BAPE Brief: Alternative Technologies for Residual Waste Management

Presented by André Carrière, President
Coalition against the Danford Megadump

Summary
The Coalition against the Danford Megadump is concerned that megadumps generate both chemically-contaminated water and biogases such as methane which is 23 times worse than carbon dioxide as a greenhouse gas. The geo-membrane liner technology used for landfills will not prevent leakage of untreated water containing various dangerous contaminants (i.e. leachate) into the underlying groundwater, then into the wetlands and streams close to the dump site and eventually into the Picanoc River. **The promoter's project plan contains no remedial measures for this devastating eventuality. This is unacceptable.**

A Megadump near the Village of Danford Lake will have an enormous impact on the HEALTH, SOCIAL, CULTURAL AND ECONOMIC aspects of the lives of anyone living here or coming here to enjoy the purity and beauty of the area. The promoter's assessment that there will only be minimal impacts is the result of incomplete work.

This brief criticizes LDC for not considering alternatives to landfill as a solution to residual waste treatment in the Outaouais. The brief looks at the alternatives, and proposes that plasma gasification which generates electricity from waste with minimal risk is by far the best option. A detailed consideration of plasma gasification is included as an Annex to the brief. It is noted that some MRCs and individual municipalities in the Outaouais have gone on record as being opposed to landfill and have independently considered the plasma gasification option. Many mayors in the Outaouais are actively campaigning for plasma gasification facilities to be established in the Outaouais.

A letter of support from Plasco Energy Group is included indicating that Plasco would be prepared to build a 100 ton per day system in the Outaouais at their own expense, and own and operate the facility, producing and selling clean electricity and the stable and non-leachable obsidian-like solid residue as a building material. The facility would offer to the municipalities a stable price for 20 years with tipping fees in the $50-$60 per ton range.

1.0 Introduction

It is clear that we are rapidly entering a post-landfill era, where newer and less risky technologies are emerging as the primary methodologies for disposing of residual waste. Citizens are leading the way in forcing governments and private developers to change their way of doing business and opt for the newer technologies. As an example of this opposition to expansion of the Carp dump in Ottawa has forced Waste Management Inc., one of the larger North American companies involved in waste management, to announce it will use its Wheelabrator waste-to-energy incineration technology to reduce the need for as large an expansion as originally planned. A second example is the 100 tons per day Plasma Gasification facility at the Trail Road dump in Ottawa which in the first week of

June, 2007 began to process waste. When processing 80 tons of waste per day, it will produce approximately 4 MW of electricity.

The instructions for the BAPE environmental impact studies states that it is required that the project promoter study alternative solutions to the problem being addressed. LDC has interpreted this requirement rather loosely and has only considered alternative landfill sites in the municipality of Alleyn and Cawood, while promoting only the landfill option. LDC has not considered alternative solutions.

It is important to note at this point that earlier studies mentioned by the promoter in the environmental impact report identified 38 potential landfill sites, none of which were in Alleyn and Cawood. Yet now the promoter has ignored all these options and has concentrated on finding a site in Alleyn and Cawood. The reasons given in the environmental impact report for selecting sites in Alleyn and Cawood are not convincing. It is more likely that the promoter first found a small municipality with a compliant mayor and council prepared to host a landfill, and only then launched a search for possible sites. Three sites were considered, and one was eventually selected, but no convincing reasons were given for selecting this one over the other two.

As an aside, it is clear from subsequent events that the municipal councilors were not aware of the implications of the project, and when they became aware by means of objections from the general public, at least two of the councilors came out in opposition to the project.

Landfill has been around for hundreds of years, often accompanied by open air burning, with the consequent pollution problems. Efforts have been made to make landfill a less risky proposition, since there is a basic understanding, even by developers who seek to make money out of garbage disposal, that landfill is not an ideal solution. The so-called “Engineered Landfills”, while being better than trench landfills, are still widely recognized to have problems. No one can consider these to be the ultimate solution for waste treatment, since they can leave a legacy of problems to haunt future generations one hundred years and more from now. The time has come to move to more permanent solutions.

In the question period of the BAPE environmental hearings statements were made by the promoter and his consultants that establishing a landfill was the only available option for the Outaouais which could be ready to meet the January, 2009 deadline for closing of municipal trench landfills. These statements are erroneous, and it is wrong to rush into a wrong decision on the technology for waste management that can have negative implications and create environmental risks for over one hundred years. It is not environmentally and socially acceptable to rush to a solution because of expediency.

2.0 The Coalition’s Criteria for selecting method of dealing with waste

The Coalition, conscious that some acceptable and viable method must be selected for dealing with municipal waste, has spent considerable time, money and person hours in researching waste management alternatives in relation to a set of widely accepted objectives. We are committed to respecting the following objectives;

The selected waste management option must …

1. *cause the lowest possible health risks to society and the lowest negative impacts on the environment;*
2. *consider waste as a valuable and useful resource rather than a problem to be hidden in a somewhat remote location;*
3. *result in the treatment of waste closest to where it is produced in order to minimize unsafe greenhouse gases resulting from excessive transportation distances, to maximize roadway security, and to minimize roadway nuisances and maintenance costs;*
4. *be socially acceptable;*
5. *be economically viable*

The information that we possess indicates that the Megadump proposed for Danford, unlike some modern alternatives, doesn't satisfy these objectives. We don't subscribe to the argument that the timetable imposed by the Quebec Government doesn't allow for other alternatives to landfill. The decision we take now is for a very long time, and will have repercussions for decades if not centuries. It is a decision that will affect our children, grand-children and generations to come. This decision must be made judiciously, must be well thought out and must be in agreement with the objectives listed.

With the above objectives/criteria in mind, we consider the following waste management alternatives.

3.0 Waste Management Alternatives

Since the Question phase of the BAPE public hearings, an article comparing the different technologies available for dealing with municipal residual waste has been posted on the BAPE web site. The article is entitled "Analyse Comparative des technologies de traitement des matieres résiduelles" by Les Consultants S.M. Inc., of Sherbrooke, Quebec, and was prepared in February, 2007**.** It is labeled as Document DB53 on the web site. The technologies compared in the report are:

− le compostage extérieur,
− le compostage intérieur,
− la méthanisation,
− le tri-compostage,
− la gazéification avec production d'énergie,
− la pyrolyse,
− l'incinération avec production d'énergie,
− la production de combustibles dérivés de déchets,
− la réduction et stabilisation
− l'enfouissement.

The list included in the report corresponds to the list investigated by the Coalition against the Danford Megadump over the past year in a search for better alternatives to landfill. The report (DB53) compares the different solutions based on economic criteria, social criteria and environmental criteria. The following table corresponds to the summary table in the document referred to, and gives the total overall ratings of the technologies based on the three criteria. The ratings are out of a total of 300 possible points, with 100 points being allocated to each set of criteria.

Synthèse de l'évaluation

Procédés de traitement	Résultat maximal	Résultat minimal	Résultat moyen
Compostage intérieur	251,9	204,3	228,2
Compostage extérieur	237,7	204,1	221,0
Gazéification	212,8	154,4	183,8
Méthanisation	213,3	147,3	180,5
Tri-compostage	204,7	153,8	179,4
Réduction et stabilisation	186,1	168,1	177,1
Pyrolyse	189,3	148,9	169,3
CDD	166,6	138,0	152,4
Incinération	165,8	126,0	145,9
Enfouissement	123,8	101,3	112,6

Composting is rated highest in the report, and we encourage the use of composting wherever possible.

- *Composting is only possible for organic materials, and is not applicable for many solid materials that can be treated by some of the other technologies listed*.

Plasma gasification is rated number 3 in the table. Plasma gasification is the technology the Coalition eventually decided was the best alternative for a region-wide solution to waste management in the Outaouais. However, we feel it should have received more points than shown in the table. The report evaluated the economic criteria for gasification on the basis of costs for three companies in the USA, for which the minimum tipping fee was $84.00 to $110.00 per ton, and the costs for building a facility were high. This evaluation did not take into consideration the model offered by the Plasco Group of Ottawa which would build, own and operate a facility and charge reduced tipping fees ($50--$60 per ton) for the garbage based on the revenue received from the sale of electricity. More will be said about this in the Plasma Gasification later.

- *Note that a plasma gasification facility can be used for a wide range of materials including such energy rich materials such as non-recyclable plastics and tires*.

Of most significance to the current BAPE hearings is that *landfill (Enfouissement) is at the bottom of the list*, receiving only 17.3 out of 100 points in the social criteria category and only 38.3 out of 100 points in the environmental area.

- *It is clear that society feels that landfill is undesirable and that the time has come for other technologies to be instituted to usher us into the post landfill era.*

4.0 Modern Incineration with energy recovery

It is somewhat surprising that incineration with electricity generation does not rate higher in the comparison. A large part of this is the perception of the public (social criteria). There is still an equating of burning to pollution of the environment, and to health and safety issues. Modern two stage incinerators offer controlled burning with cleaning of the air by scrubbers to prevent pollution. Electricity is generated by using the heat to create steam and drive turbines. However, because there is burning and creation of carbon dioxide, there is resistance to this technology. It must be noted that landfills generate methane which, as a contributor to global warming is 23 times worse over a 100 year period than carbon dioxide. *Incinerators do not generate methane*.

Incineration is used in Quebec for the treatment of waste and there are rigid standards for incinerators in Quebec. However, the heat generated has not been used to generate electricity, which is one way of creating value in modern incineration plants.

One of the concerns of people when incineration is mentioned is the potential for generating dioxins and furans. It should be noted however, that modern two-stage incineration is far superior to earlier incineration, and that such worrisome by-products as dioxins and furans have been dramatically reduced to very low levels in modern incinerators.

- Open backyard fires and fireplaces generate more dioxins and furans in North America than do incinerators.

There has been considerable publicity given recently to the improvements in modern incineration technology. Annex A is a copy of an article in the Toronto Star May 10, 2006.regarding use of incineration in Sweden. The article points out that:

"Fifteen years ago, 18 Swedish waste incineration plants emitted a total of about 100 grams of dioxins every year. Today, the collective dioxin emissions from all 29 Swedish waste incineration plants amounts to 0.7 of a gram ... quite an improvement."

In order to generate electricity an incinerator must be very large and therefore very expensive, and requires locating near a major population centre. **Annex A** refers to the cost of a 460,000 tons per year incinerator in Sweden. The Outaouais would not generate sufficient waste to support such a facility.

In its search for alternatives the Coalition considered the potential for **batch incineration on a rural local basis**, and explored this option with the MRC of Pontiac. A small Canadian company called Eco-Waste Solutions builds and installs small incinerators capable of treating 500 kg to10 tons of waste per day. These could be installed locally in buildings approximately 75 x 75 feet in size. The Quebec regulations are met by these incinerators. Two to three 10 ton units would handle the garbage requirements in the Pontiac. However, while this distributed approach would provide jobs in many areas of the Outaouais, no useful and saleable energy would be realized, and the municipalities would have to find the capital necessary to purchase and install the incinerators.

- The tipping fees for such incinerators were computed to be of the order of $100.00 per ton of garbage. There would be savings in transportation costs, so the approach could be viable.

However, when it became clear that a many municipalities favoured finding a regional solution for waste management in the Outaouais, the Coalition continued its search and settled on plasma Gasification as the best technology available, meeting all the criteria set out earlier in this brief.

5.0 Plasma Gasification with electricity generation

In researching plasma gasification, the coalition became familiar with the technology details and its benefits. Plasma gasification is not incineration. A high temperature plasma is created and focused on the waste in an oxygen starved environment. A synthetic gas rich in carbon monoxide and hydrogen (similar to natural gas) is created, scrubbed and then used to drive generators (either by combustion of the gas) or creating steam to produce electricity. During combustion, less pollution is generated than when natural gas is used. One ton of garbage yields about 150 kg of a stable, non-leachable glassy solid which can be used in asphalt, concrete, floor tiles and other building materials. Pure sulphur is also extracted and sold so there is no sulphur dioxide released into the environment.

- *After careful consideration, the Coalition concluded that plasma gasification met all the criteria listed in Section 2.0.*

The Coalition also researched many companies involved in this technology, and in particular Canadian companies, some of which they visited. A regional proposal was prepared which would handle all the waste needs of the Outaouais with the installation of one 200 tons per day facility and one 100 tons per day facility. This proposal accompanies this brief in as **Annex B**. In looking at the companies in Canada and particularly in Quebec, it became clear that if the facilities had to be in place by January 2009, then only the Plasco Energy Group, which was installing a 100 tons per day facility at the Trail Road Landfill site in Ottawa, would be in a position to supply a full facility in the required time frame. Moreover, the general public, government and Hydro Quebec officials would be able to see the Trail Road facility in operation, so would have a sound basis on which to make a decision. Consequently the Coalition approached Plasco and obtained their cooperation in preparing the proposal and their willingness to establish facilities in the Outaouais either near Gatineau or in an appropriate rural municipality.

- **No member of the coalition is an employee of Plasco, owns shares or represents the company.**

The Plasco model is based on the company building, owning and operating the facilities and charging reduced tipping fees for the garbage based on the revenue received from the sale of electricity. The Municipalities would not have to raise money for building a facility, but would only have to pay tipping fees in the range of $50-$70.00 per ton for a Plasco facility selling clean electricity generated from garbage at $0.11 to $0.13 per kWh. If any grants (government or otherwise) were received, then this would also result in a reduced tipping fee.

- A facility can be built in less than 12 months from environmental approval, not the 3 to 4 years used in the report (Document DB53).

- Thus considering that in Document DB41 filed by the Ministry of National Resources, Mr. Patrick Autotte has stated he considered that a summer/ autumn 2008 opening of a landfill site was ambitious, this means that a Plasco plasma gasification facility could be operational in the same time frame as a new landfill. So contrary to statements made by the promoter in the Question phase of the public hearings, *there is another option that is available for treatment of garbage in the Outaouais*.

- *Using the Plasco model, applying the comparison in the Table from Document DB53 to the Plasco facility would bring the resultant points scored for plasma gasification to 217.4, which makes it a very strong candidate for use, and far superior to landfill.*

In Phase I of the BAPE hearings, LDC has interpreted the information concerning the costs for treating a ton of garbage using plasma gasification in a manner to imply that the landfill option is the cheapest one available. Yet they give no operating costs in the environmental impact report for the landfill site, nor do they consider that they may need to haul in washed sand for backfill. They do show a cost of $63 million to prepare the site to receive garbage (excavation, smoothing, laying of liners, installing leachate and biogas collection systems, backfilling, etc.). This cost by itself compares to the cost of installing two 200 tons per day plasma gasification plants with electricity generating capabilities (order of $30 million each – yet please remember that the municipalities do not have to find this investment).

Dr. Lawrence Davidson, an Ottawa resident and specialist in water treatment, at the request of the Coalition, has used the procedure outlined in Landfill Economics by Daniel P. Duffy found at the following web site:
http://www.mswmanagement.com/mw_0507_landfill2.html
to prepare a spread sheet concerning costs and revenue from an Engineered landfill operation. This paper is included as **Annex C**. At a $40 tipping fee per ton the breakeven point is found to be approximately 130,000 tons of garbage per year, which is what is available in the Outaouais after reuse, recycling and composting targets are met. A similar break even figure was provided to the Coalition by Westinghouse Plasma, a company that

has installed three full 200 tons per day plasma gasification systems operating on municipal waste in Japan for over three years.

Note however, that instead of a $40.00 per ton tipping fee, two municipalities in the Outaouais (Low and Kazabazua) have confirmed that they are paying $68.00 per ton to have their waste buried in the landfill site in Lachute. On top of this is the $10.00 per ton tax to the Quebec government to promote recycling. The Comité ad hoc sur la gestion des matières résiduelles en Outaouais tabled at the Table des préfets de l'Outaouais le 12 mars 2007, notes that LDC had in 2005 offered a tipping fee of $75.00 per ton to the MRC de la Vallée del la Gatineau.

- *On the basis of the landfill fee discussion above, the question which must be asked is "Can plasma gasification compete with landfill in offering waste treatment facilities to the municipalities in the Outaouais?" The answer is an emphatic **yes**.*

The business plans for Plasco Energy Group of Ottawa, which is currently commissioning a100 tons per day plasma gasification plant at the Trail Road landfill site in Ottawa, call for a revenue stream when the plant is duplicated elsewhere equivalent to $185.00 per ton of garbage treated. This allows a suitable profit to be made by the company.

- ***The municipalities, however, do not see this cost, nor do they have to pay for installation of a plasma gasification facility***.

Rather the municipalities see a guaranteed tipping fee negotiated in advance and stable for 20 years. The tipping fee is dependent on the amount of electricity generated by the plasma gasification plant and the rate paid to Plasco for the electricity – negotiations are concluded on this rate prior to a contract being signed with a municipality.

For every $0.01 per kWh received by Plasco for electricity, Plasco is able to reduce the tipping fee by $10.00 per ton. To put electricity prices into perspective,

- Ontario utilities retail electricity to residents at a lowest rate of $0.068 per kWh, and at peak periods the rate rises to $0.097.
- New Brunswick sells electricity for $0.092 per kWh.
- The average price for electricity in the USA is $0.098 US per kWh.
- In New York, a major customer of Hydro Quebec, the price for electricity is $0.14US per kWh.

Receiving a price of $0.12 per kWh from Hydro Quebec for the electricity produced from garbage in a 100 ton per day plant to be established in the Outaouais, would mean that, in the absence of other revenue sources, Plasco would have to charge tipping fees of $65.00 per ton, which is less than that now spent by Low and Kazabazua to landfill their garbage in Lachute, and less than that offered by LDC as reported above..

- *In fact, in documents provided by Plasco to the Coalition and distributed to various mayors, Plasco offers to contract to treat waste for $53.00 per ton, which is well within the range quoted by LDC for a landfill site in Danford*.

A 200 tons per day unit is stated by Plasco to be capable of being approximately 15% more efficient in generating electricity than a 100 tons per day unit, since there is enough heat that co-generation (use of the gas and heat) is possible. This means that more electricity would be available per ton of garbage, and either tipping fees could be lower than offered at Trail Road, or the electricity prices that Hydro Quebec would pay could be reduced to $0.11 per kWh. While $0.11 and $0.12 per kWh are premium prices for electricity in Quebec, discussions have been initiated by Plasco with officials from the Quebec Government and from Hydro Quebec regarding such prices and are ongoing. Early indications suggest that these discussions are positive. As a case in point, Hydro Quebec is already negotiating contracts for wind power at a rate of $0.09 per kWh.

- *It should also be noted that the Federal government will contribute an additional $0.01 per kWh for electricity from either wind or biomass and that the plasma gasification facility qualifies under biomass*. Contact Dhetheri@nrcan.gc.ca

- *With an agreement by Hydro Quebec for electricity purchase, plasma gasification will be very competitive with landfill on the basis of tipping fees, so that LDC's statements in Phase 1 of the hearings regarding costs are incorrect and self-serving*.

There is no question that plasma gasification plants will be used in Canada for treating municipal waste and generating electricity in the process. In the area around Edmonton a number of municipalities have banded together and have formed a credit-worthy corporation, guaranteed by the Albertan government. The municipalities will contract to provide fixed amounts of garbage to this corporation, which then will guarantee to supply 300 tons of garbage per day to a plasma gasification plant.

- *In the Institute of Electrical and Electronics Engineers Inc. monthly journal Spectrum (March, 2007), it is reported that Ontario plans by 2017 to be generating 250 MW of electricity from plasma gasification of garbage. This is equivalent to 25 facilities each processing 200 tons per day of garbage, which is a significant commitment to a technology that is now available at the commercial level of 100 and 200 tons per day.*

LDC has also made much of the reduction of trucking distance of 135 km for transport of garbage from Gatineau to Lachute to 85 km to the proposed site in Alleyn and Cawood. However, the distance to a plasma gasification plant can be considerably less than this, since the choice for a site is not as restrictive as for a landfill site.

- *Very little land is required for plasma gasification (4 acres for a100 tons per day unit and 5 acres for a 200 tons per day unit) as compared to landfill (38.5 hectares for the proposed site in Alleyn and Cawood).*

This means that a plasma gasification plant could be located in a municipality which has an industrial zone or possibly even in an area where agricultural zoning applies (zoning change would be necessary for only a small area), since there is negligible prospect of environmental contamination and the agricultural land supply is not significantly impacted.

- In Phase 1 of the BAPE hearings, the promoter and others commented that other sites in the Outaouais close to the City of Gatineau could not be used for landfill because of the agricultural nature of the land.

However, a location could be selected for plasma gasification in the southern part of the region, so that trucking distances for waste from Gatineau would be less than 20 km, which is far less than the 80 km to the proposed site in Alleyn and Cawood. Thus transportation-related environmental pollution could be reduced dramatically by building a 200 tons per day plasma gasification plant near the City of Gatineau. A second unit for 100 tons per day could be built farther north to treat the waste from a number of MRCs, again keeping trucking distances low.

6.0 Conclusion

An alternative and less risky technology has been proposed for the Outaouais, viz. plasma gasification. We are in a time where plasma gasification is being demonstrated on a scale appropriate to municipal waste management. It would be disastrous to rush into a wrong decision to establish new megadumps in the Outaouais or anywhere else in Quebec for that matter, simply because of an edict that trench landfills must close by January, 2009. Such a decision would have negative implications and create unnecessary environmental risks for over one hundred years. **It is not environmentally and socially acceptable to rush to a solution because of expediency**.

- *We suggest that the BAPE Commission recommend the rejection of the application for a landfill in the municipality of Alleyn and Cawood.*
- *We also recommend a moratorium on new landfills in Quebec to allow an assessment period for superior technologies such as plasma gasification to prove themselves in full-scale commercial facilities such as the one in Ottawa for which construction was completed during the week of May 28 and processing of garbage was scheduled to begin in the week of 4 June, 2007*.
- *It should be noted that the Coalition has the support of over 4000 citizens. They have remained interested and supportive of our efforts over the last 2 years since our creation. They have been able to do so through our website, through an important number of public meetings, through regular media articles, and through personal exchanges with the executive members of the Coalition. Together we are indicating that it is now time to embrace better waste management practices and technologies than landfills which are socially divisive, risky and unnecessarily destructive of precious land, water and air.*
- *We are very appreciative of the opportunity that these B.A.P.E hearings have afforded us to share the results of a tremendous amount of volunteer work. We are confident that it will serve to make a difference in the final decision.*

Annex A

Integrated Waste Management in Sweden

Where incineration is not a dirty word
As Toronto battles to find a solution to its garbage crisis, Sweden offers a solution
TORONTO STAR
May 10, 2006.
MAGNUS SCHÖNNING
The industrialized world produces a never before seen amount of wealth and goods for its citizens. This is true for both Sweden and Canada. One needn't look far, however, to see how this generation of richness is slowly burying us in a mountain of waste.

In Canada, two examples come immediately to mind. Toronto sends more than 975,000 tonnes of its household garbage to Michigan every year, while Ottawa residents are currently embroiled in a fierce debate about the expansion of a local landfill.

Canadian cities could learn a lot from the Swedish approach to waste management. Sweden's view on basically all environmental problems is to take a holistic approach and acknowledge the complexity of the issues. There is never a quick fix, and policies, regulations and actions must be taken at all levels of society and be adapted to regional and local needs.

The goal of waste management, in any country, should be to reduce the total amount of garbage generated, while reusing as much of what remains. In Sweden, more than 90 per cent of household waste is recycled, reused or recovered. By contrast, Toronto diverts about half of its household garbage from landfill and Ottawa diverts about one-third.

Things began to change when the Swedish government made the producers and distributors of goods responsible for the waste they create. By law, companies are responsible for collecting the entire waste stream stemming from their products, either on their own or through public or private contractors.

Needless to say, there is a strong economic incentive for companies to produce less waste — from products and product packaging — at the outset of manufacturing, rather than deal with it later.

By mixing economic incentives, such as garbage collection fees, with easy access to recycling stations and public awareness campaigns, Sweden has achieved very high recycling rates. **In 2004, Swedes recycled 96 per cent of all glass packaging, 95 per cent of metal, 86 per cent of corrugated cardboard and 80 per cent of electronic waste.** Waste that cannot be recycled is recovered through other means, often to local economic benefit.

In 2005, Sweden made it illegal to landfill organic waste. Instead, the waste is biologically treated to create compost, biogas and fertilizer. Today, 10 per cent of all household organic waste is treated biologically, a share that is expected to increase dramatically in the near future.

But even reducing, recycling and biological treatment only gets rid of so much. So, like many other European countries, Sweden uses the remaining waste to create energy. Thanks to a well-developed district energy system, household waste is turned into heat and electricity for hundreds of thousands of Swedish homes.

Waste-to-energy through incineration has, in Canada at least, a reputation as an environmentally hazardous process. **The truth is that modern technology has cut emissions dramatically, particularly in the case of dioxins. Fifteen years ago, 18 Swedish waste incineration plants emitted a total of about 100 grams of dioxins every year. Today, the collective dioxin emissions from all 29 Swedish waste incineration plants amounts to 0.7 of a gram ... quite an improvement.**

At the same time, these plants have more than doubled the amount of energy produced in 1985.

I had the opportunity to visit a Swedish waste-to-energy plant in Malmö and was amazed at how clean and technologically advanced it was. Going into the main control room was like stepping into a fusion of *Star Trek* and IKEA. The operator sat in a comfy chair and controlled the waste going into the incinerator with a joystick. No smells, no noise — in fact, a very pleasant work environment.

Using waste instead of fossil fuels to power district energy systems has also lowered Sweden's greenhouse gas emissions, which are three times lower per capita than in Canada. But even without all of these environmental benefits, waste incineration makes good business sense.

The Sävenäs waste-to-energy plant, located just 200 metres from the nearest residential area, is a case in point. The plant incinerates about 460,000 tonnes of waste every year to produce heat and electricity, power that is sold to Sweden's deregulated electricity market. The facility cost $286 million to build and, with annual revenues of between $36 million and $70 million, the plant will pay for itself in less than 10 years.

Waste will always be a part of our everyday life but in Sweden, we have recognized it as a valuable resource. It can be turned into compost to improve soil, biogas to fuel our cars, and heat and electricity to power our homes. Why just throw it away when so much good can come from it?

***Magnus Schönning** is first secretary at the Embassy of Sweden in Ottawa*

ANNEX B

THE CASE FOR PLASMA GASIFICATION AS A PRIMARY MEANS OF MANAGING OUTAOUAIS WASTE BY CONVERTING IT INTO ENERGY

This proposal has been developed by the executive of the Coalition Against the Danford Megadump, a group of Outaouais ratepayers united in their belief that the answer to future waste management in the Outaouais does not lie in the creation of a 545-acre [220-hectare] engineered landfill site far from where most of the waste is generated.

The information supporting the proposal has been obtained from discussions with, and documentation from, all three levels of government, the private sector and academia.

INTRODUCTION

There are several ways of reducing and managing waste. The volume of waste can be reduced by not dumping what can be re-used, composted or by employing traditional methods of recycling (paper, glass, plastics and so on). Many Western European countries have succeeded in reducing their waste substantially by these means. Nothing in this proposal should be seen as suggesting that current or planned efforts of this kind should not be pursued diligently.

Most residual waste in North America has been dumped at landfill sites though some has been incinerated; a number of these incinerator plants create energy, usually in the form of electricity... A third and more technically advanced option is plasma gasification, which converts waste into energy and other materials that have many uses. While incinerators have been substantially improved in recent years and are very popular in Western Europe, we are very impressed with the potential of plasma gasification. In Ottawa right now a sizeable plasma gasification plant to handle waste is under construction as a demonstration project funded by Plasco Energy Group, the federal and provincial governments, the City of Ottawa and the Ontario Power Authority. This plant should be fully operational in March 2007, and, if it performs as expected, we would strongly favour this option over incineration (and either one over landfill).

WHAT IS PLASMA GASIFICATION?

It is a process whereby great heat breaks down the waste into non-greenhouse gases and a glass-like residue. This is performed without oxygen being present so that no burning is involved.
The gases produced are cleaned and then used to run an internal combustion engine/generator combination. The glass-like residue is non-leachable, non-hazardous and suitable for roadbuilding and other construction uses.

A plasma gasification plant

- produces no greenhouse gas emissions, dioxins or furans, or liquid effluents requiring treatment
- needs no smokestack
- uses very little land (4 acres [1.5 ha] or so)
- generates the most electricity from precisely those waste items that remain inert in landfill sites for decades, if not centuries (plastics and tires)
- requires no outside stockpiling of waste (vehicles unload inside the plant building) – hence no unpleasant or noxious smells wafting over the neighbourhood and birds are not attracted.
- operates 24 hours a day, three shifts creating about 35 local jobs; with the exception of the engineer and manager, these jobs would need skills for which local people could readily be trained.
- Is highly regulated by government and has more stringent emission standards than for most coal fired power plants or industrial boilers.
- Is such a safe technology that a small plant has been installed on one of the Carnival cruise liners (See Appendix 4).
- **Can be used for cleaning up all Quebec landfills that are presently posing a threat to the environment (e.g. leachate)**.

THE OUTLINES OF A POSSIBLE PROPOSAL

If the Ottawa demonstration project performs as expected, a very interesting scenario could be envisaged for the Outaouais, based on a partnership between the City of Gatineau and the MRCs, with support from the Quebec Government, Hydro Quebec and possibly the federal government.

One or more plasma gasification plants could be built and operated in the Outaouais. In any Outaouais-wide strategy, one large plant would be near the City of Gatineau with likely one or more smaller plants elsewhere.

The choice as to the number and locations should be made by Outaouais municipal governments based on such criteria as minimisation of transportation costs and optimising the allocation of jobs.

Implementation of this proposal would mean

- The virtual elimination of landfills in the Outaouais, since all waste can be processed through plasma gasification. It can handle not only organic waste, but also the most troublesome types of waste, such as hazardous waste.
- All waste that was not re-used, composted or recycled by traditional means would no longer be dumped but instead would become a useful form of renewable energy and provide components for building materials. In effect, this would mean that all municipal waste (whether residential, commercial, construction or institutional) would be re-used, composted or, in one way or another, recycled
- Creation of 70 to 100 jobs in the communities where plants would be built.

Financial and operational responsibilities

While we have not fully researched all suppliers of plasma gasification equipment around the world (see Appendix 4), we have been very impressed with several of the characteristics of Plasco Energy Group (see Appendix 1):

- It is a Canadian company with its headquarters close to the Outaouais (Ottawa)
- Its Ottawa plant at Trail Road in Ottawa would provide an ongoing functioning example of what would be involved.
- Plasco plants would be financed, built, owned and operated by Plasco Energy Group, (see Appendix 1 for a profile). This combination of building, financing and operating is significant in two ways
    - ❖ Some companies build waste treatment plants but do not want the headaches of operating them. With Plasco, there is no danger of the operator not understanding fully what is required for continued performance or of the operator blaming the equipment for operator deficiencies.
    - ❖ Plasco is confident enough to build plants at its expense and only recover the investment over many years of operation, through a combination of fixed tipping fees, sale of electricity at preferred rates, or sale of the glass-like residue
.

Plasco would accept all environmental responsibility and all liabilities. It would have adequate insurance coverage. It would obtain all necessary building and environmental permits.

In return, Plasco would require four conditions to be met:

<u>Provision of 4 acres [1.5 ha] of land per plant, rent-free and tax-free</u>

This would not seem to present much of a problem.

Guaranteed tonnages of waste for the next 20 years

As indicated in the table below, current volumes of Outaouais waste going to landfills are 752 tons a day, way above the 400 tons required to feed even three plants. The Quebec Government has set targets for recycling which, if met, would reduce waste volumes to 370 tons per day. However, combining traditional forms of recycling and recycling through plasma gasification, *essentially all waste would be recycled*.

	Currently landfilled	After meeting targets
Ville de Gatineau	425	181
MRC de Pontiac	38	18
MRC des-Collines-de-l'Outaouais	102	62
MRC de la Vallée-de-la-Gatineau	123	77
MRC de Papineau	63	32
	752	370

(See Appendix 2 for more information on how these figures were derived.)

Tipping fees of about $50 per ton

Tipping fees are on the rise. $50 would not seem out of line and likely lower than some of the figures being mentioned. For example, in 2007, the Municipality of Low will be paying $68 a ton at the Lachute landfill (plus the $10 a ton tax that goes to RECYC-QUÉBEC), and there have been mentions in the media of tipping fees of over $100 coming at some sites.

Sale of electricity at higher than normal rates

Provincial governments are beginning to realise that, other than hydroelectric, alternative forms of renewable energy are unlikely to develop strongly without incentives to the producers in the form of higher prices. While some would argue that energy derived from non-organic waste should not be viewed as renewable, it would seem inappropriate not to recognise waste being diverted from becoming a problem in a landfill and turned into a source of energy as equally worthy of special financial support.

Hydro-Quebec will pay up to 9 cents per kilowatt-hour for electricity generated by windpower. In Ontario, the rates paid for renewable energy range from 11 cents to 14.5 cents per kilowatt-hour (kWh) and up to 42 cents per kWh for solar. Plasco's plant in Ottawa will be selling electricity to Ottawa Hydro at 11 cents per kWh, with the amount in excess of the normal rate (5.8 cents/kWh) being funded by the Ontario Power Authority. For a large Gatineau plant, Plasco would need 12 cents and, for the smaller ones, 13 cents per kWh to maintain a tipping fee in the neighbourhood of $50 per ton. The willingness of the Quebec Government and Hydro Quebec to pay these rates would need to be determined.

In short, Plasco would recover its investment, and operating costs and show a profit from selling electricity and other by-products, and from tipping fees (a 200 ton a day plant would generate up to 14 million watts and require only 2 million watts to operate).

Timing issues

- Quebec municipalities must close trench landfills by the end of 2008
- From the time the contract is signed, it would take from 9 to 12 months to bring a plant into operation. Hence for the 2008 target to be met, construction should start no later than late Fall 2007
- With the Plasco demonstration project scheduled to be operational in March 2007, that leaves about only 6 to 8 months to achieve the following critical decisions :

- ❖ Satisfactory evidence that the Plasco plant is performing to expectations
- ❖ Agreement among municipal governments on the number and location of plants, the relative priority of each and how to ensure the guaranteed levels of waste are delivered
- ❖ Agreement of Hydro Quebec to top-up prices for electricity sold to it
- ❖ Preparation and signing of contract documents.

This would be a real challenge but could be made easier by seeking some relief from the Quebec Government on the deadline date and/or by beginning most of the preparatory work on the critical decisions in advance of March 2007.

Under the pressure of the 2008 deadline, municipalities have been seeking alternative arrangements to cover the next few years. We do not know the extent to which particular municipalities are locked into contractual arrangements or for how long but clearly these must be taken into account in the selection of the plant(s) to pursue in the near term.

From an environmental perspective, it would be preferable to begin with the Gatineau plant since so much of Outaouais waste originates in this urban area. Such a plant could also serve at least initially some of the needs of the neighbouring MRCs.

It would be reasonable to designate the first plant as an experimental or demonstration project. It would after all be the first such large plasma gasification plant in Quebec and one of the first in Canada. If it was so designated, a full environmental assessment might be avoided, allowing rapid deployment. This has been the route followed with the Ottawa plant. Appendix 5 shows that the plasma gasification process from Plasco results in far less contaminants than the most stringent standards in Ontario and Quebec, which is a strong environmental argument for fast-tracking the technology.

SUMMARY OF BENEFITS TO OUTAOUAIS MUNICIPALITIES AND RESIDENTS

- No capital expenditures required from municipalities
- Nevertheless two or three multimillion dollar capital projects launched in the Outaouais
- Several dozen jobs for local people during the construction and of the order of 35 jobs when each plant is in place and operating
- Provision in the Plasco model for sharing revenues should hydro prices rise above expected over the 20-year period.
- No need for future landfills or landfill expansions
- Clean technology and small footprint much less worrying to those in the community where the plants are located. No smells, no unsightly piles of waste, no threat to water resources.
- Shorter haulages generally, particularly vis-à-vis Gatineau waste being transported to Lachute or Danford, and less effect of the population living along and people using the highways.
- Reduced greenhouse gas emissions (no methane generation, a gas that has 23 times the effect of carbon dioxide over a 100 year period)
- Compatible with recent policy statement on waste management issued by MRC Vallée-de-la-Gatineau.
- Compatible with the Quebec Government's objective to move towards safer forms of waste management and recycling.
- Little land needed

CONCLUSIONS

Canada still relies on landfill more than the US and much more than many countries in Western Europe, despite the advances made with incineration and the emergence of plasma gasification; and despite the environmental risks and other drawbacks associated with landfill (see Appendix 3).

As Outaouais ratepayers, we firmly believe that a concerted effort by all municipal governments should be made to move from reliance on landfill to more advanced technologies and, in particular, plasma gasification.

We would be glad to assist in any way we can to bring this proposal, or some variant of it, to fruition.

List of appendices

Appendix 1 – Plasco Energy Group

Appendix 2 - Waste Management Overview in the Outaouais and suggestions for implementing plasma gasification

Appendix 3 - Canadian and International experience with alternative approaches to waste management.

Appendix 4 - Worldwide Plasma Gasification Experience in Waste Treatment and Review of Some Companies offering the Technology

Appendix 5 - Emissions and Contaminant Standards for Plasma Gasification

APPENDIX 1 - Plasco Energy Group[1]

Plasco Energy Group is an Ottawa-based company that has developed a proprietary plasma gasification process. It has a small 5-ton per day facility in Spain which is used in treating garbage there, and which allows Plasco to experiment with its process and equipment and the operation with different garbage content. Plasco is rapidly becoming the world leader in applying the technology to treatment of residual waste after recycling.

A number of companies have rushed prematurely to try to establish plasma gasification facilities for treating municipal waste promising performance without first demonstrating that their plant worked. This has created doubts in the public's minds when the systems failed or under-performed for either technical or economic reasons.

Plasco decided to conduct considerable research first before actually proceeding to make claims. The research involved testing out each part of the process first, and then all parts together. Along the way they patented various parts of the process, and introduced features to make sure that the energy recovered was much higher than the energy used in the process. The system was designed to ensure that the resulting synthetic gas (syngas) was always of the same quality so as to run internal combustion engines efficiently. Active feedback is built into their system so that the parameters can be adjusted to achieve the same quality of gas all the time.

Having dealt with the system, Plasco then sought a method to demonstrate to everyone that the system worked. Rather than try to sell a facility to a customer, they adopted a model whereby they would finance the facility themselves, own it and operate it, so that, as in the case for many earlier systems, buyers could not blame the system for operator errors. Ottawa was selected as the demonstration site (4 acres donated by the City of Ottawa at the Trail Road Waste site), and a contract drawn up. Ontario agreed on a set of emission specifications much tighter than the incinerator specifications (See Appendix 5) and agreed to treat this as an experimental demonstration bypassing the need for a full environmental hearing. The Trail Road facility is intended to demonstrate clearly that plasma gasification is the safest and best way of dealing with Municipal Solid Waste. Plasco has extended an open invitation to all interested parties to "come and see for yourself". This particular demonstration facility is designed to handle 100 Tons of waste per day, but is licensed for only 85 tons. The equipment is being built in modules by several large firms, and is expected to be operational in early 2007 with the first electricity to be generated in March 2007. Plasco estimates that it would require only 9-12 months to build the equipment and complete the installation in future facilities.

The Plasco model for the most efficient future facilities is to parallel two 100 ton/day streams, making the facilities able to handle 200 tons per day, with the ability to also generate steam, and use the steam to generate additional electricity (a 15% improvement). The 100-ton per day unit will generate 5-6 MW of electricity of which at least 4 MW will be sold to Ottawa Hydro. A 200 Ton unit with co-generation as described would generate up to 14 MW. Note that 200 tons per day is equivalent to 73,000 tons of waste per year. To put a 200 tons per day facility in place would require only 4 acres of land donated tax free to Plasco, a guaranteed stream of waste for 20 years, and a guaranteed price for the electricity. (Note that under Ontario's new laws effective in November 2006, the electricity from the Trail Road facility will be sold for $0.11 per kWh). A similar scheme elsewhere, whereby the electricity generated from waste is sold at a premium, would allow

[1] http://www.plascoenergygroup.com

tipping fees for waste to be held at $50.00 per ton with only minor inflation increases over the 20 year period.

All parts of the Plasco system have been tested and shown to work as specified. Before starting an active marketing campaign, Plasco has elected to demonstrate a large-scale commercial system in operation, so that the general public will see that plasma gasification works. People are invited to come see the plant in operation. To alleviate public concerns over possible contamination in the gases, the gas emissions will be monitored all the time. In Ottawa, there will be a committee responsible for this monitoring and the analysis of the results. This will include representatives from the city, the province and environmental groups such as the Sierra Club. Already there is a contract in place in Ottawa for all the future garbage (additional facilities) which will become effective after the successful demonstration of the Trail Road plant. Other municipalities in Canada (for example, Montreal) have expressed strong interest in seeing the Trail Road facility in operation, while others, most notably Red Deer, Alberta, are already setting aside land for establishing plasma gasification facilities.

Plasco is well financed, reducing the economic risk to the customers. It has all the money it needs to put in facilities as requested. Many of the major world financial organizations are backing them. They will not, however, sell a facility, but will accept investment in a minority position in any particular location. For example, the Irvings of New Brunswick asked to buy a facility for their pulp and paper waste and were turned down by Plasco. They said they would buy elsewhere, but came back saying they could not find someone else to supply what Plasco offered.

Appendix 2 – Waste Management Overview of the Outaouais and suggestions for implementing plasma gasification

2.1 Introduction

(Note: Throughout this Appendix we use the term Outaouais or Partners to refer to the 4 MRCs and the City of Gatineau.)

In our opinion, any region-wide waste management solution must be feasible as well as affordable – it makes no sense to say "look at this option" otherwise. In this study, since it is a technology that can be tailored to treat all waste, we consider plasma gasification and not other alternatives to landfill in any detail. Our study proceeded in the following sequence:

Step 1: Determine how much waste is currently generated in the Outaouais, how much of this is put in landfills and how much is recycled.

Step 2: Determine the impact of the 2008 targets for recycling

Step 3: Determine the Outaouais budget for Waste Management

Step 4: Determine if Plasma Gasification is a good candidate for an Outaouais solution from the standpoint of quantities and cost impacts

Step 5: Propose possible Outaouais solutions

Based on our findings, which follow, we have concluded:

Political (local)	if there is a will, the way is there
Financial	The Outaouais probably has the funds to pay the required fees for waste treatment by Plasma Gasification.
Operational	An Outaouais waste management solution based on Plasma Gasification is feasible.
Technical	Before adoption, the Outaouais will have the ability to determine how the Plasma Gasification process operates and judge its viability (April, 2007–Trail Road demonstration project)

For installing Plasma Gasification plants in the Outaouais we have used a company called PLASCO Energy Group as a base, for several reasons (Appendix 4 refers to other companies we have considered):

1. As a local company, it is convenient to use.
2. After successfully demonstrating the Trail Road facility, Plasco would be able to implement one or more plasma gasification facilities in the Outaouais in 2008.
3. PLASCO has good information on its processes and costs, and clearly outlines its expectations/requirements of the buyer.
4. PLASCO has a business model that limits the capital required by the Outaouais.
5. PLASCO's system is proprietary to PLASCO and no other Plasma system has been demonstrated in North America of a commercial size.

This document is just a high level overview. Each of the 5 steps of the study has background information (available on request) on the methodology, assumptions, sources used and how they were interpreted.

2.2 Step 1: Determine how much waste is generated in the Outaouais, what is currently put in Landfills and what is recycled

The following is the current situation (based on waste management plans from the MRCs and the City of Gatineau). Numbers are not available for the same year in all cases, so we have used data from 2001 in some cases and up to 2004 in others. In the tables, RMW refers to residential municipal waste, CRD refers to construction renovation and demolition waste and ICI refers to industrial commercial and institutional waste. Annual tonnage in the following three tables is converted to tons per day (tpd) by dividing by 365 days since a plasma gasification plant would operate 24 hours per day every day.

Table 2.1 Current Waste (annual tonnage) Overview of Outaouais

Partners	What is currently landfilled				
	RMW	CRD	ICI	Total	Tons per day
Collines	16,174	8,623	12,539	37,336	102
Gatineau Valley	8,050	8,887	28,029	44,966	123
Papineau	11,190	2,914	8,977	23,081	63
Pontiac	4,600	4,600	4,800	14,000	38
Gatineau	104,190	12,500	38,395	155,085	425
Total	144,204	37,524	92,740	274,468	752
Tons / day	395	103	254	752	

Collines tpd	44	24	34	102
Gatineau Valley tpd	22	24	77	123
Papineau tpd	31	8	25	63
Pontiac tpd	13	13	13	38
Gatineau tpd	285	34	105	425
Total Tons / day	395	103	254	752

There were two cases where we couldn't determine quantities to a high level of certainty. In the case of the Pontiac, we could not determine what is currently put into landfills, so we estimated 14,000 of the 17,029 tons generated. As well, generally for CRD waste, we couldn't determine how much of this type of waste was also included in the RMW waste. Therefore the amount of RMW for the Outaouais may be overstated by up to 5% in some of the MRCs.

At this point is should be noted that the municipalities are responsible for RMW and CRD waste, while disposal of ICI waste must be paid for (at least in part) by the institutions themselves. In a waste management plan, however, facilities must be provided which can be used by the ICI groups.

2.3 Step 2: Determine the impact of the 2008 targets on residual waste to be managed

The following are the 2008 quantities of waste to be disposed of after the meeting of imposed targets for recycling and composting.

Table 2.2 Target residual Waste (tonnage) Overview of Outaouais

Partners	What is the 2008 Target for disposal?				
	RMW	CRD	ICI	Total	Tons per day
Collines	8,926	6,633	7,108	22,667	62
Gatineau Valley	3,065	3,660	21,438	28,163	77
Papineau	6,469	1,457	3,702	11,628	32
Pontiac	2,263	2,196	2,059	6,518	18
Gatineau	46,265	9,350	10,404	66,019	181
Total	66,988	23,296	44,711	134,995	370
Tons / day	184	64	122	370	

Collines tpd	24	18	19	62
Gatineau Valley tpd	8	10	59	77
Papineau tpd	18	4	10	32
Pontiac tpd	6	6	6	18
Gatineau tpd	127	26	29	181
Total Tons / day	184	64	122	370

It is for the municipalities themselves to determine whether these targets are met. (The target of 370 tons per day represents approximately a 51% reduction in the amount of residual waste to be dealt with). It should be noted here that (as will be shown later) the Plasma Gasification solution could contribute strongly towards meeting these targets.

In this Appendix, we provide a proposed scenario to treat the targeted amounts of waste in the case where the above targets are met, and also suggest a second scenario where plasma gasification deals with the putrescible material scheduled for composting. (Putrescibles includes, among other things, table waste, peelings, egg shells, coffee filters, grass cuttings, leaves and garden residue). This second scenario involves considering whether establishing an extensive composting plant for the Outaouais is justified. If we consider the putrescible material targeted to be composted, and the budget planned it is clear that the costs of composting are higher per ton that either landfilling it or turning it into energy via the plasma gasification process. We agree that it is undesirable to landfill it, but feel that since converting it to energy is a form of recycling/reuse of the material, then this option should also be considered in the plan. Not all this putrescible material can be composted anyhow. Our analysis shows that if the material quantities planned for composting were treated by plasma gasification, then the quantities of waste for which the municipalities would have to pay PLASCO to treat are as shown in the following table:

Table 2.3 Residual Waste (tonnage) of Outaouais to be treated when planned composting quantities are included

Jurisdiction	2008 residual waste targets including Putrescibles planned to be composted				
	RMW	CRD	ICI	Total	Tons per day
Collines	10,996	6,633	7,819	25,448	70
Gatineau Valley	5,394	3,660	21,938	30,992	85
Papineau	7,551	1,457	3,839	12,847	35
Pontiac	3,485	2,196	2,942	8,623	24
Gatineau	72,933	9,350	30,904	113,187	310
Total	100,359	23,296	67,442	191,097	524
Tons / day	275	64	185	524	

Collines tpd	30	18	21	70
Gatineau Valley tpd	15	10	60	85
Papineau tpd	21	4	11	35
Pontiac tpd	10	6	8	24
Gatineau tpd	200	26	85	310
Total Tons / day	275	64	185	524

Note that the plans for composting of putrescible material amounts to 56,102 tons in 2008 (approximately 60% of the amounts generated that are eligible to be composted are targeted – not all can be composted). Table 2.3 shows that with this included there is a 30% reduction of the amount of residual waste from the current quantities landfilled per Table 2.1.

2.4 Step 3: Determine the Outaouais budget for Waste Management

The following is our summary of the current budgets.

Table 2.4 Financial Overview of Waste Management in the Outaouais

Partners	Cost situation as per the Waste Management Plan							
	Collection	Transshipment	Transport	Elimination / Landfill	Sub-Total	Recycle	Other	Total
Collines	$1,191,597	$126,052	$230,817	$426,770	$1,975,236	$329,372	$209,949	$2,514,557
Gatineau	$3,103,300		$1,787,354	$2,572,046	$7,462,700	$1,469,700	($263,400)	$8,669,000
Papineau	$554,826		$237,782	$326,255	$1,118,863	$137,384	($50)	$1,256,197
Gatineau Valley	$474,949		$203,550	$352,171	$1,030,670	$152,306	$1,656	$1,184,632
Pontiac	$140,700		$60,300	$250,000	$451,010	$572,060*	$6,690	$1,029,760
Total	$5,465,372	$126,052	$2,519,803	$3,927,242	$12,038,479	$2,660,822	($45,155)	$14,654,146

* NOTE: A one to one comparison on recycling costs could not be carried out. Pontiac has lagged behind in introducing recycling, so the costs we have used are the estimated costs in the 2006 to 2009 period. This is why the number is anomalously higher than for Collines, for which the data shown is for actual recycling in 2001.

A detailed document is available to describe how the costs in this table were derived.

Note that there is at least $3,927,242 spent on Landfills (Column 5) – either maintaining them or paying tipping fees. This figure is based on 2001-2004 and does not reflect dump closures in the last few years and the higher tipping fees currently being paid. For example, Papineau MRC municipalities still pay about $32 per ton tipping fees in Lachute as they were partners in the Lachute dump prior to its privatization. This rate may also apply to some municipalities in other MRCs. However municipalities such as Kazabazua and Low who have contracted with this site more recently are paying $66/ton (2006) and $68/ton (2007) as are Montreal boroughs that use it. Some of that $68 is to offset these municipalities' non-participation in the capital costs of the transshipment center near Wilson's Corners, used also by MRC des Collines municipalities to achieve transportation economies in the run to Lachute.

To these amounts must be added the $10 per ton tax to the government of Quebec that is turned over to ReCyc Quebec. This organization oversees all organized recycling initiatives in Quebec. They are to promote the government waste objectives and must return 85% of the $10 tonnage tax to municipalities upon their verification of municipalities' meeting or improving towards recycling targets. The 85% rebate from ReCyc Quebec has a ceiling of 50% of recycling costs. Ironically then if the municipalities recycle more, adding extra recycling costs, reducing landfill quantities in the process, the ceiling on recycling costs will rise while the 85% payback for recycling from the $10 per ton tax to the Quebec government reduces. Eventually the two will converge at the same level, and there will be no more financial incentive to recycle except to minimize the $10/ton tax!

2.5 Step 4: Determine if Plasma Gasification is a good candidate for an Outaouais solution on economic grounds

From Table 2.4 (column 5) the municipalities currently pay a total of $3,927,242 in tipping fees and to maintain local landfills. It is our understanding that the ICI sector must pay (at least in part) for disposal of their waste.

Scenario 1

If we consider Table 2.2, which assumes that the MRCs meet the 2008 targets, there would be approximately 90,000 tons per year of RMW and CRD waste to be disposed of. If it were landfilled at an average tipping fee of $40 per ton, then the cost would be approximately $3.6 million for tipping plus $10 per ton Quebec tax. If plasma gasification is used instead, with a treatment fee of $50 per ton stabilized over 20 years, the annual cost would be $4.5 million. This is approximately $570,000 above the current costs of $3.927 million, which should be achievable. (Whether a $10 per ton tax would be charged by Quebec for treatment by plasma gasification would be a subject for negotiation).

If the landfill option were chosen, the landfill site would be in only one location and transportation costs would be high for the bulk of the waste. In contrast the plasma gasification plants would be located in much closer proximity to where the waste is generated (see Section 2.6), transportation costs would be lower, which makes the gap between current costs and potential costs even narrower. **A 20% reduction in the transportation costs shown in Table 2.4 would offset the $570,000 referred to in the paragraph above resulting in zero additional cost to the municipalities.** Thus from an economic viewpoint plasma gasification using the PLASCO model is an excellent candidate for an Outaouais solution to waste management.

Scenario 2

What would be the impact if the putrescible material were also to be treated by PLASCO?

There is a 2008 budget for composting of $3 million, which would compost only 56,102 tons. However, it should be noted that this 56,102 tons includes all the putrescible material in the RMW and ICI sectors. If the ICI sector pays its own way, this cost component would be recovered, or could be, by the Partners. At $50 per ton to treat the putrescible material, the cost to the municipalities should be approximately $2.5 million (which is $500,000 lower than the budget for composting). For the 123,655 tons of waste in the RMW and CRD sectors in Table 2.3, the total fees to PLASCO at $50 per ton would be $6,182,750. Combining the Partners $3.0 million 2008 budget for the putrescible material with the current $3,927,582 tipping fees for other waste gives a total of $6,927,582. This amount is higher than the cost for treating the RMW and CRD waste and putrescible material at $50 per ton using plasma gasification.

From this analysis, we conclude that considering either scenario, plasma gasification using the PLASCO model is viable for the Outaouais. Scenario 2 would appear to be the best one for the Outaouais from an economic standpoint.

2.6 Step 5: Possible Outaouais solutions

The Coalition has developed 3 possible options for PLASCO facilities to service the Outaouais for each of the two scenarios discussed in Section 2.5. We considered various factors in coming up with these options:

- waste should be processed close to the source of its generation
- changes in traffic flows and patterns should be minimized
- the solution should be “operational friendly” – easy for managers of waste to administer
- insofar as possible, new jobs to be equitably distributed in the Outaouais
- the solution should be fair and acceptable to all Partners

These alternative solutions are based on the following assumptions:

1. Some Partners do not have the responsibility for the Industrial, Commercial & Institutional Sector, and the Construction, Demolition & Renovation Sector. Regardless, they can control or limit the Scenarios available to those who are responsible. For example, if the Cantley dump is closed the CRD waste has to go somewhere else.
2. For those Scenarios where the Facilities are in different locations, it is assumed that PLASCO will negotiate contracts (particularly in the CRD and ICI sector) to be able to redirect some trucks from one Facility to another to ensure the Facilities operate at maximum efficiency.
3. It is assumed that the CRT facility in Gatineau will continue to function in the same manner as before.
4. It is assumed that there are up to 150 trucks (of various sizes) per day which will arrive at the Facilities with RMC, CRD and ICI waste – 50, 50 and 50 respectively.
5. We use the term “Southern Facility”. This could be a location in any of the 3 MRCs in the South, for example in City of Gatineau territory or near where the Quebec and Ontario Power Grids are to be joined. In turn, the “Northern Facility” can be anywhere in the Pontiac or in the Gatineau Valley, or both. Where we refer to a “Western Facility”, this would be a Pontiac location. It is assumed that any site selected will be a good candidate for connecting to the power grid.

Table 2.5 Options for Plasma Gasification Plants in the Outaouais

Options	Scenario 1 – 2008 Recycling Targets are met	Scenario 2 – Using plasma to treat Putrescibles as well
Option 1	Two 200 tons/day Southern Facilities to process 370 tons/day	Two 200 tons/day and one 100 tons/day Southern facilities to process 524 tons/day
Option 2	Two 200 tons/day Northern Facilities to process 370 tons/day	Two 200 tons and one 100 tons/day Northern facilities to process 524 tons/day
Option 3	One 200 tons/day Southern facility and either one 100 tons/day Western and one 100 tons/day Northern facility or one 200 tons/day Northern facility	One 200 tons/day Southern facility, one 200 tons/day Northern facility plus one 100 tons/day Southern facility

In both scenarios, there are advantages and disadvantages in each of the three options.

Option 1

Advantages:

- Good solution for ensuring all facilities are working at capacity – i.e. Plasco can redirect waste as and when needed
- 200 ton per day facilities most efficient size, reducing tipping fees due to more efficient electricity production capability
- Private companies in ICI and CRD sector will like having the facilities close by
- Best solution vis-à-vis power-grid access

Disadvantages:

- An additional 30-40 trucks a day using the 105 going down to Gatineau.
- All new permanent jobs are all in the south part of the Outaouais
- The second easiest solution for the Partners to work together to determine job, revenue and cost sharing

Option 2

Advantages:

- Good solution for ensuring all facilities are working at capacity – i.e. Plasco can redirect waste as and when needed
- 200 tons per day facilities most efficient size, reducing tipping fees due to more efficient electricity production capability
- If the Danford Lake site is used as one of the sites, then it may be easier and quicker to get approvals and environmental studies

Disadvantages:

- An additional 110-120 trucks a day using highway 105 going up to the Northern Facility.
- All new permanent jobs are all in the north part of the Outaouais
- The hardest solution for the Partners to work together to determine job, revenue and cost sharing
- Various private companies in ICI and CRD sector may not like having to go all the way up to the Northern Facilities.
- Not the best solution vis-à-vis power-gird access

Option 3

Advantages:

- If the Danford Lake site is used as one of the sites, then it may be easier and quicker to get approvals and environmental studies
- Equitable share of jobs in the Outaouais
- The easiest for the Partners to work together to determine job, revenue and cost sharing
- No significant change in traffic patterns
- Acceptable solution vis-à-vis power-grid access

Disadvantages:

- Not sure there are any

Which of the options would be chosen is left to the Partners in the Outaouais in discussions with Plasco Energy Group.

Appendix 3: Canadian and International experience with alternative approaches to waste management.

For each person living in an urban area of North America, about 2.2 kg of solid waste is generated every day. The number is about the same in Europe. The amount of waste varies with the income level of the country, but in all urban centers the flow of solid waste grows with the population. Most rural municipalities are in reasonable proximity to urban centers, and generate similar quantities of waste per person. How to deal with this waste is a major problem facing both urban and rural municipalities.

The current methods for dealing with garbage differ in North America and in Europe. In North America, we tend to simply dig a hole, line it, dump in garbage and cover it over. Such landfills are now called Engineered Landfills and are based on technology developed in the 1980s. Environment Canada, the USA Environment Protection Agency and the American Society of Civil Engineers have all stated that, with time, all landfill sites will develop problems such as leakage of leachate into the groundwater. Community support for landfill has been dropping rapidly as people appreciate these dangers and are put off by the growing scale of sites with the increased traffic and fear of the fumes emitted. Community opposition has lead to the closing of some dumps and stopping the expansion of others (Cantley and Napanee are two recent examples, one of each type). A 2004 comparison between waste management methods in the USA, Canada, Sweden, Denmark and Netherlands ("Ontario's 60% Waste Diversion Goal – A Discussion Paper", Ministry of the Environment, June, 2004) shows that Canada led all the 5 countries in landfill, with approximately 76% of its waste being buried in landfills. The USA followed behind Canada landfilling approximately 56% of its waste. In the Netherlands by contrast only 10% of waste ended up in landfills.

In Europe, there is a strong recognition that there is considerable energy contained in the waste, so European countries have moved to recover that energy. In the 2004 paper referred to above the Netherlands converted approximately 40% of its garbage into energy, with Denmark and Sweden following closely. The USA converted approximately 14% of waste into energy, with Canada lagging far behind at a mere 2-3%.

In Sweden and Germany, burying waste that has energy value is now effectively prohibited, whereas in North America, most waste is still buried. Several European countries are moving to tax, or prohibit, burying energetic waste, and in North America there is growing resistance to landfill expansion or adding new locations. Moving the waste to remote locations is costly and environmentally damaging.

An October 2006 report on how to improve Canada's climate change performance issued by the Montreal-based Institute for Research on Public Policy states:

"While waste only accounted for 4% of total greenhouse gas emissions in 2004, it is a sector where Canada could readily achieve long overdue emissions reductions….Canada's emissions from waste are 0.9 tons. In the US…0.65, in the UK and Japan 0.4, in Germany 0.2 and in Switzerland 0.1…The main reasons for Canada's high emissions from waste is that Canadians generate a considerable amount of waste, the large majority of solid waste is landfilled as opposed to incineration or recycling, and only a fraction are equipped to recover landfill gas. The anaerobic decomposition of organic waste in landfills produces methane, a greenhouse gas that is more powerful than carbon dioxide".

In a December 2004 position paper "A Review of the Options for the Thermal Treatment of Plastics", the Environment and Plastics Industry Council of Canada presented a table showing the Calorific Value of Materials. This is reproduced here.

Table 3.1 Energy Content in materials often landfilled compared with #2 Fuel oil

Material	Btu per pound	Kilojoules per kilo
#2 fuel oil	20,900	48,500
Plastics		
Polyethylene	20,000	46,500
Polypropylene	19,300	45,000
Polystyrene	17,900	41,600
PET	9,290	21,600
PVC	8,170	19,000
Coal	11,500	27,000
Newspaper	7,200	17,000
Wood	6,700	15,500
Average Mun. Solid Waste	4,650	10,800
Yard Waste	3,000	7,000
Food Waste	2,600	6,000

Clearly significant energy is contained in the different materials currently dumped in landfills in Canada. Plastics in particular represent an energy source almost on a par with #2 fuel oil – yet even after re-cycling, approximately 60% of waste plastics in Canada end up in landfill and the energy contained therein lost. Landfill is not a good solution to waste disposal of anything containing recoverable energy.

Using modern incineration technology and recovering the energy from the heated gases is applied widely in Europe. Modern incineration should not be confused with open air burning, as has been practiced in back yards or in open trench landfills. The word dioxin sparks fear whenever it is mentioned, and the word is always associated with the combustion of waste. In 2004, the U.S. EPA updated their records on the sources of dioxins. In the USA, backyard barrel burning accounted for 628 grams TEQ[2] of dioxins per year. In fact this type of burning is the principal source of dioxins in the United States. In contrast Municipal Waste Incineration (closed incinerators) accounted for only 12 grams TEQ of dioxins per year (500 times less). People who oppose energy from waste in modern incinerators, are often the same people who will sit beside a wood-burning fireplace, completely ignorant of the toxic effluents from that fireplace. (In the USA, residential wood burning accounted for 62.9 grams TEQ of dioxins in 2004, even more than coal-fired utilities (60.1 grams TEQ)). Clearly modern incineration plants are much less dangerous than things our society take for granted.

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[2] TEQ means 2,3,7,8 TetraChloro Dibenzo-p-Dioxin (TCDD) toxicity equivalents calculated according to the international toxicity equivalence system developed by the North Atlantic Treaty Organization's Committee on the Challenges of Modern Society (NATO/CCMSs) in 1989 and adopted by Canada in 1990.

Modern incineration plants meet the emission regulations laid down in both North America and Europe, which are comparable. Modern incinerators burn the waste in closed systems at temperatures up to 1100°C, in an excess of air. Given off are gases such as Carbon Dioxide and Steam. *The gas is cleaned at atmospheric pressure and the cleaned gas is only then discharged into the atmosphere or used to generate electricity (the latter in the case of larger incinerators)*. Sulphur is converted into SO_2. Metals in the waste are not melted and can be removed from the base of the incinerator and recycled. Fly ash scrubbed from the gas is a by-product, which can be used in concrete. Thus there is value-added from the energetic waste – something that does not occur for landfill.

Plasma gasification is the most advanced modern technology to dispose of waste, recovering the energy contained therein in the process. In plasma gasification, a "plasma torch" is used to turn the waste into gases and slag. *The waste does not burn, hence this process should not to be mistaken for incineration*. Rather the process is carried out in an atmosphere starved of oxygen. The high temperatures of the plasma (several thousand degrees Celsius and well above the melting point of fly ash) break the waste into its constituent molecules generating gases consisting primarily of Carbon Monoxide and Hydrogen. Hence the name plasma gasification.

The temperature used in plasma gasification is much higher than for incineration and of course high enough to convert ash into a molten slag, which when cooled is essentially a stable vitreous material (glass). This material is non-leachable, non-hazardous and suitable for use as a construction material. The gas is cleaned at high pressure and the treated synthetic gas (syngas) is used for producing either chemicals or power (running a turbo generator). For larger plants it is primarily used for producing electricity. Sulphur is recovered as a high purity element or as an acid. This is another recoverable by-product of the process. No dioxins and furans are generated by plasma gasification, so that this technology is even more benign that a wood burning fireplace.

According to presenters at a March 22, 2006 workshop put on by the Municipal Waste Integration Network (see Recycling Council of Alberta website), waste to energy plants, whether incineration-based or plasma gasification based, are the most highly regulated form of waste management with emission standards more stringent than for most coal fired power plants or industrial boilers.

Appendix 4: Worldwide Plasma Gasification Experience in Waste Treatment and Review of Some Companies offering the Technology

Experience
In our review of Plasma Gasification technology we conducted a thorough search of the web and actually visited with some plasma gasification companies. For a good overview of Plasma Gasification we particularly recommend a Power Point presentation by Georgia Tech[3]. It provides insight into the technology and shows numerous applications of the technology. One facility shown is particularly worth noting. This is a 200 Ton per day unit that has been operating at Hitachi Metals in Utashinai, Japan for the past three years. This facility treats MSW and waste from an automobile shredding plant. It is of the size we are proposing for the Outaouais, and if located in North America would be capable of dealing with the waste from 30,000 households.

Recovered Energy Inc. of the USA is a company that offers to design and install plasma gasification plants, and purports to have a financing plan that allows for plants up to 3,000 tons per day. We refer you to www.recoveredenergy.com/seeaplant.html Some comments in this web site are particularly useful in providing insight into the current status of plasma gasification sites around the world.

- "There are as many as 100 plants around the world that use plasma systems to process a variety of materials. Most of these plants are used to vitrify incinerator ash. Others are used to process medical waste, hazardous waste, PCB's and other difficult types of waste. Others are used in the steel industry for melting iron. The industry has tested every conceivable type of waste in various pilot plants. The technical viability of plasma has been well proven for many years!"

Our research corroborates this statement. The Recovered Energy web site goes on to say:

- "There are only **3 plasma gasification plants in the world that have or are operating on municipal solid waste (MSW)**. These plants are located in Japan and were built by Hitachi using the Westinghouse Plasma Corporation plasma gasification process. The largest plant has a capacity of 300 tpd of MSW.

- Regardless of what anyone else says from any other company, there is no other plasma gasification process anywhere in the world currently processing MSW other than the plants built by Hitachi."

The obvious question is: If Plasma Gasification is the best solution for waste treatment, then why are there not more plants processing MSW using plasma? If there are more than 100 plants operating on different types of waste, why not more on MSW?

The answer is simple. A plant has a high initial capital cost, and landfill tipping fees have been low, so it has been cheaper to simply haul the waste to a landfill site and bury it. There has needed to be a proper consideration of the economics to find a way to

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[3] www.p2pays.org/ref/03/02918.ppt

establish plasma gasification plants for municipalities so that the economic implications for the municipalities are not much higher than for landfill tipping.

Recovered Energy, Inc. claims to have developed the economics stating that the following factors are necessary in order for a plant to be economically viable processing MSW:

1. "The larger the plant the better the economics become. The ideal size for a plant, considering factors such as transportation, operating cost, supervision cost, maintenance cost, etc. is 3,000-5,000 tons per day of MSW (other types of waste will vary).

2. In order to maximize the production of electricity, the process should use a combined cycle gas/steam turbine to produce power.

3. There has to be some form of subsidy. The subsidy can be in the form of higher tipping fees or favorable financing terms."

REI's comments about the optimum size of the plant may well be true, if one wishes to maintain tipping fees at a very low level – for example, less than $30.00 per ton. However, this size of plant they specify is far larger than needed in the Outaouais. Based on our study of the various companies involved in plasma gasification, particularly in Canada, we believe that a methodology has been developed by PLASCO that makes it possible for them to build plants in the 100 to 300 ton per day sizes that allows tipping fees in the $50 range to be sustained over a 20 year period. This compares favorably with recent tipping fees in many landfills. (For example $68 per ton plus a $10 per ton tax in Low and Kazabazua in 2007 to $150 per ton – coupled with high transportation costs). Since we believe the methodology offered by PLASCO is viable, and certainly the only viable one by a Canadian company, we have chosen to base this proposal on PLASCO technology (which will shortly be operating in the Ottawa area), and the methodology they propose to implement facilities.

A. Plasma Companies in Quebec

We decided to look at plasma gasification companies operating in Quebec to determine if any of them (a) had a technology that had been proven or could be proven in the 2008 time frame on a large scale, and (b) had the financial capability to supply a plant without significant economic burden to the MRCs. The companies we studied are briefly profiled below.

PyroGenesis Inc.
PyroGenesis is a Montreal based company that develops and commercializes technologies, which use the intense energy found in plasma to convert waste into energy and useful materials. These systems are designed to treat a range of industrial, hazardous, clinical and municipal waste streams on land. PyroGenesis has also developed a specialty system designed to treat various waste streams on board ships. The company has clients from two of the largest marine fleets in the world namely the US Navy and Carnival Cruise Lines.

The company manufactures its own d.c. (direct current) plasma arc and a second stage burner, called a plasma-fired eductor. It's marine based systems are marketed under the label Plasma Arc Waste destruction System (PAWDS), and it currently has an approximately USD 1.5 million contract with the US Navy. That their technology is good is verified by the fact that they were selected from 35 competitors for this contract. The PAWDS system can be rapidly installed and sailors operate it unsupervised after 5 days training.

PyroGenesis is planning expansion in land based systems to treat municipal waste. A 4 ton per day demonstration system has been installed in their factory, and they say they can manufacture systems from this size to 200 tons per day. Members of the Coalition visited the factory and saw this system and glassy material generated from a variety of wastes including medical waste. The land based-systems are marketed as Plasma Resource Recovery Systems (PRRS), since glassy materials are recovered for construction, metals are recovered, and synthetic gases generated which may be used to generate electricity.

The company has approximately 20 employees. It has been offered a grant from SDTC to scale its systems, but requires additional financing and project partners to take this up. It is not financed to a level to allow it to build and operate a large waste recovery system, so would have to sell the system. The company is currently seeking additional financing.

Tekna Plasma Systems Inc.
Tekna Plasma is a business operating under the license of the University of Sherbrooke. Its role is to transfer technology from the university environment to industry. The company specializes in thermal plasma technologies and operates in collaboration with the Centre de recherches en technologie des plasmas (CRTP) at the University of Sherbrooke and McGill University. Tekna Plasma Systems offers both standard and custom plasma systems for a number of applications, including powder densification and spheroidization, the production of coatings, ultra-fine powders, chemical and ceramic synthesis, and the thermal destruction of wastes.

Tekna offers its clients a modern 2000 m2 process demonstration facility for induction plasma powder treatment, powder spheroidization, nanopowder synthesis and thermal plasma spraying. Its installations are available to evaluate the technological viability of particular applications and also for small-scale commercial production runs.

Tekna Plasma Systems Inc. specializes in the manufacturing of powder processing, plasma spray systems and diagnostic instruments for plasma used in R&D fields. The product line includes three principal groups: r.f. (radio frequency) induction plasma systems, d.c. (direct current) plasma spray systems and enthalpy probe systems.

The business level is somewhere between $1,000,000 and $5,000,000 per year.

Enerkem Technologies Inc.
This is a Quebec company, which specializes in gasification technology. We have not yet had the opportunity to visit so are not able to comment on the degree of its involvement in plasma technology. It is involved in waste treatments, and has completed a project with SDTC assistance. The project was the "development of a complete technology platform for the production of alcohol biofuels derived from complex wastes, using municipal solid waste as the demonstration feedstock". The consortium members were Enviro-Access Inc, the Quebec Government, SOQUIP Energy Inc, Université de Sherbrooke and the City of Sherbrooke. Total project value was just over $2million with Sustainable Development Technology funding of $750,000. The project was approved in 2002 and has been completed. Enerkem's syngas treatment systems would certainly find application as the second stage in a plasma gasification plant. The company has just signed a contract with the City of London (England) for the installation of a plasma gasification plant on the Thames.

Fabgroups Technologies Inc.,
Located in Saint-Laurent, Quebec, Fabgroups is another Quebec company involved in plasma treatment of waste. They label their technology as plasma-assisted sludge oxidation (PASO). They state that it delivers economical reduction of biological sludge volume by a factor of 20, has low operating costs, inert resultant ash, offers a significant reduction of greenhouse gases and has the ability to generate useful heat from the sludge. Their process is intended to provide oxidation of municipal, agricultural and industrial sludges. The technology was developed at Hydro-Quebec's electrotechnology and electrochemical development center (LTEE), patented by Hydro Québec and licensed through Fabgroups Technologies Inc., PASO is based on a rotary kiln working at 600 deg. C and at atmospheric pressure, equipped with an air plasma torch.

Operating temperature is between 500 C and 600 C. The plasma arc supports the oxidation process by generating ultraviolet radiation and highly chemical active radical and ionic compounds, which catalyze the cracking and oxidation reactions by different intensities. The calorific value of the organic sludge is used as a principal heat source, generating steam). Hydro-Quebec lists the following applications of the technology:

Pulp and paper	Primary and secondary sludge
Municipal Services	Sludge from wastewater treatment plants
Agribusiness	Sludge containing fats, proteins, glucose
Other areas related to environment	Stabilization of industrial waste
	Sludge with high levels of contaminants

Our conclusion is that none of these companies would be able to provide the necessary large-scale systems in the 2008 time frame imposed by the Quebec government.

B. Some US Companies

Based on our research, there are certainly a number of US companies and international companies that feel they can provide plasma gasification systems for MSW treatment. Since we were looking for a Canadian solution, we decided not to list all the companies here.

We have already mentioned one of the companies, **Recovered Energy, Inc**., in the introductory section to this Appendix. It has no experience in building large systems, and believes that to be economical, systems should handle upwards of 3,000 tons per day. In studying their proposed systems of this size, it is clear that they would rely on plasma torches from Westinghouse Plasma Corporation, which incidentally was involved in all three of the largest systems in Japan.

We feel that it is worth commenting further on Westinghouse Plasma Corporation.

Westinghouse Plasma Corporation has the greatest experience in providing plasma gasification systems to treat industrial and municipal wastes. As noted they were involved in the largest three systems in Japan installed by Hitachi Metals for treating MSW. They have been involved in many international projects using plasma torches dating back to the 1980s.

Westinghouse manufactures plasma torches and offers Plasma Reactors as standard products. As their web site www.westinghouse-plasma.com states:

"During the last decade, Westinghouse conducted many successful experiments, designs and have developed plants involving the gasification and/or vitrification of simulated MSW (municipal solid waste), ASR (auto shredder residue), Bio-mass and other industrial liquid and solid wastes in a plasma reactor. The gasification test material feed could range from low Btu MSW (1600 kcal/kg) to high Btu, simulated auto shredder residue (4500 kcal/kg).

The Plasma Reactors converts the feed into, primarily carbon monoxide, CO and hydrogen, H2. The inorganic components of the feed get converted to molten slag which is removed as vitrified by-product."

In addition to the plasma reactors, Westinghouse Plasma operates and provides the Westinghouse Plasma Systems mobile unit, Pyroplasma, which houses in a 40 foot trailer “an advanced plasma system, which changes the molecular structure of chemical wastes; for example, changing hazardous wastes into non hazardous substances. The Pyroplasma system is unique in its ability to achieve the high temperatures required to destroy pumpable organic chemical wastes. The system has demonstrated the capability of meeting emission standards of regulatory agencies in the United States and Canada. Here is a superior alternative to landfill disposal and other treatment processes.”

We recommend that anyone not yet convinced that plasma gasification is a viable technology for dealing with hazardous and other wastes, review the Westinghouse Plasma Corporation web site. In particular, they should study the listing of some of the major projects in which this company has been involved.

Appendix 5 Emissions and Contaminant Standards for Plasma Gasification

Table 5-1. Emissions from PGP Gas Power Generation in comparison to MoEE Standards – Plasco Energy Group

Air Emissions (Monitored after combustion engine in Plasco system)	Tightened Incinerator Requirements Issued in 2004 by Ontario MOE (A-7)	European Standard	Jenbacher Engines Using Natural Gas	Jenbacher Engines Using Landfill Gas (Trail Road)	Conventional Coal-base electrical generation (world bank standards)	Standard Automobile Engine (Drive Clean)	Jenbacher Engines Using gas from Plasco Energy PGP Process for Ottawa
HCl	18 ppmv	7 ppmv* (10 mg/Rm3)	nil	10 ppmv	nil	nil	3.3 ppmv
SO2	21 ppmv	19 ppmv* (50 mg/Rm3)	1 ppmv	12 ppmv	750 ppmv	7.5 ppmv (low S gas)	3 ppmv
NOx	110 ppmv	159 ppmv* (200 mg/Rm3)	200 ppmv* (250 mg/Rm3)	200 ppmv* (250 mg/Rm3)	365 ppmv	600 ppmv	<110 ppmv
Organic Matter	100 ppmv	10 mg/Rm3	10 ppmv	100 ppmv	200 ppmv	200 ppmv	10 ppmv
Particulate Matter	17 mg/Rm3	10 mg/Rm3	10mg/Rm3	10 mg/Rm3	50 mg/Rm3		10mg/Rm3
Dioxins and Furans	80 pg/Rm3	**100 pg/Nm3**	nil	nil (See **note 1**)	low	(diesels can emit high levels of dioxins)	nil (See **note 2**)

* Converted from the format originally quoted by the specification or as applied to the engine used. The original format is found in parentheses.

Rm^3 refers to reference cubic meter. Ppmv refers to parts per million by volume.

Note 1 – In normal operation, levels of dioxins and furans are non-detectable. During equipment or process malfunctions, dioxins may be formed. During these brief and infrequent periods, combustion of landfill gas has been shown to produce up to 100 picograms/Nm3 of dioxins.

Note 2– In normal operation, the Plasco process dissociates waste to the atomic level – dioxins and furans are absent at the exit from the converter. During equipment or process malfunctions, dioxins may be formed (mainly in the gas quality control section) until the equipment is shutdown, or until the process is re-stabilized. During these short and infrequent transition periods, the facility may produce 0-30 picogram/Nm3 of dioxins and furans.

Table 5-2 Plasma Gasification Slag Leachate Toxicity Comparisons (mg/L-fully crushed sample) (1994)

Element	Biomedical Slag Leachate	Soda Bottle Leachate	Ontario Regulations
Arsenic	0.026	0.002	2.5
Barium	0.0037	0.12	100.0
Boron	0.011	0.43	500.0
Cadmium	<0.002	0.47	0.5
Chromium	<0.004	<0.01	5.0
Lead	<0.02	12.2	5.0
Mercury	0.000085	<0.0001	0.1
Selenium	0.003	0.002	1.0
Silver	<0.01	<0.02	5.0
Zinc	0.042	0.16	

Annex C

http://www.mswmanagement.com/mw_0507_landfill2.html

Landfill Economics

By Daniel P. Duffy

The following is the first of a series of three articles that will examine the costs involved in each stage of a generic landfill's lifetime, show how to do pro forma statements for profit and loss, analyze the tax and financial aspects of each stage of operation (e.g., how much to set aside annually in a sinking fund to allow for post-closure monitoring and maintenance), and illustrate the unique profitability of landfill operations given a certain minimum market share.

This first article looks at the proposed landfill's market and potential for waste receipt, as well as the site investigation, engineering, design, and permitting costs.

The second article will examine the cost of construction for site facilities and for each landfill cell. Additionally, the operating cost and disposal volume of each overlapping cell will be described to show how cash flow will change over the operating life of the landfill.

The last article will look at the costs of landfill capping and closure, installation of gas management systems, and post-closure care and maintenance costs (and how to plan ahead for each).

The first landfill location is the geometric layout of the landfill within the property. The landfill geometry should maximize the most disposal volume per acre of landfill footprint. The second landfill location avoids those areas or setbacks that either constrain or preclude landfill construction. The third landfill location is the regional location of the proposed landfill with its population and disposal rates determining potential market share.

Landfill Profitability

The two basic ru*les of landfill profit*abili*ty are volume equ*als earnings and area equals costs. Landfills are unique among industrial or construction operations in having relatively high upfront capital costs and relatively low unit operating costs (as measured in dollars per ton of waste received). This means that after a relatively high break-even point, landfill operations become very profitable as operating costs drop to literally pennies on the ton.

A landfill's capital costs are directly related to the installation of lined and capped areas. For large landfills, all other capital costs (weighing systems, office trailers, maintenance buildings, security fencing, access roads, etc.) are incidental by comparison. To offset these capital costs, the maximum amount of waste volume must be placed within the landfill's lined area. The most efficient area footprint for maximizing volume is a square landfill. For example, a square landfill with dimensions of 1,000 by 1,000 feet can have a maximum height of waste of 250 feet (with final slope of 25%, or 4 horizontal to 1 vertical).

This 25% grade is a standard established by regulations and ensures stability against mass slope failure. Access roadway earthen berms are usually tacked onto the final grades to allow for vehicle movement. These are individually designed to be stable under anticipated traffic loads. Another option is the stepped slope where the final grades are cut back into the landfill at regular height intervals. The cutbacks are usually used as access roads and are the same width. The purpose of this design is to reduce potential mass failure weight, making the slopes even more stable. However, this configuration results in a loss of potential disposal volume. To compensate for this loss, many states allow steeper than 25% slopes (up to 33% slopes) between the benches, provided the design includes a thorough analysis of all types of localized and mass slope failure.

A rectangular landfill with the same footprint area having dimensions of 500 by 2,000 feet can have a maximum waste height of only 125 feet (as determined by the smaller dimension). Both have the same lined areas and capital cost, but the second has only half the potential waste disposal volume and associated earnings.

But landfills rarely reach a peak. Typically a minimum flat area of about 4 acres is left at the top to allow enough elbow room to choreograph equipment and trucks during final closure. “Flat” indicates a minimum sloped area of at least 2% grade (1 foot vertical to 50 feet horizontal). Again assuming a square footprint, this flat area would measure approximately 400 by 400 feet. With a flat area at the top, the volume of the landfill above the existing ground surface is determined by the formula for the volume of a truncated pyramid: V = (H / 3) * (B1 + B2 + sqrt [B1* B2]) * (1/27), where V = volume (cubic yards), B1 = area of the landfill footprint (square feet), B2 = area of the contour elevation lines (square feet), and H = landfill height above existing ground surface (feet).

The maximum allowable height of a landfill is usually limited by local ordinance. Depending on the landfill’s location, the local government will set limits on how high it can go to minimize the landfill’s visual impact on its surroundings. Isolated landfills, or those located in terrain that is already hilly, will tend to be higher than those close to communities or on flat terrain. If no local or state regulation mandates a maximum height of the landfill, its height will be indirectly limited by the effects of the waste loading on the landfill’s structural elements or underlying hydrogeology. A mass of waste that results in the crushing of leachate collection pipes at the bottom of the landfill or that results in severe foundation settlement under the landfill would not be allowed.

So assuming a hypothetical landfill with a top flat area of almost 4 acres (400 by 400 feet, or 160,000 square feet), final grades of 25% and a maximum height of 100 feet, its footprint area would be 1,440,000 square feet (1,200 by 1,200 feet). Its volume above the existing ground surface would be calculated as follows: V = (100 / 3) * (1,440,000 + 160,000 + 480,000) * (1/27); V = (100 / 3) * (2,080,000) * (1/27); V = 2,568,000 cubic yards (approximate).

A similar computation is done to determine the volume of the landfill below existing grades. The maximum allowable depth of a landfill is usually determined by hydrogeological considerations such as the need to maintain a minimum vertical isolation distance between the landfill’s liner and the highest recorded groundwater level. Also, the sideslopes of the excavation performed to establish the grades of the landfill’s liner system are no steeper than 33% (1 vertical to 3 horizontal). Using the above example, and assuming a maximum depth of 33 feet, the flat landfill bottom would have an area of 1,000 by 1,000 feet, or 1,000,000 square feet. Like the top of the landfill, the bottom is not truly flat but has a shallow grade (to promote leachate collection) of 1% or 2%. Its volume below the existing ground surface would be calculated as follows: V = (33 / 3) * (1,440,000 + 1,000,000 + 1,200,000) * (1/27); V = (33 / 3) * (3,640,000) * (1/27); V = 1,483,000 cubic yards (approximate).

Total landfill volume would be 4,051,000 cubic yards. For purposes of planning, the landfill capacity should be rounded to an even 4 million cubic yards. Given the limits of surveying accuracy (even with GPS), greater accuracy on this scale is neither possible nor necessary.

The landfill’s footprint is a little over 33 acres. Of these acres, approximately 29.33 are 25% final grades. Being sloped, these have a surface area 1.03 times greater than the flat footprint area, or 30.2 acres. Final surface grades needing cap and cover are therefore approximately 1 acre greater than the footprint, or 34.0 acres. The bottom of the landfill includes approximately 10.1 acres at 33% grades. These slopes have a surface area 1.05 times greater than the flat footprint area, or 10.6 acres. The bottom grades needing a liner and leachate system are therefore approximately 0.5 acre greater than the footprint, or 33.5 acres. Total acres of landfill construction (cap and liner) are 67.5 acres, giving a ratio of volume to area of almost 60,000 cubic yards per constructed acre. This number is the primary metric in determining a landfill’s profitability.

Landfill Location
Subtitle D of the Resource Conservation and Recovery Act details the regulations governing the

siting, construction, operation, and closure of municipal solid waste landfills. There are six areas defined by Subtitle D where the construction of a landfill is effectively precluded: near airports, in floodplains, in wetlands, on fault lines, within seismic impact zones, and over unstable areas.

No landfill or portion of a landfill can be located within 5,000 feet of an airport runway servicing propeller-driven aircraft or within 10,000 feet of a runway servicing turbojet aircraft. As landfills attract birds and other vectors, the setback is designed to minimize the potential for bird strike on aircraft. Though it is possible to do a demonstration study that purports to show that the potential for bird strike is insignificant for a location near an airfield, it is very unlikely that a regulatory agency will approve any such demonstration given the grave risks involved. Practically speaking, no property near an airfield should be considered for landfill development.

No landfill or portion of a landfill can be located within the limits of a floodplain resulting from a 100-year storm event. These limits are usually defined by flood insurance rate maps published by FEMA. It is possible that infringement on a floodplain will not result in significant restriction of floodway flow rates and reduction in temporary water storage, or that the flood will not cause significant erosion and washout of landfill waste; however, regulatory agencies are very cautious about allowing such construction, which would require significant (and expensive) armor rock protection of the landfill's outboard slopes.

Landfills cannot be constructed in or near wetlands because they might reduce water quality, jeopardize the existence of endangered species, degrade or reduce the wetland, impact fish and wildlife, or threaten a catastrophic release or toxic discharge from the landfill. Any landfill operator would have to show the regulatory agency that such degradation is not possible. State and federal agencies are extremely protective of wetlands and typically will require an absolute standard of assurance. Furthermore, every acre of wetlands lost to landfill construction has to be mitigated (new wetlands constructed to replace the destroyed wetlands), often at a ratio of 5 new acres to 1 destroyed acre. Like properties containing floodplains, properties with wetlands can still be used for landfill development, but such properties will have the extent of landfill construction severely constrained.

Potentially unstable geological conditions (fault lines, karsts topography, and seismic impact zones) are to be avoided by landfill developers. No landfill can be located within 200 feet of a fault line that has experienced movement in recent (Holocene) time. A fault zone 400 feet wide effectively precludes most landfill construction. Seismic impact zones are those areas with a 10% or greater probability that the maximum horizontal acceleration in lithified earth material, expressed as a percentage of the earth's gravitational pull (g), will exceed 0.10 g in 250 years. Landfills in seismic zones must be redesigned to withstand potential seismic forces (flattened slopes with expensive loss of disposal volume, or expensive reinforced construction). Though the regulations only forbid landfills directly over unstable, cavernous terrain, the potential effects of such terrain extend far beyond their boundaries. A relatively small cavern that develops into a sinkhole as a result of landfill disposal overburden may shift earth hundreds of feet away. Trying to accurately predict the potential extent of such damage is almost impossible.

So of the forbidden areas, only airports completely negate a property's landfill development potential. Floodplains, wetlands, and unstable geology will severely restrain landfill development over a large portion of a property. These would then require either the expensive purchase of property that can't be developed or an even more expensive capital cost for engineering and construction to mitigate their potential for damaging the landfill. The ideal landfill location, from a cost-minimization point of view, would avoid all of these restricted areas.

Potential Market-Area Share

A landfill's potential market area is typically limited to the county it is located in and the ring of counties immediately adjacent to the landfill's county. Additional sources of waste include long-haul waste from transfer stations outside of the landfill's immediate market area, river-barged waste if the landfill is adjacent to a navigable river, and rail haul waste if the landfill is adjacent to an active rail spur. For the purpose of this hypothetical analysis, the landfill's market will be conservatively limited to its county and adjacent counties.

Also for the purposes of this analysis, the hypothetical landfill described above will be located in a county (county A) with seven surrounding counties (counties B through H), eight counties total. The counties are a mix of urban and rural areas with varying populations and population growth rates (see Table 1).

Table 1.

COUNTY	POPULATION (current)		RECENT GROWTH RATES (last three years)
A	178,070		8.20%
B	62,520		1.90%
C	33,906		-0.50%
D	29,105		-2.60%
E	53,555		1.90%
F	193,097		1.50%
G	752,366		8.20%
H	145,986		17.90%
Total	**1,448,605**	**Average**	**4.56%**

According to the EPA, the average American throws away 4.5 pounds of municipal solid waste each day. Urban counties tend to have higher rates of recycling and incineration than rural counties. Urban areas on average landfill 60% of their waste, while rural counties tend to landfill approximately 70%. These factors determine the total daily average waste disposal for the market area (see Table 2).

Table 2.

COUNTY	POPULATION (current)	DAILY WASTE GENERATION (4.5 lb per capita)	AMOUNT LANDFILLED (EPA data)	AMOUNT LANDFILLED (lb/day)	AMOUNT LANDFILLED (tpy)
A	178,070	801,315	60%	480,789	87,744
B	62,520	281,340	70%	196,938	35,941
C	33,906	152,577	70%	106,804	19,492
D	29,105	130,973	70%	91,681	16,732
E	53,555	240,998	70%	168,698	30,787
F	193,097	868,937	60%	521,362	95,149
G	752,366	3,385,647	60%	2,031,388	370,728
H	145,986	656,937	60%	394,162	71,935
Total	**1,448,605**	**6,518,723**		**3,991,822**	**728,508**

Though landfill profits are directly related to tons received at the gate, landfill operations are based on cubic yards of airspace utilized for disposal. For planning purposes, the compacted, in-place density of waste should be about 0.55 tons per cubic yard (40 pounds per cubic foot). Using this conversion factor allows us to estimate annual airspace utilization and plan the operational lifetime of the proposed landfill (see Table 3).

Table 3.

COUNTY	AMOUNT LANDFILLED (tpy)	AIRSPACE UTILIZATION (yd³/yr)	AIRSPACE UTILIZATION (ac*ft/yr)
A	87,744	159,535	99
B	35,941	65,347	41
C	19,492	35,440	22
D	16,732	30,422	19
E	30,787	55,976	35
F	94,149	171,180	106
G	370,728	674,051	418
H	71,935	130,791	81
Total	**727,508**	**1,322,742**	**820**

The hypothetical landfill described above with a disposal volume of 4 million cubic yards represents approximately three years' worth of disposal capacity of the entire market area. At a volume-to-area ratio of 60,000 cubic yards per acre, the proposed landfill (on average) will require the construction of 22 acres per year. Assuming the landfill captures only 10% of the market share, it will operate for 30 years constructing 2 to 3 acres per year of lined area.

Now that the total market and its growth rate have been established, the local competition can be examined. Sometimes a landfill will publish its data on amount of tonnage received, but often this information is proprietary. All that is typically published is the maximum allowed tonnage as mandated by the landfill's operating permit. What is usually easier to get is tipping fees. Table 4 summarizes what is known about the hypothetical landfill's competition.

Table 4.

COUNTY	AMOUNT LANDFILLED (tpy)	LANDFILLS IN COUNTY	DISPOSAL RATE (tpd)	TIPPING FEES ($/ton)	POTENTIAL MARKET ($/yr)
A	87,744	1		$32.00	$3,544,858
B	35,941				$1,452,016
C	19,492				$787,477
D	16,732	1	1,800	$40.00	$675,973
E	30,787	1		$30.00	$1,243,795
F	94,149	1	850	$58.00	$3,803,620
G	370,728	1	440	$42.00	$14,977,411
H	71,935				$2,906,174
				Average	
Total	**727,508**	**5**		**$40.40**	**$29,391,323**

The projections in Table 4 estimate a total annual waste disposal market of approximately $29 million per year at an average tipping fee of approximately $40 per ton.

Assuming that the proposed landfill is located in county A (as a replacement for the old, existing landfill), truck routes ensure that it will get the bulk of the waste in counties B and C, and it gets 10% of the waste in counties D through H, then it can expect an annual disposal rate of approximately 200,000 tpy. At an average tipping fee of $40, its projected annual gross revenues would be $8,000,000. These revenues can be expected to increase at roughly the same rate as the market area's population, approximately 4.5% per year.

At 200,000 tpy, the landfill will utilize approximately 363,000 cubic yards of airspace per year. With a total capacity of 4 million cubic yards, its projected operational lifetime would be 11 years.

Site Investigation and Hydrogeological Studies

Instead of directly purchasing a property for landfill development, the landfill operator typically buys an option to purchase the property at a given price at a later date. Prior to final purchase, a thorough investigation of the site's hydrogeology is performed. This investigation is often more important to the state regulatory agency than the subsequent engineering design and permit application. The cost of a purchase option can vary wildly depending on the location and inherent value of the land, anywhere from $10 to $1,000 per acre. Furthermore, the property to be purchased may be larger than what is required for landfill development, including areas where the landfill location regulations preclude landfill development.

The state regulations will mandate the format and contents of the hydrogeological investigation. These include (at minimum)

- determination of background groundwater quality;
- site map showing existing wells, properties' soil borings, bodies of water, wetlands, surface drainage features, and regional topography;
- observation well records and soil borings to identify and locate local aquifers;
- groundwater elevation map showing stabilized water-level readings and groundwater flow directions;
- evaluation of site soils and earth materials including soil classifications, strength characteristics, in-place densities, and location of bedrock; and
- a series of geological cross-sections illustrating the site's hydrogeology.

The number, location, and spacing of exploratory borings and the number, location, and spacing of monitoring wells are usually arrived at by negotiations with the state regulatory agency. These "negotiations" often take the form of multiple cycles of hydrogeological investigation plan submittal and regulatory review and comment, followed by resubmittal. As a result, the cost of a hydrogeological study can also vary widely. The plan writing itself typically costs less than $100,000, but the physical site investigation may bring the total cost up to $500,000. Each plan and review iteration (which may require additional fieldwork) could add more than $100,000 per resubmittal.

As a follow-up to the site investigation study, the landfill operator will need to prepare and submit a series of site monitoring plans for air, dust, surface water, landfill gas, and especially groundwater. The plans will detail the location frequency and methodology for each type of sample and describe testing procedures and statistical methods used for analyzing the test results. Again, the cost of these plans could be measured in hundred-thousands of dollars and be subject to multiple submittal-review-revision cycles.

Engineering Design and Permitting

Someone once said that "those who love both sausage and the law should not watch either one being made." Though not nearly as bad, the permitting process can be similar.

The elements of landfill engineering design are simple and straightforward. Each state has basic standards for construction that have to meet the minimum requirements of the federal Subtitle D regulations. These standards dictate the overall dimensions of the landfill's components. Some states require 5 feet of clay in the liner; others require only 3 feet. Some require a double liner and matching double-layered leachate collection system, while others allow landfills to get by with only a single liner and leachate system.

The style, contents, and format of the design presentation itself are often spelled out in a state's waste regulations. Other states allow the engineer to present the design in any format he or she pleases, provided it is coherent and includes all of the information required by the regulations. Either way, a landfill permit design contains five categories of documents: plan drawings, detail drawings, engineering computations, material and construction specifications, and supporting documentation. Each engineering design permit submittal will typically cost between $100,000 and $200,000. As with the other submittals, this is subject to multiple cycles of review and revision—even if the engineering is accurate, complete, and well thought-out.

Summary: Time and Money

Not to put too fine a point on it, the process of landfill development and permitting can be very expensive and time-consuming. A good rule of thumb is five years from conception to the first day of operations with costs

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Part 2

Part I examined a hypothetical landfill's market and potential for waste receipt; as well as its site investigation, engineering, design, and permitting costs.

This second article examines the cost of construction for site facilities and for each landfill cell. Additionally, the operating cost and disposal volume of each overlapping cell are described to show how cash flow will change over the operating life of the landfill.

Part III will look at the costs of landfill capping and closure, installation of gas management systems, and post-closure care and maintenance costs (and how to plan ahead and provide financial assurance for each).

The Hypothetical Landfill

As laid out in the previous article, the total landfill volume would be approximately 4 million cubic yards. The landfill's footprint is square with dimensions of 1,200 feet, and is a little over 33 acres. Because of sloping, the final surface grades needing cap and cover are approximately 34 acres. Similarly, the bottom of the landfill needing a liner and leachate system is 33.5 acres. Total acres of landfill construction (cap and liner) is 67.5, giving a ratio of volume to construction area of almost 60,000 cubic yards per constructed acre.

The landfill is located in an area with a waste disposal market of approximately $29 million dollars per year at an average tipping fee of approximately $40 per ton. Assuming that the landfill gets the bulk of the waste from three counties in the market area and 10% of the market in the remaining five counties in the market area, then it can expect an annual disposal rate of approximately 200,000 tons per year. At an average tipping fee of $40, its projected annual gross revenues would be $4.4 million. These revenues can be expected to increase at roughly the same rate as the market area's population, approximately 4.5% per year. At 200,000 tons per year, the landfill will utilize approximately 363,000 cubic yards of airspace per year. With a total capacity of 4 million cubic yards, its projected operational lifetime would be 11 years. During that operating life, the landfill will construct an average of 3 acres of lined cells and/or final cover each year.

Landfill Construction Costs

Up to this point, the landfill operator has completed (and spent money on) a complete landfill siting and hydrogeological study. This included a topographic survey of the site and the establishment of highest stable groundwater elevation contours. All of this site information has been graphically represented by site plans and cross sections. With this data, the landfill designer was able to complete and obtain approval for a landfill design that includes a layout of the landfill footprint, its maximum excavation depths (and its total excavation volume), location of all of the ancillary site features and support facilities (scale, access roads, security fence, parking lot, office trailer, etc.), the maximum landfill height above existing grades, the location and extent of surface water runoff, and sedimentation management controls.

Prior to any construction, the landfill site will be cleared and grubbed. Depending on the nature and extent of the existing vegetation, the costs of clearing and grubbing can run from $1,000 to $4,000 per acre, with $3,000 being typical. At minimum, those areas that will require initial construction (the ancillary facilities and structures areas and the initial waste disposal cell) will require clearing and grubbing. However, to avoid multiple mobilization costs for the clearing and grubbing contractor, the entire site may be cleared and grubbed at once. Subsequent site maintenance can be performed to prevent the growth of woody vegetation during the lifetime of the landfill. Cleared wood can be either hauled offsite or chipped onsite and stockpiled for future use as mulch.

A site survey was performed previously (either as a ground survey or an aerial survey) as part of the hydrogeological evaluation. During this survey, benchmarks were established, site features located and topographic contours drawn. A second site survey is required to stake the various construction areas of the site. This staking includes building corners, roadway centerlines, and a grid staking of the first waste disposal cell. Grids should be laid out at 50-foot intervals aligned with the limits of the landfill. Survey stakes should also be set at 50-foot intervals along slope break lines (crest of slope, toe of slope, along the center leachate collection pipeline, etc.). The cost of grade surveying can run from $5,000 to $8,000 per acre, with $7,000 being typical. Additional survey shots will be taken at these grid points and break line points through the cell excavation and construction process, but this is done as part of quality assurance/quality control, and is done to ensure establishment of proper slope and grades. The costs of these tasks should be included in the QA/QC effort.

Once the site has been surveyed, staked, cleared and grubbed (and while ancillary facilities and structures are being built) work can begin on the landfill itself. The first step is to establish liner construction grades and elevations by excavation and/or placement of structural fill. Most landfill construction requires excavation within the landfill and the use of the excavated soil (if it is suitable for construction purposes) to construct structural fill berms around the landfill perimeter. Excavation in good soil can cost between $2 and $6 per bank cubic yard. Structural fill soil berms can cost between $6 and $10 per cubic yard.

Exceptionally stiff subsoils, shale, and rock formations may require blasting prior to excavation. Though some stiff soil may be broken up by a dozer ripper attachment, it is usually more cost-effective to blast. Blasting costs (drilling, setting charges, explosives, safety requirements) will be at least an equivalent of an additional $1 per bank cubic yard, with prices falling for larger volume excavations.

Conversely, certain unsuitable soils—such as peat moss and other highly organic soils—must be completely removed from underneath the landfill, and beyond the landfill limits if necessary. Such excavation usually costs twice that of normal soil excavation and will require an equivalent amount of structural fill soil backfill. This results in a cost per bank cubic yard of $10 to $22.

For our hypothetical landfill the maximum average excavation depth is 33 feet. Assuming that blasting is not required and unsuitable organic soils are not present, the average amount of excavation per acre is 50,000 to 55,000 cubic yards. Excavation volumes will be less along the landfill boundary due to the need for 33% slopes to establish grades, and will be greatest over the "flat" floor of the landfill's center. Excavation costs per acre will run from $100,000 to $330,000 per acre.

The landfill is assumed to have a minimal structural fill berm constructed along the landfill's perimeter to provide anchoring for the liner elements and structural toe stability for the final waste slopes. With 10-foot height and 33% interior and exterior slopes, this berm will require 11 cubic yards of fill soil per linear foot (varying somewhat with the lay of the land). The total perimeter of the hypothetical landfill is 4,800 linear feet, resulting in a berm of approximately 53,000 cubic yards. With a landfill footprint of 33 acres, the average amount of perimeter berm constructed per acre would be 1,600 cubic yards. The perimeter berm cost per acre would be between $10,000 and $16,000. This is just an average for long-term planning purposes. The landfill's geometry is such that the actual amount of berm required per acre will vary greatly during construction (acres adjacent to corner boundaries will require more berm, acres in the middle of the landfill will require none).

Once the base grades have been established, the landfill's liner and leachate management system can be constructed. Most states require only a single liner and leachate system for municipal solid waste, and require a double system for hazardous waste landfills only. The lowest element of the liner/leachate system is the compacted clay liner. The construction of a clay liner is much more stringent in terms of material specifications, construction effort, and quality assurance. The required in-place density and moisture content will be determined by Proctor curves and tested by Boutwell test pads to assure that the maximum allowable permeability is achieved (usually 1 x 10ee-7 cm/sec). The results of these analyses and field tests will determine the weight of the compacting equipment, the penetrating length of the compactors sheepsfoot pad, the number of passes required to achieve compacted density, and the field moisture content required for the construction effort. The cost of a clay liner runs from $10 to $20 per cubic yard (depending on the ready availability and quality of the clay). State agencies require clay liners with a minimum thickness of 2 feet to 5 feet, resulting in the need for 3,200 cubic yards to 8,100 cubic yards per acre. The cost per acre of clay liner construction will vary from $32,000 to $162,000. A well-chosen landfill site with sufficient good clay onsite will tend to have lower costs.

After the clay liner has been constructed and certified, work can begin on the geosynthetic components of the liner and leachate management systems. A composite liner system consists of the clay liner overlain by a high density polyethylene (HDPE) geomembrane. As with any other plastic, the cost of geomembrane can vary wildly depending on the current price of oil. This price may even change during the course of a single construction season if a summertime gas shortage increases the price of oil (yet strangely, the cost of geomembrane never seems to fall as the result of a sudden gas glut). The thickness of the geomembrane used in liner systems is typically 60 mils. Smooth geomembrane is used on the flat floors of the landfills while roughened geomembrane with a textured surface is used on the 33% side slopes. The cost of smooth geomembrane can vary from $0.50 per square foot to $0.75 per square foot. Textured geomembrane will tend to cost $0.20 per square foot more than the smooth variety.

The hypothetical landfill has a total lined area of 33.5 acres divided into 23 acres of floor and 10.5 acres of slope. An average lined acre will have approximately 70% smooth geomembrane and 30% textured membrane resulting in a cost of installed geomembrane varying from $24,000 to $35,000 per acre. The actual cost per acre will vary based upon geometry of the landfill and the location of the cell being constructed.

Some sort of protective geotextile is installed immediately above the geomembrane to provide a cushion and minimize impingement of the liner. This can be either a simple geotextile or more often a geocomposite drainage blanket. The geocomposite consists of a factory bonded three-layer sandwich: nonwoven geotextile bottom cushion, geonet drainage medium, and a top geotextile filter. It provides both protection for the underlying geomembrane and more rapid removal of leachate. The costs of two-sided geocomposites with 8-ounce per square yard nonwoven geotextile layers will vary as with the geomembranes, with a typical price range from $0.75 to $1.00 per square foot. The total cost per acre of geocomposite varies from $33,000 to $44,000.

Above the geocomposite is a layer of high permeability granular material (sand and aggregate). Typically, a minimum thickness of 2 feet is required, resulting in a total granular volume of 3,200 cubic yards per acre. The cost of granular material, like the cost of clay, will vary wildly depending on local availability and quality. The cost of granular material can range from $15 to $20 per cubic yard, resulting in a per acre cost of $48,000 to $64,000. Often, a geotextile filter blanket is placed above the granular soil layer, but this is not recommended.

Installed within the granular soil layer are the leachate collection pipes and fittings, gravel pipe mounds, collection sumps, extraction pumps, force mains and storage tanks. The pricing of each component is unique, but can be roughly prorated on a per acre basis.

Assuming a parallel spacing of 200 feet, each acre will have approximately 220 linear feet of leachate collection pipes. With a unit price per foot ranging from $4 to $8, the cost per acre would be $880 to $1,760.

The amount of aggregate filter material mounded around and above the collection pipes to a height of 3 feet will cost $20 to $25 per linear foot of pipe (this includes any separation geotextile installed on the aggregate). The total cost per acre would be between $4,400 and $5,500.

One leachate collection sump is installed per disposal cell. A typical cell covers an area of approximately 10 acres. The collection sump requires intricate welding of the geomembrane, more extensive QA/QC testing as this is the point where leachate accumulates, and the installation of large diameter (18 inches and larger) riser pipes. Total cost for a sump installation can be about $15,000 to $20,000, resulting in a pro rated per acre cost of $1,500 to $2,000.

Each leachate sump and riser assembly will house extraction pumps, discharge hoses, pipe fittings, and connections. The cost of these components will be between $8,000 and $12,000, resulting in a pro rated per acre cost of $800 to $1,200.

An above-ground leachate storage tank (5,000-gallon capacity minimum) will be installed on average for every 100 acres of landfill. At a cost of $50,000 to $100,000, the pro rated per acre cost would be $500 to $1,000.

Connecting the leachate extraction risers to the leachate storage tanks is a series of double-walled (minimum 4-inch interior diameter) HDPE force mains. The cost of trenching, pipe, installation, bedding, and backfill can range between $20 and $25 per linear foot. Assuming one pipeline per storage tank (or per 100 acres of landfill area) and a distance of 1,000 linear feet, the pro rated cost of the force main would be $200 to $250 per acre.

The total cost per acre of the leachate management system would be between $8,000 and $12,000 (approximately).

In addition to the physical acts of construction and installation, management and quality oversight is required. This is typically done by independent third-party consultants and breaks down as follows:

- Geomembrane liner construction management costs from $18,000 to $20,000 per acre.
- Clay liner construction management costs from $2,000 to $4,000 per acre.
- Overall project management costs from $12,000 to $16,000 per acre.
- Construction surveying and drawings costs from $6,000 to $10,000 per acre.
- Earthwork (structural fill and excavation) QA/QC costs from $15,000 to $20,000 per acre.
- Liner (clay and geomembrane) QA/QC costs from $16,000 to $20,000 per acre.
- Leachate management system installation QA/QC costs from $6,000 to $9,000 per acre.

Total overhead and quality control would therefore range from $75,000 to $100,000 per acre.

Table 1 summarizes the above initial construction costs and the typical cost per acre of landfill construction.

Table 1. Typical Construction Costs				
Clear and Grub	$	1,000	$	3,000
Site Survey		5,000		8,000

Excavation		100,000		330,000
Perimeter Berm		10,000		16,000
Clay Liner		32,000		162,000
Geomembrane		24,000		35,000
Geocomposite		33,000		44,000
Granular Soil		48,000		64,000
Leachate System		8,000		1002,000
QA/QC		75,000		100,000
TOTAL		$336,000		$774,000

The cost of constructing a landfill can range from $300,000 to $800,000 per acre, with the main cost difference due to availability of clay and ease of excavation. For the purposes of this study, the hypothetical landfill will be assumed to be well sited with ample clay and easy excavation. Its cost of construction per acre will be approximately $350,000.

Support Facilities Construction Costs

Typically all of the ancillary structures and facilities (with the possible exception of the access roads) are constructed up front. Assuming a square landfill footprint of 1,200 feet by 1,200 feet, the landfill's perimeter access road would have a length of approximately 1,250 along each side for a total of 5,000 feet. Given the possible setbacks from the property line required by the state regulatory agency, and the area required for other facilities, the security fence could be approximately 6,000 feet. Cost for support facilities and structures are summarized as follows:

- Each building's cost will depend on its function and may vary as much as $10 to $100 per square foot. Office buildings will cost between $60 and $100 per square foot, maintenance buildings between $50 and $70 per square foot, with shacks and tool sheds closer to $10 to $20 per square foot. Assuming 10,000 square feet of maintenance and 3,000 square feet of office space, the cost of onsite buildings will range from $680,000 to $1 million.

- Fencing costs between $10 and $20 per linear foot with gates costing between $1,000 and $2,000 per linear foot. Signage placed along the fence (usually at 200-foot intervals) will cost between $10 and $20 each. Total security barrier costs would range from $65,000 to $130,000.

- Modular truck scales and associated computer systems can cost between $100,000 and $150,000 each (one per landfill)

- Wheel wash facilities can cost between $200,000 and $250,000 (one per landfill).

- Gravel roads cost between $1 and $2 per square foot while asphalt roads cost between $6 and $9 per square foot. Assume only gravel roads and parking lots are constructed with a 24-foot width at 5,000 linear feet. The total access road costs would range from $120,000 to $240,000.

- Total support facility and ancillary structure costs would range from $1.165 million to $1.77 million. Given its size, it is assumed that the hypothetical landfill will need minimal support facilities and is located so as to minimize costs at $1.2 million.

Disposal Fees and Operations Costs

As previously stated, the landfill is in a market area with an average tipping fee of $40 per ton. Each landfill acre will have an average disposal capacity of 60,000 cubic yards. At an average in-place density of 0.55 tons per cubic yard, this is equivalent to 33,000 tons per cubic yard. Therefore, each acre has a gross profit potential of $1.32 million (though this will vary significantly during the lifetime of the landfill since some cells will be able to place waste in masses that overlay the slopes of previous waste disposal cells). The entire 33-acre landfill has a gross profit potential of approximately $43.5 million.

By comparison the 33.5 acres of liner construction will cost $11.725 million. With the support facilities and structures, the total capital costs prior to final closure would be approximately $13 million.

Operating costs involve staffing, utilities, equipment operations (leasing or loan payments, fuel, oil, lubricants, maintenance, etc.), leachate disposal and treatment, scale operations, paperwork, recordkeeping, billings, engineering staff and services, environmental monitoring, and daily cover applications. Equipment is the single largest operating cost closely followed by daily cover.

At 200,000 tons per year, the average daily waste receipt would be between 500 and 600 tons (a relatively large amount by real world standards). At minimum, this landfill would require

- A front end loader for onsite hauling of bulk material and small construction tasks (CAT 950 or equivalent).
- A dozer (CAT D7 or D8) equipped with a trash rack to spread dirt and waste.
- A steel, wheeled compactor (CAT 826G or equivalent) to compact the waste and achieve maximum possible in-place density.
- Additional equipment such as water spray trucks (to hold down dust), scraper, backhoe, several pickup trucks, and a road grader.

The total unit cost of operations is relatively small compared to the landfill's capital costs. This makes landfill economics unique among industrial or construction operations (a landfill is both). As a percentage of the tipping fee, operating costs can run from 5% to 15%. Larger landfills will have a smaller percentage. Table 2 provides a summary of typical annual operating costs.

Table 2. Typical Operating Costs	
Operations (equipment, staff, facilities and general maintenance)	$500,000
Leachate Collection and Treatment (assumes sewer connection and discharge cost of $0.02/gal.)	$10,000
Environmental Sampling and Monitoring (groundwater, surface water, air gas , leachate)	$30,000
Engineering Services (consulting firms and in-house staff)	$60,000
This is equivalent to $3 per ton, or 7.5% of the tipping fee	

Determining Cash Flow

The cost of the support facilities and ancillary structures is incurred prior to the start of landfill operations, in Year 0, $1.2 million. The first three acres of lined cells will also be constructed in Year 0 at a cost of $350,000 per acre, or $1.05 million. The total costs incurred in Year 0 would therefore be $1.55 million.

On average, each year will require the construction of another 3 acres at a cost of $1.05 million. However, larger areas may be constructed at greater intervals, such as 9 acres every 3 years. Annual operating costs will be $600,000 for a total average annual cost of $1.65 million.

Each year, the site receives 200,000 tons and charges a tipping fee of $40 per ton. This results in annual gross revenues of $8 million. This results in an annual “net” profit (before interest and taxes) of $6.35 million. Assuming that no final cover is constructed during the first year of operations, the payback period for the initial start-up costs in Year 0 is about 3 to 3 months. However, this does not include annual costs for partial installation of final cover or disbursements to a sinking fund to cover the costs of the 30-year post-closure care.

Part 3

The first article examined a hypothetical landfill’s market and potential for waste receipt; as well as its site investigation, engineering, design and permitting costs.

The second article examined the cost of construction for site facilities and for each landfill cell. Additionally, the operating cost and disposal volume of each cell was described to show how cash flow will change over the operating life of the landfill.

This last article looks at the costs of landfill capping and closure, installation of gas management systems, and post closure care and maintenance costs (and how to plan ahead and provide financial assurance for each).

The Hypothetical Landfill

As described in the first article, we are using a hypothetical landfill to illustrate the financial aspects of landfill operations. This landfill has the following characteristics:

- Total landfill volume is approximately 4-million cubic yards.
- The landfill’s footprint is square, having dimensions of 1,200 feet, and is a little over 33 acres.
- The final surface grades needing cap and cover are approximately 34.0 acres.
- The area of the bottom of the landfill needing a cap and leachate system is 33.5 acres.
- Total acres of landfill construction (cap and cap) is 67.5 acres, giving a ratio of volume to construction area of almost 60,000 cubic yards per constructed acre.

The landfill is located in an eight-county area and services all or part of the waste-disposal needs of each of the counties. The local waste disposal market can be described as follows:

- a total waste disposal market of approximately $29 million dollars per year;
- an average tipping fee of approximately $40.00 per ton;
- of this amount, the landfill has an annual disposal rate of approximately 200,000 tons per year; and
- its projected annual gross revenues would be $4.4 million.

The landfill construction and operations will occur in the following stages, with their associated costs:

- the landfill will utilize approximately 363,000 cubic yards of airspace per year;
- its projected operational lifetime is 11 years;

- the landfill will construct an average of 3 acres of lined cells and/or final cover each year;
- support facilities and ancillary structures, which are constructed first, will cost about $1.2 million;
- the landfill's cost of construction per lined acre will be approximately $350,000; and
- total annual operating costs will be $600,000 (equivalent to $3 per ton, or 7.5% of the tipping fee).

Landfill Closure Costs

The first step in landfill closure is the surveying of the surface to receive final cap and cover. Surveying is performed throughout the operational lifetime of the landfill and its individual disposal cells to track airspace utilization and ensure that minimum and maximum slopes are adhered to. These activities are best included with the costs of landfill operations (as described in the second article). However, as the landfill or cell reaches its final development grades a formal survey is performed to ensure that actual grades and elevations do not exceed those in the permit design. Usually, this final survey is performed at 100-foot grid points and at 100-foot intervals along major breaks in the slope line. This is fewer survey points than is typically required to establish grades for cell and cap construction, so the cost per acre is less expensive. The cost of final grade surveying can run from $3,000 to $6,000 per acre with $5,000 being typical.

Once the final waste grades have been certified by the surveyor to be at final design grades, construction can begin on the final cap and cover. The first layer to be installed in the final cover system is the gas management layer. This is usually a loose layer of soil spread into place to allow the free migration of landfill gas under the cap and prevent the accumulation of gas pockets. Extreme care has to be used when choosing and placing this material. Purely cohesionless soil, such as sand, may not have the internal strength required to repent the slippage failure of the overlying cap. Cost per cubic yard will vary from $15.00 to $20.00. The cost per acre of gas management layer construction will vary from $24,000 to $32,000. Sometimes a geocomposite blanket is used instead of loose soil, but this tends to clog over time.

A compacted clay cap is then constructed over the gas management layer. The construction of a clay cap is stringent in terms of material specifications, construction effort, and quality assurance. The effort is made more complicated by the fact that the clay is often being compacted over an unstable or soft trash surface. The required in-place density and moisture content will be determined by Proctor curves and tested by Boutwell test pads to assure that the maximum allowable permeability is achieved (usually 1 x 10ee--5 cm/sec). The results of these analyses and field tests will determine the weight of the compacting equipment, the penetrating length of the compactor's sheepsfoot pad, the number of passes required to achieve compacted density and the field moisture content required for the construction effort. The cost of a clay cap runs from $8.00 to $16.00 per cubic yard (depending on the ready availability and quality of the clay). State agencies require clay caps with a minimum thickness of 2 feet, resulting in the need for 3,200 cubic yards per acre. The cost per acre of clay cap construction will vary from $26,000 to $51,000. A well-chosen landfill site with sufficient good clay onsite will tend to have lower costs.

After the clay cap has been constructed and certified, work can begin on the geosynthetic components of the final cap. A composite cap system consists of the clay cap overlain by a high density polyethylene (HDPE) geomembrane. As with any other plastic, the cost of geomembrane can vary wildly depending on the current price of oil. This price may even change during the course of a single construction season if a summer time gas shortage increases the price of oil (yet, strangely, the cost of geomembrane never seems to fall as the result of a sudden gas glut). The thickness of the geomembrane used in cap systems is typically 40 mil. Smooth geomembrane is used on the flat final grades of the landfills while roughened geomembrane with a textured surface is used on the 25% slopes and terraces. The cost of smooth geomembrane can vary from $0.40 per square foot to $0.50 per square foot. Textured geomembrane will tend to cost $0.15 per square foot more than the smooth variety. Often very low-density polyethylene (VLDPE) geomembrane may be used in the cap instead of HDPE.

The hypothetical landfill has a total lined area of 34 acres divided into 4 acres of flat grades and 30 acres of steep slopes. An average lined acre will have approximately 90% smooth geomembrane and 10% textured geomembrane resulting in a cost of installed geomembrane varying from $18,000 to $23,000 per acre. The actual cost per acre will vary based on the geometry of the landfill and the location of the cell being constructed.

To prevent the build-up of percolating precipitation on the impermeable geomembrane cap, a geocomposite drainage layer is installed. This layer will window out somewhere downslope at discreet points to vent percolation back to the surface as runoff. The geocomposite consists of a factory-bonded three-layer sandwich: nonwoven geotextile bottom cushion, geonet drainage medium, and a top geotextile filter. The costs of two-sided geocomposites with 8-ounce-per-square-yard nonwoven geotextile layers will vary as with the geomembranes, with a typical price range from $0.75 to $1.00 per square foot. The total cost per acre of geocomposite varies from $33,000 to $44,000.

Above the geocomposite is a layer of protective cover soil thick enough and fertile enough to support a thick growth of vegetation, and to provide enough protection against frost penetration. Typically, a minimum thickness of 2 feet is required, resulting in a total granular volume of 3,200 cubic yards per acre. The cost of cover soil, like the cost of clay, will vary widely depending on local availability and quality. The cost of cover soil can range from $4.00 to $8.00 per cubic yard, resulting in a per acre cost of $13,000 to $26,000.

Once final cover soil has been placed, its surface is to be hydroseeded and fertilized to grow a grass cover for protection against erosion and gullying. A layer of mulch is applied to hold the seed in place until it germinates. Cost for seeding, mulch, and fertilizer varies from $1,000 to $2,000 per acres.

Installed through the final cap and cover are the collection wells, header pipes and fittings, and condensate drip legs of the landfill gas management system. Each landfill also has at least one blower flare assembly for safe destruction of the extracted gas (usually one flare per 100 acres of landfill). The pricing of each component is unique, but can be roughly prorated on a per acre basis.

- Gas probes typically cost $6,000 to $8,000 each and are installed at a rate of one per 10 acres. Cost per acre would be between $600 and $800.
- Gas extraction wells and associated fittings cost between $8,000 and $10,000 each, depending on their depth. At a rate of one per acre, the costs per acre would be between $8,000 and $10,000.
- Assuming about a 200-foot average spacing interval, header pipelines are installed at a rate of 200 feet per acre. Costing $100 to $120 to install, their cost per acre varies from $20,000 to $24,000.
- A gas collection blower and flare assembly connected to the extraction well field by the header pipes will cost from $40,000 to $50,000 each. At an installation rate of one per 100 acres, per acre cost would be between $400 and $500.

The total cost per acre of the landfill gas management system would be between $29,000 and $35,000.

Installed over the final cap and cover are the swales, discharge channels, and culverts of the surface water run-off control system. Each landfill also has at least one sedimentation retention pond for the extraction of sediment and reduction of off-site run-off discharges. The pricing of each can be roughly prorated on a per acre basis:

- Assuming about a 200-ft. average spacing interval, collection swales and discharge channels are installed at a rate of 200 feet per acre. Costing $10 to $15 to install, their cost per acre varies from $2,000 to $3,000.
- Assuming culverts are installed at a rate of 100 feet per acre, and with the cost varying from $25 to $30 per linear foot (depending on the culvert type and diameter), the cost per acre would be from $2,500 to $3,000.
- A sedimentation basin will cost from $50,000 to $100,000 each. At an installation rate of one per 100 acres, per acre cost would be between $500 and $1,000.

The total cost per acre of the surface water runoff control system would be between $5,000 and $7,000.

In addition to the physical acts of construction and installation, management and quality oversight is required. This is typically done by independent third-party consultants and breaks down as follows:

- geomembrane cap construction management costs from $18,000 to $20,000 per acre;
- clay cap construction management costs from $2,000 to $4,000 per acre;
- overall project management costs from $12,000 to $16,000 per acre;
- construction surveying and drawing costs from $6,000 to $10,000 per acre;
- earthwork (structural fill and excavation) QA/QC costs from $15,000 to $20,000 per acre;
- liner (clay and geomembrane) QA/QC costs from $16,000 to $20,000 per acre; and
- leachate management system installation QA/QC costs from $6,000 to $9,000 per acre.

Total overhead and quality control would therefore range from $75,000 to $100,000 per acre.

Table 1 summarizes the above closure costs and the typical cost per acre of landfill closure.The cost of closing a landfill can range from $227,000 to $326,000 per acre, with the main cost difference due to the cost of clay and cover soil. For the purposes of this study, the hypothetical landfill will be assumed to have a closure cost of approximately $250,000 per acre.

TABLE 1.

Task	Low Cost	High Cost
Final grades survey	$ 3,000	$ 6,000
Gas management layer	24,000	32,000
Compacted caly cap	26,000	51,000
Geomembrane cap	18,000	23,000
Geocomposite		

	33,000	44,000
Cover and vegative soil	13,000	26,000
Seed, much, fertilize	1,000	2,000
Gas management system	29,000	35,000
Run-off control system	5,000	7,000
QA/QC	75,000	100,000
Total	$227,000	$326,000

Post-Closure Care and Maintenance Costs

Most operators are required to care for and maintain their landfills for a minimum period of 30 years after final closure and cessation of landfill disposal operations. Post-closure costs can be divided into four broad categories, depending on their cost basis:

- site security maintenance (annual cost per 1,000 feet of perimeter);
- landfill cover and mechanical systems maintenance (annual cost per acre);
- monitoring wells and gas probes (annual cost per each); and
- environmental monitoring (annual cost monitoring associated with the landfill).

Site security maintenance consists of fence repair and replacement, sign replacement, and gate replacement. Fence replacement is performed annually and usually involves about 20 feet of perimeter fence per 1,000 feet of fence. The unit cost of replacement varies from $10.00 to $15.00 per foot of fence replaced. The hypothetical landfill has a 6,000- foot-long security fence, resulting in an annual repair effort of 120 feet, costing from $1,200 to $1,800. An average of one sign will be replaced each year at an incidental cost of $10.00 to $20.00 each. The main entrance gate will have to be replaced on average once every 10 years at a cost of $1,000 to $2,000, resulting in an average annual cost of $100 to $200. Over a 30-year post-closure care period, security maintenance will cost between $3,000 and $6,000. Since this hypothetical landfill has an area of 33 acres, these costs become $90 to $180 per acre

The landfill itself will also need tending to. Each year the landfill's cover vegetation should be mowed at the cost of $20 to $30 per acre. The cover soil will probably need repair to a depth of 1 foot at an average rate of 0.03 acre per year, at a cost of $4.00 to $100 per cubic yard, resulting in an annual cost of $200 to $400 per acre. The same damaged cover soil areas will need reseeding at a rate of 0.03 acres per acre at a cost of $1,000 to $2,000 per acre, resulting in an annual cost of $30.00 to $60.00 per acre. Surface water runoff control structures will also need dredging and excavation at a rate of about 100 cubic yards per acre of landfill every five years, at a cost of $2.00 to $4.00 per cubic yard, resulting in an annual cost of $40.00 to $80.00 per acre. Total cover maintenance will cost from $290 to $570 per acre per year. Over a 30-year post-closure care period, cover maintenance will cost from $9,000 to $17,000 per acre.

Other per-acre site post-closure care costs include maintenance of the mechanical systems managing landfill gas and leachate extraction. Leachate maintenance of pipes should occur at a rate of 100 feet to 300 feet of pipe per acre, twice per year. This operation costs the equivalent of

$100 to $300 per acre per year. Leachate extraction pumps and associated controls are usually replaced at a rate of one replacement every five years at a cost of $40,000 to $45,000. With a pump for every 10-acre cell, this works out to $800 to $900 per acre per year. Total leachate maintenance costs will vary from $900 to $1,200 per acre per year. Over a 30-year post-closure care period, leachate system management costs will vary from $27,000 to $36,000 per acre.

Landfill gas system maintenance can also be prorated on a per acre basis. Annual maintenance averages $50 to $70 per well, with an average of one gas well per acre. Maintenance of the header pipe lines and other appurtenances averages $2.00 to $2.50 per linear foot. At an average 200 linear feet of header pipeline per acre, the cost of maintaining the pipelines varies from $400 to $500 per acre. Total annual gas system costs per acre will be $450 to $570. Over a 30-year post-closure care period, leachate system management costs will vary from $13,500 to $17,100 per acre.

Groundwater monitoring wells and landfill gas probes will need replacement on occasion. Typically, this happens at an annual cost equal to 2% of the capital costs of either the monitoring wells or probes. If a site has 10 wells, the annual cost of well replacement and repair will be equal to the cost of installing one-fifth well. If a site has 50 probes the annual cost of well replacement and repair will be equal to the cost of installing one probe. The number of wells and probes are not directly related to the number of landfill acres. Each site typically has a minimum of four wells--- one up-gradient and three down-gradient. Also, the minimum number of gas probes is four--- one on each side of the landfill. At a unit cost of $7,000 per well and $3,000 per probe, total capital costs for a 4 x 4 system would be $40,000. The annual maintenance and repair cost for probes and wells would be $800. For a hypothetical 33-acre landfill, this is equivalent to $20 to $30 per acre. Over a 30-year post-closure care period, probe and well maintenance, and replacement costs will vary from $600 to $900 per acre.

Environmental monitoring must be performed throughout the post-closure care period. These sampling and analysis events are usually performed as follows:

- groundwater monitoring (two events per year) at a total annual cost of $3,000 to $4,000;
- surface water monitoring (two events per year) at a total annual cost of $2,500 to $3,000;
- leachate monitoring (one event per year) at a total annual cost of $2,500 to $3,000;
- landfill gas monitoring (four events per year) at a total annual cost of $800 to $1,200; and
- statistical analysis (annually) at a cost of $6,000 to $8,000.

Air quality monitoring is usually not required during post closure. The total annual environmental monitoring costs vary from $15,000 to $19,000. For a hypothetical 33 acre landfill, this is equivalent to $450 to $575 per acre. Over a 30-year post-closure care period, environmental monitoring costs will vary from $13,500 to $17,250 per acre.

Table 2 summarizes the above post-closure care and maintenance costs and the typical cost per acre of 30 years of post-closure landfill maintenance.

TABLE 2.

Task	Low Cost	High Cost
Security and fencing	$ 90	$ 180

Final cap and cover	9,000	17,000
Leachate mechanicals	27,000	36,000
Landfill gas mechanicalss	13,500	17,100
Wells/probes	600	900
Environmental monitoring	13,500	17,250
Total	$64,000	$88,000

The cost of post-closure care and maintenance can range from $64,000 to $88,000 per acre, with the main cost difference due to the cost of clay and cover soil. For the purposes of this study, the hypothetical landfill will be assumed to have a post-closure care cost per acre of approximately $70,000 per acre.

The wild card in the above cost estimates is the treatment and disposal of leachate extracted from the landfill during post-closure. The amount of leachate generated (and the associated costs for treatment) is inherently unpredictable. Computer models, such as HELP, usually show leachate production reduced to nothing after a complete final cap has been installed over the landfill. Real-world experience shows that this is obviously not the case, as leachate production usually continues for some time after closure. Since the landfill's cap has effectively sealed off the landfill from additional inflow of percolation, this post-closure leachate represents leachate discharges already present in the landfill. Such discharges should not continue for the entire post-closure care period.

Trust Funds and Financial Assurances

Closure costs are accounted for during landfill operations. Those portions of each completed cell that have achieved final grades usually have to receive final cap and cover within three to six months (if weather conditions allow). The amount of acreage receiving final cap and cover will vary each year depending on the size of the current cells and the geometry of the landfill. On average, the area receiving cap and cover annually will equal the number of acres being built, with a lag time determined by the current cell's operational lifetime. Initial cells will receive less cover than later cells. With an 11-year operational lifetime for the hypothetical landfill and the average annual construction of 3 acres for disposal, the average (over the operational lifetime of the landfill) annual cap and cover costs will be $750,000.

There are several financial mechanisms allowed under most solid waste regulations to provide assurance that sufficient funds will be available to handle anticipated post-closure care costs and a contingency for corrective actions: trust fund, surety bond, letter of credit, insurance policy, local government or corporate guarantees, or multiple financial mechanisms. The most commonly used mechanism to ensure that sufficient money is available for post-closure care is the trust fund. Contingencies are often handled by the taking out of an insurance policy, with the monthly or annual premiums rolled into the overall post-closure care costs.

Trust funds are established to ensure that when the landfill closes there are sufficient funds available at the start of the post-closure care period to meet anticipated expenses. For a trust fund used to demonstrate financial assurance for post-closure care, the first payment into the fund must be at least equal to the current cost estimate for post-closure care, divided by the number of years in the pay-in period (in this case, 11 years, the operational lifetime of the hypothetical landfill). The amount of subsequent payments is determined as follows:

Next Payment = (CE – CV) / Y
CE is the current cost estimate for post-closure care (updated for inflation or other changes), CV is the current value of the trust fund, and Y is the number of years remaining in the pay-in period.

Conclusion, Comments, and Caveats

No doubt some readers of these three articles will question the costs sited for each task or landfill element. The dollar figures quoted may be different from what they have experienced. The costs listed by the articles are based on a study performed for a major solid waste company's Midwestern region of operations. Since the Midwest is a mixture of expensive urban areas and less costly rural areas, it represents a good average for landfill construction and operations costs. Landfills in the more urban Northeast or West Coast will experience higher costs. Those in the more rural mountain, plains and southern regions of the country will have generally less expensive landfill costs. However, the prices charged by landfills in these more expensive and less expensive areas are proportionally greater or smaller.

http://www.mswmanagement.com/mw_0507_landfill2.html