

WASTE MANAGEMENT IN REMOTE RURAL COMMUNITIES ACROSS THE CANADIAN NORTH: CHALLENGES AND OPPORTUNITIES

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ABSTRACT

We report results from a two-phase mixed methods research study to illustrate challenges and opportunities of waste management within the rural circumpolar and boreal regions of Canada. In the qualitative research phase, data were obtained from archives, semi-structured interviews with community partners, an information meeting with a community grassroots organization, and a participatory action meeting to develop a case study of the Labrador waste management system. Like many regions across the world's boreal belt, the study area consists of a population centre surrounded by diffuse, rural communities (many of which are inhabited by Indigenous and First Nations persons), multiple land uses, and complex governance considerations. The area faces harsh climatic conditions (e.g. frigidly cold temperatures and extended winters) that challenge biological processes and organic waste decomposition. These regions are often highly reliant upon natural resources and temporary labour forces to drive economic development, and they bear the environmental consequences of legacy wastes after project closures. In the qualitative research phase, we identify factors contributing to the accrual, management, and transport of inorganic waste across the study region to select a priority waste stream for an economic analysis in the quantitative study phase. In the quantitative phase we build an economic enterprise budget to assess costs associated with converting waste biomass from the construction of the Muskrat Falls hydroelectric dam into biochar with either a fast or slow mobile pyrolysis system. We include photos of the study region and we present an Excel-based spreadsheet tool as a supplemental file.

1. INTRODUCTION


1.1 Challenges and opportunities of waste management in circumpolar and arctic communities

This study utilizes a two-phase mixed methods research process to characterize waste management practices and socio-economic issues within circumpolar and boreal regions of Canada. We first report results from the qualitative phase of a mixed methods research project to create a case study of Happy Valley-Goose Bay, a coastal region situated in northeastern mainland Canada, within the eastern-most province of Newfoundland and Labrador (see Figure 1). In the quantitative research phase, we develop an economic enterprise budget for converting biomass waste (primarily black spruce) from construction of the Muskrat Falls hydroelectric dam into biochar. The enterprise budget and accompanying report are included as

supplemental files.

We assert that parallels can be drawn between the study area and other regions of Canada's North, as well as the rest of the world with similar climate and population. These regions merit attention because they are often on the peripheries of geo-political spaces in developed nations (Vodden, Baldacchino, and Gibson, 2015). These communities disproportionately shoulder the social costs (including the subsequent waste streams) of projects that propel the economic interests of the nation as a whole. Resource extraction, hydroelectric power development, and military installations for example yield subsequent waste flows and environmental impacts (Hird, 2016). Implementation of these large natural resource projects not unexpectedly leads to large quantities of organic wastes, as well.

For example, the recent Muskrat Falls hydroelectric dam project located in the study region has generated

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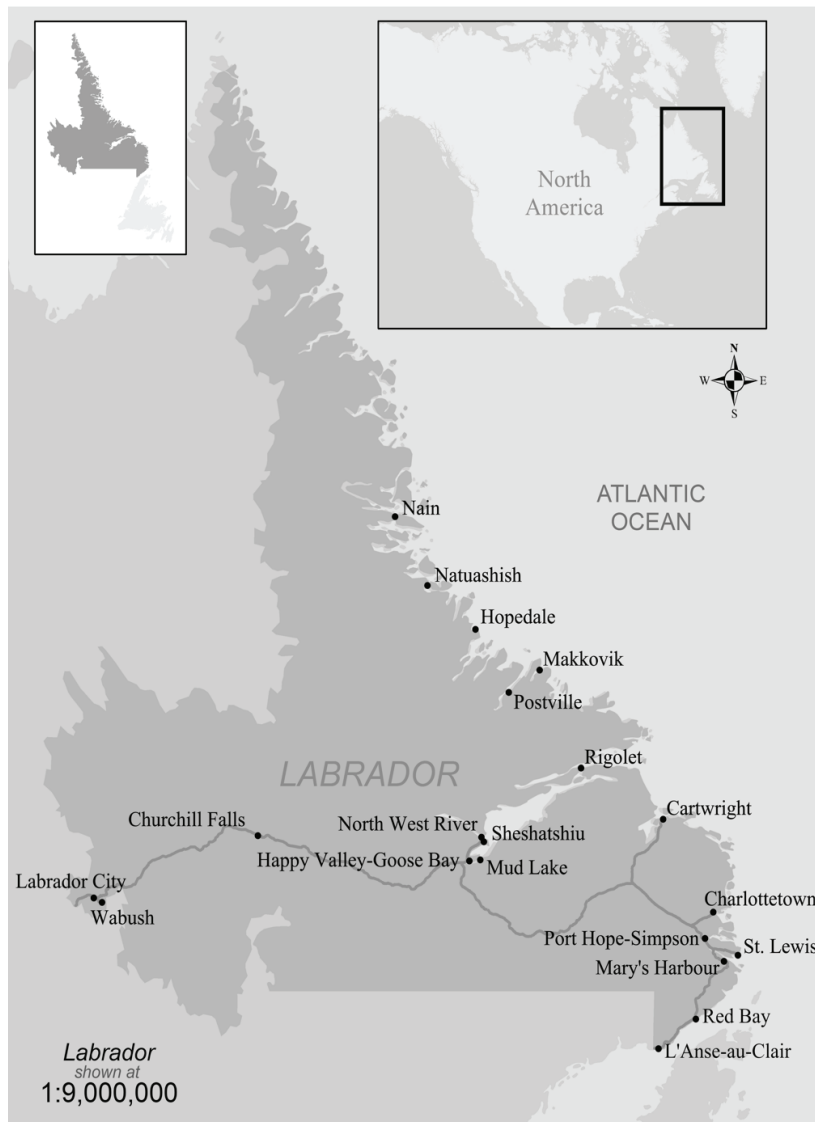


FIGURE 1: Map of Labrador. Cartography credit: Myron King and Morgon Mills.

more than 2 million m³ of wood, equivalent to roughly 1.25% of Canada's annual timber harvest. Although the waste accumulates in Labrador, the economic benefits and energy security are often realized by other provinces such as nearby Québec, Ontario, and Nova Scotia, as well as by Canada as a whole, through the sale of hydroelectric power to the United States (Canadian Hydropower Association, 2018; Lorinc, 2016). There is also disparity between the geographically separated areas within the province. A key objective of the Muskrat Falls hydroelectric project is to improve the province's energy security and to lower electricity prices, which are among the highest in Canada. However, Labrador communities sustain the land impacts, including the costs of the mobile labour force that largely consists of Newfoundland residents who fly in and out of Labrador leaving behind household wastes.

Furthermore, the Labrador Indigenous communities, whose self-identities are formed with the land and natural attributes, disproportionately endure negative environmental and social consequences (Bharadwaj et al., 2006;

Waldron, 2015). There are negative linkages between waste management practices and the quality and quantity of "country foods" that are hunted or harvested by Indigenous communities where subsistence hunting and foraging are integral to food security (Schiff and Bernard, 2018). Zagozewski et al. (2011) explicitly document that, "...solid waste disposal has been identified as a major environmental threat to First Nations Communities" (p. 9). According to the authors, one of the first well-documented cases of the presence of environmental contaminants on First Nations communities includes mercury poisoning in the Asubpeeschoseewagong Netum Anishnabek community in the 1960's as a result of the Dryden Chemical Company discharging chemical waste directly into the English-Wabigoon river system, a main water source for the Grassy Narrows First Nations Community located north of Kenora, Ontario. Similar environmental concerns have been expressed by Labrador Indigenous communities, as well.

Environmental justice, scientific concerns about methane emissions generated by filling the Muskrat Falls hy-

droelectric dam site, and the potential for methylmercury contamination of Labrador communities (Levin et al. 2007), and Indigenous communities in particular (Calder et al., 2016), has generated contentious activism that has been chronicled extensively in the media (Breen, 2017; CBC News, 2017). Understandably, this has made collaboration with the Nalcor, the agency overseeing dam construction, difficult on many levels, including coordination of waste management practices. In sum, clearly Labrador is encumbered with a disproportionate burden of waste in the effort to advance goals that benefit the province of Newfoundland and Labrador, and Canada as a nation.

1.2 Summary of literature and study region

As shown in Figure 1, Labrador is a large (269,134 km²) coastal region in north-eastern mainland Canada. Its climate is predominantly subarctic in inhabited areas, with boreal forests broken by alpine and coastal barrens, giving way to tundra in the north. The largest population centre (10,227 people, or 38% of Labrador's population) is the Upper Lake Melville area around Happy Valley-Goose Bay in central Labrador (Statistics Canada, 2017), at the head of the Hamilton Inlet estuary, which drains the Churchill River and several other major watersheds. Within the Churchill River valley in particular, soils are derived mainly from glaciofluvial sands and silts, with pockets of organic soils in poorly drained areas and acidic, sandy soils elsewhere, including in Happy Valley-Goose Bay proper (Walker, 2012; Fonkwe, 2016), where soils have low organic content and little ability to immobilize nutrients (Abedin, 2015) or pollutants (Abedin, 2017a; Abedin, 2017b). However, despite its subarctic designation, the area has warm summers, no permafrost, and an average frost-free period of 104 days (St. Croix, 2002).

Demographically, the region is majority Indigenous persons, with 52% of Happy Valley-Goose Bay's population reporting an Indigenous identity (Statistics Canada, 2011). Indigenous majorities are in the three outlying communities of North West River (about 550 people) and Sheshatshiu Innu First Nation (a reserve of about 1300 people), both 35 km to the north, and Mud Lake, a hamlet of about 50 people a few kilometres east and across the Churchill River. Local municipal histories are comparatively short, with a settled population of 129 in the whole area as recently as 1901, predominantly representing mixed Inuit-European trappers, fishers, and subsistence hunter-gatherers, with some timber harvesters at Mud Lake and an additional, uncounted nomadic population of Innu (a First Nations people) living traditionally on the land.

In Labrador, like much of the Canadian North, remoteness, low population densities, limited local capacity, and lack of local control in public decision-making make waste management complex. Waste accumulation from extractive industries and landfilling practices imperils drinking water quality. In a study of the Canadian Arctic and the Canadian territory Nunavut in particular, Daley et al. (2015) note that most of North America relies on wastewater buried conveyance systems, but it's impractical for the Canadian North due to extremely low temperatures. In Nunavut, water storage is separated into two tanks, one for drinking

and one for wastewater. Municipal trucks attempt to provide drinking water delivery and wastewater removal daily, which is frequently disrupted by adverse weather (Daley et al., 2015). One engaged community partner, Healthy Waters Labrador, developed a Comprehensive Environmental Management Plan (2012) promulgating six critically important waste issues; of primary concern is the lack of sewage and wastewater treatment facilities in watershed communities and the need for improved management of municipal solid waste.

As a province, Newfoundland and Labrador has one of the highest waste disposal levels per capita in the country. According to the Multi Materials Stewardship Board (MMSB), it is estimated that more than 400,000 tonnes of municipal solid waste (MSW) materials are generated each year in the province; organic waste comprises as much as 30% of all waste generated. Freezing temperature and snowfall make transport difficult much of the year, and the low temperatures slow decomposition so most organic and inorganic waste are landfilled (Zhang et al., 2013; Walker, 2012). For example, it is not uncommon for snow cover to remain for six consecutive months in the Happy Valley-Goose Bay population centre, and somewhat longer in other northern communities. Storage space becomes increasingly scarce and pedestrian/vehicle access to storage areas becomes increasingly difficult during winter months and towards the end of spring. The Gulf of St. Lawrence freezes and coastal transportation is unavailable for much of the year; the southern coastal ferry service runs about July-October, depending on ice conditions. Thus, it may be infeasible to store waste at on-site locations, or to transport materials elsewhere in a timely manner from the fall through spring months (October through April). There are also indirect climate impacts on settlement patterns, industry, and community systems. These factors exert pressure on households to dispose of waste illegally by land or sea, a behavior that has been noted in the past (Ritter, 2007), but that has also been demonstrated to take place at an increasing rate across the province after localized dump sites were closed (Harris Centre, 2017; Storey et al., 2017; Neil, 2017).

The waste management issues noted in the study region are similar to those noted across the Circumpolar North (generally defined as the ecosystem north of 60° latitude) and within the boreal forest biome 50°-60° latitude. These regions are sparsely populated, ethnically diverse with a large population of Indigenous communities, (approximately 40 different ethnic groups reside in the Circumpolar North, according to Cunsolo Willcox et al., 2015), and highly reliant upon mineral extraction and forestry to drive the economy. They also reflect a sustained history of disruption from colonialism and military installations.

Several waste management studies have been conducted in boreal climates within Europe, including Greenland (Eistead and Christensen, 2013), Siberia (Starostina et al., 2014), and other parts of northern Canada (Chouinard et al., 2014). Incineration and open dumping into unlined landfills are common practices in these rural regions. The ground is often too cold to allow organic waste to disintegrate, and toxic emissions disperse from leachate (Eisted,

2013; Samuelson, 2013). Studies have found ammonia nitrogen, polycyclic aromatic hydrocarbons, and total petroleum hydrocarbons, putting human and environmental health at risk (Samuelson, 2013). In addition to potential health impacts stemming from contaminated waste water and food sources, Czepiel et al. (2003) note that sanitary landfills are the leading anthropogenic source of methane emissions, which constitute roughly 25 times as much global warming potential as carbon dioxide.

We believe that parallels can be drawn between our study area and other regions of the world, like Tibet, that are experiencing waste management issues associated with infrastructure development projects and tourism. At an average altitude of over 4,000 metres, the Tibetan Plateau also has a sensitive, fragile ecosystem (Jiang et al., 2009). With over 41,000 glaciers and vastly expanding permafrost, Tibet is a major source of drinking water for over half of the world's population, but since the region has limited waste management facilities, waste burial or burning waste are the most common (Dong, Tan, & Gersberg, 2010). The Qinghai-Tibet railway, a state project, has led to an influx of tourism. A "floating population" is projected to increase municipal solid waste by approximately one-third, to 4942 tonnes/day in 2020 from 3597 tonnes/day in 2006 (Jiang et al., 2009). Studies by Ding and Wang (2018) note project that the proportion of municipal solid waste produced by tourists in Tibet increased from 2.99% to 20.06% over two years, and it is estimated that it will increase to 33.49% in 2025. Large cities have been equipped with sanitary landfills, however, surrounding Tibetan communities have dealt with the influx of solid waste by dumping into garbage piles, or rivers and streams (Jiang, 2009; Dong, Tan, & Gersberg, 2010). This rise of municipal waste by means of an industrial public project and a transient population, like the Qinghai-Tibet railway, draws parallels to the struggles Labrador finds with waste management due to industrial military projects, mobile populations, and resource extraction projects.

In summary, based upon a review of the literature conducted in similar climates, we assert that we are the first to engage in a mixed methods research approach to study waste in Labrador and in climatically similar regions. We believe that a mixed methods research methodology facilitates local community empowerment in that it has yielded a focused economic budgeting study of a waste stream that is an environmental priority, and that may also present potential economic development opportunities. Results from our study could inform waste management and community development projects in similar regions like Tibet and elsewhere in the boreal and arctic regions of the North.

2. METHODS

2.1 Mixed methods research approach

Waste management is one of many inter-related public systems for community well-being, and it is therefore best understood from a holistic perspective that takes a wide view of agency, including not only diverse municipal and high-level governmental structures, but also community values and practices. This approach is adapted from

well-established literatures on community health and well-being (e.g. Srinivasan, O'Fallon, and Dearth, 2003; Parlee and Furgal, 2012), and ecohealth (Charron, 2011). It is especially relevant in the context of Northern and Indigenous communities where governance systems and cultural practices may not conform with external structural paradigms. Similar recognition in climate change studies has led to a broader appreciation of the importance of taking into account the inter-relatedness of community systems, especially as they intersect with issues of community resilience (Ruscio et al., 2015), connectivity to the land (Cunsolo Willox et al., 2013), and the impacts of extractive resource development (Parlee, 2015; Southcott, 2015). The present research project has therefore employed a community-based perspective in all phases, beginning with a foundational partnership with the local municipality of Happy Valley-Goose Bay, who originated the underlying research program. This study is situated as part of a larger multi-institutional, multi-disciplinary project on facilitating sustainable communities and sustainable resources in the Arctic. Specifically, the overall objective of the waste management project is to investigate how resource development may provide communities with economic and strategic opportunities to overcome existing challenges, while simultaneously acknowledging the social and economic costs associated with resource development-related waste production. Like others before us have shown, we assert that these are inextricably linked, in that costs associated with waste management may be recovered and transformed into opportunities. We posit that this premise holds true across the Canadian North and in other similar regions in the world with similar climates and social structures. Identification of the waste characteristics is a first step in actualizing these benefits, and it lays the groundwork for a cost-benefit analysis of priority waste streams.

Mixed methods research is a broad process for a line of scientific inquiry that integrates and synthesizes both qualitative and quantitative processes, either simultaneously or sequentially (Newman et al. 2003). The methodology we employed was consistent with an integrative two-stage qualitative-quantitative research typology described in Tashakkori and Teddlie (2010). There is a vast literature on qualitative research techniques. Creswell (2003) notes that 19 complete qualitative procedures have been outlined in the sociological literature alone that form a continuum of qualitative research strategies. This continuum ranges from unstructured ethnographic data collection techniques where the researcher is a passive observer who listens to the language of the natives (Spradley 1979), to highly structured interview or case study methods where the interviewer controls the delivery of the questions with almost rigid precision (Yin 2003).

One important outcome is the creation of a quantitative model through theoretical data triangulation (interpreting data from more than one theoretical or disciplinary perspective) and the separation of qualitative data. In his seminal publication, *The Research Act in Sociology*, Denzin (1970) advocates for the use of triangulation, which is defined as the integration of multiple methods to study a research problem. Lewis-Beck, Bryman and Futing Liao

(2004) also emphasise that using multiple research methods presents a good validity check for research methodology and findings. There is some debate over the nomenclature of “mixed methods,” but most authors have reached consensus that mixed methods research involves a degree of synthesis.

The downside of mixed methods research is that the division between quantitative and qualitative research may become unclear as the approaches become increasingly integrated. However, Tashakkori and Teddlie, editors of pivotal mixed methods research texts (2010), summarize a prevailing thought in the field: combining both qualitative and quantitative approaches in social sciences seems to many researchers to be a natural or intuitive process (2010). To frame our contribution in the context of Denzin’s work, some engineering and waste management studies involve a narrower version of methodological triangulation by using focus groups to develop a survey for quantitative data collection. In contrast, we integrate more than one qualitative research approach to collect and interpret data for a complex system. We utilize multiple qualitative research approaches due to the limited number of individuals dispersed across a large region who have knowledge about the region’s waste management processes.

The specific objective of the qualitative research phase was to identify the sources and types of waste streams in Labrador and to contextualize these findings within the waste management literature. Based upon the waste streams identified in the qualitative research phase, we selected one priority waste stream to apply quantitative methods to develop an enterprise budget of the costs of converting waste biomass from the construction of the Muskrat Falls hydroelectric dam into biochar. Results from the quantitative phase an Excel spreadsheet budget tool and supporting project report are available as a supplemental supporting document.

2.2 Qualitative data collection

In the qualitative research phase, from March 2016 through June 2017 we obtained historical public records archived at the Town of Happy Valley-Goose Bay and within the Labrador Institute of Memorial University of Newfoundland to determine waste generation sources in Labrador, with the goal of selecting a priority waste material for additional quantitative analysis as well as policy recommendations for additional analysis. Data were collected and compiled from archival literature reviews and consultation with community partners. We also conducted semi-structured, participatory interviews and discussions with 21 community partners, where at least one investigator asked a similar series of open ended questions, and data were transcribed in real time and clustered by themes (Keske et al., 2011; Creswell, 2003). Partners that have been affiliated with the project, all of whom directly work with community or municipal waste management processes or northern environmental conservation, are listed in the Acknowledgements. Other partners, some of whom are involved with waste management through contracting or other research projects were individually approached at the May 2017 Labrador Research Forum. In addition, we

conducted a qualitative, participatory action meeting in May 2017 at the Labrador Research Forum, where approximately 35 persons were invited to share their perspectives about challenges to northern waste management systems as part of an ideas generating session. This session was promoted as an opportunity to provide a context for dialogue about research addressing solid waste management issues, especially in rural and remote areas, by bringing together researchers, funders, and potential partners to brainstorm about already identified needs and research gaps, and to explore new possibilities specific to Labrador. Data from the Labrador Research Forum were recorded by two note takers, and interview data were otherwise recorded by a single note taker. These data were categorized by theme and frequency by which they were raised. Following the Labrador Research Forum, we conducted an information meeting with the Happy Valley-Goose Bay Recyclers, a community grassroots organization.

2.3 Quantitative data collection

After potential waste streams were identified in the qualitative research phase a priority waste stream, black spruce and fir biomass from the construction of the Muskrat Falls hydroelectric dam, was selected for additional economic study. Consultation with the community partners revealed interest in recent research results on the potential for biochar as a soil amendment in Labrador for agriculture and soil remediation (Abedin, 2015; Abedin, 2017a; Abedin, 2017b). Biochar is essentially charcoal made from organic matter, and the efficacy of biochar from various biomass inputs has received increasing attention in the scientific literature during the past decade. Quantitative data for the economic analysis were obtained from a literature review of biomass and biochar literatures, including biochar production in northern climates with an abundance of biomass, and slower degradation processes due to lower temperatures. Eighty different sources were used to construct the budget tool.

The enterprise budget consists of fixed and variable costs for building and operating a prospective biochar production project co-located at the Muskrat Falls hydro-electric mega-project under construction by Nalcor Energy. We provide the Excel-based tool as a supplemental document. Spreadsheet users may select from a range of parameters like hours of production per day, technical efficiency, and pre-processing equipment, depending upon desired production input and output variables. Hence, the enterprise budget could be adapted according to different locations in Labrador or rural, northern Canada with a similar ecosystem.

The range of production inputs, cost structures, and parameters were informed, in part, by the local community partners who participated in the qualitative data phase, and who had knowledge of the volume and locations of waste biomass piles, and waste patterns of the study region. The budget was developed to summarize the costs relevant to instituting a new biomass to biochar production facility in Labrador, with the goal of attracting either potential investors or government partners interested in pursuing commercial biochar production or co-locating a multi-purpose

biomass waste management facility with the hydroelectric dam. Future investors or government agencies can impute their customized values into the spreadsheet to reflect proprietary cost information. Revenue streams were not included in the budget tool, although this would be a logical extension for the next phase of research.

3. RESULTS

3.1 Labrador waste flows and waste management

Following the qualitative data collection process, we developed an overview and timeline of waste management practices, summarized in Figure 2. The timeline captures the relationship and co-existence between military legacy waste, colonialism, and resource extraction that is similar to many other communities across the Canadian Arctic, Alaska (U.S.), Greenland, and Iceland. Directly following World War II, sixty-three temporary military settlements, including Happy Valley-Goose Bay and other Labrador communities, were erected to form the Distant Early Warning (DEW) radar line to defend against potential Soviet attacks in northern Canada. The construction and operation of a military base at Goose Bay led to rapid population growth and a shift away from Indigenous and pre-industrial waste management practices towards a series of disjointed waste management strategies. Until 1990 household wastes were discarded in nearby landfill locations, compacted and bulldozed. These practices and other regulatory shortfalls have left a legacy of contamination, particularly by petrochemicals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and

heavy metals, which has prompted a range of site assessments, monitoring studies, and remediation projects since the early 1990s (summarized in Fonkwe, 2016). The most substantial, long-lasting environmental impacts of military development have been at Hopedale, Saglek, and Happy Valley-Goose Bay. Military operations have clearly influenced the waste management and socio-economic community changes within the study region, and in other northern communities across the world. Additional discussion about the chronology and evolution of the Happy Valley-Goose Bay landfill is presented in Keske et al. (2018). Hird (2016) also provides detailed discussion about legacy military wastes left behind from the DEW Line.

Wastes that are an extension of colonialism and military disturbances have created an endogenic relationship with the present-day community infrastructure. For example, community infrastructures and lifestyles were shaped by natural resource projects, like the Churchill Falls hydroelectric station and the Muskrat Falls hydroelectric dam that is currently under construction (Mills and Keske, 2018). However, these community infrastructures are also at odds with the natural waste decomposition processes of the arctic and boreal environments; additional resource development projects perpetuate the cycle of unsustainable waste management practices. As demonstrated in Figure 2, population increases correspond with military installations and with resource development. These population influxes shape the culture of the community and leave behind legacy wastes. To illustrate this, we now briefly discuss the present-day waste management practices within two communities Happy Valley-Goose Bay and Nain.

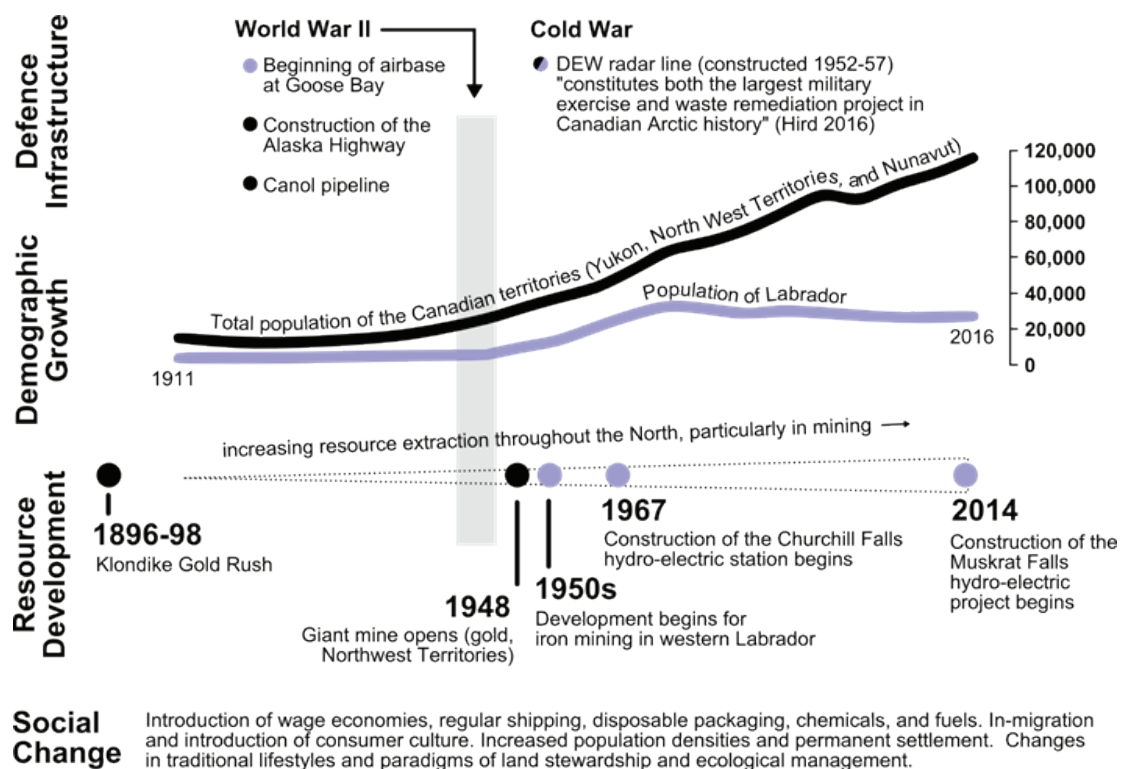


FIGURE 2: Defence infrastructure, demographic growth, resource development and social change as colonial impacts on waste systems in Labrador and across the North.

3.1.1 Happy Valley-Goose Bay

Figure 3 illustrates the different sources of waste generated in the Happy Valley-Goose Bay study region; some waste is reused or reclaimed by grass roots community organizations. Municipal waste is collected from dispersed locations and processed in a number of different ways, including incineration and composting, but waste is chiefly disposed at the municipal landfill. Photo 1 shows an aerial photograph of the Happy Valley-Goose Bay landfill.

As shown in Figure 3, waste is also collected by a provincially-contracted recycling depot for prescribed materials; by independent, commercial waste management contractors; by the health authority (hospital-generated medical wastes); through a municipal drop-off location for organic yard wastes; by commercial scrapyards; by a new municipally-run compost initiative; and by grassroots resident-led strategies, such as composting, burning (including as heating fuel), reuse, unauthorized dumping and littering, and a volunteer-led recycling initiative, the Happy Valley-Goose Bay Recyclers group, which pays for the trucking of household recycling to a plant in Newfoundland.

Not surprisingly, after years of sustained outside contact, food consumption patterns have also changed correspondingly. Several at-risk Indigenous communities have a higher incidence of consuming pre-packaged foods (Schiff and Bernard, 2018), a practice that is associated with lower income households. The municipality and waste collection service providers and community partners have noted a higher incidence of food packaging waste in lower income communities compared to the rest of the community. This increases the amount of bulk food packaging waste sent to the landfill. This places communities in a difficult position where they collect disproportionately more waste from some areas, but generally opt not to impose extra fees out of concern that residents will dispose of waste illegally



PHOTO 1: Aerial photograph of Happy Valley-Goose Bay municipal landfill. Photo credit, Jason Dicker. The Happy Valley-Goose Bay landfill is surrounded by wooded biomass. The Goose River flows nearby, which serves as a source to Mud Lake.

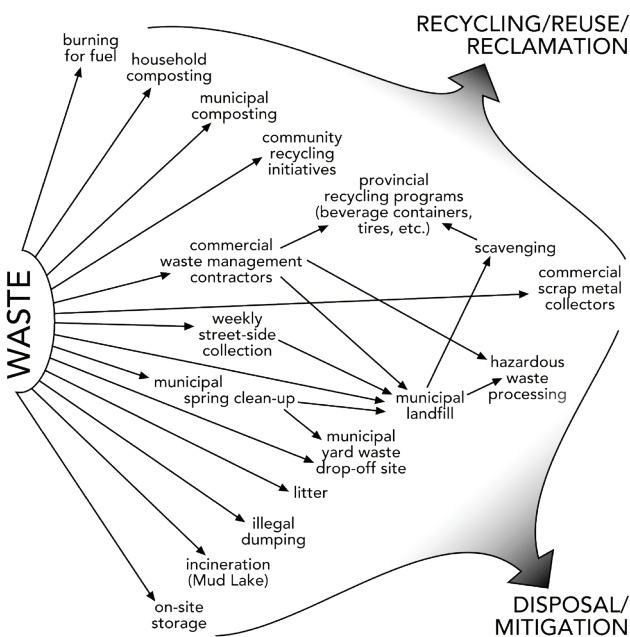


FIGURE 3: A flowchart of selected household waste management flows in Happy Valley-Goose Bay.

(Harris Centre, 2017). The Town of Happy Valley-Goose Bay notes that it is not uncommon for waste to be dumped at the landfill entrance outside of business hours when the gate is closed.

A number of factors also contribute to high levels of landfill harvesting (colloquially known as “scavenging”). Despite being illegal, landfill harvesting practices are common at the Happy Valley-Goose Bay municipal landfill, as well as in small communities across Labrador’s north-eastern coast. In 2016, landfill harvesting resulted in the death of a minor child (CBC News, 2016). Reclamation of commercial wastes like lumber or construction supplies is also common, but this unfolds differently, because it is more predictable. For example, once a week a company may make materials available for public collection, which assists interested parties in a safe and planned transfer of reused materials.

Apart from the municipal landfill, solid waste in Happy Valley-Goose Bay is processed in various ways. Since 1996 waste diversion and recycling programs in Newfoundland and Labrador have been funded and managed through a British Crown agency, the Multi-Materials Stewardship Board (MMSB). The MMSB is funded by levies on beverage containers and tires, as well as the sale of recyclable materials collected under its programs (MMSB, 2017).

The most significant quantity of household waste is not collected weekly. It consists of items too voluminous to be bagged or boxed – such as demolition or renovation

debris, yard waste, old appliances and furniture, and other bulky household items. Water-using appliances such as water heaters, washing machines, and dishwashers are particularly frequently discarded, given the medium-term corrosiveness of the municipally-supplied water (Fonkwe, 2016; Fonkwe and Schiff, 2016; CBC News, 2008). Our site visits of the municipal landfill confirm a large number of water heaters among a number of used appliances, though the rate at which these appliances are discarded compared to the rest of Canada has not been assessed, though a comparison may be of merit. An example of the high volume of appliance waste is shown in Photo 2.

As shown in Photos 3 and 4., as part of the annual “Spring Cleaning” waste sorting and collection event, furniture, appliances, construction debris, wood for burning. Spring cleaning is presented at the side of the curb, and community members are encouraged to collect and transport items that they wish to reuse.

Mobile labour forces also contribute to landfill and household wastes. Table 1 summarizes differences in the wastes generated by different communities (SNC Lavalin, 2016, p. 7), with a disproportionate amount of waste in the Happy Valley-Goose Bay area arising from the Muskrat Falls hydroelectric development project and the temporary labour force. In order to house workers for the development and operation of these large projects, some resource developments have established temporary camps (Muskrat Falls), permanent settlements (Churchill Falls), or created entirely new public municipalities (Labrador City). The autonomous governance and the scale of these large projects, coupled with an understandable need for privacy places a dilemma on municipal waste management. There is a need to accommodate the additional waste stemming from the resource related development documented in Table 1. If the Muskrat Falls project could collaborate with the Town of Happy Valley-Goose Bay, there would be synergies between recycling and scalable waste management practices, along with landfill disposal fees that were commensurate with landfill access. However, difficulties with doing so prompted the Muskrat Falls project to take on their own waste management practices. In spring 2017, Muskrat Falls began incinerating its own waste in response to an increase to landfill tipping fees incineration (Barker, 2017).

Aside from the Muskrat Falls construction and mobile labour household waste, waste biomass exists from forest clearing associated with the Muskrat Falls reservoir and transmission line clearcutting. The total volume of merchantable timber produced from has been estimated at 2,172,300 m³ (Nalcor, 2009, p. 10), but to date this substantial material resource has been underused. Some wood has been made freely available for domestic use by residents of Happy Valley-Goose Bay, North West River, and Sheshatshiu (Nalcor, 2015), but as frequently reported in the media (e.g., Canadian Press, 2014), the cost of transport has been a major barrier for initiatives to commercialize the resource. Processing the material on site might present a cost-effective approach to managing the waste.

The homogeneity and availability of the waste biomass prompted a subset of community partners to prioritize biomass waste streams for further economic analysis. More-



PHOTO 2: The accumulation of appliance wastes in the Happy Valley-Goose Bay landfill.



PHOTOS 3-4: Photographs of Happy Valley-Goose Bay Spring Clean-up taken Tuesday, June 6, 2017. Photo credit, Morgon Mills. As shown in the photographs, there can be a large quantity and an assortment of household items. Many households sort the wastes to make collection and trading easier for others.

TABLE 1: Estimated waste production (t/year) in Labrador communities near Happy Valley-Goose Bay.

	Population	Dwellings	Estimated Waste (t/yr)
HVGB	7552	2843	6919
North West River	553	225	262
Sheshatshiu	1314	291	748
Mud Lake	539	23	912
TOTAL	9473	3382	7955

over, a series of studies indicated that converting biomass from the waste wood to biochar was technically feasible (Abedin, 2015), and that biochar application in the study area shows promise for mine tailing remediation (Abedin, 2017b) and reduction in toxic leachate and greenhouse gases from the municipal solid waste stream (Abedin, 2017a).

3.1.2 Labrador's remote, self-contained communities

Since waste management also presents challenges specific to rural northern communities that are accessible only by air and sea, it is worthwhile to extend our discussion to the community of Nain, Labrador. Nain also exemplifies other northern Indigenous communities that have experienced periods of disruptive, ongoing colonialism and the Voisey's Bay nickel deposit is a source of both economic development and waste.

With a population of 1,125 (Statistics Canada 2017), Nain is the largest of the five communities in the Labrador Inuit Land Claims Area, under the regional jurisdiction of the Nunatsiavut Government. It was also the site in 1995 of a case study in Inuit community waste management, conducted in partnership by the Inuit Tapirisat of Canada and the Labrador Inuit Association (Harris et al., 1995). As noted in the case study, waste management is a community responsibility, shared by local residents, and requiring leadership from local government (i.e. regionally today, the Nunatsiavut Government, and municipally the Nain Inuit

Community Government or NICG).

The NICG operates a dump site and regular weekly residential and commercial garbage collection. The dump is sorted by waste stream (e.g. household wastes, automotive, appliances, oil drums, scrap metal). Since winter weather, permafrost, and the scarcity of topsoil make landfill burial impractical, combustible waste streams are processed by incineration. Recent photographs of the dump are presented in Photo 5 and Photo 6.

Even with the summer solstice imminent, snow remains along the narrow pathway to the open landfill. Water and waste accumulate into several sludge pools. Other sections of the landfill serve as a place where auto parts and appliances may be recovered. At the time these photos were taken, one of the researchers observed employees conducting an open burning at the landfill that had a noticeable effect upon air quality in the hamlet of Nain, where smoke tends to linger into town from over the hill. Although the skies are blue at the landfill, the air quality in town was smoky, filled with odor, with unclear visibility.

Photo 5 and Photo 6 illustrate the realities of landfill harvesting during summer in Nain. The red truck provides a frame of reference. In May 31, 2017 at the beginning of summer there is substantially more waste than August 23, 2017, when volumes of waste have been collected after three months of summer, and before snowfall begins.

Given the remoteness and ecological sensitivity of the area, as well as the reliance of the Inuit population on wildlife and forage for food security, environmental concerns associated with the dump site have special significance. One challenge is its location near the ocean without lining or leachate remediation measures, potentially leading to impacts on aquatic ecosystems and human health. As in many rural landfills, terrestrial wildlife are also potentially affected, with wildlife scavenging resulting in potential contamination of the food web and increased risk of adverse human-wildlife contact. This is exacerbated by the lack of organic waste diversion, since composting for agriculture is not a major strategy due to the cold climate, permafrost,



PHOTOS 5-6: Photo 5 shows waste in the Nain open landfill on May 31, 2017. Photo 6 presents waste in the Nain open landfill on August 23, 2017. Note the same red truck appears in both photos, but auto parts and other wastes have been scavenged.

and poor soils. Ammunition is a particular concern, especially given its prevalence in a community reliant on hunting. Its inclusion in household waste destined for incineration can potentially endanger workers, landfill users, and equipment. Harsh winters with heavy snowfall also lead to widespread litter, since snow and ice often block garbage bins and impede waste transportation, causing inefficient roadside pickup and scattering of household waste by stray dogs and crows.

3.2 Quantitative research results

As previously discussed, consultation with a subset of community partners led to the prioritization of waste biomass for the economic study. Several options were considered that could accomplish dual goals of waste collection and co-production of a desirable output or commercial product. For example, conversion of municipal household waste into biogas either at the household level or as a large community greenhouse (for food production) were considered. Other waste sources identified during the qualitative research phase were also considered, but not prioritized because the dispersed collection points made cost control challenging. The homogeneity of the woody biomass makes this waste management project tractable, in part because dedicated capital equipment can be purchased for the specific waste, and the biomass is consistently available. Moreover, as Abedin (2017b) demonstrates, biochar presents a potential to reduce toxic leachates emanating from extraction projects.

Due to the number of log piles (pits) left after forest clearance, the enterprise budget focused on the use of a mobile pyrolysis unit to reduce capital costs and to take advantage of the waste accumulations in different areas. Photos of the waste biomass are shown in Photos 7 and 8. Most piles have been present since being clear cut in during 2012-2013. The largest of these pits is located right next to the Muskrat Falls site. For the operation described in this report, biochar production would take place at the pit nearest Muskrat Falls, while Happy Valley-Goose Bay would be the business headquarters.

The enterprise budget provides options for the user to choose between using slow and fast pyrolysis units. Slow pyrolysis serves as the default because it usually produc-

es more biochar than fast pyrolysis (Pratt & Moran, 2010; Kung, McCarl, & Cao, 2013; Ahmed, Zhou, Ngo, & Guo, 2016; Ronsse, Van Hecke, Dickinson, & Prins, 2013), and the proposed Labrador project is primarily focused on producing biochar as an output. Slow pyrolysis also has lower pre-treatment costs (Ahmed, Zhou, Ngo, & Guo, 2016; Wrobel-Tobiszewska, Boersma, Sargison, Adams, & Jarick, 2015), which is favourable for a small-scale operation, like the proposed mobile pyrolysis units.

Fixed and variable costs (such as permitting fees and labour wage rates, respectively) have been customized to be consistent with the study region, although the tool allows the user to modify values that may be more reflective of elsewhere. For example, the spreadsheet user can choose whether production will be an outdoor seasonal operation, an indoor operation during winter months with an outdoor operation during summer months, or a year-round outdoor operation. While the year-round outdoor operation might not be very realistic, it is still the most desirable operating condition and it is therefore set as a default.

The Enterprise Budget Excel file is broken into four Excel sheets, and specific instructions, along with references, are provided in an accompanying report. The first Excel sheet contains the fixed costs for biochar production, which do not change with the amount of biochar produced. This includes machinery costs, miscellaneous costs, overhead charges, and total fixed costs. Total fixed costs are equal to the sum of repair and maintenance, insurance, depreciation, interest, and tax.

The second sheet contains all variable costs for biochar production, fixed costs from the first sheet, and total fixed and variable costs. The variable costs include fuel, oil and lubricants, labour, and other miscellaneous costs. The value of the variable cost per tonne of biochar produced is calculated in the same way as the fixed costs are calculated. The annual variable cost is divided by the actual days worked per year multiplied by technical efficiency, with the sum divided by the tonnes of biochar produced in a day.

The third sheet contains all the parameters for the model that can be changed depending on the operation's expected efficiency, such as hours per day for machinery use, pre-processing, and bagging. The fourth sheet contains data tables and enterprise budget calculations. These ta-



PHOTOS 7-8: Wood piles cleared for Muskrat Falls transmission lines. Photo credit: Morgon Mills.

bles include data on business permits and fees, administrative costs, labour rates, days worked and paid, equipment depreciation, maintenance costs, fuel consumption, lubricant consumption, and miscellaneous other data.

The largest constraint to using a mobile pyrolysis unit is the limited amount of biochar that can be produced. Additional equipment is still needed for preprocessing and pyrolysis, even though the scale of the operation is very small, and many of these machines will not be used to their full capacity. Examples of the additional equipment include a horizontal grinder, rotary screener, and a biochar bagger. Total costs would most likely not rise at the same level as the operation's scale, meaning that units capable of producing more biochar could lower the per-tonne cost of production.

An obvious drawback of this project would be the difficulty in finding a market for the biochar, and potentially high shipping costs to a distribution centre. Since Happy Valley-Goose Bay is a remote community in northern Canada additional shipping costs would likely need to be added to the budget. The community is optimistic that some of the biochar may be retained locally for agricultural or remediation purposes. Abedin (2015) has already demonstrated that biochar application can significantly improve soil fertility and increase crop production in Happy Valley-Goose Bay soils, and that there is potential for mine site remediation (Abedin, 2017b). However, production and storage of the biomass provides an option value for using the biomass, which has already been clear cut and is otherwise slowly beginning to decay.

4. DISCUSSION AND CONCLUSIONS

4.1 Changing the narrative: Engaging local communities for collaboration and co-investment

Though it's been said before, engaging community partners is critically important to creating synergies that will take root in a community. In our case, the community partners from the Town of Happy Valley-Goose Bay facilitated the qualitative data collection process, and their feedback led us to pursue the development of an enterprise budget tool to evaluate costs of establishing and operating a biochar processing plant in the study region. Furthermore, the presence of one our authors in his hometown of Nain serves to ground truth many of the observations in each of the respective study areas, and it provides better insight into the different areas of Labrador in relation to one another.

4.1.1 Local education and community waste recovery initiatives

Grass roots organizations provide an important role in educating the community about waste reduction and recovery. There must be incentives for households and commercial operations to adhere to waste management practices in order to achieve societal benefits, though the impacts that each household exerts onto the community or on the environment may not be immediately recognizable. Like other public utilities including electricity generation (Fox-Penner, 2010), there are paradoxical tensions

between ensuring that there is enough waste volume to facilitate municipal waste collection as a public service and providing incentives for households to change their behavior to achieve societal goals. This creates perverse incentives for unsustainable waste management practices. Specifically, households may not see the value of reducing their waste volumes, in part because they are being encouraged to routinely supply waste as part of the weekly household waste removal cycle. Yet, policy makers have expressed that they are uncomfortable with setting a limit on the number of bags allocated to each household, out of valid concern that it will increase the incidence illegal dumping. Thus, households receive positive reinforcement for sending unsorted waste streams for municipal collection without a clear sense of how their waste affects environmental quality and the region's waste management practices in general.

Community collaboration and grass roots efforts play an important role in disseminating information and shaping behavior. Waste management practices must be socially acceptable for widespread community adoption (Berhe et al., 2017). Since the beginning of the project, the grass roots Happy Valley-Goose Bay Recyclers group has continued to build momentum and to generate support for sustainable waste collection and landfill diversion of both household and light industrial wastes. As of May 2018, the group's Facebook page had 510 members, and they report 30 dedicated households whose donations and dropped-off recyclables have established the feasibility of their model provided that residents who use the service continue to remain willing to fund it. This group is hosted without cost in a large storage shed owned by a local small business, and relies upon volunteer labour to accept, sort, and palletize recyclable materials. Benefits identified by the group are above and beyond the usual advantages of waste diversion, and they include the education of children and the furtherance of a culture of environmentalism. Organizers have pursued funding opportunities with the municipality, provincial government, and local businesses, and an account has also been set up whereby residents locally dropping off beverage containers for the provincial MMSB recycling program can have the refunds donated to the Happy Valley-Goose Bay Recyclers group. They state that the chief limitation for the program is one of scale, as there is limited potential for expansion without significant infrastructure acquisitions, although the door is open for future collaboration.

4.1.2 Community co-investment and management in waste management projects

If the proposed biomass to biochar pyrolysis project is to truly take hold in the community, it's critical for Nalcor, the Indigenous communities, and the Town of Happy Valley-Goose Bay to engage collaboratively and to have joint ownership in the financial and operational aspects of the proposed centre. An obvious next step is that biochar production and any waste management project co-located with the Muskrat Falls hydroelectric dam provide communities with co-ownership and co-investment opportunities. These partnerships are critical in order to develop

appropriate incentives, including a distribution of benefits and management over time and space (in other words, in a sustainable manner for all). Ideally, this would foster increased community participation in decision-making and governance of the waste management process. As efforts gain momentum and as communities grow, this may even extend to Indigenous owned waste management services. Citizen action boards must also be comprised of representation from Indigenous governance, in order to ensure decisions are made with the best interests of these communities in mind.

In fact, it is our hope that the enterprise budget will facilitate more conversation between the groups. Since we've identified biomass to biochar processing costs, there is more time to pursue constructive discourse, project financing, and locating buyers for the biochar. The budget tool is Excel-based, and there is flexibility for its use in other northern regions across the world where biomass is being considered for biochar production.

4.1.3 Frozen in time? Community response to military waste across the North

It is also important to recognize that military and legacy wastes from sustained periods of colonial contact have left enduring impacts on Indigenous and marginalized communities across the world. As warming of the Arctic continues, and legacy waste sites thaw, additional environmental impacts from previous disturbances will unfold. It will be important for those responsible for the waste to step forward and lead remediation efforts. We urge scientists and policy makers to focus more resources on raising global awareness of buried military waste across the North, and the importance of collaborating with Indigenous and settler communities on the socio-economic barriers that contribute to unsustainable waste management practices. Community engagement will be critical to effectuating safety and clean-up at all scales from local to international.

4.1.4 Turning trash into treasure with improved waste matching and sorting

More sophisticated waste matching and sorting practices are needed both within the landfill, and to divert waste away from the landfill. Either the Town of Happy Valley-Goose Bay or Indigenous Governments could create a social media trading post to match those who are in need of cardboard boxes of specific dimensions with individuals who are looking to discard these materials. The communities could allocate storage areas specifically for holding cardboard containers and building supplies, including auto parts or construction materials, so that these may be acquired in a relatively safe manner.

Sorting and organizing the landfill spaces to allow for specific waste streams (e.g. auto parts or furniture) would guide harvesters to more specific locations and times that would involve less contact with heavy equipment. Additional labour force training to facilitate these sorting practices could include community outreach programs that would facilitate improved matching and sorting processes. It may also be possible for the provincial or federal governments

to provide financial incentives to divert some wastes (e.g. plastic bottles or appliances) away from communities but return revenues from bottle collection back to the communities of origination.

4.1.5 Policies that balance community health while recognizing the practicalities of waste management in the North

We believe that the precautionary principle, essentially taking preventive action in the face of uncertainty, is particularly important for informal waste recovery practices. Landfill and curbside harvesting are realities in the rural Canadian North, although it is difficult to ascertain the scale and scope of the waste streams recovered and the household prevalence of participation. Many of the activities are illegal and are likely underreported. However, acknowledging that these activities are common practice is a first step towards the goal of facilitating a safe environment for waste recovery and reuse, while planning a vision of other sustainable, safe waste management programs.

As previously discussed, many households already store wastes for an annual spring cleanup and engage in curbside waste harvesting. Since the public is already accustomed to these practices, there is opportunity to expand these programs during different times of the year. For example, a second fall clean-up event, combined with a dedicated storage unit for sorted waste materials, could provide households the option to access the materials and to repurpose these at other desirable times (e.g. preparation for the December holiday season, and February Carnival celebrations).

From a practical perspective, the province might consider creating legislation that would essentially indemnify the municipalities for facilitating waste trading and create more waste bartering/trading opportunities through the waste collection, sorting, transportation, and sorting processes. This may be a good place to start, though the implications of implementing such a policy would obviously require its own research study. As shown by Keske and Loomis (2008), there is some evidence to suggest that these policies work for natural resources on multi-purpose lands in rural communities.

4.2 Conclusions

In conclusion, waste management in Canada's circumpolar and Arctic North is complex. Moving forward, a multitude of socio-economic and climatic considerations must be considered in order to develop strategies, policies, regulations commensurate with 21st century lifestyles, and to accommodate uncertainty associated with global climate change. However, optimistically speaking, attention to the development of a sustainable waste management program provides opportunity to foster community cohesion and drive innovation, like converting waste biomass into a biochar operation.

We have been fortunate to partner with the municipality of Happy Valley-Goose Bay, who has been actively pursuing research and innovation in waste management and environmental stewardship for many years. Their vision prompted us to engage in a holistic approach to con-

ducting a waste management study of Labrador, and to position waste management in the Arctic as a resource issue that affects all of Canada and the worldwide circumpolar North. We assert that this holistic approach is a strength of the paper. Presenting results from the qualitative phase is a unique contribution to the waste management literature for circumpolar and boreal regions of the world. Moreover, using the qualitative research results to prioritize an economic study should reinforce the importance of engaging communities in waste management decisions. We hope that others in northern communities across the globe will benefit from the first steps that this community has taken to evaluate the feasibility of a biomass to biochar project and to effectuate sustainable waste management.

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