MORRISON HERSHFIELD

WASTE TO ENERGY BACKGROUND PAPER

Yukon Energy Charrette
March 6-9, 2011

Prepared by Don McCallum, P.Eng.,
Morrison Hershfield Ltd.

www.morrisonhershfield.com

Tel: 604 454 0402
Email: dmccallum@morrisonhershfield.com

WASTE TO ENERGY BACKGROUND PAPER

Yukon Energy Charrette
March 6-9, 2011
Prepared by Don McCallum, P.Eng., Morrison Hershfield Ltd.

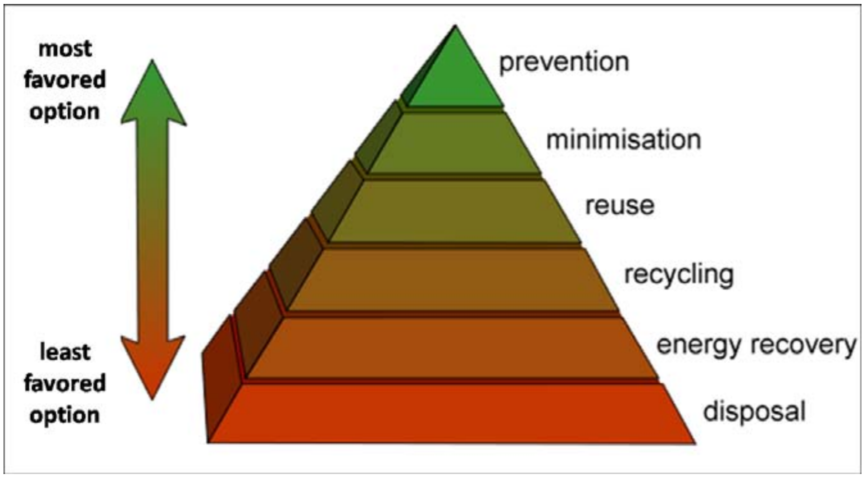
WASTE AS A RESOURCE

Increasingly, untreated municipal waste is being viewed as too valuable a commodity to relegate to disposal methods that meet objectives solely focussed on environmental and public health protection and aesthetics. With anticipated global shortages of critical nutrients such as phosphorus and increasing demand for renewable energy supplies, the heating value and nutrient content of liquid and solid wastes are ripe for exploitation (BC Ministry of Community Development, 2009). In the case of municipal solid waste (MSW), waste to energy applications are being implemented world-wide for the purpose of thermally treating waste and recovering energy in the process.

Energy recovery from wastes is consistent with and complementary to modern integrated waste management practices as illustrated in the waste hierarchy model below (Figure 1). Efforts to prevent and minimize the generation of waste are clearly the most effective use of scarce resources and avoid environmental issues associated with waste handling, treatment and disposal. Reuse and recycling follow in the hierarchy, subject to the availability of economically feasible end-use markets. Energy recovery precedes the final and least favoured option, which is the land disposal of residual wastes.

Approximately 130 million tonnes of MSW are combusted annually in over 600 waste to energy (WtE) facilities that produce electricity and/or steam for district heating (Themelis, 2003). Europe has experienced especially rapid growth in facility commissioning over the last decade as a result of high energy and waste disposal costs and regulatory initiatives (e.g. “Landfill Directive”) that mandate reduced use of landfills for untreated waste (IEA 2003).

Figure 1 - Waste management hierarchy



In North America, there are currently 88 waste to energy plants operating in United States and 7 facilities in Canada, fuelled by 27 million tonnes of MSW annually (EESI 2009). Metro Vancouver's Burnaby facility (280,000 tonne per year) has been in operation since 1988, and currently generates 146 GWhr of electricity and 200,000 tonnes of steam sales per year (Metro Vancouver 2010).

TECHNOLOGY APPLICATIONS

Thermal technologies used to recover energy from MSW are generally classified as either "conventional combustion" or "advanced thermal" technologies. Conventional combustion encompasses a range of technologies including mass-burn, modular 2-stage combustion, batch combustion and fluidized bed combustion technologies. While "mass-burn" is the most commonly applied technology, each of the conventional technologies has many decades of operating experience at commercial scales (Stantec 2010a). With the exception of fluidized bed combustion, these conventional technologies generally do not require extensive pre-processing of the MSW feedstock. The common attributes of conventional technologies are illustrated in Figure 2. In each application bottom ash is produced during the combustion process and fly ash in the flue gas cleaning process. Energy recovery is achieved through the production of steam in a boiler. The steam may be utilized to generate electricity in a steam turbine generator or sold directly for commercial or process heat purposes. The heat content of steam exiting the steam turbine generators can also be utilized for district heating purposes.

A summary of the seven Canadian operating waste to energy facilities (all using conventional thermal technology) is provided in Table 1.

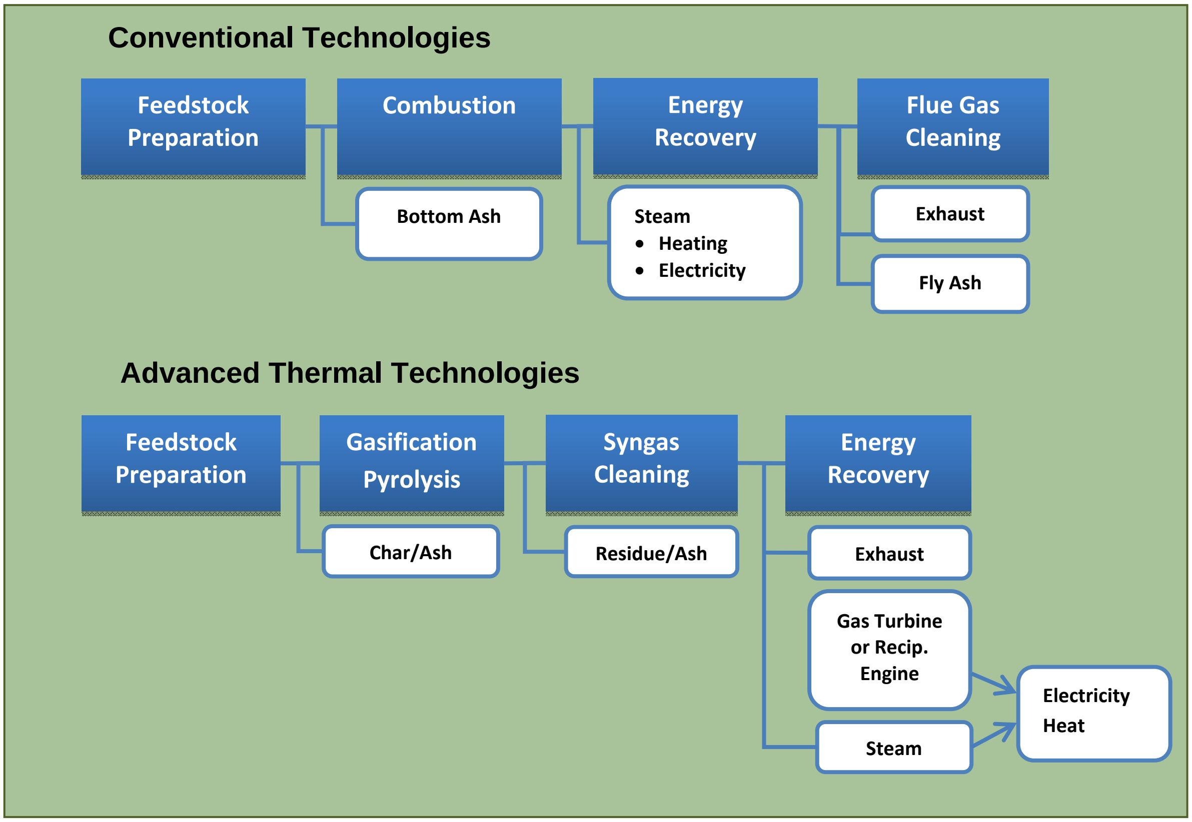
Pyrolysis and gasification, as well as ultra-high temperature gasification using plasma are considered advanced thermal technologies. While some of these technologies have been applied extensively to other feedstocks (e.g. coal) they are less proven on a commercial scale for the processing of MSW than conventional technologies. Figure 2 (bottom portion) illustrates the common attributes of advanced thermal technologies. After extensive pre-processing of the waste, thermal energy is used to create a synthetic gas (syngas) and char. The syngas is chemically cleaned before it is burned so that complex post combustion air pollution control is minimized, or not needed at all. The cleaned syngas is used to generate electricity either directly in a gas turbine or a reciprocating engine, or indirectly through the generation of steam. Waste heat can also be utilized for district heating purposes.

Plasco Corporation currently operates a demonstration-scale plasma arc gasification WtE facility in Ottawa, Ontario. A Canadian MSW gasification project is currently being developed by the City of Edmonton and Enerkem. This 300 tpd project will use fluidized bed gasification technology to produce a syngas which will then be processed into methanol and ethanol. Construction has commenced and is expected to be complete by the end of 2011[1].

---

[1] www.enerkem.com

Figure 2 - Comparison of Conventional and Advanced WtE Technologies



modified from Stantec (2010a)

Table 1 - Overview of Canadian Waste to Energy Facilities

Location	Technology	Process Units	Annual Permitted Capacity (tonnes)
Burnaby, BC	Mass-burn	3 X 240 t/ day	280,000
Quebec City, QC	Mass-burn	4 x 230 t/ day	300,000
Levis, QC.	Primary combustion chamber	1 x 80 t/ day	25,000
Iles de la Madelaine, QC	Mass-burn	1 x 31 t/ day	4,500
Brampton, Ont.	2-stage modular	5 x 91 t/day	150,000
Charlottetown, PEI	2-stage modular	3 x 33 t/day	25,000
Wainright, Alta.	3-stage modular	1 x 29 t/day	4,000

Source: Stantec (2010a)

WASTE FEEDSTOCK AVAILABILITY

It is assumed that a Yukon waste to energy facility would be located in Whitehorse to take advantage of the concentration of MSW within the capital city. Potential feedstocks could include City of Whitehorse MSW, used tires, waste crankcase oil and abattoir wastes. MSW from surrounding communities, some of which is currently trucked to Whitehorse's landfill, is also a potential feedstock source for a waste to energy facility.

A recent waste audit conducted by the City provides a breakdown of components within the waste stream and allows for a calculation of the waste heating value. Table 2 provides an overview of the City of Whitehorse MSW composition.

Total waste tonnages potentially available for a waste to energy facility located in Whitehorse are presented in Table 3. The summary is based on an analysis of historical waste tipping rates at the City of Whitehorse landfill and supporting studies. Waste heating values were calculated from the literature using the waste audit information collected by the City.

Waste generation in Whitehorse exhibits strong seasonal trends with peak rates occurring in late spring and summer. This waste generation profile would result in lower waste to energy facility electricity production during the periods of highest demand.

Table 2 - City of Whitehorse Waste Composition (from Walker 2010)

Material	Waste Composition Weighted Average (%)
Paper	13.5
Glass	1.3
Metals	6.7
Plastic	9.1
Organics	17.1
Composite	9.3
Wood Waste	15.3
Inert Materials	2.3
Gypsum Wallboard	6.3
Textiles	2.8
Rubber	0.4
Carpet and Underlay	2.2
Electronic Waste	3.2
Personal Hygiene Products	2.5
Hazardous Waste	1.6
Biomedical Waste	0.5
Pet Waste	1.2
Fines	0.3
Fibreglass Insulation	0.6
Other	3.7

Table 3 - Waste tonnages and heating value potentially available for a Whitehorse WtE Facility

Waste Stream	Annual Waste Flow (tonnes)	Waste Heating Value (HHV) (GJ/tonne)	Annual Heating Value (GJ/yr)
MSW Generated within the City of Whitehorse	21,320	14.3	304,000
MSW Generated outside Whitehorse	2,669	13.2	35,000
Tires	299	30.0	9,000
Waste Oil	239	37.2	9,000
Abattoir Waste	250	2.0	500
Total	24,777	14.4	***358,000***

Source: Morrison Hershfield (2010)

ELECTRICITY PRODUCTION POTENTIAL

The potential electricity production for export from waste to energy facilities is dependent on a range of factors including feedstock heating value and efficiencies within the combustion and energy recovery processes. Table 4 provides a range of reported electricity exports (expressed on a kWhr per tonne basis) observed in operating facilities using a range of technologies. It can be expected that lower energy recovery efficiencies may be observed in smaller facilities (< 50,000 tonnes per year). Observed electricity production for export in a range of smaller European WtE facilities (Table 5) confirms lower electricity production rates (86 – 335 kWhr/t) than reported for the industry as a whole.

A WtE facility constructed in Whitehorse will be a relatively small plant in comparison to the majority of WtE applications constructed world-wide. As a result, it can be expected that lower energy conversion efficiencies will be obtained. The lower energy conversion efficiencies may be partially offset by a feedstock with higher than average heating values (14.4 GJ/tonne as estimated in Table 3). It should also be expected that improved efficiencies will be achieved in a new facility compared to older facilities. Based on these considerations, a range of 300 – 600 kWhr / tonne can be used to predict electricity production from a Whitehorse facility. Assuming waste volumes of 25,000 tonnes per year, ***annual electricity exports would range between 7.5 and 15 GWhr.***

Electricity generated from WtE facilities is generally a firm and consistent supply of power because of the consistent supply of the waste feedstock. However, as previously discussed, average daily waste volumes generated in the winter in the Whitehorse can be less than half the volumes generated during the spring and summer periods. This seasonal variability is detrimental to the potential viability of a WtE plant because the facility would be operating at its lowest throughput (and lowest efficiency) during periods when the local demand for renewable electricity is at its highest. The impact of this could be partially or totally offset if a complementary biomass feedstock (such as wood waste) could be sourced during the winter period.

Table 4 - Reported Electricity Production Ranges for Various WtE Technologies

Technology	Electricity Production Range kWhr / tonne
Conventional – older	500 – 600
Conventional – newer	750 – 850
Gasification	400 – 800
Plasma Arc Gasification	300 – 600
Pyrolysis	500 – 800

Source: Juniper (2007a), Juniper (2007b)

Table 5 Electricity exports from Smaller European WtE facilities

Location	Electricity Sold	Annual Capacity	Year Built	Built By
	kWhr/T	Tonnes/yr		
Montale/Agliona, Italy	109	33,000	2001	Technitalia
Livorno, Italy	168	44,000	2003	SECIT
Poggibonsi, Italy	149	20,400	1997	NR
Statte, Italy	86	48,700	2001	VonRoll
Terni, Italy	317	27,000	1998	SECIT
Carhaix, France	317	30,000	NR	Novergie
Planguenoual, France	292	42,000	NR	Novergie
Rosier d'Egletons, France	335	40,000	NR	Novergie
Averoy, Norway	210	32,000	2000	Energos
Sandness, Norway	320	39,000	2002	Energos

Notes:

1. Italian and Norwegian Small Scale Incinerator/WTE plant data, taken from ISWA (2006); French WtE data obtained from Benhamou (2010);
2. NR: not reported

Complementary Heat Utilization Applications

Waste to energy technology is particularly well suited to various forms of combined heat and power applications. Many facilities such as Metro Vancouver's Burnaby WtE plant sell a portion of the steam produced to nearby industries while utilizing the remaining steam for electrical power generation. In other facilities, such as the Wainright, Alberta plant, all the produced steam is sold to industry and no electricity is produced. There are no known industrial applications for process steam currently in the Whitehorse area.

Many WtE facilities utilize the waste heat exiting steam turbine generators for District Heat applications. Recovering this energy resource can improve the energy efficiency of the entire

WtE facility from less than 20% (with only electrical power generation) to over 60% (and as high as 90%) with utilization of the waste heat. The challenge for a Whitehorse WtE facility would be to find customers and the appropriate infrastructure for utilizing waste heat in a District Heating application. Assuming the demand for district heat in Whitehorse existed, a WtE facility could generate at least 40 GWhr per year in usable waste heat (assumes recovery of 50% of the waste heat exiting the steam turbines). Based on an average heating area intensity[2], this amount of heat could provide space heating needs for approximately 150,000 m^2 of floor area. As a point of comparison, the floor area of Yukon College buildings within Whitehorse is 33,429 m^2 (Stantec 2010b).

ENVIRONMENTAL ISSUES AND OPPORTUNITIES

Waste to energy facilities encompass a number of environmental considerations that range from emission controls to the potential generation of greenhouse gas offset credits. Potential air emission issues from waste to energy plants include the discharge of a range of contaminants including dioxins and furans, heavy metals, particulates, sulphur dioxide and nitrogen oxides. The adoption of standard operating procedures and modern air pollution control equipment effectively controls each of the contaminants listed above, ensuring that the most stringent emissions standards can be achieved (EESI 2009).

Operation of a WtE facility can result in reduced greenhouse gas emissions. One significant area of potential reductions is in avoided emissions associated with landfilling of waste. Landfilling of MSW results in the creation and emission of methane as the waste gradually decomposes. Up to 1.6 kg of carbon dioxide equivalent emissions may be emitted from each kg of waste landfilled, where there are no landfill gas recovery systems in place (IEA 2003). On this basis, a Whitehorse WtE facility could result in the reduction of over 30,000 tonnes of GHG emissions per year through avoided methane emissions at the landfill. The actual emission reductions would be somewhat less as a result of the combustion of non-biodegradable material (ie. plastics). Additional greenhouse gas emission reductions may result from the displacement of fossil-fuel generated electricity emissions, depending on the nature of the displaced power (e.g. diesel-generated vs. hydro-generated) and the determination of the biogenic portion of the MSW feedstock (typically ranges between 60 – 80%; IEA 2003).

REGULATORY ISSUES

It is expected that a waste to energy project located in Whitehorse would require a screening – level (Designated Office) assessment under the Yukon Environmental and Socio-Economic Assessment Act (YESAA). After obtaining a YESSA approval a number of operating permits and authorizations may be required including authorizations issued under the following Acts and Regulations:

---

[2] Average Whitehorse building heating intensity of 0.264 MWhr/m2/yr as provided in Stantec (2010b)

- *Environment Act*,
    - Air Emissions Regulations
    - Solid Waste Regulations
    - Storage Tank Regulations
    - Special Waste Regulations
- *Lands Act*
    - Land Use Regulations
- *Waters Act*
- City of Whitehorse *Zoning Bylaw*

The facility should be capable of achieving all applicable regulatory standards and there is expected to be no insurmountable regulatory obstacles to proceeding with the project.

TECHNOLOGY RISKS AND TIME TO MARKET

The technology risks associated with a Whitehorse waste to energy project differ depending on the class of technology considered. Conventional combustion technologies coupled with steam cycle electrical power generation, as described in this paper, are well proven, with many applications that have been operating for over a decade at waste throughputs less than 50,000 tonnes per year. Several technology providers offer modular process units that are compatible with available waste volumes within Whitehorse. The waste throughput of a Whitehorse facility (25,000 tonnes per year) would be at the lower end of the range of WtE applications that generate electricity. This presents some risks of lower energy recovery efficiencies, particularly owing to the seasonal variability in waste generation rates. This risk could be mitigated if a complementary biomass waste source was available to reduce the variability in feedstock availability.

Proceeding with an advanced thermal technology, as described in this paper, would carry additional technology risks in the short-term. These risks follow from the fact that few facilities have yet been constructed at a commercial scale and operating experience is sparse compared with conventional technologies. However, several characteristics of these advanced thermal technologies are attractive for smaller applications such as Whitehorse. In particular, utilization of the generated syngas directly in reciprocating engines to produce electrical power (instead of using a steam cycle) could allow for higher efficiencies at lower waste throughputs. Additionally, the electrical generation technology (internal combustion engines) is quite similar to the existing YEC diesel generators, thereby reducing and simplifying operating requirements.

The time to market for electricity sales proceeding with conventional waste to energy technology is assumed to be 3 – 5 years, if an aggressive approach to technology selection and regulatory approvals is taken. It can be assumed that the time to market proceeding with an advanced thermal technology is >5 years as a result of the current lack of commercial operating experience.

ELECTRICITY COST

The capital costs of constructing a waste to energy facility can range between $600 and $1,200 per installed annual waste tonne based on recently constructed European plants, with higher unit costs generally associated with lower volume facilities (Stantec 2010a). Based on available Whitehorse waste, capital costs would range between $15 - 30 million. Operating costs typically range between $50 and $100 per tonne.

The construction and operation of waste to energy facilities are typically funded through revenues obtained from both waste tipping fees and energy sales. Waste tipping fees are charged to waste generators in consideration of avoided landfill-related costs and can range widely depending on the jurisdiction. For the purpose of estimating a cost of electricity generation, it is assumed that a Whitehorse waste to energy facility would receive $100 per tonne in tipping fees. Based on receipt of these tipping fees, ***the estimated cost of electricity generation ranges between $0.15 - $0.40 per kWhr***. The range reflects current uncertainty in capital and operational costs and energy recovery efficiencies.

SUMMARY

A growing interest in utilizing waste to energy facilities is being driven by the need to conserve landfill space, minimize environmental liabilities, reduce greenhouse gas emissions, and obtain renewable sources of energy.

Approximately 25,000 tonnes per year of municipal solid waste could be available to a waste to energy facility located in Whitehorse. This facility would generate between 7.5 and 15 GWhr per year of electricity for export at costs ranging between $0.15 and $0.40 per kWhr. An additional 40 GWhr per year of waste heat could also be provided for district heat applications if a demand existed.

Utilizing conventional combustion technology, the time to market for electricity sales is assumed to be 3 – 5 years, if an aggressive approach to technology selection and regulatory approvals is taken. Risks associated with low energy recovery efficiencies could be mitigated if a complementary biomass waste source was available during periods of lower waste generation.

Advanced thermal technologies present the possibility of improved energy recovery efficiencies and electricity generation methods (reciprocating engines) similar to technology used by Yukon Energy Corporation. Owing to the current lack of commercial operating experience, technology risks are higher and the time to market is >5 years.

REFERENCES

BC Ministry of Community Development, 2009. Resources from Waste: A Guide to Integrated Resource Recovery. Prepared for the Ministry of Community Development, Government of British Columbia.

EESI 2009. Reconsidering municipal solid waste as a renewable energy feedstock. Prepared by the Environmental and Energy Study Institute, Washington DC, July 2009. www.eesi.org

IEA 2003. Municipal solid waste and its role in sustainability. A position paper prepared by IEA Bioenergy. www.ieabioenergy.com/library.php

ISWA 2006. Energy from Waste, State of the Art Report, Statistics, 5th Edition. Prepared by the International Solid Waste Association, August 2006.

Juniper 2007a. Large scale EFW systems for processing MSW. Research report prepared by Juniper Consulting Services.

Juniper 2007b. Small to medium scale EFW systems for processing MSW. Research report prepared by Juniper Consulting Services.

Metro Vancouver 2010. Waste to Energy Facility: Fact sheet. Prepared by Contracted Services Division, Metro Vancouver.
http://www.metrovancouver.org/about/publications/Publications/WasteEnergyFactsheet.pdf

Morrison Hershfield 2010. Waste to Energy Preliminary Engineering - Technical Advisory Support: Technical Memorandum #1 - Feedstock Analysis (DRAFT). Report prepared for Yukon Energy Corporation, November 22, 2010.

Stantec 2010a. Waste to Energy: A Technical Review of Municipal Solid Waste Thermal Treatment Practices. Prepared for Environmental Quality Branch, Environmental Protection Division, BC Ministry of Environment. URL: http://www.env.gov.bc.ca/epd/mun-waste/reports/pdf/BCMOE-WTE-Emissions-final.pdf Access Nov 22, 2010.

Stantec. 2010b. District Energy System Pre-feasibility study, City of Whitehorse Yukon. Prepared for Energy Solutions Centre, Government of Yukon, March 8, 2010.

Themelis, N. 2003. An overview of the global waste-to-energy industry. Waste Management World, July-August 2003.

Walker & Associates. 2010. City of Whitehorse Solid Waste Composition Study. Draft Report. Prepared for the City of Whitehorse. 28 pgs +Appendices.