8,523,082.31	$ 10,071,658.98	$ 18,594,741.29	$ 149.81	
Duncan to Duke Point	32 miles	53 km	42 minutes	30,119	6,024	917,905.57	$ 843,325.74	$ 1,101,486.68	$ 1,944,812.42	$ 64.57	
TOTAL = Operating and Fuel Cost				174,241		9,920,478.53	$ 21,804,315.61	$ 11,904,574.23	$ 33,708,889.84	$ 193.46	$ 155.84
Gold River WTE Site									$ -		
Church Rd to Gold River		222 km	151 minutes	20,000	4,000	2,537,142.86	$ 2,013,333.33	$ 3,044,571.43	$ 5,057,904.76	$ 252.90	
Arboretum to Gold river		275 km	191 minutes	42,062	8,412	6,609,734.28	$ 5,355,887.71	$ 7,931,681.13	$ 13,287,568.85	$ 315.90	
Duncan to Gold River		310 km	219 minutes	30,119	6,024	5,335,326.11	$ 4,397,341.36	$ 6,402,391.33	$ 10,799,732.68	$ 358.57	
Hartland landfill to Gold River		370 km	275 minutes	124,123	24,825	26,243,055.09	$ 22,755,802.27	$ 31,491,666.11	$ 54,247,468.38	$ 437.05	
TOTAL = Operating and Fuel Cost				216,303		40,725,258.33	$ 34,522,364.68	$ 48,870,309.99	$ 83,392,674.67	$ 385.54	$ 385.54

Truck Transfer Haul Analysis

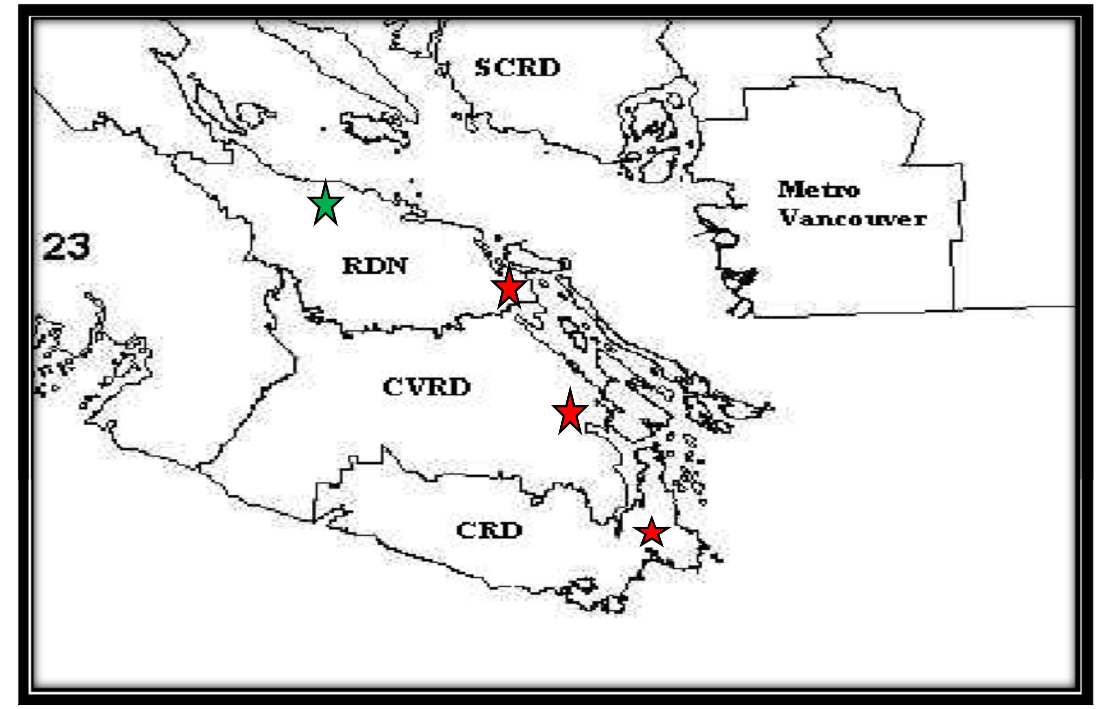
Assumptions:

Collection routes not included in the transportation analysis.
Transportation analysis starts from where waste is typcially dropped off (i.e. TS or Landfill)
Transfer vehicles are deisel trucks and unit price for deisel i
Transportation analysis starts from where waste is typcially dropped off (i.e. TS or Landfill)
Average fuel economy of tranfer trucks is 2.5 km/L (~5.86 mpg)
Unit operating cost for a driver and truck is $100/hr
Waste transfer volumes to be provided by RD staff

Waste quantities collected from the local areas where potential site would be located is assumed to require no additional transporation.

CRD transfer station is assumed to be located at Hartland Landfill (although a TS near the city would have savings).

Backhaul opportunities not taken into consideration.



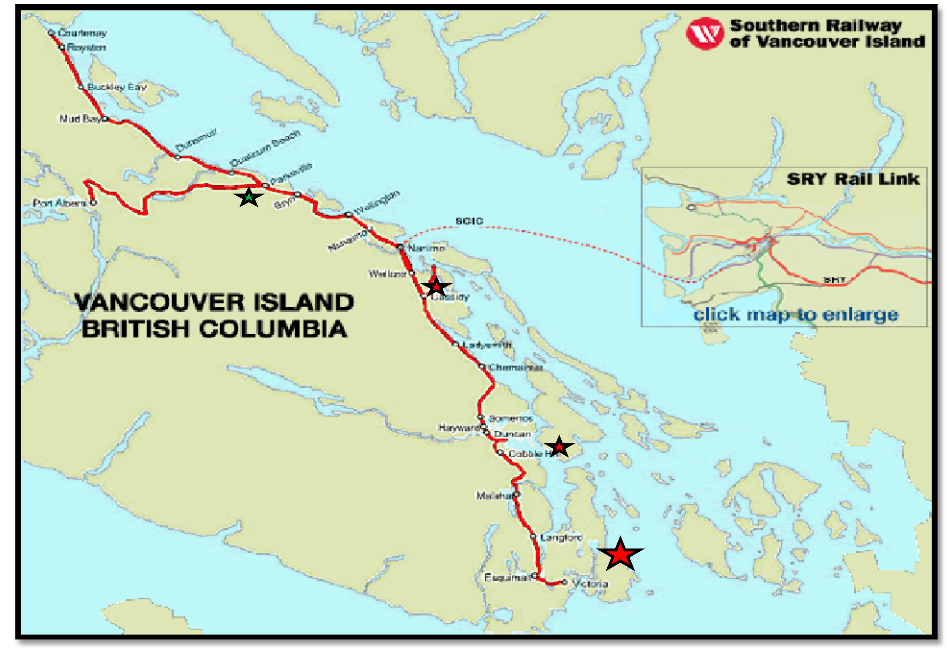
Factors for Calculation		
Collection Truck Average Load Size:	27	tonnes/load
Unit Operating Cost (Truck and Driver):	$ 100.00	per hour
Transfer Truck Fuel Economy:	2.5	km/L
Diesel Fuel Cost:	$ 1.20	per litre

	Distance (mi)	Distance (km)	Travel Time	Waste transferred (t/yr)	Truck Loads to travel (# truck/yr)	Fuel Use (L/yr)	Annual Operating Cost (Truck, Driver and Fuel)	Unit Transport Cost ($/t)	Unit Transfer Station Cost ($/t)	Total Transfer Haul Unit Cost ($/t)	Total Transfer Haul Cost ($)	System Wide Unit Cost ($/t)
Capital Regional District												
Duncan to Hartland Landfill	36 miles	60 km	56 minutes	30,119	1116	53,544	$ 272,482	$ 9.05	$ 22.62	$ 31.67	953,756.91	
Nanaimo to Hartland Landfill	71 miles	118 km	103 minutes	42,062	1558	147,476	$ 711,834	$ 16.92	$ 43.14	$ 60.06	2,526,261.16	
Church Rd TS to Hartland Landfill	89 miles	148 km	124 minutes	20,000	741	87,901	$ 411,654	$ 20.58	$ 23.95	$ 44.53	890,554.32	
TOTAL = Operating and Fuel Cost				92,181		**288,922**	**$ 1,396,106**	**$ 15.14**	**$ 32.27**	**$ 47.41**	**4,370,572.39**	$ 20.21
Cowichan Valley Regional District											-	
Church Rd TS to Duncan	53 miles	88 km	68 minutes	20,000	741	52,346	$ 230,716	$ 11.54	$ 23.95	$ 35.48	709,616.05	
Nanaimo to Duncan	32 miles	53 km	42 minutes	42,062	1558	66,468	$ 297,861	$ 7.08	$ 43.14	$ 50.22	2,112,288.53	
Victoria to Duncan	36 miles	60 km	56 minutes	124,123	4597	220,662	$ 1,122,926	$ 9.05	$ 22.71	$ 31.76	3,942,146.01	
TOTAL = Operating and Fuel Cost				186,185		**339,476**	**$ 1,651,620**	**$ 8.87**	**$ 27.46**	**36.33**	**6,764,050.59**	$ 31.27
Regional District of Nanaimo											-	
Church Rd. TS to Duke Point	32 miles	53 km	40 minutes	20,000	741	31,605	$ 136,691	$ 6.83	$ 23.95	$ 30.78	615,591.36	
Victoria to Duke Point	71 miles	118 km	103 minutes	124,123	4597	435,195	$ 2,100,583	$ 16.92	$ 22.71	$ 39.64	4,919,802.70	
Duncan to Duke Point	32 miles	53 km	42 minutes	30,119	1116	47,595	$ 213,286	$ 7.08	$ 22.62	$ 29.70	894,560.50	
TOTAL = Operating and Fuel Cost				174,241		**514,395**	**$ 2,450,660**	**$ 14.06**	**$ 22.84**	**36.90**	**6,429,954.56**	$ 29.73
Gold River WTE Site											-	
Church Rd to Gold River		222 km	151 minutes	20,000	741	131,556	$ 530,706	$ 26.54	$ 23.95	$ 50.48	1,009,606.17	
Arboretum to Gold river		275 km	191 minutes	42,062	1558	342,727	$ 1,403,103	$ 33.36	$ 43.14	$ 76.50	3,217,531.06	
Duncan to Gold River		310 km	219 minutes	30,119	1116	276,647	$ 1,146,298	$ 38.06	$ 22.62	$ 60.68	1,827,573.26	
Hartland landfill to Gold River		370 km	275 minutes	124,123	4597	1,360,751	$ 5,846,939	$ 47.11	$ 22.71	$ 69.82	8,666,158.62	
				216,303		**2,111,680**	**$ 8,927,047**	**$ 41.27**	**$ 26.79**	**68.06**	**14,720,869.11**	$ 68.06

Rail Haul Analysis

Assumptions:

1. Waste is shipped by intermodal containers
2. Intermodal containers are double stacked on flatbed railcars
3. Some transfer stations will need to be retrofitted with compactors
4. CRD needs to build a TS at the Hartland Landfill and waste delivereed to an intermodal yard
5. Intermodal transport only apply from RDN to CRD sites.
6. Assume Arboretum is about 8 km from an intermodal yard with a rail spur.
7. Intermondal containers hold 27 tonnes of waste
8. CVRD waste is transfer hauled directly because of proximity to RDN or CRD site (50-60 km)
9. Waste quantities based on 2015 projections.
10. Fuel and operating cost from CVRD to WTE site included in rail haul assessment.
11. For Gold River option, railway only runs up to Courtenay, BC (therefore need to transfer haul 160 km to Gold River)



Rail haul about 120 km between Victoria and Arboretum and at an average speed of 50 km/hr. Hence, round trip travel about 5 hours. Fuel consumption based on locomotive consumption rate of 200 gallons per hour. Therefore, round trip travel consumes 1000 gallons or 3780 litres of deisel fuel.

Fuel consumption: 3,780 L/trip

Railcars transported ranges from 9 to 18 per day, and operates 5 days per week. This is well below the capacity of the locomotive.

Annual Rail Fuel Consumption: 982,800 L/yr

Rail haul delivery cost (by SRY Rail) estiamted at $1050 per railcar. Each railcar holds about 54 tonnes.

Unit Rail Delivery Cost: $ 19.44 per tonne

Loading and Unloading containers at Intermodal yard estimated to cost $1.50 per tonne for each side.

Rail haul to Courtenay about 190 km from Victoria and at an average speed of 50 km/hr. Therfore, round trip travel under 8 hours. Fuel consumption based on locomotive consumption rate of 200 gallons per hour. Therefore, round trip travel consumes 1520 gallons or 5745 litres of deisel fuel.

Fuel consumption: 5,745 L/trip or 1,493,700 L/yr

Factors for Calculation		
Collection Truck Average Load Size:	27	tonnes/load
Unit Operating Cost (Truck and Driver):	$ 100.00	per hour
Collection Truck Fuel Economy:	2.1	km/L
Diesel Fuel Cost:	$ 1.20	per litre

	Distance (mi)	Distance (km)	Travel Time	Waste transferred (t/yr)	Intermodal containers to move	FUEL Annual fuel comsumed to deliver containers (L/yr)	Unit cost to deliver to Intermodal Yard and load ($/t)	Railway cost from Pt. A to Pt. B ($/t)	Unit cost to deliver from intermodal to WtEF and unload ($/t)	FUEL Annual fuel consumption to deliver from intermodal yard to WTE site (L/yr)	Ammortized Intermodal Yard cost ($)	Unit cost for railcars ($/t)	Transfer Station Unit Cost ($/t)	Total Cost per Tonne	System Wide Unit Cost ($/tonne)
Capital Regional District															
Duncan to Hartland Landfill	36 miles	60 km	50 minutes	30,119	1,116	63,743.4	$ 8.71						$ 22.62	$ 31.33	
Arboretum to Intermodal Yard	0 miles	8 km	10 minutes	42,062	1,558	11,869.3	$ 3.07	$ 19.44	$ 5.43	29,673.33	473,400.00	$ 1.91	$ 43.14	$ 73.00	
Church Rd TS to Intermodal Yard	32 miles	53 km	40 minutes	20,000	741	37,389.8	$ 7.18	$ 19.44	$ 5.43	14,109.35	473,400.00	$ 1.91	$ 23.95	$ 57.91	
TOTAL = Operating and Fuel Cost				92,181	3,414	113,002.5				43,782.68	946,800.00			$ 66.38	$ 28.29
Cowichan Valley Regional District											-				
Church Rd TS to Duncan	53 miles	88 km	68 minutes	20,000	741										
Nanaimo to Duncan	32 miles	53 km	42 minutes	42,062	1,558										
Victoria to Duncan	36 miles	60 km	56 minutes	124,123	4,597										
TOTAL = Operating and Fuel Cost				186,185											
Regional District of Nanaimo															
Church Rd. TS to Arboretum	32 miles	53 km	40 minutes	20,000	741	37,624.9	$ 7.20						$ 23.95	$ 31.14	
Hartland landfill to Victoria intermodal yard	12 miles	20 km	25 minutes	124,123	4,597	87,564.4	$ 5.43	$ 19.44	$ 3.07	35,025.77	946,800.00	$ 1.72	$ 22.71	$ 52.38	
Duncan to Arboretum	32 miles	53 km	40 minutes	30,119	1,116	56,660.8	$ 7.20						$ 22.62	$ 29.82	
TOTAL = Operating and Fuel Cost				174,241	6,453	181,850.18				35,025.77	946,800.00			$ 51.48	$ 41.47
Gold River WTE Site															
Church Rd to Gold River		222 km	151 minutes	20,000	741	156,613.8	$ 28.04						$ 23.95	$ 51.98	
Arboretum to Gold River		275 km	191 minutes	42,062	1,558	408,008.3	$ 35.22						$ 43.14	$ 78.36	
Duncan to Victoria Intermodal yard		25 km	25 minutes	30,119	1,116	26,559.8	$ 5.64	$ 22.36	$ 21.85	169,982.51	473,400.00	$ 1.69	$ 22.62	$ 74.16	
Hartland landfill to Victoria Intermodal yard		20 km	25 minutes	124,123	4,597	87,564.4	$ 5.43	22.36	$ 21.85	700,515.32	236,700.00	1.69	$ 22.71	$ 74.04	
				216,303	8,011	678,746.2				870,497.83	710,100.00			$ 76.14	$ 76.14

Estimation for Transfer Station Costs

Transfer Stations		Annual Design Capacity (t/yr)	Daily Design Capacity (t/d)	Capital Cost ($M)	Annual Amortized Cost (over 25 years)	Unit Catipal Cost ($/t)	Unit Operating Cost ($/t)	Unit Transfer Station Cost ($/t)
	Church Road	20,000	100	1.0	$ 78,900	3.9	20	23.9
	Arboretum	42,062	150	15.0	$ 1,183,500	28.1	15	43.1
	Bings Creek	30,119	100	1.0	$ 78,900	2.6	20	22.6
	Hartland Landfill	124,123	400	20.0	$ 1,578,000	12.7	10	22.7
	Barge Loading TS	216,300	750	45.0	$ 3,550,500	16.4	12	28.4

Note: At 6% interest, the annual payments for every $1M borrowed (over a 25 year amortization period) is $78,900.
Barge loading transfer station includes $15M for waterfront industrial property and $30M for TS building.
Assume barge loading TS unit operating cost is $10/t plus $2/t for barge loading and wrapping.

Intermodal Yards		Facility Size (Ha)	Unit Property Price ($M/ha)	Property Price ($M)	Site Improvements ($M)	Annual Amortized Cost (over 25 years)	Property Cost ($)
	Nanaimo	1	4	4.0	2.00	$ 473,400.00	$ 6,000,000.00
	Victoria	1	4	4.0	2.00	$ 473,400.00	$ 6,000,000.00
	Courtenay	2	1	2.0	1.00	$ 236,700.00	$ 3,000,000.00

Barge Haul Analysis

Barge travel from Metro Vancouver to Gold River ~ 500 km
Barge travel from Victoria to Gold River ~ 360 km

Tug boat and barge speed ~ 15 km/hr
Tugboat fuel consumption ~ 200 GHP

Staffing on Tugboat:		5	crew member
Shifts per tugboat:		2	shifts
Crew Salary:	$	80,000.00	per year
Number of Tugboats:		3	
Crew Operating Cost:	$	2,400,000.00	per year
Tugboat & Barge Cost:	$	18,000,000.00	
Annual Amortization Cost:	$	4,266,000.00	
Estimated Tugboats & Barges Cost:	**$**	**9,286,800.00**	
Unit Cost for MV:	$	18.57	

Travel time:

Gold River to Metro Vancouver	33.3	hrs	(~1.5 days)
Gold River to Victoria Habour:	24	hrs	(1 day)

Tugboat Fuel Consumption (diesel):

Gold River to Metro Vancouver	25,200	L/trip	2,620,800	L/yr/tug
Gold River to Victoria Habour:	18,144	L/trip	1,886,976	L/yr/tug

Round-Trip Tugboat Cost (assume $4000/hr)

Gold River to Arboretum:	$	266,667	/trip	$	13,866,666.67	/yr
Gold River to Victoria Habour:	$	192,000	/trip	$	9,984,000.00	/yr

Total Fuel Consumption (annual):

Tug and Barge Fuel Consumption:	1,886,976	24% of total
Transfer trailer fuel consmption:	308,298.36	
	2,195,274	L/year

Total annual operating cost:

Tug and Barge Annual Cost:	$	3,095,600.00	30% of total
Transporation and Loading:	$	8,058,134.27	
Truck and Fuel Cost:	$	2,634,329.23	
	$	**13,788,063.50**	per year

Factors for Calculation			
Collection Truck Average Load Size:		27	tonnes/load
Unit Operating Cost (Truck and Driver):	$	100.00	per hour
Tractor Fuel Economy:		2.5	km/L
Diesel Fuel Cost:	$	1.20	per litre

Barges in BC can hold upto 168 containers (max capacity of 4200 tons or 3810 tonnes)
assuming 27 tonnes/container, barge capacity would be exceeded (i.e. 4536 tonnes)
Therfore, barge can hold 141 containers of waste.

	Distance (mi)	Distance (km)	Travel Time	Waste transferred (t/yr)	Loads to Deliver	Fuel Used (L/yr)	Unit Hauling Cost ($/t)	Transfer Station Unit Cost ($/t)	Total Unit Cost ($/t)
Gold River WTE Site									
Church Rd to Victoria Harbour		150 km	130 minutes	20,000	741	88,888.89	$ 21.38	$ 23.95	$ 45.33
Arboretum to Victoria Harbour		118 km	103 minutes	42,062	1,558	147,476.45	$ 16.92	$ 43.14	$ 60.06
Duncan to Victoria Harbour		60 km	56 minutes	30,119	1,116	53,544.49	$ 9.05	$ 22.62	$ 31.67
Barge Loading Facility (Victoria Harbour)		5 km	8 minutes	124,123	4,597	18,388.53	$ 1.17	$ 28.41	$ 29.58
Total				216,303	7,270	308,298.36			$ 37.25

		Wt	Distance	t-Km	%
Metro Vancouver	500000 t/yr	70%	500	250000000	76%
TRI-RD	216000 t/yr	30%	360	77760000	24%
Total	716000			327760000	