Assessing the Feasibility of Landfill Mining in Whitehorse, Yukon

Honours Thesis Summary Document

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Table of Contents

Introduction

As global demand for non-renewable resources continues to grow, partly due to rising populations and income levels in the Global South, the need to identify new sources of these materials continues as well. However, this also comes at the same time as a growing desire among many industries and nations to implement practices of sustainable development, which has been defined by the Brundtland Commission as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"[1]. Furthermore, concerns about the environmental and health implications of many resource extraction projects, as well as resistance to these projects from environmental organizations and local groups including indigenous communities, have brought increasing scrutiny to the methods of extracting those resources in the first place.

On the other side of the resource lifecycle are questions about how best to manage the waste that is generated by our resource consumption activities. Despite the commonality of the "3 Rs", reduce, reuse and recycle, the success of these practices is greatly varied from place to place. Landfilling, due to the relative ease and low costs associated with this process, continues to be the fate of much of our solid waste. However, there is a growing interest within the waste management community in the practice of "landfill mining". Landfill mining is the practice of excavating materials previously held in landfills or dumps, with a number of different goals including increasing landfill space, assessing the composition of the landfill, landfill site remediation and material reuse by way of incineration or recycling.

Recently, the notion of "enhanced landfill mining" has emerged, which has the specific goal of using previously landfilled materials as resources for energy generation or resource recovery. An enhanced landfill mining full-scale pilot project has begun in Belgium, much to the interest of people involved in waste management as researchers and industry workers alike.

Though the project in Belgium is taking place in the context of a densely populated region in which space for new landfills is scarce, it is possible that landfill mining projects could be a feasible option in many parts of the world. This paper will explore the feasibility of landfill mining in Whitehorse, Yukon. Whitehorse is a relatively remote community, but is very much dependent on its connection to southern Canada for most of its resources. It is also currently struggling with questions about appropriate energy sources to replace its back-up diesel generators. Furthermore, Whitehorse has a number of organizations active in issues of waste management, and has recently passed an updated Solid Waste Action Plan with the goal of 50% waste diversion by 2015. It is within this context that this paper will explore the potential of a landfill mining project at the Whitehorse Solid Waste Facility.

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[1] Brundtland Commission, 1987

Whitehorse Context

Over the past few years, several separate-yet-related issues, reports and initiatives have converged around waste management and energy in Whitehorse to create an environment that is conducive to an examination of the feasibility of landfill mining.

Issue 1: Landfill Capacity

In January 2013, the consulting company Morrison-Hershfield published a Landfill Cost Assessment report for the City of Whitehorse. According to the report, the landfill was constructed in 1987 with an estimated total capacity of 2,500,000 m^3; when allowing for a 750 mm final cover, this is reduced to 2,262,000 m^3. As of 2012, it was estimated that 24% of landfill air space capacity had been consumed. Furthermore, waste production has been increasing at a rate above population increases in the city. At the same time, waste diversion rates (recycling and composting) have remained around 20%.
With all this in mind, Morrison-Hershfield made 3 lifespan estimates:

- 34 years with current diversion rates
- 45 years with enhanced diversion
- 150 years with a waste to energy facility

Previous work had set the estimated landfill lifespan to be 78 years. Landfill closure costs are currently set at $13.5 M, plus post-closure monitoring for 20 years at $50,000/year.

Issue 2: Updated Solid Waste Action Plan

In August 2013, Whitehorse City Council adopted a new Solid Waste Action Plan (SWAP). The SWAP notes that waste generation in Whitehorse increased by 88% since 2000, which also represents an increase in per capita waste generation of 34% over 12 years.
The SWAP is focused on the target of increasing waste diversion rates from ~20% to 50% by 2015 largely through two methods:

- Banning cardboard from the landfill; and
- Collecting organic materials for composting from commercial, institutional and multi-household buildings[2]

Issue 3: Yukon Energy Back-up Generator Replacement Needs

Yukon Energy is currently looking to replace its aging diesel generators, which are currently used to provide back-up energy if the hydro dams shut down or demand exceeds capacity.
In 2011-2012 Yukon Energy researched the potential of a waste-to-energy (WtE) facility as the alternate back-up system. Two reports on the feasibility of such a project were published. The first report had concluded that WtE would indeed be

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[2] City of Whitehorse, 2013. *Whitehorse Solid Waste Action Plan*

much less expensive than diesel at $0.16/kWh but an updated version published in 2012 concluded that the cost per kWh would in fact be nearly double the original estimate, at around $0.31/kWh. This was largely because the enhanced diversion rates of 50% by 2015 would considerably reduce the feedstock available. The updated report included the estimated costs associated with using wood biomass in addition to MSW, as well as a slightly smaller WTE facility capacity[3]. Thus, Yukon Energy announced in April 2012 that it would not be proceeding with the WtE option in the near future[4].

Since then, Yukon Energy has been examining the possibility of building a liquid natural gas (LNG) facility as the new back-up generator. However, this proposal has generated much controversy from the community.

Issue 4: Plastic-to-Oil Machine

In 2012, Andy Lera, a local entrepreneur, partnered with P&M Recycling to bring a plastic-to-oil machine, developed by the Japanese company Blest, to Whitehorse for a pilot project. The machine uses plastics #2,4,5 and 6 (polyethylene, polystyrene and polypropylene), which are sorted at P&M from the containers that customers bring them, and produces fuel oil from them.

The plastic-to-oil machine has thus recently become one more actor in waste management issues in Whitehorse, with a particular potential future interest in resources in the landfill.

Whitehorse: Current Waste Management Practices

Waste management in Whitehorse is made up of a number of different organizations that all work interdependently. These include the landfill, now known as the Whitehorse Waste Management Facility; two private recycling processing centres, as well as community bottle depots in nearby rural areas; compost, which includes composting services contracted by the City government as well as private composting facilities in backyards/neighbourhoods; and the plastic-to-oil machine, which is run in partnership with one of the recycling centres, P&M Recycling.

Landfilling

The City of Whitehorse operates the Whitehorse Waste Management Facility, which includes the Son of War Eagle Landfill, as well as sites for composting and an area for dropping off recyclable materials.

The landfill accepts items such as household waste, construction and demolition waste, old furniture and old appliances[5]. Most of the items dropped off at the landfill

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[3] Morrison Hershfield, 2012. *Waste to Energy Updated Design Basis and Business Case Analysis*

[4] Yukon News, April 20, 2012. *YEC Parks Waste-to-Energy Option*

[5] City of Whitehorse, 2014. *Waste Management Facility*

are subject to tipping fees, which range from $1-250 depending on the item and its size. Recyclable items do not have a charge provided they are sorted appropriately and disposed of in their designated bins.

Recycling

Recycling in Whitehorse is carried out by two recycling processers, Raven Recycling and P&M Recycling. Items accepted for recycling include plastics, paper/cardboard, beverage containers such as aluminum cans and waxed cartons, glass and tin[6]. Additionally, Raven Recycling accepts styrofoam, electronic waste such as batteries and computers, and certain types of scrap metal such as copper and stainless steel. The two facilities receive, sort and bale the different commodities, which are then shipped elsewhere for further processing.

Composting

Composting in Whitehorse happens in two ways: either by the City's contracted composting company located at the Whitehorse Waste Management Facility, or by households on their own property.
Organics are one of the key items identified in the SWAP as an important part of the 50% diversion goal, since although the facilities exist to divert them, they have been found to be a large percent of the volume within the landfill[7].

Plastic-to-oil Machine

The Blest B-240 plastic-to-oil machine operated by Andy Lera in collaboration with P&M Recycling, Cold Climate Innovation and the Yukon Research Centre began operating in 2013.
The machine uses a process called thermal depolymerization, which involves plastics going through pyrolysis in order to be reduced to a petroleum product that can be used for heat or transport[8]. The plastics used in the process include #2 (high-density polyethylene), 3 (polyvinyl chloride), 4 (low-density polyethylene), 5 (polypropylene) & 6 (polystyrene).
According to a report published by Rising Sun Innovations earlier this year, the machine has been more successful than previously expected in terms of both financial and environmental considerations.

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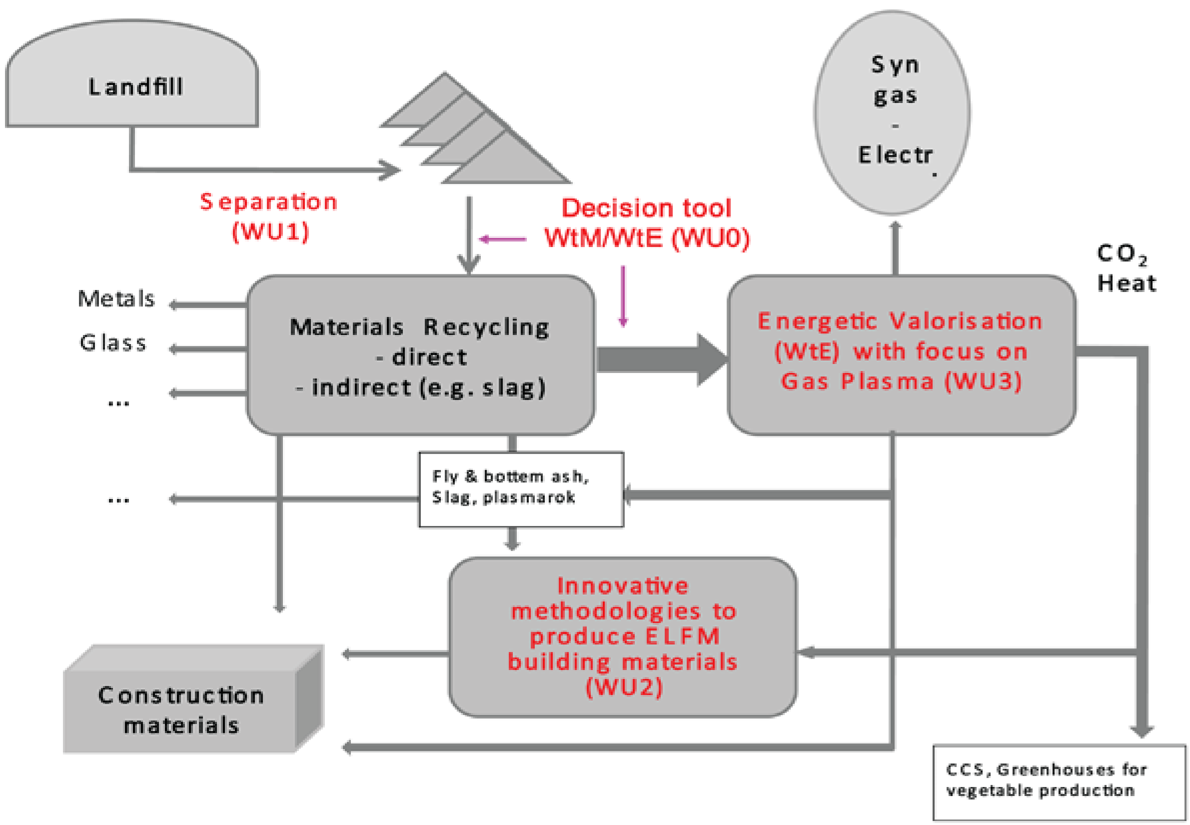
[6] Raven Recycling *What Can I Recycle?*
[7] City of Whitehorse *Solid Waste Action Plan – Details and Implementation Document*
[8] Rising Sun Innovations, 2014. *Plastic to Fuel Report*

Landfill Mining

Landfilling remains one of the most common ways of dealing with solid waste worldwide, since it is a relatively cheap and technically simple method. Over the last several decades, the simplicity and effectiveness of landfilling has come into question. Waste diversion initiatives such as "the 3 Rs" and composting have aimed to reduce the amount going into landfills. There is also an interest in landfills themselves. A combination of diminishing raw resource quantities and a shortage of space for new landfill sites in densely populated areas has meant that growing numbers of academics and companies in the waste management sector are looking at the potential of "mining" already-existing landfills.

The first documented landfill mining project took place in 1953 in Tel Aviv, Israel[9] where a company excavated fine materials from the landfill site for use as a soil amendment in nearby citrus groves.

In the last few years, a new concept has emerged among academics and industry-members called "enhanced landfill mining", and it has been defined as "the combined and integrated valorization of distinct landfilled urban waste streams as both materials and energy while meeting the most stringent ecological and social criteria."



Intended paths for landfilled materials. Source: Waste Management World

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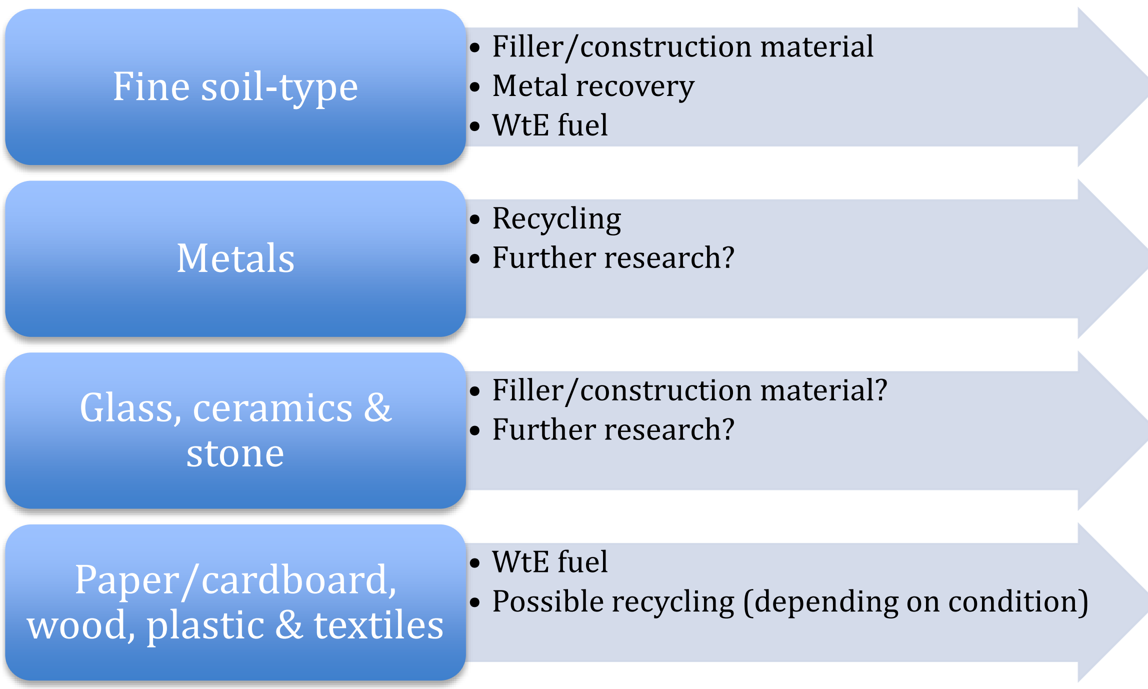
[9] Savage et al, 1993. *Landfill Mining: Past and Present*

In the context of this research, enhanced landfill mining is the most appropriate approach for the following reasons:

- The goal is similar to the idea of Zero Waste, the SWAP's driving concept
- It is unlikely that landfill mining in Whitehorse would be feasible solely on its potential to increase landfill capacity and lifespan; recyclable materials and feedstock for a waste-to-energy facility could increase interest in the project

The above graph shows the pathways of previously landfilled materials at the REMO landfill site in Belgium, where a full-scale project is currently taking place.
Other researchers have recommended the following paths for the most common landfilled materials:



Estimated Whitehorse Material Quantities and Potential Paths

Estimated Total Material Volumes

Table 3 presents the full estimated volumes and masses of all of the materials discussed in the rest of the study. Some items that were present in the waste composition report, such as gypsum wallboard and electronic waste, are not included. For that reason, the total percentages of each material do not add up to 100%. Additionally, Table 3 shows the likely total amount of fine material, if this includes everything that has degraded over time.
In all, the Whitehorse landfill likely contains over 250,000 tonnes of landfilled

material.

Material	Estimated original amount			Degraded	Estimated current amount		
	%	Volume (m3)	Mass (kg)		%	Volume (m3)	Mass (t)
Total contents		600,117				600,117	
Paper/Cardboard	13.6	67,333	50,499,792	~ 50%	6.8	33,667	25,250
Wood	15.1	74,759	37,379,748	~ 50%	7.6	37,380	18,690
Plastic	9.1	45,054	33,790,302	< 1%	9.0	44,603	33,452
Textiles	2.8	13,863	10,397,016	< 5%	2.7	13,170	9,877
Organics	17.3	85,652	64,238,706	> 90%	1.7	8,565	6,424
Composite	9.3	46,044	34,532,946	< 5%	8.8	43,742	32,806
Metal	6.7	33,171	23,220,002	< 1%	6.6	32,840	22,988
Fines	0.3	1,485	1,113,966	N/A	31.0	153,396	105,685
	74.2						
Total (waste)		367,361	255,172,478			367,361	255,172

Table 3: Estimated total amounts of materials in the Whitehorse Landfill

Recycling

Although paper products, glass, metals and plastics are all normally recyclable, only metals are likely to be in good enough condition to be recycled after being extracted from a landfill. Paper products would likely degrade too much, glass would likely break into small pieces and plastics are likely too contaminated.
According to the waste composition report, of the 6.7% of all waste that was metal, and 2/3 of this was steel products. However, most ferrous materials are not accepted for recycling so it is possible that 2/3 of the metals found in the landfill would not be easily recycled. The beverage containers and other non-ferrous metals, however, could likely be recycled fairly easily, depending on the contamination.

Metal	
Total mass (t)	22,988
Est. % non-ferrous	30
Total t non-ferrous	6,896

Table 4: Estimated total mass of metals in Whitehorse landfill.

Using the assumption that ~30% of metals in the landfill are non-ferrous, this gives us a total of 6,895 tonnes of recyclable metals with Whitehorse's current metal recycling capacity. This is out of a total of close to 23,000 tonnes of metals sitting in the landfill, as seen in Table 4.

Plastic-to-Oil

The plastic-to-oil machine being operated by Rising Sun Innovations in Whitehorse accepts plastic types #2, 3, 4, 5 & 6. Based on the percentages in the Whitehorse waste composition report, I have estimated usable plastics to be at 50% of the landfill's total plastic contents. From these calculations, more than 16 million kg of plastic could be available. The mass of plastics was measured in kg in order to easily convert this amount to the number of liters of oil that would be generated, as the ratio is roughly 1:1. This is summarized in Table 5.

Plastic	
Total mass (kg)	33,452,399
Est. % for plastic-to-oil	50
Est kg for plastic-to-oil	16,726,200
Est volume of oil (L)	16,726,200
Resulting barrels of oil	105,196

Table 5: Estimated amount of plastic and oil that could be generated.

Composting

The Whitehorse waste composition report found organics to be the largest fraction by weight (17.3%). As has been stated before, it is likely that organic material within the landfill would have degraded over time, resulting in soil-like material. However, inquiries to Garret Gillespie, who operates Boreal Composting at the Whitehorse Waste Management Facility, regarding the composting potential of degraded materials were answered with a clear negative. He believes that the level of contamination in those materials is likely far too high[10]. For this reason, potential compost was not calculated.

Waste-to-Energy

Waste-to-energy is the most commonly proposed use for previously landfilled materials, particularly when levels of contamination are too high to realistically attempt to recycle them. Combustible materials include plastic, paper/cardboard, textiles, wood and other organics.

In Whitehorse, these combustible materials are some of the largest fractions of the waste going to the landfill: paper, 13.6%; plastic 9.1%; organics 17.3%; wood 15.1%; textiles 2.8% and 'composites' 9.3%[11]. In total, up to 57.9% of what was found in this waste composition assessment could be combustible fuels.

For use in WtE, the calorific values of each commodity must be found. The estimated calorific values of each commodity are summarized in Table 6 based on other

[10] Gillespie, personal communication, March 5, 2014

[11] Maura Walker and Associates, 2011. *Son of War Eagle Waste Composition Study*

research. The total mass of combustible materials is summarized in Table 7. As the results in Table 7 show, there are over 100,000 tonnes of combustible materials available in the Whitehorse landfill. The WtE facility projected by Morrison-Hershfield (2012) has a capacity of 25,000 t/year so the landfill likely contains enough materials to run a facility for at least 4 years. If a combination of freshly produced waste and landfilled materials were used, the fuel source would be spread out over many more years.

Material	Estimated current amount			Calorific Value	Est Total Energy Content	
	%	Volume (m3)	Mass (kg)	(MJ kg-1)	(MJ) total min	max
Total contents		600,117				
Cover material		105,020				
Waste material						
Estimated MSW						
Estimated C&D						
Paper/Cardboard	6.8	33,667	25,249,896	11	277,748,856	
Wood	7.6	37,380	18,689,874	18	336,417,732	
Plastic	9	44,603	33,452,399	19-28	635,595,581	936,667,172
Textiles	2.7	13,170	9,877,165	18.8	185,690,702	
Organics	1.7	8,565	6,423,871	Unclear		
Composite	8.8	43,742	32,806,299	Unclear		
Metal	6.6	32,840	22,987,802	N/A		
Fines	31	153,396	105,685,173	2.2-4.8	232,507,381	507,288,830
Total (waste)		367,361	255,172,478			

Table 6: Estimated calorific value of materials in the Whitehorse landfill

Combustibles	
Total mass (t)	103,349
Original WtE facility capacity(t/yr)	25,000

Table 7: Estimated total combustible materials in the Whitehorse landfill

Project Implications

The following section will outline some of the economic, environmental & health, and operational implications of an enhanced landfill mining project in Whitehorse.

This section will include the following assumptions: 1) That landfill mining would only be done in conjunction with the construction of a waste-to-energy facility which would be operated by Yukon Energy as a replacement for aging diesel back-up generators; 2) That this project would be done in collaboration with existing waste haulers and processors.

Economic Implications

When Yukon Energy chose to end its research into using a Waste-to-Energy facility to replace its aging diesel generators, it did so because the costs would be too high to justify the project. Compared to that plan, the following costs are diverted in a landfill mining scenario:

- Biomass as additional fuel: $780,000 ($104/t X 7500 t)
- Purchasing, storing, handling and chipping biomass : $1,800,000
- Landfill closure: $13,500,000
- Landfill post-closure monitoring: $1,000,000 ($50,000/yr X 20 yrs)

That being said, landfill mining would also bring with it other costs including the following:

- Landfill excavation, screening and processing equipment
- Processing facility
- Labour and energy associated with that processing.

Environmental and Health Implications

The process of mining a landfill is certainly not without environmental impact. Potential impacts include the following:

- Noise
- Emissions and leachate from the landfill itself

Many of the studies on the topic have found the health and safety hazards associated with those project to be low, but there remains a need for further research into the long-term impacts.

The construction and operation of a waste-to-energy incinerator would also have impacts on the surrounding environment. During operation, incinerators to produce some emissions, including the following in small amounts:

- CO
- HCl
- HF
- HBr
- HI
- NOX

- SO_2,
- Volatile organic compounds (VOCs)

In addition, the process also produces bottom ash and fly ash, both of which can be hazardous to human health and must be property stabilized and disposed of. Furthermore, in the past many concerns have been raised about the production of dioxins by waste incinerators and they are indeed produced in small quantities. However, these can be reduced by selecting a facility with sufficient efficiency and pollution control mechanisms to minimize the production of all of these harmful substances

On the other hand, waste incineration would involve the diversion of some greenhouse gas emissions, including those emitted by the current generators and methane gas being emitted from the landfill as it currently stands. Model calculations have found a close to 100% probability of avoided GHGs via landfill mining.

Operational Implications

Landfill mining in Whitehorse would require certain facilities in order to operate. These include the following:

- A facility in which excavated materials could be dried, screened, sorted and cleaned
- A WtE incineration facility

Another question to consider, as was mentioned previously, is how an enhanced landfill mining project would impact the management of freshly generated waste. The concerns that have been raised about the potential for a WtE facility to compete with existing waste diversion efforts in Whitehorse are extremely important and valid, and great care would have to be taken in order to ensure that diversion remains the main goal of current residents.

Questions of Ownership

One issue that has not been touched on so far is the ownership implications of a landfill mining project, and that raises questions such as the following:

- Would it be run by Yukon Energy, which in itself has no experience with waste management?
- Should it be carried out mostly by private organizations, perhaps local companies that do have the technical experience required?
- Once we begin to think about waste as a resource, rather than just a problem that needs to be dealt with, how does that affect our ideas around ownership of that resource?
- Since the waste itself has been communally generated, should whatever

benefits come from it be held in common, including any financial benefits?

- Is it possible that this be a project that would bring together the multiple partners and stakeholders in waste management and energy production in Whitehorse, along with the general public, so as to attempt to meet all of the needs which have been identified over the course of previous conversations about these issues?
- Could Whitehorse be an example of effective inclusive project design and management, which could serve as a model for other communities considering similar questions?

Conclusions and Recommendations for Further Research

This paper is only the first step in answering the questions about the feasibility of an enhanced landfill mining project in Whitehorse. As such, there is a great deal of space for further work on the topic, if this were to become an attractive subject for other researchers. For example, an assessment of the costs of such a project would be needed, depending on the scale of such a project. This should also be combined with an evaluation of the savings and benefits, including the larger societal benefits such as avoided greenhouse gas emissions. Furthermore, there would need to be much more work in terms of engaging all relevant stakeholders, in order to design a system which would not compete with existing waste management efforts and instead could enhance them. Of course, a waste composition assessment of the inner contents of the landfill would provide considerably more information about its contents and the level to which things have degraded. Additionally, more work could be done into the long-term environmental impacts of enhanced landfill mining generally, though some modeling research has already been carried out.

Enhanced landfill mining is only just beginning to be talked about in the literature about waste management. The next several years could be an important time to explore the potential of landfill mining in other communities. This assessment is hopefully one more component in this ongoing conversation.