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Composition and Volumes of Waste from Northern and Remote Communities: A Survey of the Literature

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Executive Summary

Northern and remote communities have challenges in waste management. Isolation means they are not able to export their waste as is done in many places in the rest of Canada. An option for handling waste in situ is to attempt to recover the energy value and displace local diesel power generation. The amount and composition of waste generated in these communities needs first to be understood.

A survey of the recently published reports on waste management provides the necessary information. There is a high variability in reported rates of waste generation, from a low of 110 kg/person/year to a high of 1870 kg/person/year.

There is less information on the composition of the waste from these communities. The range of heat value is from 8 MJ/kg to 11 MJ/kg.

This information translates into a potential for electric power generation from waste from a low of 0.4% of community requirements to a high of 9.1% of community requirements. The question of whether there are technologies available remains to be addressed.

Table of Contents

Figures and Tables

1. Introduction

Remote communities face two challenges for sustainability: using imported fossil fuel (primarily diesel) for heat and power, and unsophisticated waste management practices. There is limited data available on the composition of community waste, therefore values for southern communities are commonly used [1]. The GHG emissions from diesel generation are matched by those for transportation of the fuel to the remote communities, so recovering the energy value from community waste has double benefit. Waste-to-energy can potentially be a dispatchable[1] power generation technology that can displace diesel fuel for remote communities.

The waste management hierarchy gives priority to reduction and reuse, then recycling, before energy recovery. Isolated communities have limited options for reuse and recycling. Connected northern communities, as in the Yukon, may have more success accessing the recycling options in other parts of Canada.

Energy conversion for the whole waste stream is difficult and too expensive at the scale of the small communities under consideration. Source separation of paper and plastics, as done for recycling in the south, may be a way of extracting the most energetic components with much lower processing cost. This should also provide a better feed material for potential conversion technologies such as gasification.

The first step is to establish the actual volume and composition of the waste produced in communities and the energy value of the major components. There are two considerations for the impact of an energy–from–waste technology: diversion of waste from the landfill and how waste–to–energy could supplement communities' electricity demands can potentially have positive environmental and socioeconomic benefits. Additional impacts, such as air emissions, lifetime of the community landfill and costs, are not considered here.

A final word on terminology: incineration is the combustion of waste without energy recovery; waste-to-energy is the recovery of the energy value of the waste in heat and/or electric power.

[1] Dispatchable means that the power is available as needed, in contrast to the intermittent nature of wind and solar.

2. Literature Review

A recent report on the status of waste management in Canada was prepared for the Canadian Council of Ministers of the Environment (CCME) [2], providing a national picture of waste management and the conditions in the provinces and territories. The data were extracted from the Statistics Canada reports on waste management. However, the confidentiality constraint means that Statistics Canada cannot report on Prince Edward Island and the Territories.

The per capita waste disposal rate was 729 kg per person per year in 2010 for Canada. This includes residential (37%, 270 kg/person/year) and non-residential waste (63%, 359 kg/person/year). The diversion rates were 33% for residential waste and 19% for non-residential waste. The national average expenditure on diversion was $86/person to achieve the average diversion of 236 kg/person, or $364 for each tonne of waste diverted.

The national average data provides benchmarks for comparison by northern and remote communities. The per capita residential waste production rate of 270 kg/person/year could be a surrogate for remote communities in the absence of better measures. The average cost for diversion of $364/tonne is a benchmark for the expenditures to keep waste out of the landfills.

With regards to the Territories, the Yukon Territory has communities in closer geographic proximity and road connectivity, so a more regional approach is used. There are approximately 29 operating public waste disposal sites in the territory. The community of Old Crow has a "mobile batch oxidation system" that was installed in 2012. This system extended the life of the local landfill from less than ten years to approximately 100 years. Acquisition of the unit was jointly planned between the Yukon government and the local First Nation. Emissions from the unit are regulated under the the Environment Act permit for the facility. There has been an open burning ban on MSW at public solid waste disposal facilities in effect since 2012.

Each community in the Northwest Territories has its own solid waste disposal facility, some of which are legacy sites not designed by an engineer, with no operation or maintenance plans. There are 33 operating landfills.

The situation is similar in Nunavut. Each community has its own landfills, some of which are legacy sites. These are above ground dumps. Most communities (excepting Iqaluit, Rankin Inlet, and Repulse Bay) practice open burning of waste. There is a program of recycling cans, with communities receiving money for each sea container filled. There are 25 landfills operating in Nunavut.

The report identifies several opportunities for improvement in waste management in the Territories:

- Increasing diversion, particularly of tires, white goods, vehicles and Construction, Renovation and Demolition (CRD) materials;
- Improving storage of hazardous materials;
- Stopping open burning;
- Applying modern standards to the design and operation of waste handling facilities;
- Controlling access to all disposal sites; and
- Monitoring of the amounts disposed.

The composition of the waste was estimated in an earlier report [3] on waste management in Canada. For 1992, the energy containing components were: paper – 6%; organic – 23%; plastic – 5%. The remaining 46% were metal, glass and other inorganics. This covers both residential and non-residential community waste streams.

Three reports by Arktis Solutions Inc. [1, 4, 5] look at the waste management situation in the three territories. The first report [4], released in 2010, provides an overview of the state of waste management in the three territories. The second [1], released in the following year, is focused on Nunavut. The third [5], provides technical guidance for waste handling and landfills.

The 2010 Arktis report provides a ‘typical’ waste composition for the Northwest Territories and Nunavut, reproduced here, Table 1.

Table 1 - 'Typical' waste composition for the Northwest Territories and Nunavut [4]

	Waste Type	Weight %
Energy Carriers	Food Waste	20.3
	Cardboard	9.8
	Newsprint	2.4
	Other paper products	14.8
	Wood	9.9
	Textiles	3.8
	Plastic, rubber, leather	14.0
	Subtotal	**75.0**
Non-energetic	Diapers	3.8
	Cans	4.4
	Other metal products	6.2
	Glass, ceramics	5.7
	Dirt	4.9
	Subtotal	**25.0**
	Total	**100**

Waste management profiles were developed for six communities, two for each territory – the capital and a small community. These were Whitehorse and Telsin (Yukon), Yellowknife and Hay River (Northwest Territories), and Iqaluit and Resolute (Nunavut). These cover a range of population size, accessibility, and impact of industrial or military presence. Table 2 summarizes the information on waste amounts and characteristics.

Table 2 - Summary of waste disposal rates and characteristics for six communities in the territories [4]

Name	Population	Waste disposal rate (kg/person/yr)	Characteristics
Whitehorse	20,461	750	No specific composition provided.
Telsin	144	440[2]	72% domestic garbage; 12% garden waste; 12% recyclables.
Yellowknife	18,700	700	37.1% paper; 26.1% organics; 12.4% plastic; 3.2% textiles; 2.9% wood.
Hay River	3,957[3]	520	No specific composition provided.
Iqaluit	6,184	670	No specific composition provided.
Resolute	229	564	22.8% food waste; 19.3 paper products; 17.6% plastic, rubber, leather, textiles.

The second report [1] is centred on the territory of Nunavut and the best practices for waste management there. Although the first report had data on the waste characteristics of two communities in Nunavut (Iqaluit and Resolute), this report used a single solid waste generation figure of 8.5 m^3/person/year (approximately 860 kg/person/year). This number is based on discussions with community staff. The operating and maintenance budget was $173/person/year requiring 1.8 FTE staffing. It was noted that most communities in Nunavut have no restriction or control of access to the waste facilities. Also, all communities except two practice regular open burning of community waste. The report also contains a cost benefit analysis of three options for changes to waste management in Nunavut:

1) Modified Landfill: Engineered landfill with separate cells for the different categories of waste.

2) Thermal Destruction: Fuelled incineration of most community waste, without energy recovery, and landfill for the post-combustion solids and bulky items.

3) Shift and Separate: Composting of organics separate from community waste, with landfill for the remainder.

[2] The total waste generation rate is 191.4 tonnes/year, but the population figure used for Telsin is 435.
[3] Including the Hay River Dene 1 Indian Reserve (309).

Waste composition was estimated using the published literature, not specific to northern communities.

The third report [5] is a technical support document for landfills in the Canadian North. The demographic and waste generation statistics were presented, as collected from the communities. However, the quality of the data is uncertain since some may be based on assumed generation rates not on systematic study or direct measurement.

The distribution of population for the three territories is given in Figures 1 and 2. Each territory has only one population centre with more than 4,000 inhabitants. The Yukon has two-thirds of its population concentrated in the capital, Whitehorse. The population of the Northwest Territories is also concentrated in Yellowknife (45%). Nunavut has a more dispersed population, with 37% in communities of 1,000 to 2,000 inhabitants, and only 20% of the population in the capital, Iqaluit.

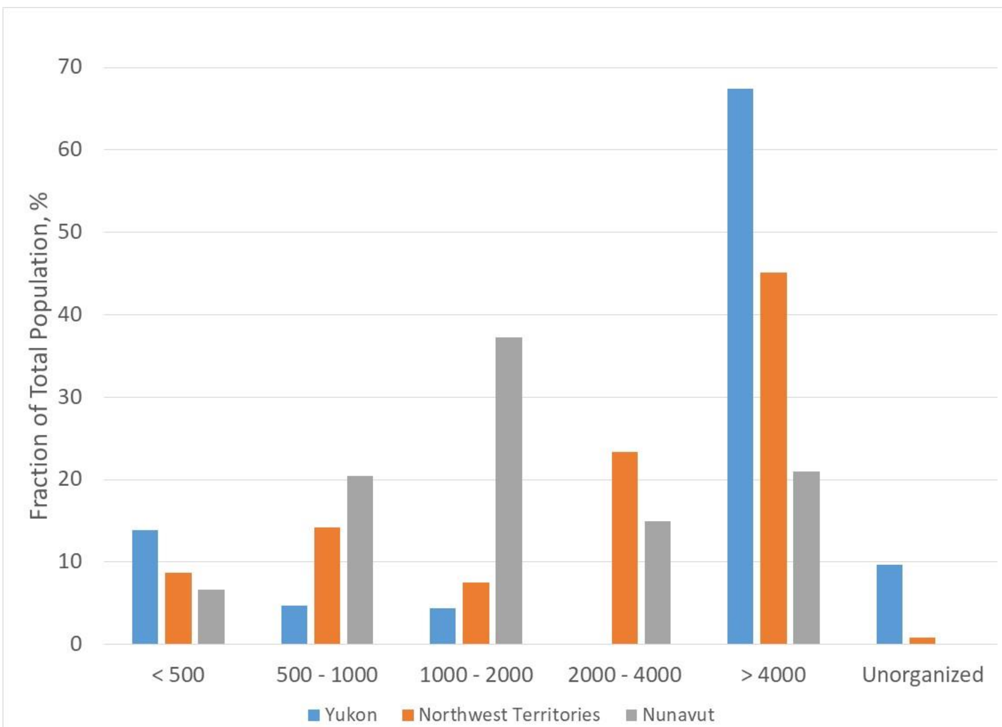

Figure 1 - Population distribution for the three territories according to community size [5].

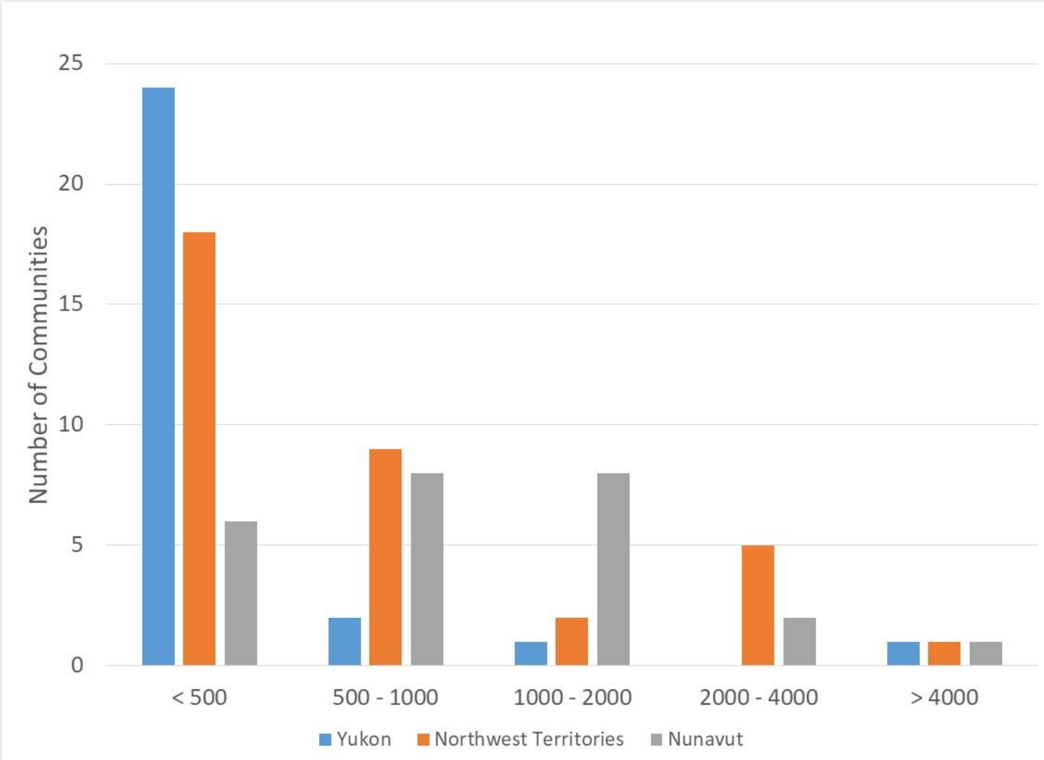

Figure 2 - Distribution of communities in the three territories according to population size [5].

Waste generation statistics are given in Table 3. The per capita rates show great variability, from a minimum of 110 kg/person/year to the maximum of 1870 kg/person/year. The range of the average rates for the territories is from 640 kg/person/year to 850 kg/person/year, in line with the figures reported for the provinces in [2].

Table 3 - Statistics on waste generation for the three territories [5].

Characteristic	Statistic	Yukon	Northwest Territories	Nunavut
Population	*Total*	30372	41464	29474
	Community Average	980	1243	1188
	Community Median	200	460	820
Annual Quantity of Waste Generated (tonnes/year)	*Total*	37475	49000	27308
	Community Average	1561	1485	1092
	Community Median	219	250	695
	Community Minimum	12	5	49
	Community Maximum	17417	34975	8198
Annual Quantity of Waste Generated per Capita (kg/person/year)	*Community Average*	750	640	850
	Community Median	790	540	810
	Community Minimum	110	530	220
	Community Maximum	1030	1870	1790

Yukon Energy was considering increasing its electrical generation capacity for the Yukon with a waste-to-energy (WTE) combined heat and power (CHP) facility. A pair of reports [6, 7] looked at the design basis and business case for a mass-burn system with steam-driven power generation and district heating. The motivation was to avoid expensive diesel generation (costing approximately \$0.30/kWh). The initial analysis showed that the CHP system could provide electricity costing between \$0.16/kWh and \$0.18/kWh, a significant saving. There would also be significant benefits in reduced air emissions (particulate matter, NO_x, CO). However, incorporation of the desired diversion target of 50% by 2015 required the inclusion of purchased biomass in the early years of the project, increasing the power cost to \$0.31/kWh, which removed the cost savings relative to diesel generation. The environmental benefits were not part of the business case decision. Waste diversion in Whitehorse reached 31% in 2015 [8].

There was a study of the waste handling situation and options for change for the federal government facilities (DND, NRCan – Polar Continental Shelf Program) [9, 10]. A quantitative analysis of the waste of the two federal facilities, or the Hamlet of Resolute was not done. The value of 2 kg/person/day (730 kg/person/year) was used as the waste generation rate. The recommendation was for an incineration system to be installed. A system was installed in the spring of 2018 [11].

Environment and Climate Change Canada (ECCC) issued a technical guide for waste management in Northern and Remote Communities in 2017 [12].

3. Analysis

For remote communities that are off-grid and and do not have access to wood (above the treeline), there is a stong correlation between population and the annual electrical power generation, shown in Figure 3. This provides a measure of the energy requirement for the communities, which is 6.3 MWh/person/year.

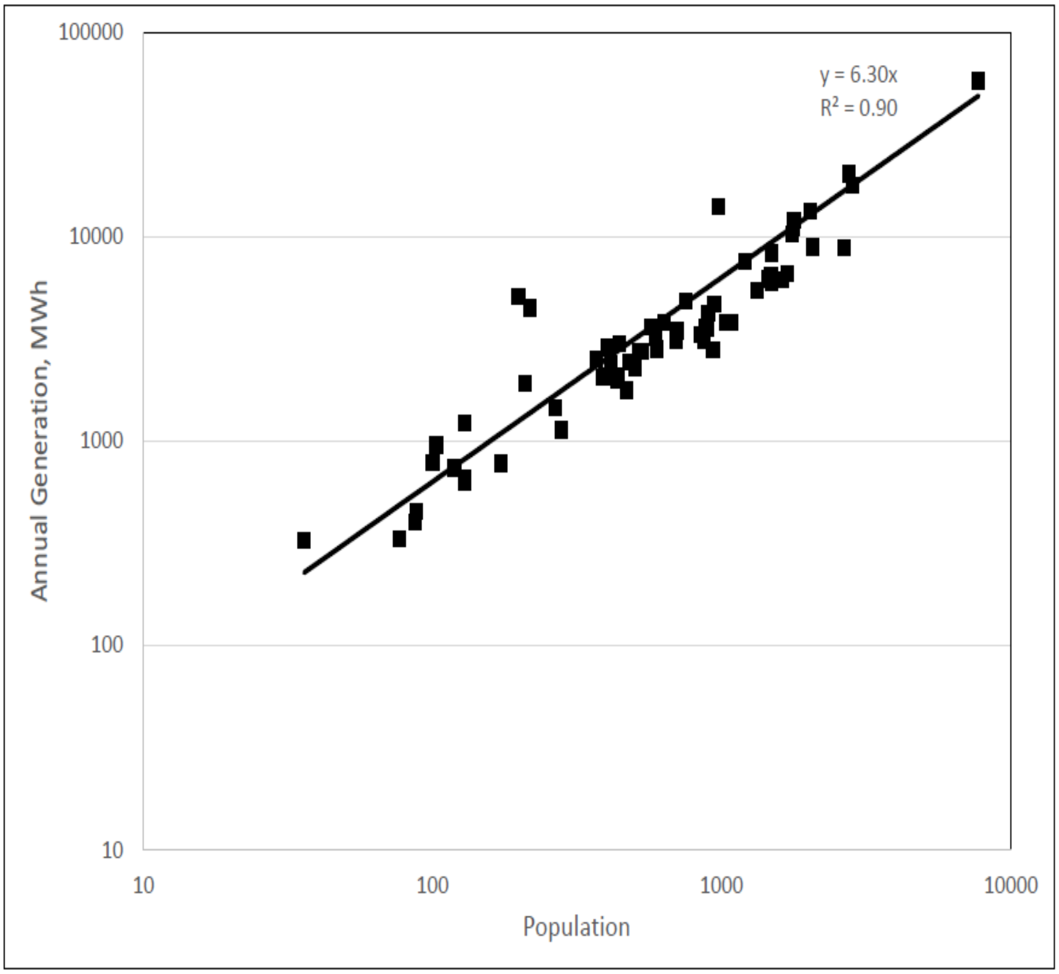

Figure 3 - Correlation of annual power generation with population of single off-grid communities in NT, NU, QC, and YT without access to wood.

The amounts and composition of the waste generated in the remote communities can be used to provide an estimate of the energy content of the waste. For that, the composition and the energy content of each component is needed. Appendix A has the basic properties of various waste components as reported by Tillman [13]. The HHV is the measure of the chemical energy to be released by combustion. There are three compositions in the previous section – the 'typical' (Table 1), for Yellowknife and Resolute (Table 2).

Table 4 has the energetic properties of the three waste compositions. The fraction of energy containing material ranges from 60% to 82% and the HHV from 8 MJ/kg to 11 MJ/kg. Note that the HHV is the energy available per kilogram of all the waste, not just the energy containing fraction. The 'typical' composition can be used to describe the 'typical' energy resource for waste from remote communities.

Table 4 - Energetic properties of the three waste compositions for remote communities from the literature review.

Waste Composition	Fraction Energetic, %	HHV, MJ/kg
'Typical'	75	10
Yellowknife	82	11
Resolute	60	8

The low and high values (8 MJ/kg and 11 MJ/kg) are used with the statistics of waste generation in Table 3 to produce the range of energy available from waste for the territories in Table 5. This is the raw energy content, conversion to electricity will have a certain efficiency depending on the technology used. The correlation for electricity requirement is 6.3 MWh/person/year. At 10% conversion efficiency to electricity, a realistic value, the fraction of the electricity generation requirement from waste is given in Table 6. The estimates range from 0.4% to 9.1% of the total annual electricity requirement.

Table 5 - Statistics for raw energy content of community waste based on waste generation statistics in Table 3.

	Statistic	Yukon	Northwest Territories	Nunavut
Energy Content of Waste Generated per Capita (MWh/person/year), Low	Community Average	1.7	1.4	1.9
	Community Median	1.8	1.2	1.8
	Community Minimum	0.2	1.2	0.5
	Community Maximum	2.3	4.2	4.0
Energy Content of Waste Generated per Capita (MWh/person/year), High	Community Average	2.3	2.0	2.6
	Community Median	2.4	1.7	2.5
	Community Minimum	0.3	1.6	0.7
	Community Maximum	3.1	5.7	5.5

Table 6 - Fraction of electricity requirement for remote communities as a percentage based on the statistics for energy in waste in Table 5 and 10% conversion efficiency.

	Statistic	Yukon	Northwest Territories	Nunavut
Fraction of electricity requirement (%), Low	Community Average	2.6	2.3	3.0
	Community Median	2.8	1.9	2.9
	Community Minimum	0.4	1.9	0.8
	Community Maximum	3.6	6.6	6.3
Fraction of electricity requirement (%), High	Community Average	3.6	3.1	4.1
	Community Median	3.8	2.6	3.9
	Community Minimum	0.5	2.6	1.1
	Community Maximum	5.0	9.1	8.7

4. Conclusion

There is a large variability and uncertainty in the literature about the amounts and composition of waste generated in northern and remote communities. This is in part intrinsic to the nature of the waste and its generation, influenced by local economic activity and population size. There is a large range in the per capita rate of waste generation for these communities. There is relatively little data on the composition of the waste. However, the impact of the variability of the energetic fraction on the energy content is much smaller.

The energetic fraction of the community waste ranges from 60% to 82% by mass. Recovering the energy from this material would significantly increase the diversion rate from the landfill.

The production of electricity from this fraction of the waste may have a significant impact on the displacement of diesel. The wide range of waste generation rates translates into a very wide range of electrical power potential – from 0.4% of community requirements up to 9.1% of community requirements. Better information on local waste generation and the availability of suitably scaled technologies would decide on the relative merits of WTE or incineration.

5. Glossary

CRD	Construction, Renovation, and Demolition waste
EFW	Energy-From-Waste; any technology that recovers some of the energy value in the waste
ICI	Industrial, Commercial and Institutional
Incineration	Thermal processing (usually combustion) of waste without recovering energy, or with recovery that is less than the energy input
LFG	Landfill gas, a mixture of gases, rich in methane, from the anaerobic decomposition of organic material in the landfill
MSW	Municipal solid waste, which is the total waste stream from residential and ICI sources, including CRD
Organics	Organic waste composed of biodegradable waste from plant or animal origin, from domestic or industrial sources
PPP	Packaging and Paper Products
WTE	Waste-to-Energy, the thermal or biological processing of waste to produce heat, power, or fuel

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Appendix A : Energy Content for Waste Materials

Table 7 - Basic properties of energetic waste components, after Tillman [13].

Name	Ash	Moisture	HHV (MJ/kg)
Corrugated cardboard	2.3	20	14.5
Newsprint	1.6	25	14.5
Magazine stock	13.1	16	12.7
Other paper	9.1	23	12.7
Plastics	8.6	15	26.9
Rubber and Leather	22.5	10	19.6
Wood	2.8	16	16.1
Textiles	2	25	15.3
Yard Waste	10.1	45	9.3
Food Waste	5.1	60	7.6

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