Renewable Natural Gas (Biomethane) Feedstock Potential in Canada

TorchLight Bioresources

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EXECUTIVE SUMMARY

Renewable natural gas (RNG), also known as biomethane, is a near-pure methane gas that can be blended with natural gas and used for building space heat/hot water, industrial process heat, electricity generation, and transportation. Although much higher cost than current (2020) natural gas prices, RNG can be produced to be cost competitive with diesel fuel. Its ease of integration within the existing natural gas infrastructure and lower carbon intensity than natural gas and diesel has led to significant interest in fuel switching to RNG for greenhouse gas emission reductions. Previous studies have estimated Canada's RNG potential using top-down analyses of national and provincial livestock manure, urban waste, industrial waste, landfill gas, and crop residue resources. While these analyses have helped to justify establishment of a small but growing RNG industry in Canada, Natural Resources Canada sought to better understand the RNG feedstock potential at a more localized geographic scale.

TorchLight Bioresources was contracted by Natural Resources Canada to complete an analysis of RNG resources at a regional level of detail. As RNG resource data are not available country-wide at a municipality scale, the Canada Census Division was selected as the discreet geographic unit. Potential RNG feedstocks livestock manure, biosolids (sewage), wastewater, urban organics, corn silage, crop residues, pulp mill sludge, landfills, and unallocated forest resources were quantified and mapped. It was estimated that the theoretical annual RNG potential in Canada is 809 PJ. However, this unconstrainted estimate will not be reached commercially due to competing feedstock demands, logistical constraints, and economic viability. The feasible RNG potential was estimated to be 155 PJ. This is equal to 3.3% of Canada's current natural gas consumption and 1.3% of Canada's total energy consumption. By far the largest RNG opportunity is crop residues, followed by landfill gas. Livestock manure, biosolids, wastewater, urban organics, and pulp mill sludge could provide approximately 40 PJ, which is equal to 0.9% of Canada's natural gas consumption and 0.3% of Canada's energy consumption.

The highest RNG opportunity regions include southwest Ontario and Quebec (corn residue silage, hog and poultry manure, landfills) and large cropland regions of Saskatchewan and Alberta (crop residues, cattle manure in Alberta). However, should crop residues be excluded, the largest RNG opportunity regions are near Canada's major population centres. A comparison of potential provincial RNG supply relative to demand showed Alberta and British Columbia are likely to be the largest importers of RNG if volumetric blending of 5% is required in every province. Ontario and Quebec have the largest theoretical RNG production potential, but this volume is highly dependent upon theoretical corn, including grain silage, that may not be available due to competing consumers.

The greatest GHG impact of RNG is likely to be the associated reduction in methane emissions from landfill and livestock operations. Given the small volume of RNG that could be produced in Canada relative to national energy demand, the Government of Canada should seek to assess and optimize the role that RNG and natural gas infrastructure can play in reaching its 2050 Net Zero goal.

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1 INTRODUCTION

1.1 Background

Under the Paris Agreement, Canada has committed to reduce domestic greenhouse gas (GHG) emissions by 30% by 2030 relative to 2005 levels.[1] To meet national GHG emissions targets, increase resilience to climate change, and grow the economy, the Government of Canada, along with the provinces and territories and in consultation with Indigenous peoples, established the Pan-Canadian Framework on Clean Growth and Climate Change. A key policy under this Framework is the Clean Fuel Standard (CFS). The CFS will require obligated parties to reduce the life cycle carbon intensity (CI) of the fuels they supply. The objective of the CFS is to reduce Canada's GHG emissions by 30 Mt CO_2e per year by 2030. The CFS covers all fossil fuels, including those in liquid, solid, and gaseous states of matter. It is anticipated that renewable natural gas (RNG), a high-methane content gas that can be injected into existing natural gas pipelines and blended with natural gas, or used as a transportation fuel, could be an important CFS compliance fuel depending on its cost relative to other compliance measures.

Several studies have estimated the theoretical and practical RNG and/or biogas potential in Canada or specific provinces. A non-exhaustive list of studies is presented in Figure 1. Nationally, the potential for conventional RNG, which includes upgraded biogas and landfill gas, has been estimated to range from 90 to 218 PJ per year. Canada currently consumes 4,300 PJ of natural gas annually, indicating a potential maximum conventional RNG blend rate of 2 to 5%.[2] These blend rates exclude the potential future use of RNG for transportation, which would decrease the potential blend rate with natural gas.

Figure 1. Selected Estimates of RNG Potential in Canada

Study	Authors	Client	Geography, Year	Scope/Sector	RNG Potential (PJ)
Canadian Biogas Study Benefits to the Economy, Environment and Energy[3]	Kelleher Environmental, Robins Environmental	Canadian Biogas Association	Canada, 2013	All residuals, including crop residues; corn silage and pulp mill sludge excluded	89.5
Potential Production of Methane from Canadian Wastes[4,*]	Alberta Research Council, Canadian Gas Association	Canadian Gas Association	Canada, 2010	All residuals, but crop residuals limited to 20%; corn silage and pulp mill sludge excluded	218
Resource Supply Potential for Renewable Natural Gas in B.C.[6]	Hallbar Consulting, Research Institute of Sweden	Gov't of BC, FortisBC, Pacific Northern Gas	British Columbia, 2017	All residuals; feasible estimated at 4.4 PJ in near term and 11.9 PJ in long term	7.6 (theoretical in the near term)
Renewable natural gas production in Québec[7]	WSP, Deloitte	Energir	Quebec, 2018	Crop residues, agri-food residuals, landfills; manure and pulp mill sludge excluded	25.8

*Used as primary reference of potential in *Renewable Natural Gas Technology Roadmap for Canada* (Canadian Gas Association)[5]

1.2 Project Purpose, Scope, and Approach

Since RNG can be transported using existing natural gas infrastructure and used as a fuel for heavy duty ground transportation, one of the fastest-growing sources of GHG emissions, there is great interest in opportunities to increase RNG production in Canada. However, there is significant uncertainty regarding the quantity of RNG that could be produced in specific regions and at a given price. This uncertainty is more pronounced than for other forms of bioenergy due to the high costs of transportation of many feedstocks, as dictated by their high moisture content and low bulk density, and the need to locate RNG production facilities in relative close proximity to a natural gas pipeline or RNG consumer. A high feedstock transportation cost means economically-viable RNG production potential is highly localized and dictated by the concentration of feedstocks within a very limited geographic area. Recognizing the importance of local data to national decarbonization and energy policy, Natural Resources Canada sought to better understand, at a regional level of detail, RNG production potential in Canada. TorchLight Bioresources was contracted to quantify regional RNG feedstock resources across Canada and to identify high-yielding feedstock regions. Within the high RNG opportunity regions, a high-level analysis of current feedstock use and disposal was used to estimate the 'available' RNG feedstocks. This availability was also linked to potential scenarios of RNG production cost. Aggregated, this information provides an understanding of the potential RNG flows within and between provinces.

The scope of the project included all potential biomass RNG feedstocks, excluding primary agriculture crops and animal fats. An exception was provided to corn silage, including grain and feed corn, as it is a primary feedstock for RNG production in the EU. The justification for exclusion of animal fats,[i] vegetable oils, and grains (other than corn) is that these can be used for 'drop-in' liquid biofuels of renewable diesel, biodiesel, and ethanol. Crop residues were considered within scope. Feedstocks were generally divided into two categories of conventional RNG feedstocks and advanced RNG feedstocks. Conventional RNG feedstocks are those that can be converted into RNG via upgrading of landfill gas or biogas from conventional anaerobic digestion (AD). AD feedstock options include animal manure, biosolids (sewage) and wastewater, urban organics (residential and commercial food waste), pulp mill sludge, corn (including grain) silage, and agricultural crop residues including wheat, barley, and oat straw. Advanced RNG feedstocks, such as forest harvest residues and roundwood, are those that require gasification and methanation (or alternate thermal route) technology. Categories of feedstocks are listed in Figure 2.

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[i] It is known that some animal fats are currently used in Canada's anaerobic digesters, but the majority are used for biofuel production or exported to other countries.

Figure 2. RNG Feedstock Categories and Examples

Category	Feedstocks	Conversion Technology
Conventional	Animal Manure Biosolids Wastewater Urban Organics Food and Beverage Facility Residues Pulp Mill Sludge Corn Silage (including Grain) Wheat, Barley, Oat Straw	Anaerobic Digestion & Biogas Upgrading
	Landfill Gas	Landfill Gas Upgrading
Advanced	Roundwood Sawmill Residues Forest Harvest Residues	Gasification & Methanation Pyrocatalytic Hydrogenation
Out-of-Scope (likely to be used for other products)	Wheat, Barley, Oat Grain Vegetable Oil Animal Fats	Grains to ethanol Vegetable Oil and Animal Fats to Renewable Diesel/Biodiesel

Both conventional and advanced RNG feedstocks were quantified by Canada Census Division across Canada. In Ontario, Quebec, and Atlantic Provinces, Census Divisions typically align with county boundaries. In Western Canada, census divisions outside cities are generally geographically larger.[8] For some feedstocks, including pulp mill sludge, food and beverage facility residuals, feedlots, and landfills, data is typically point-source. In contrast, crop residues, corn silage, and non-feedlot livestock data are collected on an area (polygon) basis. For urban population feedstocks, including biosolids and urban organic waste, the feedstock potential was spread across an entire Census Metropolitan Area (CMA). The potential for each feedstock by Census Division was mapped in ArcGIS, with point source data aggregated by Census Division. These maps are presented in Section 2, with data presented in Appendix 1.

The all-feedstock theoretical conventional and advanced RNG potential was quantified by each Census Division and sixteen high-yielding feedstock regions were identified. Given the pre-commercial status of advanced RNG, a priority was placed on regions with a large conventional RNG potential. A high-level assessment of current feedstock use and fate within these regions was conducted. The high opportunity Census Divisions and their feedstocks are identified and described in Section 3 of this report.

Although not the primary focus of this project, a brief review of technology readiness and RNG production costs was completed. Using this information and estimates on feedstock cost, the production cost of RNG under various scenarios was estimated. This included capital expenditure (CapEx), feedstock, and non-feedstock operating expenditure (OpEx) estimates. Finally, estimated RNG potential by province was compared with Canadian Energy Regulator-projected natural gas demand in each province in the year

2040. This comparison enabled the development of projections on interprovincial RNG trade to meet specified blend levels of 1%, 5%, and 10%. A discussion on the role of RNG in Canada's decarbonization strategy and recommendations on Government of Canada priorities to realize Canada's RNG potential are also provided.

2 REGIONAL RENEWABLE NATURAL GAS POTENTIAL

A variety of data sources were used to quantify RNG potential at a Canada Census Division level of detail.[ii] Whenever possible, Government of Canada data from Statistics Canada, Environment and Climate Change Canada, National Research Council, Natural Resources Canada, Agriculture and Agri-Food Canada were prioritized and used. The RNG potential by Census Division is presented in terajoules (TJ), with one TJ equal to 1,000 gigajoules (GJ) and 1,000 TJ equal to one petajoule (PJ). RNG yields are presented per GJ and national contribution by resource in PJ. To put the resource potential in perspective, Canada's total primary energy supply, which includes the energy content of fuels prior to conversion (e.g., to electricity), was 12,100,000 TJ (12,100 PJ) in 2018. Natural gas constituted approximately 40% of this figure.[2] It should be noted that all estimates of conventional RNG potential do not take into consideration competing demand by existing feedstock users, including existing biogas plants.

2.1 Manure Resources

Livestock manure is a primary resource for conventional biogas and RNG production in Canada, the U.S., and EU. In Canada, most livestock manure is applied to agricultural land as a source of nutrients. In addition to electricity and heat generation, consumption of manure in AD facilities serves an important role in waste disposal in areas with high nutrient loadings (e.g., Lower Fraser Valley of British Columbia). Canada's livestock industry growth is flat, with increases in poultry and hog production offsetting declines in beef cattle production. Manure production is typically calculated as a percent of body weight, with notable differences between species. Based upon previous studies, assumed manure production, manure recovery rate, and biogas and RNG yield per tonne are presented in Figure 3. As Canada is not a large sheep or goat producer, those livestock are excluded from the total.

Figure 3. Livestock Manure Resource Assumptions

Type	Units (head)	Manure Production (t/yr)	Recovery Rate (%)	Biogas Yield (m^3/t)	Biomethane (m^3/yr)	RNG Energy (GJ/yr)[b]
Dairy Cows	1	22.6	82	28	281	10.4
Beef Cattle[a]	1	12.4	80	25	136	5.0
Hogs	1	1.8	90	41	39	1.4
Layer Chickens	1,000	44	95	75	2,027	75
Meat Chickens	1,000	29	95	75	1,351	50
Turkeys	1,000	110	95	75	5,081	188

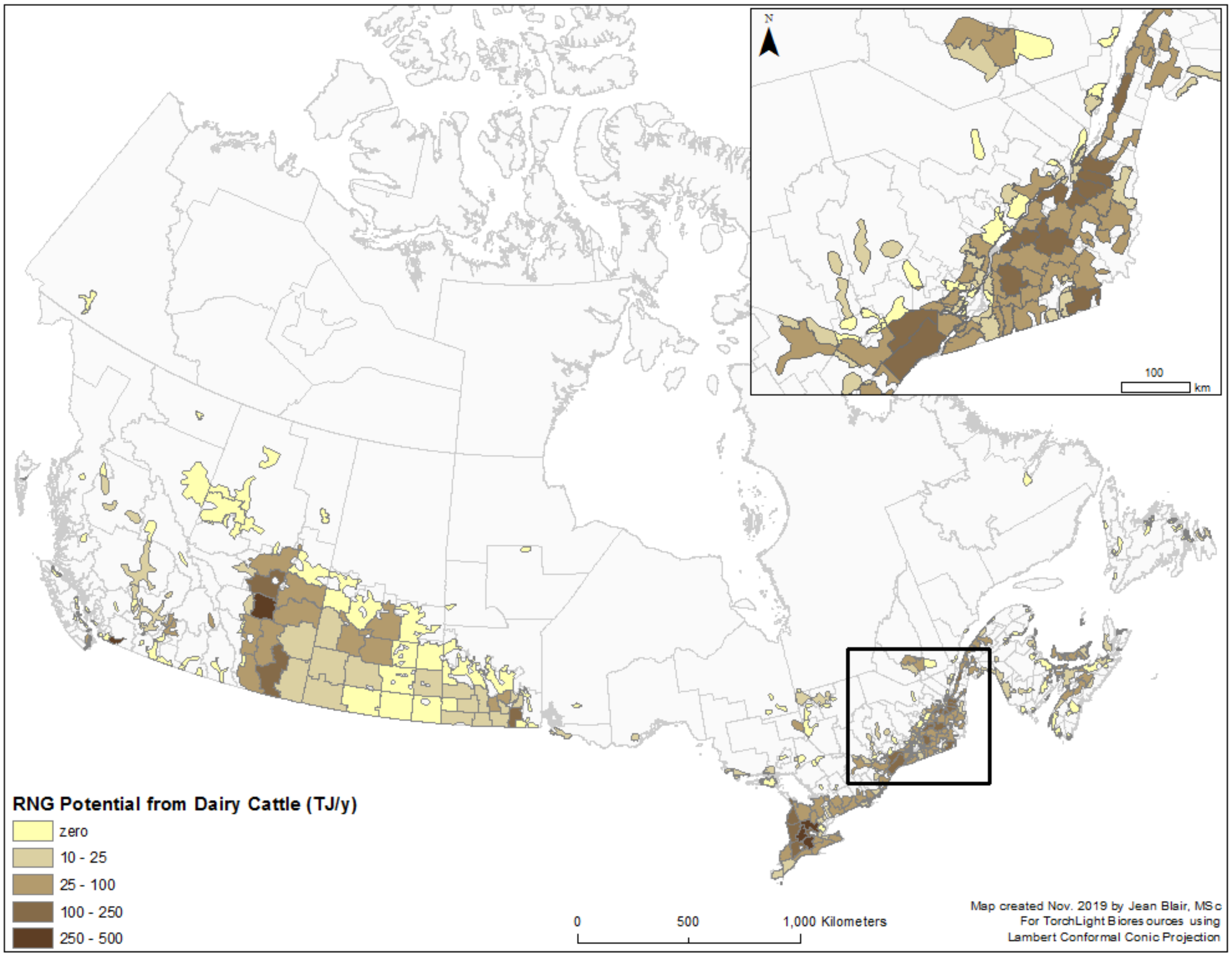
[a]Feedlots only; beef cattle outside of feedlots excluded due to the difficulty of collecting manure
[b]Yield of manure alone, assuming no co-digestion
References: [9,10,11,12,13]

[ii] Census Division is the second-highest level of detail of the Canada Census and roughly corresponds to counties

The 2016 Census of Agriculture, completed by Statistics Canada, was the source of data on dairy cows, hogs, and poultry head count and location.[14] Location was given by Census Division, with an overlay of the agriculture ecumene (the area where agriculture activity in present). It was assumed the head count included in the Census of Agriculture is representative of the average head count throughout a calendar year. Due to the difficulty in recovering manure from beef cattle outside a feedlot, Census of Agriculture data was not used for beef cattle. Instead, the Canadian Cattlemen Feedlot Guide, which includes feedlot locations and capacities, was used to identify point sources of manure.[15] It was assumed that feedlots have an average capacity factor of 80% throughout the year.

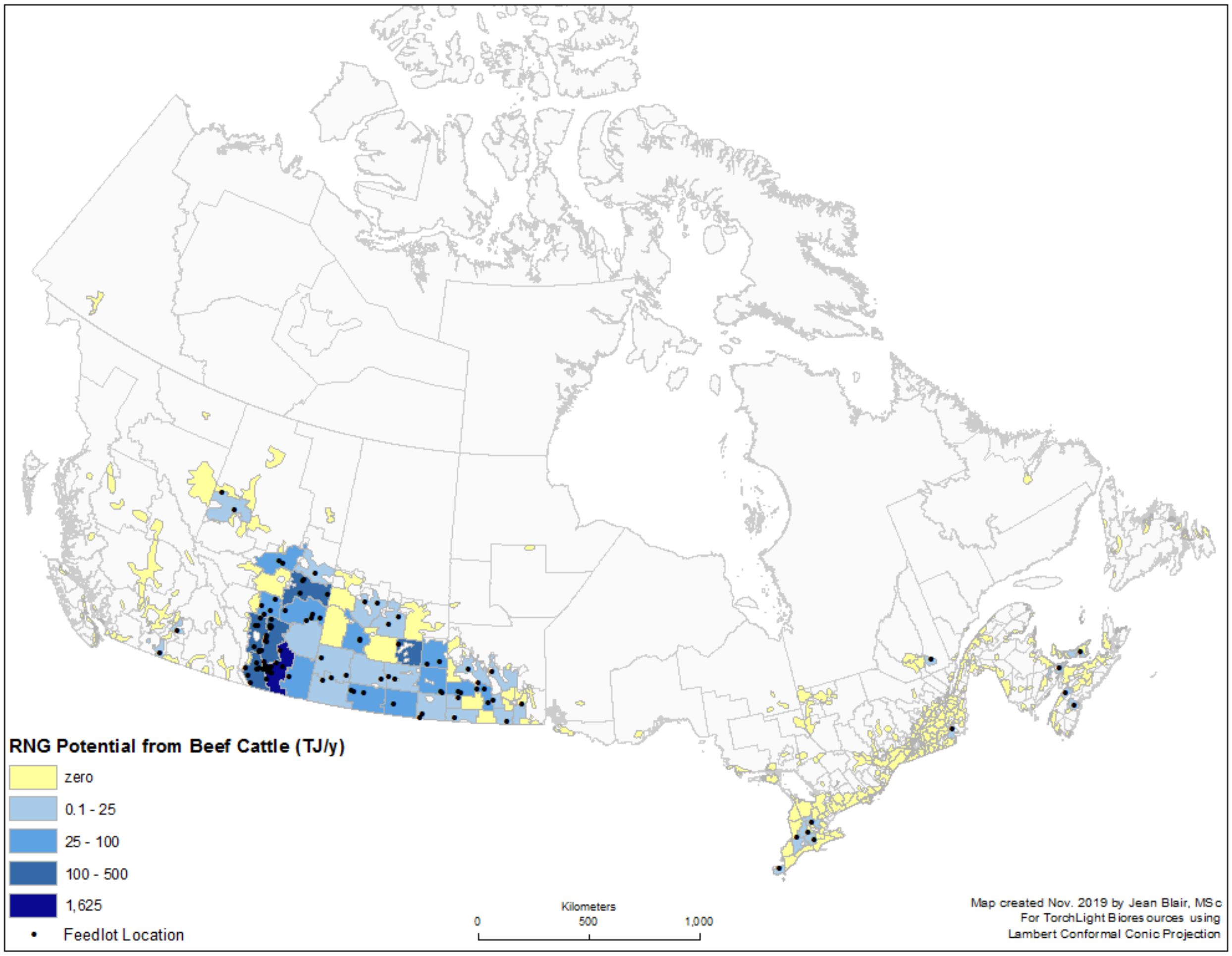
Based on 2016 Census of Agriculture data, the Feedlot Guide, and RNG energy yield assumptions presented in Figure 3, the manure-based RNG energy potential by census region was mapped for each livestock type. These are presented in Figures 4 to 7, with poultry was grouped into a single map. The theoretical annual potential for RNG from livestock manure in Canada was estimated to be 40 PJ or 1,100 M m^3. While this figure has recovery rate assumptions included, some of this energy resource will not be viable for RNG projects due to low regional resource densities and associated challenging economics for feedstock delivery to centralized production sites and natural gas pipelines.

Figure 4. Dairy Cow Manure RNG Production Potential



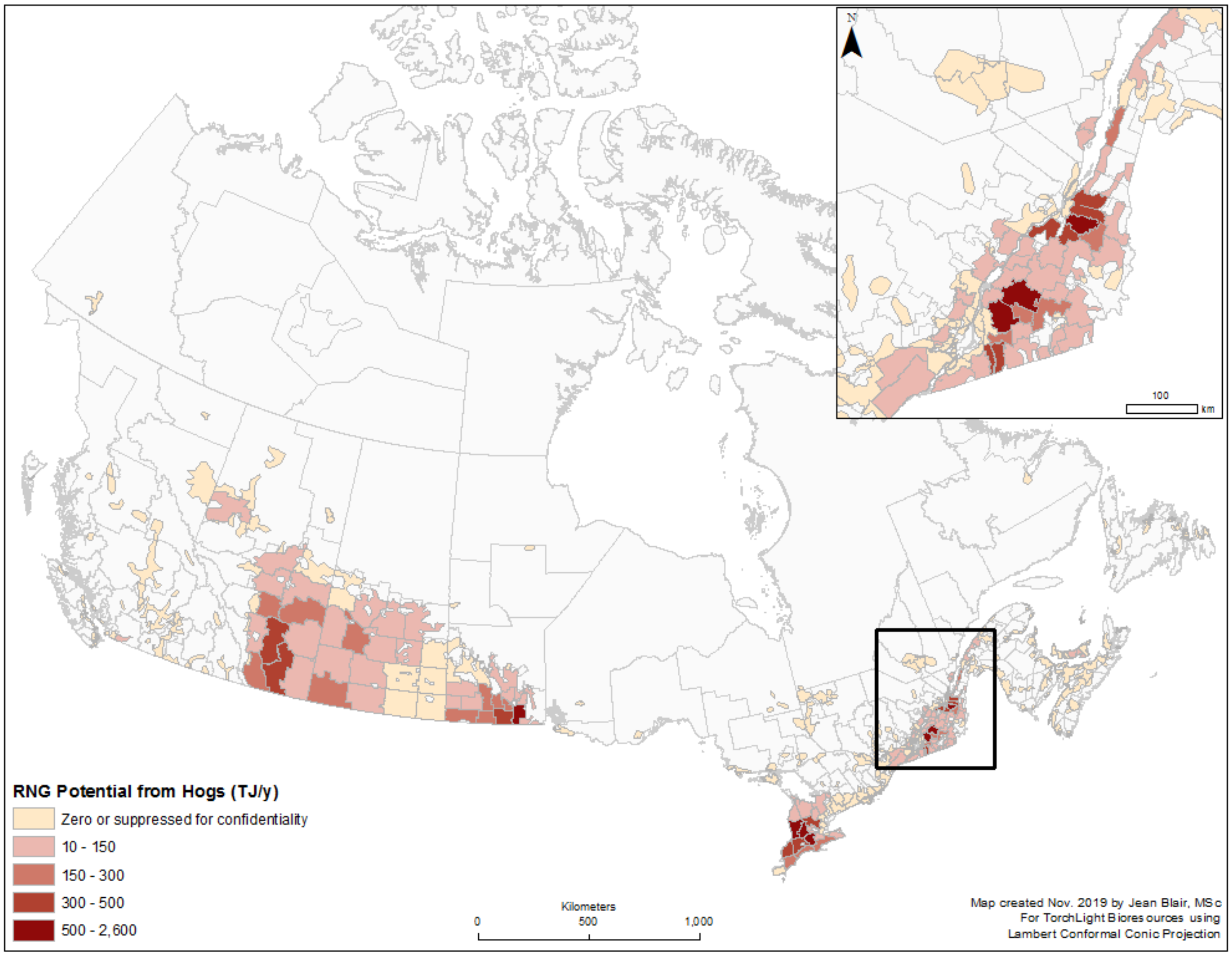
Reference: [14]

Figure 5. Beef Cattle Manure RNG Production Potential (Feedlots)



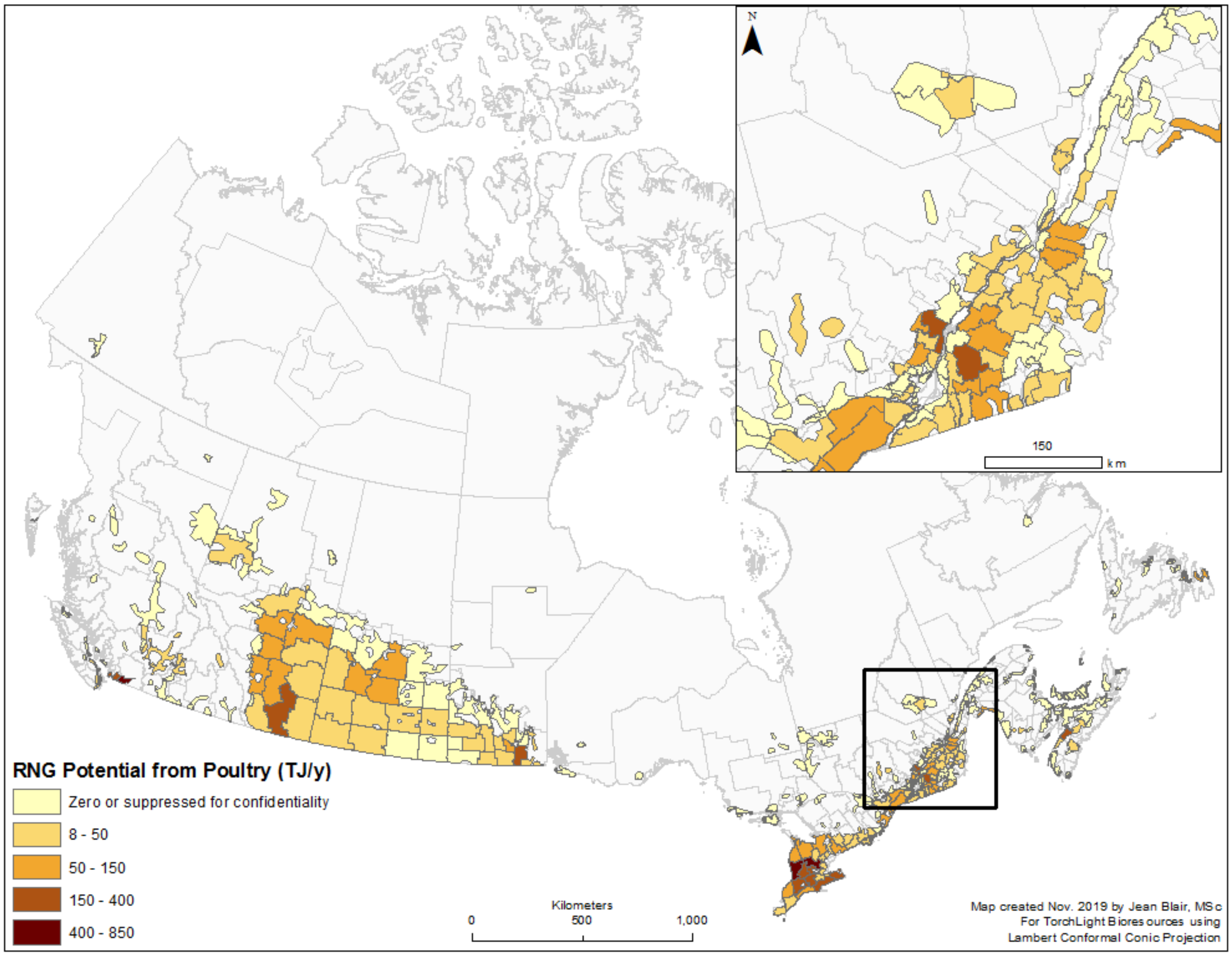
Reference: [15]

Figure 6. Hog Manure RNG Production Potential



Reference: [14]

Figure 7. Poultry Manure RNG Production Potential



Reference: [14]

2.2 Biosolid/Wastewater Resources

Biosolids, or sewage sludge, are concentrated by wastewater treatment plants. Production is proportional to population. RNG potential estimates are based upon population statistics and the resource opportunity is greatest in urban centres. The National Research Council of Canada (NRC) quantified wastewater production for each municipality in four provinces: Ontario, Quebec, Alberta, and Newfoundland. This data was contrasted with previous estimates of per capita wastewater production and dry matter/biogas potential per volumetric unit of wastewater. In order to calculate and map the biosolids-based RNG potential in Canada, the following assumptions were made:

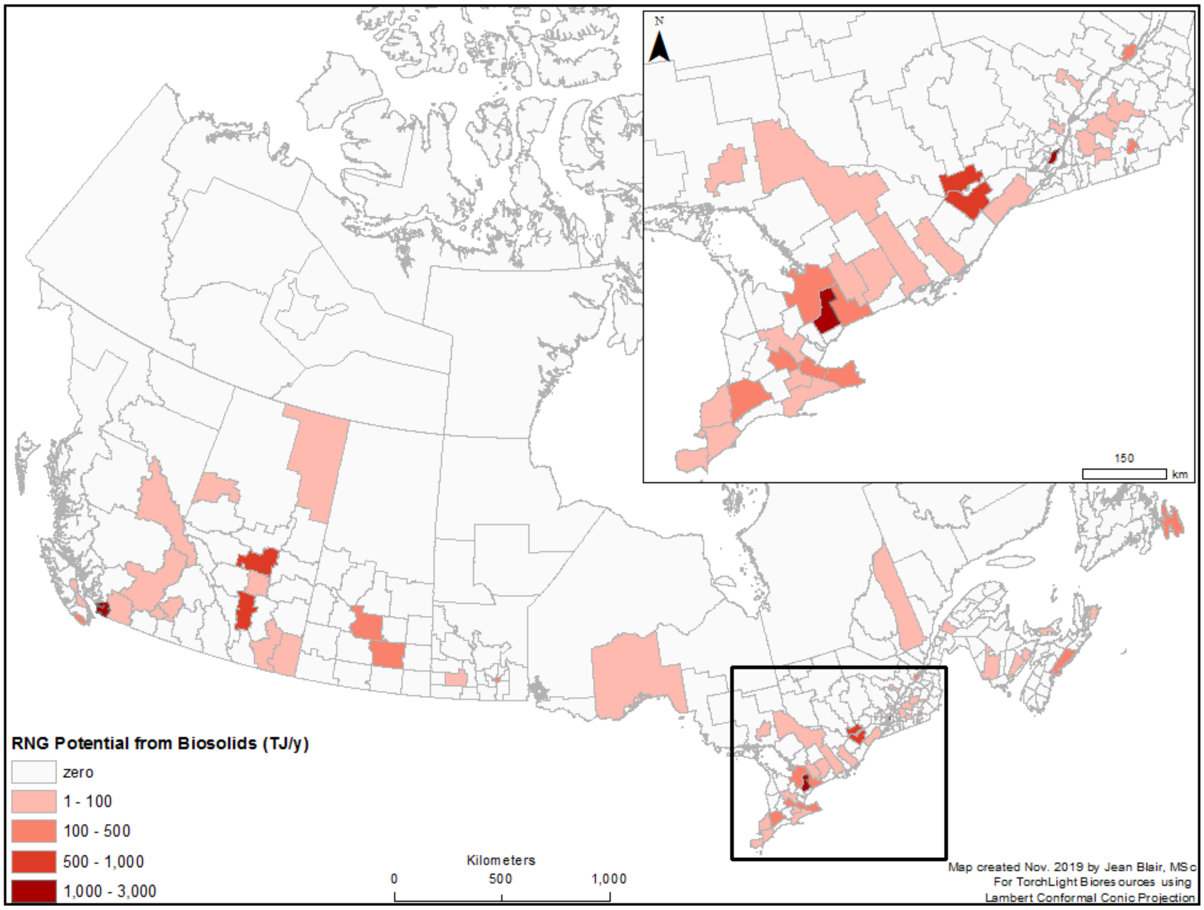
- Annual per capita wastewater production: 170,000 litres
- Wastewater dry matter content: 263 kg/ML
- Annual per capita wastewater dry matter production: 44.7 kg

- Biogas yield per (dry) tonne of dry matter: 475 m^3
- Methane content of biogas: 65%
- Annual per capita RNG potential: 0.5 GJ

References: [13,16,17,18,19]

Regions with low population densities have poor biosolids resources and are thus unlikely to support RNG projects consuming significant quantities of biosolids. Consequentially, only Census Agglomerations (CAs) and Census Metropolitan Areas (CMAs) were considered as potential biosolids resource locations. CAs are urban areas with a core population of at least 10,000, while CMAs are urban areas with a core population of at least 100,000. Areas with a population centre less than 10,000, which represent 24% of Canada's population and include non-urban rural areas, were assumed to have zero biosolids potential. Approximately 19% of Canada's population live in rural areas outside a population centre of 1,000 or more.[8] Since several Census Divisions can constitute a single CMA and wastewater processing is typically centralized for a CMA, the biosolids opportunity across a CMA is allocated to the most central Census Division. These are presented in Figure 8. Based upon this urban area-focused analysis, the annual RNG resource potential in Canada is 14 PJ or 380 M m^3.

Figure 8. Biosolids RNG Production Potential



Reference: [20]

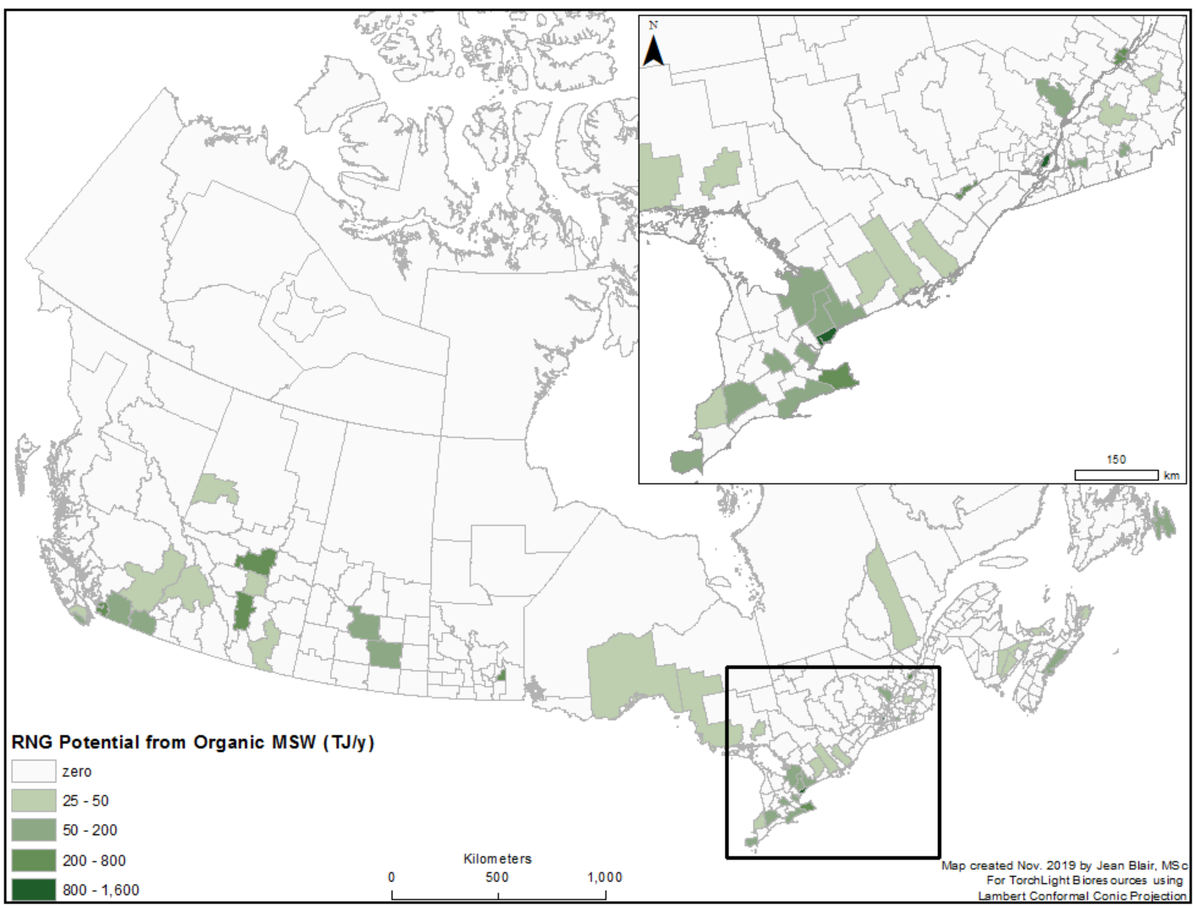
2.3 Urban Organic Resources

Canada's urban organic RNG resources (source separated organics or SSO), including food waste and non-woody yard waste, were quantified using data compiled by the NRC. Resources were calculated and mapped on a CA/CMA basis, with resources allocated to the Census Division central to a CMA (Figure 9). As with biosolid resources, collection of food waste in low population density regions may be economically difficult to justify for some municipalities. Industrial food and beverage processing facility resources are excluded from these calculations and efforts to quantify these resources are described in Section 2.4. The annual urban organic resource RNG potential in Canada is estimated at 8 PJ or 216 M m^3. The RNG calculations assumed:

- Biogas yield per dry tonne: 415 m^3
- Biogas methane content: 65%
- Total solids content: 24%

References: [13,21,22]

Figure 9. Urban Organics RNG Production Potential



Reference: [20]

2.4 Food and Beverage Facility Residuals

The food and beverage sector is Canada's largest manufacturing industry, employing more than 250,000 people at over 11,000 facilities. Domestic food and beverage facilities provide approximately 75% of the processed food and drinks consumed by Canadians every year. These facilities are an important source of potential feedstocks, primarily in the form of food processing residuals and wastewater, for RNG production. Unfortunately, despite extensive investigation and efforts to identify specific facilities and their RNG production potential, it was determined that there is no publicly available Canadian database of facilities and their production capacity. Statistics Canada has collected a database of all production facilities, but only tracks revenue and does not have physical production capacity data. Industry associations were not willing to provide member and broader industry data, despite repeated requests. Without individual facility production capacity, it is not possible to estimate the RNG potential from food and beverage facilities at a Canada Census Division level of detail as was completed for other feedstocks considered in this report. In order to determine the RNG potential from the food and beverage processing sector, a database of facilities and their waste discharge information, combined with estimates for chemical oxygen demand (COD) loading and biochemical methane potential (BMP), must be created. A database of this type, named the Excess Food Opportunities Map, is publicly available in the United States from the Environmental Protection Agency. The lack of a similar database and map in Canada is an impediment to the growth of the RNG sector because developers lack data on available resources.

While the lack of food and beverage processing facility data is a notable gap in the RNG feedstock quantification analysis of this report, there are several reasons that the results for total RNG potential should still be considered fairly accurate. The first is that previous national assessments of food and beverage facility RNG potential have found a limited potential contribution. The Canadian Biogas Study, completed by Kelleher Environmental and Robins Environmental, estimated 5.6 PJ of RNG production potential from commercial source-separated organics.[3] This is less than 7% of the national potential identified in the report and less than 4% of the feasible potential estimated in this report. The provincial estimates from the Canadian Biogas Study are presented in Figure 10. The second reason is that wastewater from food and beverage production facilities is typically disposed of in municipal wastewater treatment systems. Therefore, these figures are already included in Section 2.2, which estimates biosolid and wastewater RNG potential. Finally, the vast majority of food and beverage processing facility residue/waste would not be available for direct RNG production because it is currently being used as animal feed. Without a major change in livestock feeding operations, the RNG potential from these facility residues will be small. It is estimated that more than 85% of U.S. food processing facility residue is consumed by livestock. This would exclude feedstocks such as dairy product residue, including whey. Since food processing residue is already used as animal feed, the 'potential' for this feedstock is already included in the estimate for manure resources because redirecting this feedstock to RNG production would cause a drop in other potential feedstock availability (e.g., corn) to compensate for reduced food waste feed. Therefore, it is projected that very little food and beverage facility waste is not already included in resource estimates for other RNG feedstock categories. Adding this material to the total resource estimate may result in double counting.

Figure 10. Commercial Organics Potential (Canadian Biogas Study)

Jurisdiction	RNG Potential (M m^3/yr)	RNG Potential (PJ/yr)
British Columbia	17.4	0.5
Alberta	30.1	1.1
Saskatchewan	6.7	0.2
Manitoba	5.8	0.2
Ontario	61.8	2.3
Quebec	30.1	1.1
New Brunswick	2.6	0.1
Nova Scotia	2.3	0.1
Newfoundland and Labrador & Prince Edward Island	-	-
Territories	-	-
Canada	**160**	**5.6**

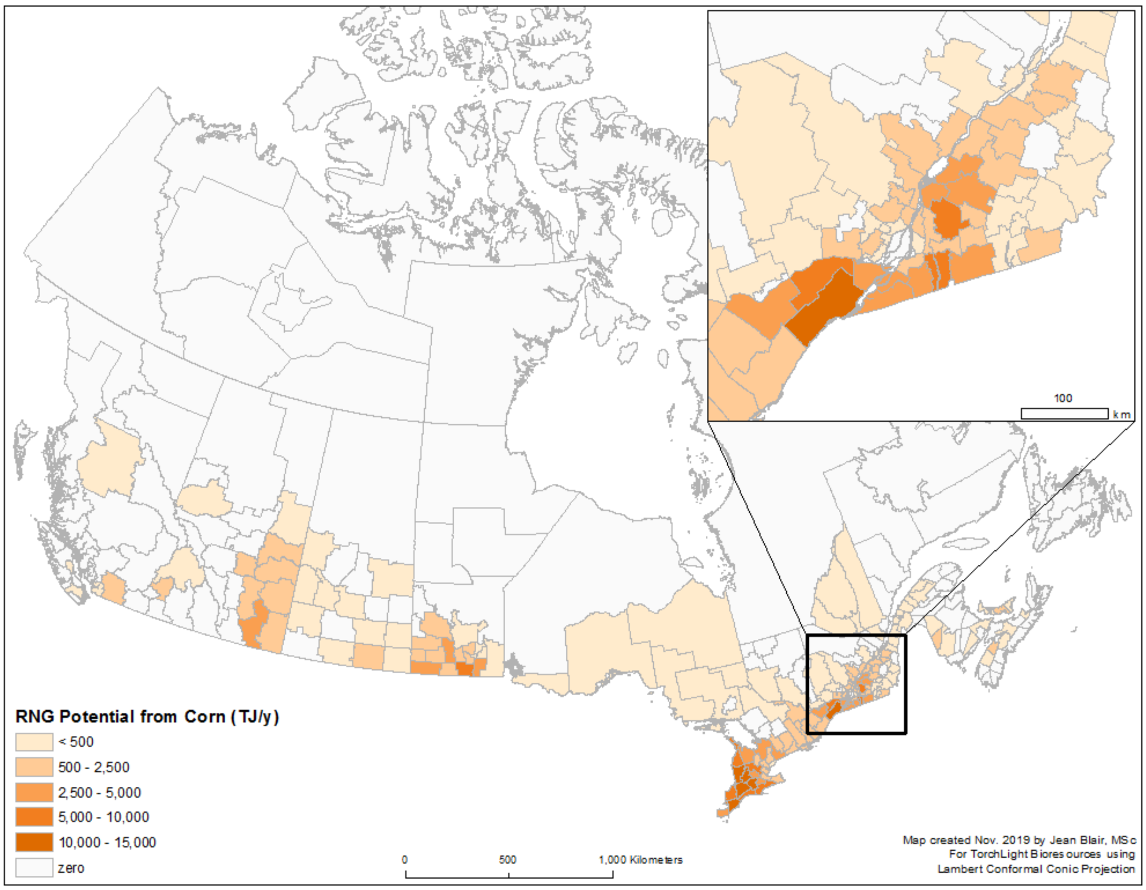
Reference: [3]

2.5 Corn Silage

Although not included in several previous RNG feedstock resource assessments, corn silage is the leading feedstock for biogas production in Germany – the world's largest producer of biogas. In Canada, corn silage production is for livestock feed and there is little to no silage production for biogas or RNG.

Quantification of the RNG production potential from corn silage is based upon Census Division level total corn crop area data sourced from the 2016 Census of Agriculture. Since the Census of Agriculture does not collect crop yield data, this information was sourced from Agriculture and Agri-Food Canada's Biomass Inventory Mapping and Analysis Tool (BIMAT). However, the data in the tool is from the period of 1985-2000, making it very out of date. To compensate, the average changes in provincial corn grain crop yields between 2000 and 2018 were applied to Census Division figures from BIMAT. Where no BIMAT data was available (e.g., corn crop in Manitoba), the provincial average for 2018 was used. Biogas yield was assumed to be 610 m^3 per dry tonne of corn silage.[13,22] Of all conventional resources considered, corn silage, including allocation of current grain/field corn acreage for corn silage, had the greatest RNG potential at 287 PJ or 7,760 M m^3 per year (Figure 11). However, the grain corn and corn silage portions of this estimate are already in demand for animal feed, ethanol, and food markets. Only stover from grain corn is an unallocated, 'available' feedstock. This may change, depending on future economics, energy policies, and market drivers.

Figure 11. Corn Silage RNG Production Potential

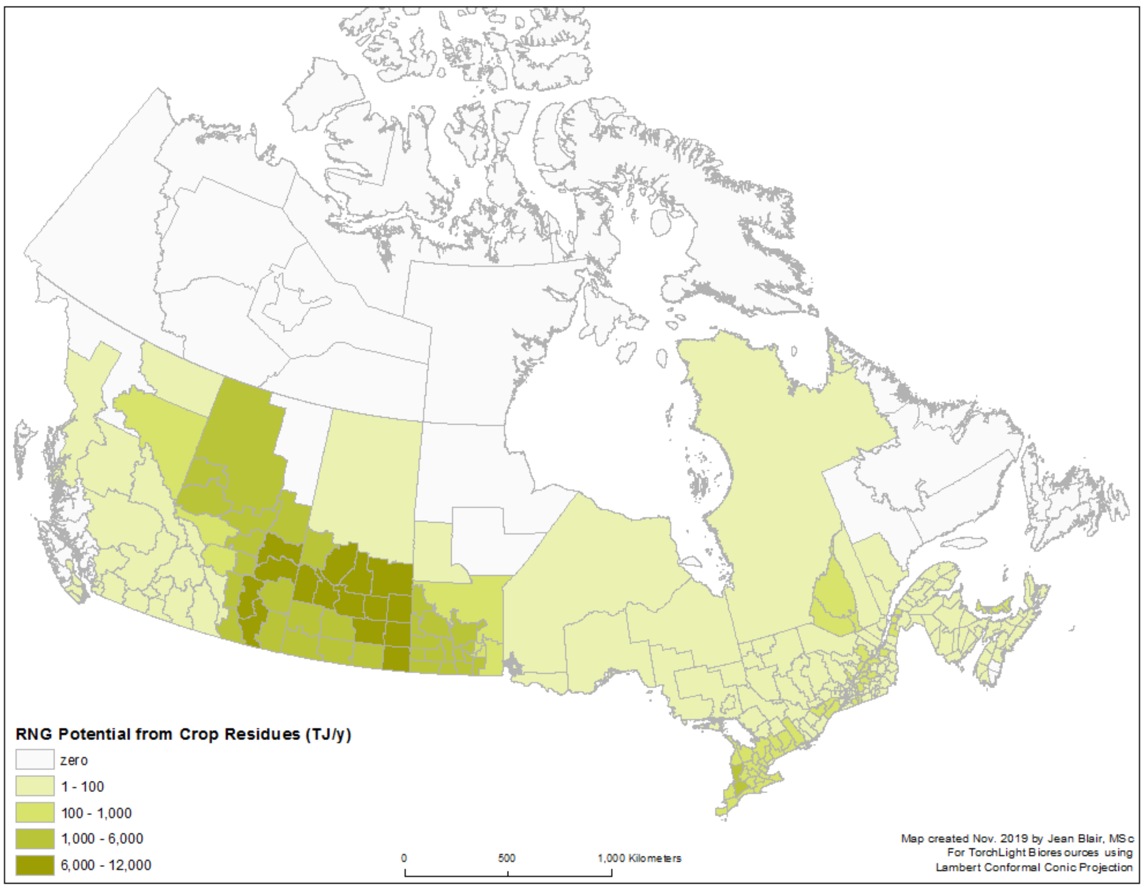


References: [13,14,22,23,24]

2.6 Crop Residues

Recent technology advances in pre-treatment and material cycling have permitted 100% crop residue biogas production, but this is rarely practiced. Co-digestion of crop residues with other feedstocks, such as urban organics, is the most common approach for biogas production from this resource. The primary source of data for the crop residue feedstock quantification was BIMAT. As already noted, BIMAT data is out of date. Since 2000, wheat production has gone up while barley and oats production has gone down, resulting in only modest changes in overall residue availability. Given the scope and required detail for the analysis, use of BIMAT data for crop residues was deemed reasonable. Straw and chaff from wheat, barley, and oats were included in the aggregated estimate. Corn stover is excluded, as it is included in the corn silage results in Section 2.4. A biogas yield of 400 m^3 per dry tonne of straw was assumed. After accounting for residue retention to ensure adequate soil carbon and moisture, the potential for RNG production from wheat, barley, and oat straw residues in Canada is 250 PJ or 6,750 M m^3 (Figure 12). This is the second largest potential, after corn silage, of any conventional resource. However, the energy output is notably less than would be produced from direct combustion of the same material.

Figure 12. Wheat, Barley, and Oats Crop Residue RNG Production Potential



References: [13,14,22,23,24]

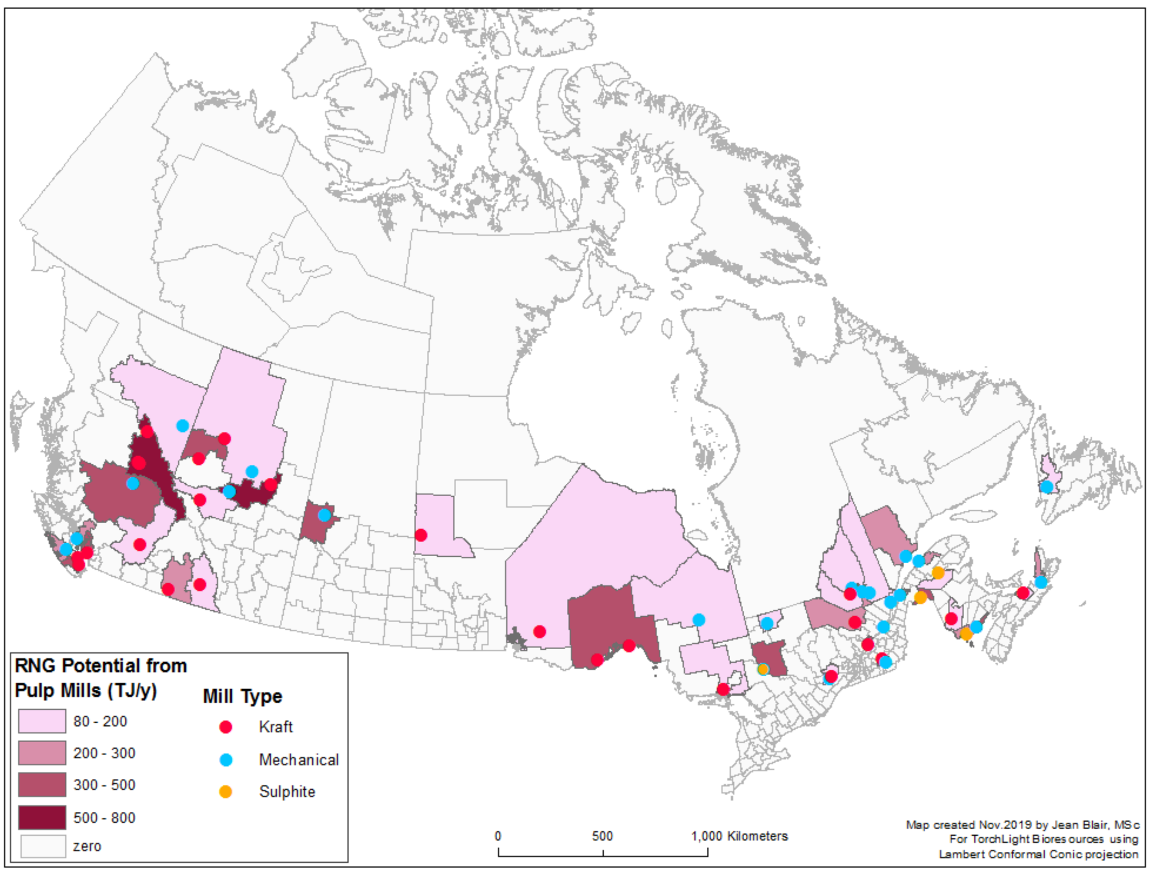
2.7 Pulp Mill Wastewater and Sludge

Pulp mills process wood into pulp, which is used to make paper and other fibre products. Significant quantities of sludge and wastewater are produced as by-products and can serve as feedstocks for biogas production. Three of Canada's pulp mills have operating AD systems. The rate of sludge production is highly mill specific, but general assumptions can be made about the ratio of sludge and biogas potential to pulp output. This ratio differs based upon pulp mill type, with the three major types being kraft (sulphate-based chemical), sulphite (or dissolving chemical), and mechanical. Information from existing pulp mill AD installations, combined with figures from the literature, were used to estimate RNG potential. The total Canadian RNG potential from pulp mill sludge and wastewater was determined to be 12 PJ (315 M m^3), based upon the following yield assumptions:

- Kraft: 25 m^3 biogas (0.5 GJ) per tonne of pulp
- Sulphite: 65 m^3 biogas (1.3 GJ) per tonne of pulp
- Mechanical: 40 m^3 biogas (0.8 GJ) per tonne of pulp

References: [25,26,27,28,29]

Figure 13. Pulp Mill RNG Production Potential



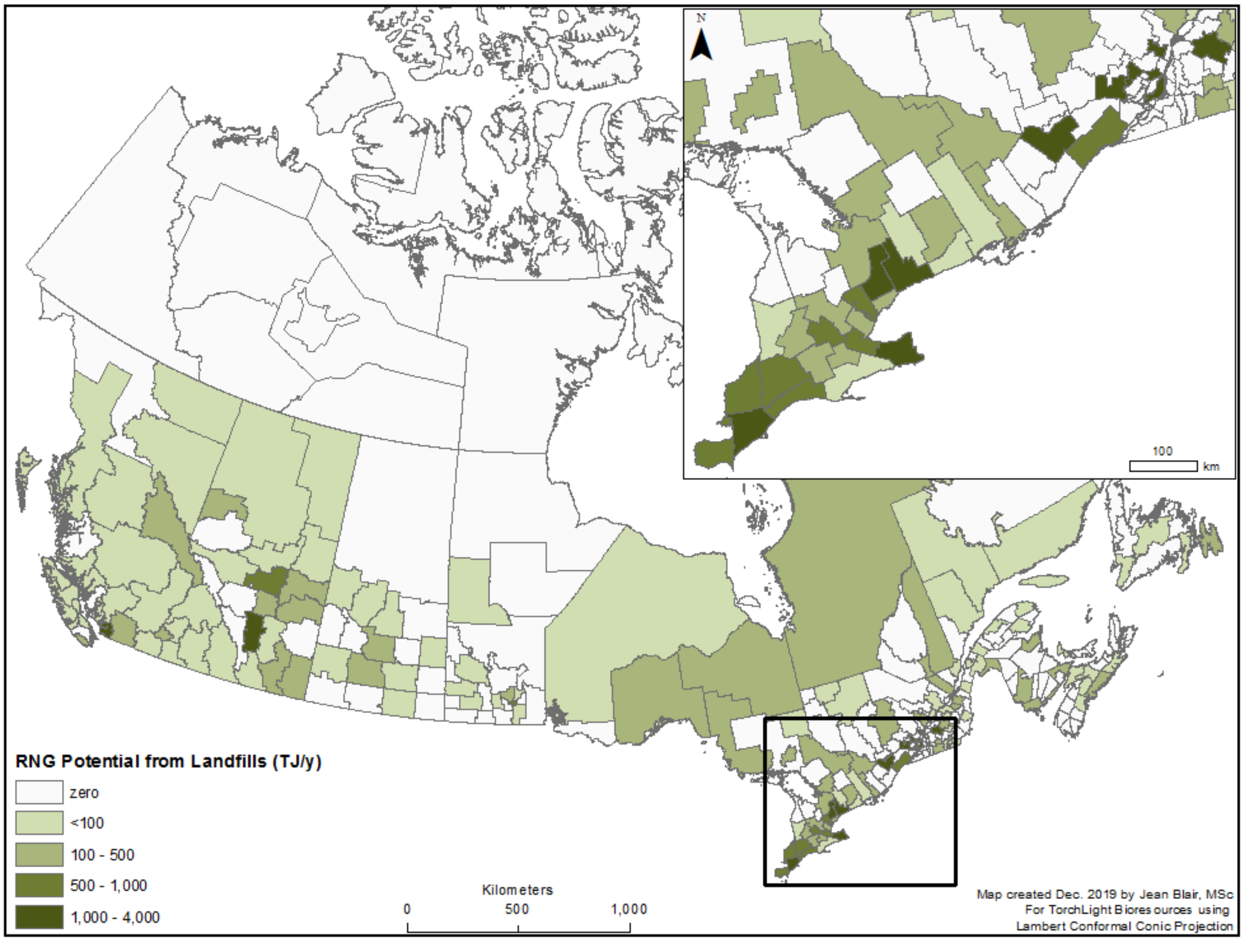
Reference: [30]

2.8 Landfills

Landfill gas, like biogas, has a 50-60% methane content and can be readily purified into RNG. It can be captured from existing (open and closed) landfills using pipeline systems and delivered to a central processing facility. It can also be produced for decades following the closure of a landfill. While there may be opportunities to combine biogas and landfill gas for upgrading in centralized, multi-source facilities in close proximity to each other, the different gas components and geographical constraints mean landfill gas-based RNG projects are likely to be stand-alone landfill gas-to-RNG plants. This contrasts with AD projects, where multiple feedstocks can be mixed and consumed at a single facility to increase biogas production and facility scale. Landfill scale, location, and age all impact landfill gas potential.

Environment and Climate Change Canada compiled a national database of landfills and used climate, landfill age and design, and waste delivery rate to estimate annual landfill gas output. Based upon a review of existing RNG projects in the U.S. and the EU, it was determined a minimum landfill gas output of 9,000 GJ (9 TJ) per year would be used as the cut-off for RNG potential quantification. As an example of existing RNG projects near this scale, the Salmon Arm Landfill RNG project is BC has a capacity of 16,000 GJ (16 TJ) per year. Based upon Environment and Climate Change Canada (ECCC) landfill gas estimates and the scale cut-off, the national RNG potential for landfills is 49 PJ or 1,300 M m^3 (Figure 14). This includes landfills that already generate electricity and/or useful heat from landfill gas.

Figure 14. Landfill RNG Production Potential



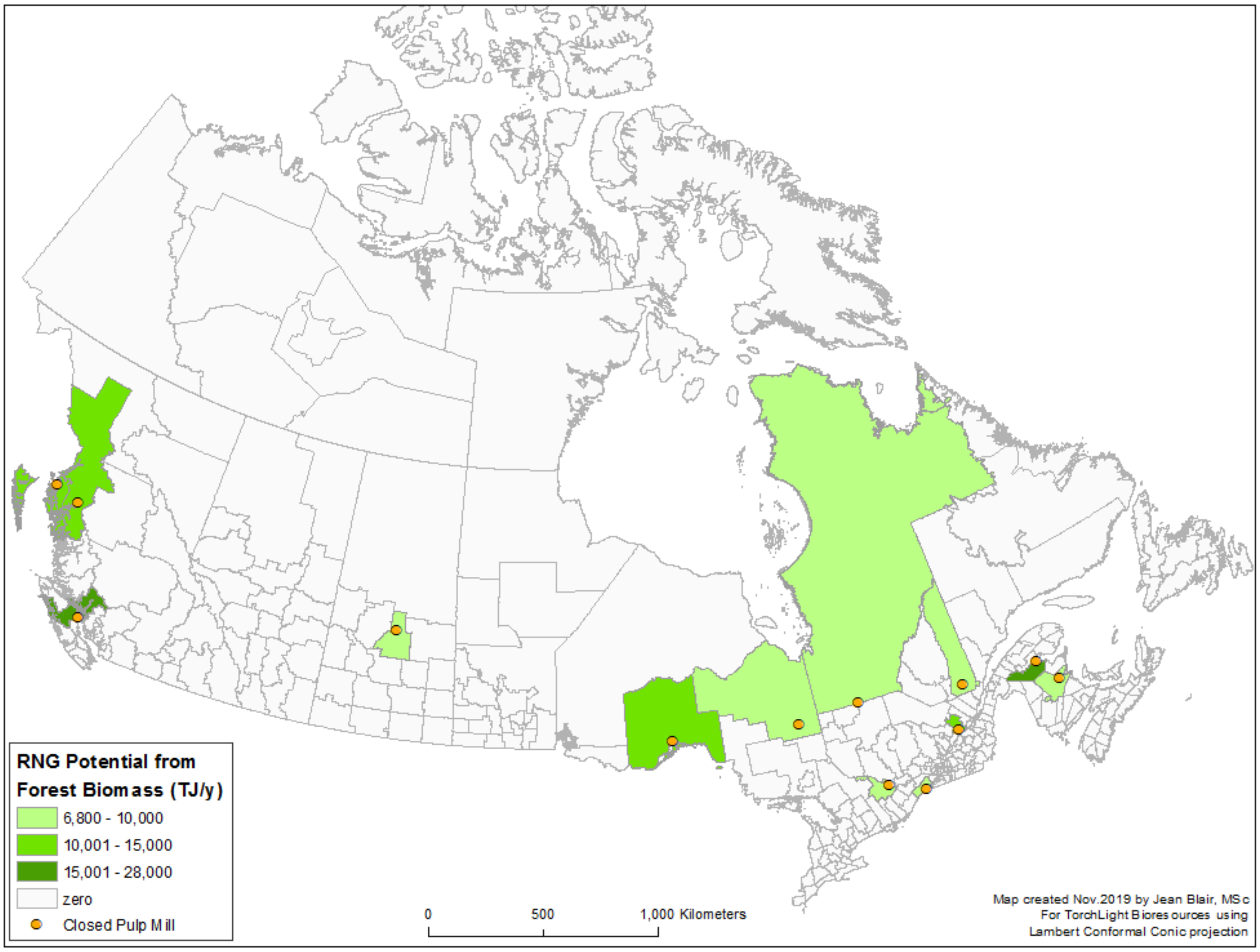
Reference: [31]

2.9 Forest Resources

Conversion of woody forest resources, including roundwood (tree trunk), harvest residues, and mill residues, requires utilization of 'advanced' gasification or pyrolysis-type technologies to produce RNG. However, none of these technologies are commercial at present. Since technology assessment is not a major component of this work, it was decided that for RNG potential quantification purposes, the most well-known process for RNG production from wood – gasification followed by syngas clean-up and methanation to methane – would be assumed. Globally, there are no commercial facilities using this process. The only demonstration-scale project to date, GoBiGas in Gothenburg, Sweden, found very significant economies-of-scale and determined a commercial plant would need to be approximately 6,300 TJ (6.3 PJ) RNG output capacity.[32] This equates to an annual feedstock consumption of approximately 500,000 dry tonnes, or 1 M m^3 of wood fibre, per year.

Tenure-based management of Canada's publicly-owned forests means securing 500,000 dry tonnes of wood fibre as harvest residues will be challenging. Competition for fibre from existing pulpwood and residue-consuming facilities, including pulp mills, means establishment of a wood-to-RNG plant consuming 500,000 dry tonnes per year is unlikely to happen near successful forest products clusters. However, since 1999, 38 pulp mills have closed in Canada, while no greenfield mills have been built.[30,33] Pulp mills were typically built in regions with sufficient wood resources to support their operations, so the ability of a region to support a pulp mill provides a reasonable indicator of whether the region could support a new wood-to-RNG facility. In the absence of a Canada-wide, sub-regional wood fibre supply and flow analysis, it was determined that the best approach for quantifying advanced RNG potential from forest resources was to assess the capacities of closed pulp mills and to use those capacities as an indicator of wood fibre availability. Based upon closed mill capacities, it was determined Canada could support 13 RNG production facilities consuming 500,000 dry tonnes, including pulpwood, mill residues, and harvest residues, per year or more (Figure 15). Assuming a wood-to-RNG energy yield of 60%, the RNG potential from forest resources in Canada was estimated to be 150 PJ, or 4,050 M m^3, per year.[40] While this is notably lower than previous estimates for RNG potential from Canada's wood resources, such as the 670 PJ estimated by Abboud et al. (2010),[4] it should be considered a more realistic medium-term figure for forest-based greenfield facilities that will require forest tenure and/or highly secure feedstock supply agreements in order to finance an anticipated single plant CapEx of C$700 M to C$1 B.[40,46] Certainly, the absolute potential could be dramatically greater – up to ten-fold higher is estimated – especially if Canada adopted active forest management on Crown timberlands. However, this does not represent the current, realistic potential.[42]

Figure 15. Forest Resources RNG Production Potential



Reference: [30,33]

2.10 Aggregated Resources & Regional Opportunities

Based upon the individual resources estimated in Sections 2.1 to 2.9, the total theoretical RNG resource potential in Canada is estimated to be 809 PJ (Figure 16). This is equal to 17% of Canada's current natural gas consumption. However, this figure should not be interpreted as a realistic future RNG production volume. Of the 809 PJ, 150 PJ requires wood-to-RNG production – a pre-commercial technology pathway. In addition, of the remaining 660 PJ, approximately 540 PJ consists of straw (wheat, barley, oats) and the national corn crop (including grain corn and corn silage). Much of this material is currently consumed by other sectors (e.g., corn silage grown for animal feed) and/or is subject to significant annual supply variability (crop residues). This leaves 120 PJ per year, or 2.5% of Canada's annual natural gas consumption, which assumes all available conventional 'waste' and landfill gas feedstocks are converted to RNG. Not all of these resources will be available for RNG production. Some of these resources will be available for biogas production but will not be located close enough to an existing pipeline to warrant the cost of upgrading. Energy could still be recovered if there is a local use for the energy or opportunity to sell electricity to the grid. The Census Division scale of the analysis, combined with the lack of publicly available accurate maps on natural gas distribution and transmission pipelines, make it difficult to determine the proportion of this potential that will be geographically constrained. This is particularly true for landfill gas, which constitutes over 40% of the conventional RNG resource (excluding corn silage and crop residues), and numerous landfills do not currently have natural gas access. At present, 45 of the 327 landfills included in the ECCC database use at least a portion of the captured landfill gas for energy, with four generating RNG. An additional 67 landfills have landfill gas capture systems but flare the landfill gas.[31]

Figure 16. Theoretical RNG Potential, by Resource

Resource		Theoretical Potential (PJ)
Animal Manure		
	Dairy Cows	9.1
	Beef Cattle	3.5
	Hogs	19.4
	Poultry	8.8
Agricultural Crop		
	Corn Silage (Grain & Feed)	286.7
	Other Crop Residues	249.6
Urban		
	Biosolids & Wastewater	14.1
	Urban Organics	7.9
	Landfills	48.7
Forestry		
	Pulp Mill Sludge	11.8
	Wood	149.6
Total		**809.1**

The 2010 national biomethane potential study completed by the Alberta Research Council and the Canadian Gas Association found a crop residue RNG potential for Canada of 218 PJ per year, which was based upon an assumption of 20% of crop residues, including corn stover, being converted.[4] Applying a 20% conversion rate for crop residues and corn crop (including silage and grain) quantified in the current study would yield 228 PJ per year, making the results relatively comparable. When compared to the 2013 Canadian Biogas Study, which estimated a total RNG potential of 89.5 PJ, the results presented here appear high.[3] However, the Canadian Biogas Study sought to determine a *realistic* volume of RNG that could be brought to market and included a variety of economic, market, and logistical filters in the results. A reasonable assumption that 40-70% of potential feedstocks, as quantified here, could be used for RNG production would result in a national RNG potential estimate of 91 – 160 PJ per year, which is consistent with the Canadian Biogas Study results.

The total conventional RNG potential, by Canada Census Division, is presented in Figure 17. As noted above, total conventional RNG potential is dominated by the two agricultural feedstocks of crop residues and the total corn crop (as silage). High opportunity Census Divisions include several in southwest Ontario, the largest corn-producing region in Canada, and a number in Saskatchewan and Alberta, where geographically-large Census Divisions and abundant cropland lead to significant crop residue resources. However, as noted, Canada's corn crop is largely grown for animal feed and ethanol production, not biogas production, while prairie crop residue availability can swing dramatically from year-to-year due to weather (namely precipitation) variation. When these two agricultural crop feedstocks are removed from the total conventional RNG estimate (Figure 18), the highest opportunity Census Divisions are located in close proximity to, or in, Canada's major urban areas, or home to a large, concentrated livestock population. These latter areas include 'Feedstock Alley' in southern Alberta and the dairy and hog-production regions of southwestern Ontario and Quebec. High opportunity regions are identified and described in more detail in Section 3.

Figure 17. Total Conventional RNG Production Potential, by Census Division

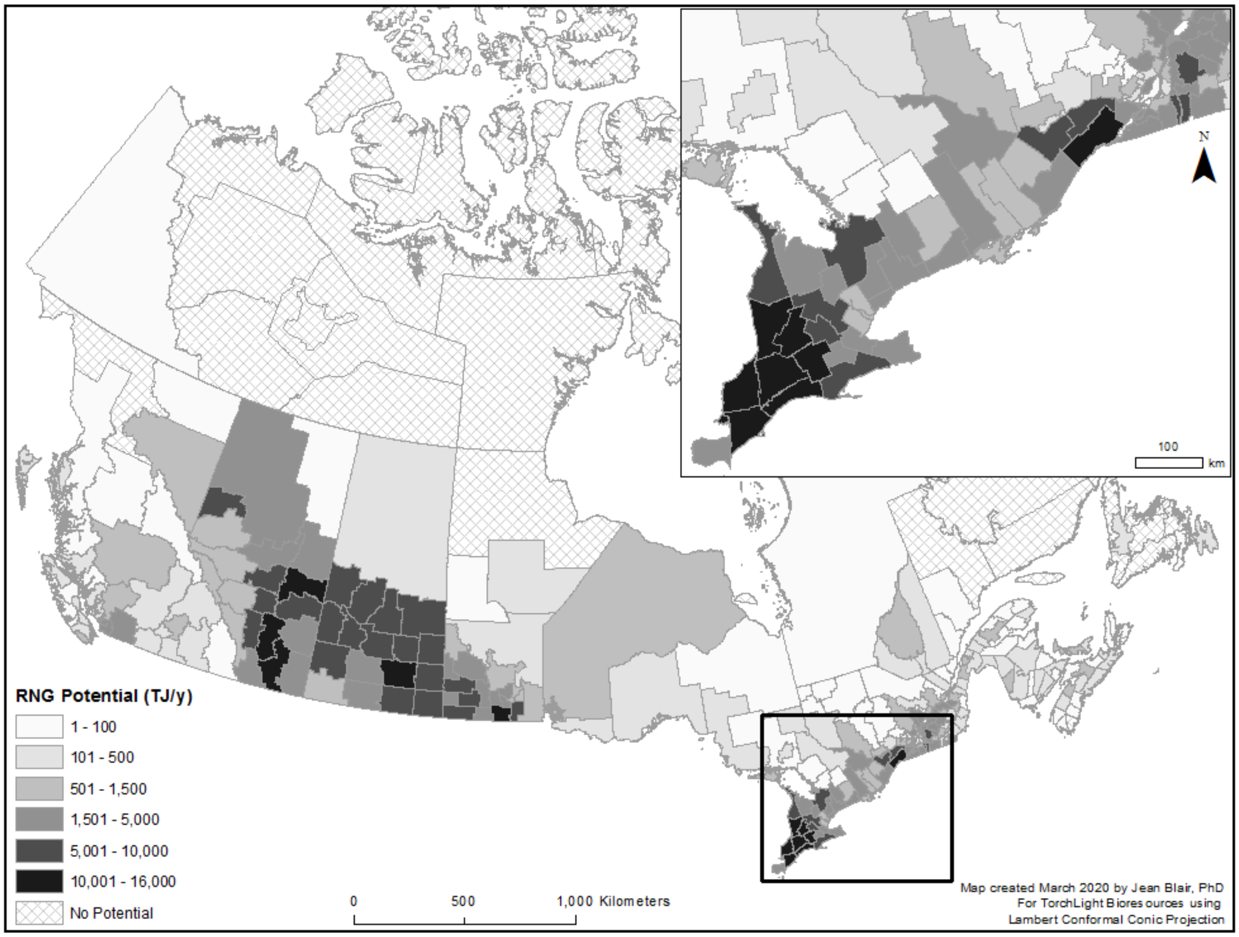
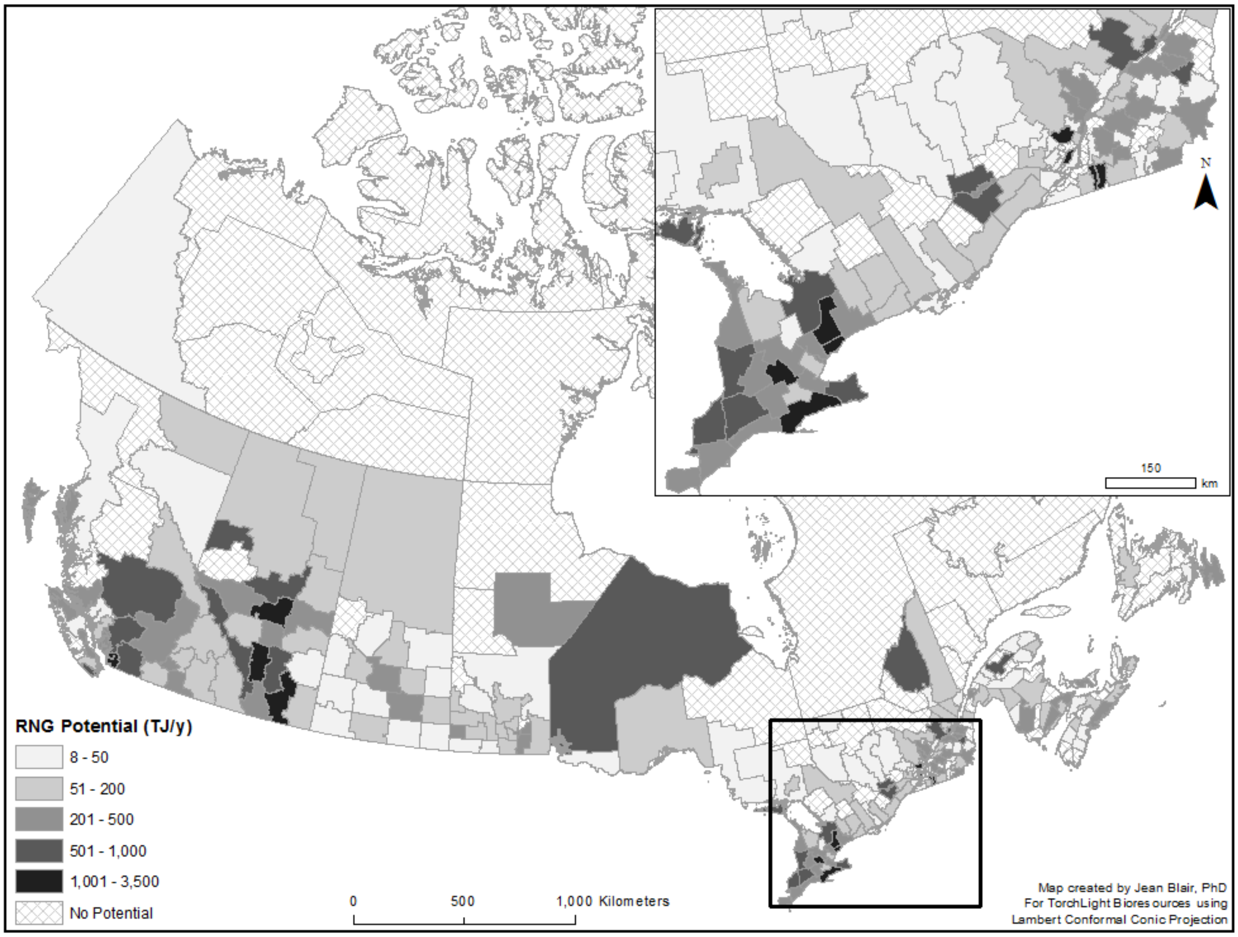


Figure 18. Conventional RNG Potential, Excluding Agricultural Crop Feedstocks, by Census Division



2.11 Conventional RNG Provincial Potential

The inclusion or exclusion of agricultural crop feedstocks (corn crop and wheat, barley, and oat straw) has a significant impact on the total conventional RNG resource potential by province (Figure 19). While Ontario and Quebec are the leading provinces for resource potential under both scenarios due to the country's largest human populations and substantial dairy and hog production, the situation is different in western Canada. When crop residues are included, total resource potential is primarily driven by crop production, with Saskatchewan ahead of Alberta and Manitoba. British Columbia is far behind these prairie provinces. When crop residues are excluded, municipal and industrial waste are the key feedstocks. Under this scenario, British Columbia, with a greater population than any of the prairie provinces, has the third greatest potential nationally. The territories are excluded from Figure 19 as they all have an RNG potential less than 0.5 PJ per year.

Figure 19. Annual Theoretical Conventional RNG Potential, by Province

Province/Territory	RNG Potential (Including Herbaceous)	RNG Potential (Excluding Herbaceous)	Feedstocks Exceeding 2.5 PJ/yr Potential
British Columbia	20	16	Corn silage, hog manure, landfills, pulp mills
Alberta	105	15	Crop residues, corn silage, landfills, cattle feedlot manure
Saskatchewan	112	3	Crop residues, corn silage
Manitoba	70	4	Crop residues, corn silage
Ontario	224	41	Corn silage, landfills, crop residues, biosolids/wastewater, hog manure, poultry manure, urban organics
Quebec	116	38	Corn silage, landfills, hog manure, crop residues, pulp mills, biosolids/wastewater, dairy manure
New Brunswick	5	4	-
Nova Scotia	4	2	-
Prince Edward Island	2	0	-
Newfoundland and Labrador	1	1	-
Canada	**660**	**123**	**All**

3 HIGH-OPPORTUNITY REGIONS

In Canada, many regions, as categorized by Census Division, have opportunities to produce RNG. Of Canada's 294 Census Division, 126 have a theoretical potential to produce 1 PJ of RNG or more per year. This makes RNG resources dramatically more geographically diverse than conventional natural gas resources, 98% of which comes from less than fifteen Census Divisions in Alberta and British Columbia. However, RNG resource potential is far from evenly distributed across the country. The top sixteen RNG resource potential Census Divisions account for almost one third of Canada's total potential. These Census Divisions are listed in Figure 20. Thirteen of the sixteen top Census Divisions have an RNG resource opportunity exceeding 10 PJ per year and are shaded black in Figure 16. The remaining three include two high crop residue potential Census Divisions in Saskatchewan and Alberta, and Les Maskoutains, Quebec, which is home to the Saint-Hyacinthe Biomethanation Plant, the second largest RNG project in the world at almost 0.5 PJ. Given the significantly higher potential for corn and straw feedstocks compared to other conventional waste resources, all sixteen Census Divisions are leading agricultural crop producers. In general, corn silage, including the entire corn crop, is the largest resource opportunity in Ontario and Quebec, while crop residues (straw) are the largest resource opportunity in western Canada. Corn crop opportunities also tend to be in the same region as livestock manure and dairy processing waste opportunities due to the use of corn grain and corn silage as animal feed.

While RNG potential quantification to this point has treated the different feedstocks as distinct categories, the ability to co-digest feedstocks affects total RNG because it can increase the overall biogas yield. However, in most provinces, regulations restrict the amount of off-farm material that can be brought onto a farm, thereby limiting co-digestion opportunities. Such regulations would have to be revised to permit project greater co-digestion project development on farms.

Figure 20. Canada Census Divisions with High RNG Production Potential

Census Division Identifier	Census Division Name	Province	Resource Potential (PJ)	Leading Feedstocks
3539	Middlesex	ON	16.9	Corn silage, crop residues, landfill, hog and poultry manure, biosolids/wastewater
3540	Huron	ON	16.3	Corn silage, crop residues, poultry manure
3536	Chatham-Kent	ON	16.3	Corn silage, landfill, crop residues
4810	Division No. 10	AB	13.6	Crop residues, corn silage, landfill
3532	Oxford	ON	13.2	Corn silage, crop residues, poultry manure
4802	Division No. 2	AB	13.0	Crop residues, corn silage, cattle manure, landfill
3531	Perth	ON	12.3	Corn silage, crop residues, poultry manure
4805	Division No. 5	AB	11.8	Crop residues, corn silage, cattle manure
3501	Stormont, Dundas and Glengarry	ON	11.6	Corn silage, landfill, crop residues
3538	Lambton	ON	10.9	Corn silage, crop residues, landfill, hog manure
3534	Elgin	ON	10.9	Corn silage, landfill, crop residues
4603	Division No. 3	MB	10.3	Corn silage, crop residues
4706	Division No. 6	SK	10.2	Crop residues, corn silage
4715	Division No. 15	SK	9.7	Crop residues
4806	Division No. 6	AB	9.5	Crop residues, landfill, biosolids/wastewater, urban organics, cattle manure
2454	Les Maskoutains	QC	9.5	Corn silage, poultry manure

3.1 Southwest Ontario Grain Corn, Stover, and Corn Silage

Corn is the largest crop by volume in southwestern Ontario, with stable or growing acreage on a year-over-year basis. The production of grain corn results in significant corn stover residues. They are produced in a 1:1 ratio, with 1 tonne of stover per tonne of grain. As grain yields have continued to increase, more stover is produced on the land. There are significant benefits to partial stover removal so that germination of subsequent plantings is not impaired by a thick layer of biological material. This residue oversupply situation is a result of improved yields, which result in enhanced biomass production. In the absence of new markets for corn stover in southwestern Ontario, the increasing quantities of corn stover may require greater amounts of stover be turned under by plowing or rough tillage. This return to soil-disturbing cropland management, which has been phased out over the past two decades, means the environmental benefits of no-till cropping, such as greater carbon sequestration and reduced N_2O emissions, are not realized.

Approximately equal masses of stover and grain are produced by the corn plant. In southwestern Ontario, grain corn is used for direct animal feed (60%) and industrial products (40%), including ethanol, corn starch, and distillers grains (animal feed), with the distribution between these two categories relatively stable and affected only by significant adjustments in futures prices. A very small pool of grain corn is retained for future seeding as most is regulated by proprietary regulations.

Some stover must remain on the soil surface following harvest to support soil and ecosystem health; while the amount necessary varies depending on soil type, topography and climate, healthy ecosystems can be sustained by about 30 to 50% residual stover. At the present time, stover is underused with minor amounts serving as AD feedstock or as feed or bedding for dairy cattle. An industrial corn stover feedstock stream was developed by a farmers' co-operative to convert stover into cellulosic sugars for use in industrial and food applications. However, the technology developer, Comet Biorefining, has put the company's plans on hold. Restarting this development could present a potential competitor for RNG facilities, but the model of a modern co-operative indicates the availability of ample biological feedstock and the willingness of the farming community to contract with industrial operators.

Corn silage is produced annually from feed corn as an energy-dense dairy cattle feed. Because corn silage requires specialized equipment for harvest and storage, it is being slowly replaced by production of "cob meal" (high moisture cob meal), composed largely of corn cobs, which is more cost effective than feeding dried corn because there is no energy required to dry the kernels. RNG producers would need to compete with livestock producers in order to secure silage feedstock, driving a shift in market dynamics. In the absence of this shift, the primary feedstock available for RNG production from southwestern Ontario's corn industry will be corn stover. Current realistic availability, using grain production data, assuming a 1:1 production rate, and deducting for required soil sustainability retention, is 4.8 Mt per year. This represents 30-40 PJ per year of RNG potential vs. a total regional theoretical potential of close to 200 PJ if all corn material (grain, stover, and current silage) was directed to RNG production. It is highly unlikely this latter volume could be achieved without a combination of significant increases in yield and a major reduction in animal feed and/or ethanol feedstock demand.

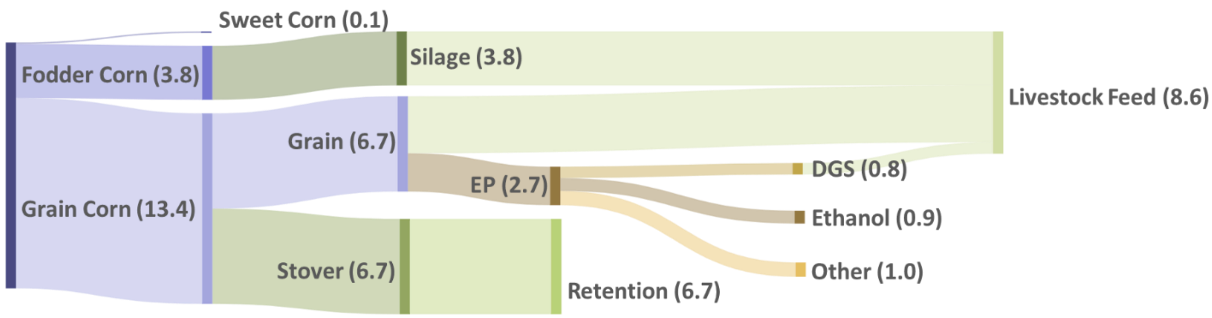
Figure 21 presents three potential southwest Ontario corn industry material flow scenarios. Scenario A is the current industry structure. Scenario B represents how RNG could be produced from corn stover without impacting existing consumers – namely the livestock feed and ethanol producers. Scenario C represents a potential long-term restructuring of Ontario's corn industry in the absence of ethanol demand, as potentially driven by reduced light duty vehicle liquid fuel demand, but continued livestock feed demand. It should be clearly stated that Scenario C is not intended to represent a likely or desirable scenario, particularly in the short or medium term. In fact, demand for ethanol is anticipated to significantly increase in the short and medium term to meet light duty fuel CI requirements. Given

Scenario B has 75-80% of the RNG production of Scenario C, but also supports continued operation of southwestern Ontario's ethanol and livestock industry, Scenario B clearly adds greater value and recognizes the importance of previous capital investments. The realistic RNG potential from the existing corn industry is likely only 15-20%, or roughly 40-60 PJ, of the theoretical 287 PJ estimated in Section 2.5.

Figure 21. Current and Potential Southwest Ontario Corn Industry Material Flows

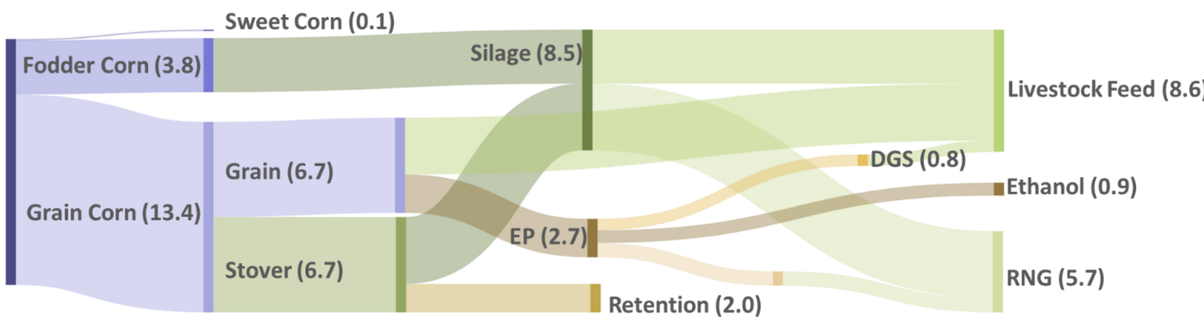
Scenario A. Current Situation*

All figures in megatonnes



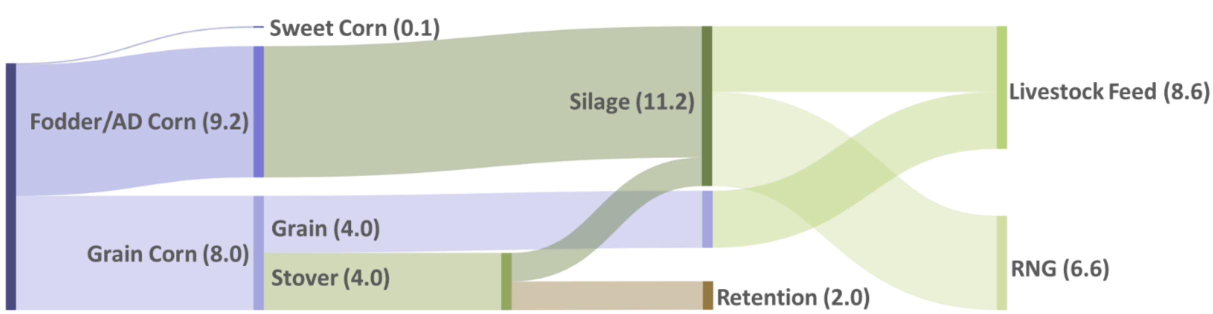
Scenario B. RNG Production Integration with Existing Industry*

All figures in megatonnes



Scenario C. RNG Production in the Absence of Ethanol Demand*

All figures in megatonnes



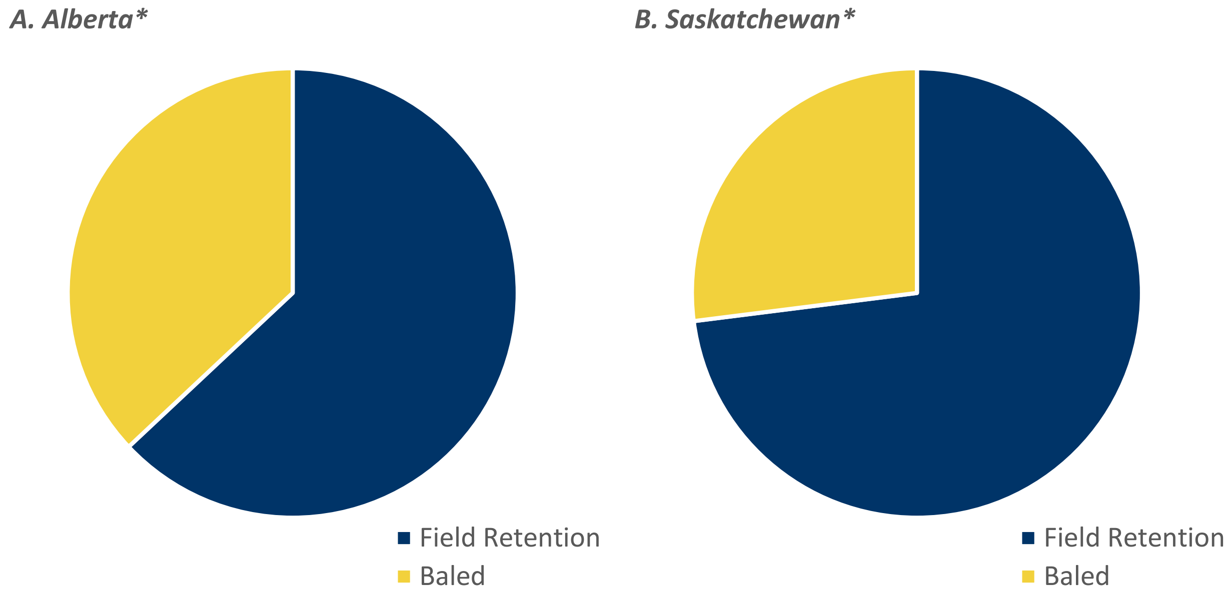
*EP = Ethanol Plant; DGS = Distillers Grains and Solubles

3.2 Prairie Crop Residues

Crop residues, including straw, are included as feedstocks for co-digestion biogas projects in North America and Europe. A 100% straw biogas plant is operating in Germany, with a U.S. facility under construction.[41] Straw from wheat, barley, and oats is the largest potential RNG resource in the prairie provinces of Saskatchewan, Alberta, and Manitoba. As the home of over 40% of Canada's cropland, Saskatchewan leads the country in potential crop residue availability. In addition, it has a much smaller livestock sector than Alberta, meaning competition for straw from existing buyers is limited. Baling (straw removal) tends to be more prevalent on mixed farms with both livestock and crops, but the number of farms of this type is in decline. This makes Saskatchewan a leading candidate for a straw-based RNG industry. However, due to climate variability from year-to-year, there is a very large range in the annual availability of crop residues in the prairies – particularly in moisture-limited regions of southern Saskatchewan and southern Alberta. Crop residue retention is important for maintaining both adequate moisture and soil carbon levels, and reducing erosion. Previous studies of the availability of prairie crop residues have found annual ranges from zero to four or more tonnes per hectare.[34] This variability is a major logistical, financing, and operational hurdle that will need to be overcome if a straw-based RNG industry is to reach significant scale in the prairies. Equally important is the degree to which agricultural producers will want to become involved in a straw harvest business, including their ability to make a profit from straw removal while still protecting soil health. Climate change, with higher temperatures and reduced prairie precipitation, is expected to increase the variability of crop residue availability.

In Alberta, the most recent available estimates indicate 28 to 50% of all 'available' straw is removed for the animal bedding market (Figure 22A), with the percentage dependent upon seasonal growing conditions, productivity, and demand from the livestock sector. However, removal rates also vary significantly by Census Division and a 2007 study found a geographic range from 20% to almost 100%.[36] The primary determining factor is local livestock sector demand. In Saskatchewan, over two-thirds of crop residues are retained on the field (Figure 22B). In both provinces, there is virtually no open burning of stubble/crop residues.

Figure 22. Estimated Crop Residue Fate in Alberta and Saskatchewan



Reference: [35,36]
*Average of 2001 and 2007 estimates; baled indicates removal

It should be noted that accurate, Census Division level-of-detail, data on crop residue fate in the prairies is limited and the most recent national survey of producers was conducted in 2001. This is a major data gap that needs to be filled if Canada is to pursue development of any crop residue-based energy industry. Interviews with numerous Alberta and Saskatchewan agricultural organizations and government officials were conducted to better understand crop residue fate in those provinces, but additional information was limited and several referred to Agriculture and Agri-Food Canada's BIMAT platform, which uses crop data from 1985-2000.

3.3 Landfill Gas

Several significant population centres are located in Census Divisions listed in Figure 20. These include Calgary, Lethbridge, London, Cornwall, Chatham-Kent, and St. Thomas. In addition, the City of Toronto-owned Greenlane Landfill is located in Elgin County (also home to St. Thomas). Based upon data from ECCC, none of the landfills located in Census Divisions listed in Figure 18 are capturing *and* utilizing landfill gas for electricity generation or RNG production.[31] Some of the landfills do have landfill gas collection systems but flare the gas with no energy or fuel production. Most large landfills in Canada capture landfill gas but of the 112 with capture systems, only 40% utilize the gas for energy. The remaining 60% flare gas and many of these could be candidates for RNG production. As of 2014, only 3.5% of total landfills in

Canada recover landfill gas, although many lacking capture systems are small and the economics for RNG will be challenging.[37] Nevertheless, landfill gas is a significant underutilized RNG resource opportunity.

3.4 Alberta Cattle Manure

Alberta is by far the largest beef producer in Canada, with approximately 60% of feeder cattle (steers and heifers for feeding or slaughter) located in Alberta.[38] It is generally impractical and uneconomic to collect and utilize manure from cattle on rangeland or pasture. However, prior to slaughter, cattle in Alberta are typically transported to feedlots for 'finishing' – increasing the size and growth rate of cattle by shifting feed from forages to grain. While manure is not as easy to collect as in a dairy barn operation, feedlot operators usually use a central 'pack' of bedding and manure, which is built up over time, and can be removed for anaerobic digestion, provided it is free of earth and stones.

Most feedlot manure in Alberta is composted and applied to cropland for use as a fertilizer. However, the volume of manure produced can exceed the availability of land for application. In addition, due to microbes, such as *E. coli* in the manure, waterbody setback limits are in place to prevent contamination.[39] There are two biogas plants in Alberta, Lethbridge Biogas and GrowTEC, that co-digest manure with local organic wastes to produce electricity and heat. However, a large opportunity exists to increase the biogas, and by extension, RNG, production from feedlot manure and 'packs' in Alberta.

3.5 Ontario and Quebec Hog and Poultry Manure

Ontario and Quebec are Canada's second and third largest producers of hogs, after Manitoba, and the largest producers of poultry. Most production occurs within several small geographic areas in southwest Ontario and southern Quebec, with the Census Division of Le Haut-Richelieu, QC having the highest concentration of hog manure production in the country. The RNG production potential from hog manure in this single Census Division is 2.6 PJ.

Hog manure, which is high in moisture content, is typically collected in a lagoon, making on-farm biogas generation the most economically attractive and feasible approach for energy generation. Transportation of liquid hog manure is high cost and is unlikely to be economical for distances exceeding 10 km. Thus, liquid hog manure is primarily used as a fertilizer for croplands in close proximity to hog operations. Biogas production from this hog manure could occur prior to land application. The most likely scenario for RNG production from hog manure is co-digestion, with urban organics, dairy manure, and/or crop residues, at existing hog operations, although combination with other feedstocks (e.g., urban organics or crop feedstocks) must take into consideration the ability of farmers to field apply resulting digestate using existing low solids injection or surface spread equipment. In some cases, it may be possible to have multiple small biogas plants connected by biogas pipeline to a central biogas upgrading (to RNG) facility. While AD may impact the total nitrogen available from hog manure, there is still opportunity to utilize the resource for RNG production in Ontario and Quebec while continuing application of the remaining digestate. The availability for RNG production is a function of RNG value, the availability of other feedstocks, the distance to a natural gas pipeline, and the cost of replacing the manure-based nitrogen with synthetic fertilizer.

Poultry manure (litter) is much lower in moisture content than hog manure but 'contaminated' with feathers and bird parts that can compromise immediate land application. The lower moisture content, and hence higher energy content per wet tonne, permits the litter to be transported longer distances than hog manure. Prior to land application or processing into 'organic fertilizer' for horticultural and homeowner markets, poultry litter is usually composted in earthen pits to reduce pathogens and degrade feathers and bird parts in the litter. As poultry are often raised on wood shavings and/or sawdust, composting can take a significant time. This use of wood shavings will also pose a major challenge for use of the material in fully mixed digester and a shift to straw-based bedding, which constitutes a minority of production at present, would be required. While poultry litter could be combined with liquid hog or dairy manure for medium-solids AD, as is practiced by Fraser Valley Biogas, it could also serve as a high-solids AD feedstock prior to land application – provided the ammonia content is addressed. Due to the low moisture content, poultry manure can also be used as a direct combustion or gasification fuel, which may impact competition for the resource in the future. This is not practiced at present in Canada. However, the ash following combustion has no nitrogen fertilizer value, which means AD followed by land application of digestate is the primary means of producing both energy and fertilizer from the resource.

4 TECHNOLOGY & COSTING

RNG production technologies can be generally grouped into three types: 1) anaerobic digestion (AD) biogas production technologies; 2) biogas and landfill gas upgrading technologies; and 3) advanced conversion technologies (e.g., wood-to-RNG). The primary technologies are described in Sections 4.1-4.3, with production cost examples and provided in Section 4.4.

4.1 Anaerobic Digestion Technologies

Anaerobic breakdown of biomass into biogas is a four-stage process:

1. **Hydrolysis** – biomass polymers, such as starch, hemicellulose, and lipids, are broken down into smaller molecules such as sugars and fatty acids. Acetate and hydrogen (H_2) produced during hydrolysis can be used directly by methanogens for methane production
2. **Acidogenesis** – further breakdown of molecules, with primary products including volatile fatty acids, ammonia, carbon dioxide (CO_2), and hydrogen sulfide
3. **Acetogenesis** – molecules from acidogenesis are consumed by acetogens to produce acetic acid, CO_2, and H_2
4. **Methanogenesis** – methanogens utilize molecules generated by preceding stages to generate methane, CO_2, and water

AD facilities can be classified according to four primary technology attributes:

Batch or Continuous?

Batch – feedstock is added at the beginning of the process and no new feedstock is added until the four stages are complete. A single facility can include multiple batch reactors, thereby permitting continuous, albeit uneven, flow of biogas. Capital costs for batch processing are typically lower than continuous, particularly for smaller facilities.

Continuous – feedstock is added to the primary reactor on a continuous (continuous complete mixed) or staged (continuous plug flow) basis. Multiple digesters may be used in sequence. Capital costs are typically higher than batch, but throughput is generally higher.

Mesophilic or Thermophilic?

Mesophilic – digestion occurs at a process temperature of 35 to 42 °C, or at ambient temperatures of 20 to 45 °C. Processing time is typically 20-40 days, although fully mixed mesophilic systems in northern regions average about 50 days retention time. The primary organisms are mesophiles (organisms that grow best at medium/moderate temperatures).

Thermophilic – digestion occurs at a process temperature of 49 to 57 °C, with some processes up to 70 °C. Processing time is typically two weeks. The primary organisms are thermophiles (organisms that grow best at elevated/hot temperatures).

High or Low Solids Content?

High Solids – feedstocks with a solids content between 20 and 40% can be processed using either dry (stackable) or wet digestion. Dry systems, which are typically either vertical continuous plug flow reactors or horizontal batch tunnel reactors, require no additional water for the process and no mixing occurs. Wet systems involve pumping and are usually in the lower end of the 'high solids' classification.

Low Solids – digester feedstock slurry is <15% in solids content and are pumped using standard liquid slurry pumps. In general, low solids systems require greater land area and, by definition, more water treatment. However, the low solids loading permits high rates of bacteria-feedstock interaction, thereby supporting higher methane production rates.

Single- or Multi-Stage Process?

Single-Stage – all process stages occur in a single, sealed reactor/tank. While construction costs are lower than a multi-stage process, process control is also lower. This may limit productivity and biogas generation.

Multi-stage – multiple reactors are used, although most facilities only employ two for each processing chain: one for the first three stages of AD and one for the final methanogenesis stage. However, complete separation of the stages is not possible and while the second stage can employ conditions more favourable to methanogenesis, some methane generation occurs in the primary reactor.

4.2 Biogas/Landfill Gas Upgrading Technologies

In order to inject methane-rich gas into the natural gas grid, several gas quality requirements must be met. One of these is methane content; a 97-98% methane content is typically required for blending with natural gas in existing infrastructure. Biogas from AD and landfill gas can range in methane content from 50 to 60%, with CO_2 and water vapour constituting the bulk of the remainder. Other 'contaminant' gases include oxygen, nitrogen, ammonia, hydrogen, carbon monoxide and hydrogen sulfide (H_2S). In order to meet natural gas grid specifications, CO_2, water vapour, and trace gases must be removed. Of particular importance is achieving very low H_2S rates, given the compound's toxicity and corrosivity.

There are four primary biogas and landfill gas upgrading technologies and several additional technologies employed by only a few plants. The four leading technologies are pressure swing adsorption (PSA), water washing, membrane, and chemical scrubbing. All are commercially available and considered Technology Readiness Level (TRL) 9.

Pressure Swing Adsorption

PSA uses the differing properties of gases to separate them from a mixture using adsorbent materials, such as zeolites, activated carbon, and molecular sieves. Gases are placed under high pressure (4-10 bar), which encourages them to adsorb (bind) to solid surfaces. When pressure is reduced, the gases desorb (release) from the surface and the material is regenerated. For biogas and landfill gas, CO_2, O_2, N_2 and other gases are adsorbed to the solid media, while methane is able to pass through the vessel. This results in an RNG product with greater than 97% methane purity. Multiple vessels are typically used, with different adsorption materials for the removal of target gases. H_2S will permanently bind the adsorption media, so must be removed with a pretreatment (e.g., carbon filter). PSA has the ability to handle complex and changing gas mixtures depending upon the adsorbent material used.[43,44,45]

Water Washing

Water washing, or water scrubbing, uses water as the absorbent material for CO_2 and other gas removal. Biogas is injected into a pressurized vessel, typically at 6-8 bar, with water flowing countercurrent to the biogas. The contaminant gases are dissolved into the water and removed from the vessel. CO_2 and H_2S removal are enhanced as pressure is increased, since methane has a low partial pressure compared to these gases. A gas dryer is used to remove the water vapour from the RNG prior to pipeline injection. Water washing works best for simple, homogeneous gas mixtures.[43,44,45]

Membrane

Membrane technologies use a high-pressure differential across a nano-porous membrane material to drive gas separation. Gas mixture properties must be considered when selecting a membrane type. Gas separation can occur based upon differences in gas molecule size, solubility, polarity, and adsorption. The rate of membrane permeation is lower for methane than most other biogas and landfill gas components. Generally, membrane upgrading technology is chosen for small projects where minimizing capital expenditures is prioritized over lifetime operating costs, since membranes need to be replaced after several years of use.[43,44,45]

Chemical Scrubbing

Chemical scrubbing uses amine-based solutions, typically mono ethanol amine (MEA) and di-methyl ethanol amine (DMEA), for absorbing and binding CO_2 and other gases. Unlike water scrubbing, CO_2 actually reacts with the amine in the solution. Heating the amine solution releases the CO_2. Chemical scrubbing has the lowest methane slip (lost methane) of all upgrading technologies at <0.1%. This compares to 1-1.5% for water wash and PSA. H_2S can also be absorbed and released using chemical scrubbing, although a higher temperature is required for release, making pretreatment removal usually preferable.[43,44,45]

Other

Other biogas and landfill gas upgrading technologies include organic chemical-based physical absorption and cryogenic separation. These have only been deployed for a few projects and are unlikely to be used for a large number of projects in Canada.

4.3 Advanced RNG Technologies

The primary technology pathway developed for methane production from solid biomass, such as wood, is gasification followed by clean-up and methanation of the resulting syngas. This is the pathway used by the largest wood-to-RNG plant built to date, the demonstration-scale (20 MW_{th}) GoBiGas plant in Gothenburg, Sweden. Like all syngas-based chemical synthesis reactions, methanation of CO and H_2 to CH_4 requires high purity syngas. Contamination with tars and other components is a major challenge. To ensure low N_2 content and high syngas purity, the GoBiGas plant utilized an indirect steam gasifier. However, the plant still faced numerous challenges and was only able to operate continuously on wood pellets. The operators were able to achieve the target methane yield of 65% on an energy basis.[46] An analysis of this technology, which is considered TRL 6-7, was completed by TorchLight for NRCan in 2019.[47]

A unique approach to methane production from wood is being pursued by G4 Insights of Burnaby, BC. Termed 'pyrocatalytic hydrogenation', the process technology employs thermal treatment in a pressurized hydrogen atmosphere. Methane is selectively preferred over CO_2 as a product due to the lack of oxygen in the reaction chamber. Hydrogen for the process is generated using a steam methane reformer.[48] Although a novel approach to RNG production, pyrocatalytic hydrogenation has only been trialled at a pilot scale, meaning commercial deployment is unlikely prior to 2030. This technology, which is rated TRL 4-5, was included in the advanced fuels assessment completed by TorchLight in 2019.[47]

4.4 Comparative Cost Summary & Regional Costing

All economic figures are adjusted to 2019 Canadian dollars using current exchange rates and the Bank of Canada Consumer Price Index.

The costs of RNG production are highly project specific. Key variables impacting production and delivered fuel costs include:

- Feedstock type(s)
- Feedstock cost and transportation distance
- Technology type, design, and supplier
- Facility scale
- Facility location
- Proximity to natural gas lines and land cover of connecting pipeline route
- Natural gas pipeline pressure and connection requirements
- Urban vs. rural siting
- Labour and consumables costs
- Financing terms

Capital Investment

Given the wide range of potential figures for these variables, a comparison of examples of real and modelled RNG production costs was considered the most relevant approach for determining a range for RNG production costs. Figure 23 provides a comparison of numerous examples, with key variables identified. In general, previous studies have indicated more cost variability between plants using the same upgrading technology than between the technologies themselves. Scale plays a critical factor, with small RNG production projects generally burdened by high capital cost (CapEx). For example, reviews of upgrading technologies found an installed cost for upgrading technology to be between C$17 and 27/GJ annual capacity (C$3,000-4,800/$Nm^3$/hr biogas capacity) for plants with biogas capacities between 90,000 and 360,000 GJ/yr (500-2,000 Nm^3/hr biogas capacity). However, installed cost for water wash, as an example, ranged from C$17 and $107/GJ annual capacity (C$3,000-19,000/$Nm^3$/hr biogas capacity) if plant capacity range was extended to plants smaller than 90,000 GJ/yr (<500 Nm^3/hr).[50,51]

Figure 23. RNG Production Cost Examples and Estimates

Location/Source	Feedstock	Technologies	Scale (GJ/yr)	CapEx ($/GJ annual capacity)	RNG Cost ($/GJ)	Notes	Reference
Publications							
IRENA	Wastes (90%) & corn silage	AD & Upgrading (General)	18,000 - 90,000	74 - 133	$19.30+	Transportation market target	49
IRENA	Corn silage (90%) and wastes	AD & Upgrading (General)	180,000 - 360,000	60 - 71	$39.50+	Transportation market target	49
Svenskt Gastekniskt Center AB, Sweden	Biogas/Landfill Gas – Upgrading only	Water wash, PSA, chemical scrubbing, membrane	18,000 - 90,000	21 - 110	-	Upgrading only; AD facility additional	50
Svenskt Gastekniskt Center AB, Sweden	Biogas/Landfill Gas – Upgrading only	Water wash, PSA, chemical scrubbing, membrane	180,000 - 360,000	14 - 32	-	Upgrading only; AD facility additional	50
IRENA	Various	Various	General	-	19 - 57	Cost only	52
Arteconi et al.	Various	Various	Various	-	29 - 31	Cost only	53
Rotunno et al.	Various	Various	Various	-	22 - 30	Cost only	54
Rajendran et al., Ireland	Urban organics, grass silage, manure	AD, water wash	Various	123 - 137	30 - 56		55
Canada Facilities							
Fraser Valley Biogas, Abbotsford, BC	Agriculture and food processing waste	Water wash	90,000			FortisBC contract	
Salmon Arm Landfill, BC	Landfill gas	PSA	15,000	222		FortisBC contract	
Glenmore Landfill, Kelowna, BC	Landfill gas	PSA	65,000	85		FortisBC contract	
Surrey Biofuel Facility, BC	Urban organics	High solids AD & upgrading	100,000	676		Includes visitor centre, fuelling facilities, transfer station	
Woodward Avenue Wastewater Plant, Hamilton, ON	Wastewater	AD & water wash upgrading	72,000	417		Heat generation	
Lachenaie Landfill, Terrebonne, QC	Landfill	Water wash and PSA	2,940,000	17		CA LCFS pathway; Energir contract	
Ebi Énergie – Rive Nord, Berthierville, QC	Landfill	Multi-stage with membrane	1,210,000			Energir contract, sold as CNG for transport	
Saint-Hyacinthe, QC	Food processing residuals, urban organics	Water wash	224,000 - 485,000	173 - 375		Energir contract	

The International Renewable Energy Agency (IRENA) provides guidelines on the installed capital cost of RNG plants, including AD and upgrader. For AD-based RNG plants with an annual capacity of 18,000 to 90,000 GJ (100-500 Nm^3 biogas/hr), the CapEx is estimated at C$74-113/GJ annual capacity (C$13,100-20,200/$Nm^3$/hr biogas capacity).[49] As an example, a plant with an annual capacity of 75,000 GJ would have a capital cost of $5.6 to $8.5 M. For larger plants of 180,000 to 360,000 GJ annual capacity (1,000-2,000 Nm^3 biogas/hr), the CapEx was estimated to range from C$60-71/GJ of annual RNG capacity ($10,700 to 12,600/$Nm^3$/hr biogas capacity). A plant with a capacity of 270,000 GJ/yr (1,500 Nm^3 biogas/hr), the CapEx would be $16.2 to $19.2 M. For smaller plants, the upgrader contribution to total CapEx was estimate at 37-47%, while it was estimated at 27-30% for larger plants.[49] These figures assume 100% capacity all year and capacity factors need to be used to determine the actual capital cost contribution to production cost.

Currently operating RNG projects in Canada exhibit an extremely large installed capital cost per unit annual capacity (specific CapEx) range. At one extreme is the Lachenaie Landfill, Terrebonne, QC, which is a large landfill gas project and had a very low capital cost of $17/GJ annual capacity. This was for the landfill gas upgrading components only, as the landfill gas collection system was already in place. At the other end is the Surrey, BC high solids urban organics AD and upgrading facility. A much smaller project than the one in Terrebonne, the Surrey Biofuel facility also includes a visitor's centre, transfer station, and RNG fuelling infrastructure for the city's waste collection fleet. This facility had a CapEx of $68 M, or $704/GJ annual capacity. This is 41 times that of the Lachenaie Landfill but does include significant infrastructure not typically allocated to an RNG project. Another organics RNG facility, the large biogas-to-RNG plant in Saint-Hyacinthe, QC, had a CapEx of $80 M, or $375/GJ annual capacity when considering current output. This could be lowered to less than $200/GJ annual capacity if production is increased without additional major capital expenditure.

Based upon IRENA estimates and assuming 50% 'small' projects and 50% 'large' projects, the capital investment required for a 1% RNG blend rate in Canada would be $3.2 B to $4.4 B. A 5% blend rate would require a capital investment of $16 B to $22 B, while a 10% blend rate – if conventional feedstocks could be secured – would be $32 to $44 B. Using a figure of $200/GJ annual capacity, which is more consistent with facilities utilizing urban organics and food processing residual in Canada, a 1%, 5%, and 10% RNG blends would have capital investment requirements of $9.5 B, $47.5 B, and $95.2 B. These figures do not include pipeline injection facilities or natural gas line extension. Assuming a 65% average GHG reduction relative to baseline, the annual GHG reductions for a 1% blend rate would be 1.7 Mt CO_2e.[2,56] This correlates to a capital investment of $1,850 to $2,540 per tonne of annual CO_2e reductions using IRENA assumptions and $5,490 per tonne of annual CO_2e reductions using the $200/GJ annual capacity Canadian project figure. Assuming a 20-year project life and no discount factor, the capital investment alone (i.e., excluding feedstock and operating costs) per tonne of CO_2e reductions would be $93 to $127/t CO_2e for IRENA figures and $275t CO_2e for the $200/GJ annual capacity Canadian project figure. Canadian values may be notably higher due to the infancy of the industry in Canada compared to other countries, such as Germany, and cost reductions could be anticipated over time.

The contribution of CapEx to RNG production cost is a function of installed cost per unit annual capacity, capacity factor (the ratio of output-to-capacity), and cost of capital. The cost of capital takes into consideration debt-to-equity ratio, amortization period, debt rate, and required return on equity. These can be combined into the weighted average cost of capital (WACC). Several potential scenarios for the capital cost contribution to RNG production cost are presented in Figure 24. A facility of 100,000 GJ annual capacity is used for all scenarios, but it is important to recognize larger facilities will generally have a smaller CapEx per unit capacity than smaller facilities.

Figure 24. Potential Capital Expenditure Contribution to RNG Cost

Scenario	Specific Cost ($/GJ annual capacity)	CapEx ($ M)^	Weighted Average Cost of Capital (%)	Amortization (years)	Capacity Factor (%)	CapEx Contribution ($/GJ RNG)
Lowest	25	2.5	5	25	95	1.85
Highest	700	70	9	15	80	106.50
Median	150	15	7	20	85	16.40
Loan Guarantee	200	20	4	20	85	17.10
Seasonal Feedstock*	200	20	7	25	60	28.25

^Includes all development costs, including AD where applicable. Lowest figure applicable to landfill gas only.
*Assumes low capacity factor due to seasonality of crop-based feedstock (e.g., crop residues)

Feedstock Cost

Many RNG feedstocks, including urban organics, biosolids, some livestock manure, and landfill gas that is already collected and flared, can be obtained at net zero or negative cost. In the case of negative cost, RNG production facilities are paid for disposal of the feedstock; this is often called a 'tipping fee' and can be a major component of the business case for an RNG facility. At the other end of the spectrum are feedstocks that can be a major cost for an RNG facility. These include corn silage, typically the highest cost conventional RNG feedstock, crop residues, wood resources, and some manure. In the case of pulp mills, the most logical developer of an RNG facility is the pulp mill itself, which may or may not allocate a value to the process waste. Figure 25 shows the contribution of potential feedstocks to the production cost of RNG. The yield and pricing should be considered potential options under a wide range of scenarios.

Figure 25. Potential Feedstock Contribution to RNG Cost

Feedstock	Delivered Feedstock Cost	Yield of RNG per Unit of Feedstock	Feedstock Contribution ($/GJ)
Corn Silage	$170/dry tonne	12.4 GJ/dry tonne	13.70
Crop Residue (Straw)	$70/dry tonne	8.2 GJ/dry tonne	8.50
Landfill Gas	$0.04/m^3	0.0187 GJ/m^3	2.15
Urban Organics	-$100/dry tonne	10.1 GJ/dry tonne	-9.90
Hog Manure	$0/tonne	0.9 GJ/tonne	0.00

RNG Production Cost

The three primary contributors to RNG production cost are CapEx, feedstock cost, and non-feedstock operating expenditure (e.g. utility costs) (OpEx). For high-level economic analyses, OpEx is typically estimated as a function of installed CapEx. For the purposes here, annual OpEx is assumed to be equal to 5% of total CapEx. Using the CapEx and feedstock figures from above, the potential cost for RNG ranges from $6/GJ to almost $55/GJ. Several potential scenarios for 100,000 GJ/yr capacity plants are presented in Figure 26. These figures are consistent with previous publications, including a recent report by IEA Bioenergy.[57]

Figure 26. Potential RNG Production Cost Estimates

Scenario	Feedstock	Specific CapEx ($ M)	CapEx ($/GJ)	Feedstock ($/GJ)	OpEx ($/GJ)	Total ($/GJ)
SW Ontario Corn	Corn Silage & Chicken Litter	20	21.90	7.90	11.80	41.60
Urban Organics & Manure	SSO & Hog Manure	35	38.30	-5.00	20.60	53.90
Prairie Crop Residues	Straw	27.5	30.10	8.50	16.20	54.80
Landfill Gas (best case, upgrader only)	Landfill Gas	2.5	1.85	2.15	2.1	6.10
Landfill Gas (likely)	Landfill Gas	7.5	8.20	3.00	4.40	15.60

4.5 Relative Regional RNG Cost

As noted in Section 2.11, provinces vary widely in both their RNG resource availability and the type of resources that could be utilized for RNG production. As a generalization, regions of the country that can generate significant quantifies of RNG from landfill gas – namely regions with the greatest population including Ontario, Quebec, and British Columbia – will be able to generate RNG at lower cost than regions with limited landfill gas availability. While southwestern Ontario and the prairies have the greatest RNG resource potential, this potential is largely based upon the availability and cost of corn stover and straw respectively. These are also the highest cost feedstocks. Excluding landfills and agricultural crop resources, Canada's theoretical conventional RNG potential is only 75 PJ, with approximately 50% attributable to livestock manure and the other 50% consisting of urban organics, biosolids/municipal wastewater, and pulp mills wastes. Facilities consuming these latter resources, and urban organics in particular, tend to have a high capital cost. Manure-only facilities are rare in Canada due to the low yield and very high all-in cost of RNG.

5 POLICY-DRIVEN DEMAND & COMPLIANCE

5.1 Greenhouse Gas Pricing

Greenhouse gas pricing, in the form of a carbon levy, tax, or cap and trade, increases the cost of the fossil fuels to consumers, but it can have a limited impact on market demand for fossil fuels or low carbon fuels. There are several reasons for this situation. The first is fuel demand elasticity, which refers to the change in demand for the fuel that is the result of a change in fuel price. Many fuels have relatively inelastic demand, meaning the percentage change in demand is less than the percentage change in price. For example, a global meta-analysis of previous studies on energy product elasticity found that natural gas elasticity was -0.18 to -0.19 in the short-term and -0.5 to -0.6 in the long-term.[58] This means that in the short-term, a doubling in natural gas price would cause an 18 to 19% drop in demand. In the long-term, a doubling of price will cause a 50 to 60% decrease in demand. However, elasticity is likely to be even less for natural gas in Canada, given the country's reliance on natural gas for space heating, due to a cold climate, and as an industrial fuel.

The second major limitation of GHG pricing is relative energy pricing. At $50/t CO_2e in 2022, the Government of Canada's GHG Fuel Charge will increase the price of natural gas by roughly $2.50/GJ. However, adding this to a commodity natural gas price of $1-3 GJ results in a cost of natural gas, excluding transmission and distribution, of $3.50 to $5.50/GJ. This is far below the cost of production of RNG. As an example of the level of GHG Fuel Charge required to make RNG competitive with natural gas, the Government of British Columbia has permitted FortisBC to purchase RNG at up to $30/GJ. With the commodity cost of gas at $1.55/GJ in British Columbia, the premium is up to $25.95/GJ by 2022. This assumes the carbon levy is applied to natural gas but not RNG. Assuming a 65% reduction in the life cycle carbon intensity of RNG relative to natural gas, or a CI of 21.7 g CO_2e/MJ for RNG (33% lower than the average RNG pathway CI under the California LCFS, after discounting for CNG compression) and 62 g CO_2e/MJ for natural gas, this policy is the equivalent of a Fuel Charge of up to $706/t CO_2e. This level is far above any carbon price being contemplated by any country in the world at present. In the most RNG price competitive examples, namely in New Brunswick and Nova Scotia where commodity natural gas price is approximately $8/GJ, the Fuel Charge equivalent is greater than $180/t CO_2e. Therefore, it is unlikely that GHG pricing, by itself, will be sufficient to make fuel switching from natural gas to RNG economically viable.

In most markets, RNG is more price competitive with transportation fuels than with natural gas. As an example, diesel fuel at $1.00 per litre has an energy price of approximately $28/GJ. After discounting by 10% to reflect the slightly lower efficiency of RNG/natural gas engines compared to diesel engines, RNG at $25/GJ could be cost competitive, on a fuel-only basis, with diesel. This does not account for transmission or distribution charges, or processing to CNG/LNG, for RNG. The potential cost competitiveness of RNG to diesel, and by extension the dramatically lower price of natural gas compared to diesel fuel, also indicates that relative fuel pricing is not the only consideration for fuel switching.

Large emitter facilities, which produce more than 50,000 t CO_2e per year, are subject to the federal Output-Based Pricing System (OBPS) or a provincial equivalent. The OBPS is another form of GHG pricing, but with limitations on the percentage of emissions that are priced. This is to recognize the trade-exposed, competitive nature of large emitters and the significant risk of leakage – that is industrial production moving to jurisdictions with less stringent environmental regulations and lower costs. As with the Fuel Charge, the OBPS will price emissions that are not granted 'free' compliance credits at a maximum of $50/t CO_2e in 2022. The same issue of relative RNG and natural gas cost that will limit consumption of RNG in small emitters will also apply to large emitters. It is unlikely most large stationary emitters consuming natural gas will become significant consumers of RNG due to this regulation. The exception may be large emitters that can self-produce biogas for internal purposes, although, in most cases, upgrading biogas to RNG is not likely to be required.

5.2 Volumetric Blending and Displacement

While GHG pricing, such as the Fuel Charge, seeks to increase the cost of fossil fuels, thereby reducing market demand for high-carbon fuels, the Clean Fuel Standard (CFS) is a compliance-based policy designed to increase demand for low-carbon fuels and adoption of low emissions technology in the oil and gas sector. Overall, it is intended to reduce GHG emissions by 30 Mt CO_2e/yr by 2030. The CFS is based upon the principle of life cycle carbon intensity (CI) – that every fuel emits GHGs through the entire pathway of extraction, processing, distribution, and use. Obligated parties, which will include suppliers of fuel in Canada, must reduce the CI of the fuels they supply over time.[56] This policy is irrespective of the volume of fuel they supply (subject to a very low minimum), meaning demand destruction does not eliminate the need for compliance. In addition, CFS compliance is required regardless of the relative pricing of low carbon fuels to fossil fuels. Although similar in design to British Columbia and California's Low Carbon Fuel Standards, the CFS will apply to all fuels rather than only transportation fuels – as is the case in British

Columbia and California. No exemptions, other than remote communities, aviation gasoline, and international aviation/marine, are proposed.

The CFS will have three classes of fuels: 1) Liquid; 2) Gaseous; and 3) Solid. The class of fuel is dictated by the state of matter of the fuel being supplied, not by the fuel replacing it. RNG could be used to displace diesel or gasoline in the Liquid Class, while displacing natural gas could occur under the Gaseous Class. Although the design of the Solid Class regulation has not yet been established, RNG could have the potential to replace coal or petcoke in this Class. However, the volume is likely to be very low due to the significantly higher cost for RNG when compared to alternative fuels such as wood chips, wood pellets, and solid recovered fuel (SRF) that can be used to replace coal and petcoke. The Liquid Class regulation is planned to take effect in January 2022, with Gaseous and Solid Classes regulation taking effect in January 2023. From 2022 to 2030, the CI of Liquid Fuels must be reduced by 10 g CO_2e/MJ (10-12%) from a 2016 baseline. Although the CI reduction requirements for Gaseous and Solid Fuel Classes are still under development, ECCC is anticipating 23 Mt CO_2e of the 30 Mt CO_2e per year in reductions will come from the Liquid Fuel Class. Given Solid Fuel consumption outside the coal-fired electricity generation sector is relatively modest compared to fuel consumption in the other Classes, it is anticipated a majority of the remaining 7 Mt CO_2e per year will come from the Gaseous Class.

5.3 Future RNG Demand

Based upon stakeholder responses to the Canadian Renewable Gas Survey, it is anticipated almost all low CI gaseous fuel consumed in Canada by 2030 will be RNG.[59] However, CFS compliance may also come from biogas use, bio-based hydrogen use, and avoided methane emissions, with the latter likely to be lower cost than RNG blending in many cases. As presented in Figure 27, Canada consumed almost 4,300 PJ of natural gas in 2019, with approximately 1,400 PJ attributable to residential and commercial building heat (Figure 28). The Canada Energy Regulator projects national natural gas demand to rise 7.5% by 2040 to almost 4,600 PJ under its Reference Case scenario.[2] Alberta is by far the largest consumer, representing over half the national demand in both 2019 and 2030. Ontario, with a much smaller industrial thermal energy demand than Alberta, is the second largest consumer. When national natural gas demand is contrasted with the modelled RNG contribution to CFS compliance of 90 PJ and the feedstock resource availability, it is clear RNG is unlikely to displace a high volume of natural gas in Canada. This is particularly true if RNG production is limited to conventional 'waste' feedstocks, such as animal manure, biosolids, urban organics, and landfill gas. In order to achieve a 1% RNG blend rate at current consumption, 43 PJ of RNG would be required, excluding the potential demand for RNG from the transportation sector.

Volumetric requirements for RNG to meet 1%, 5%, and 10% blend rates with natural gas in 2019 and 2040 are presented in Figure 29. As potential RNG demand is so large, particularly for 10% blend rates, it may be pragmatic to focus on displacing natural gas in residential and commercial applications only rather than also including industrial applications. These volumes are also presented in Figure 29, along with RNG requirements to displace 15% of diesel consumption, taking into consideration an average 10% reduced engine efficiency.

Figure 27. Natural Gas Demand in Canada, 2019 & 2040 Projection

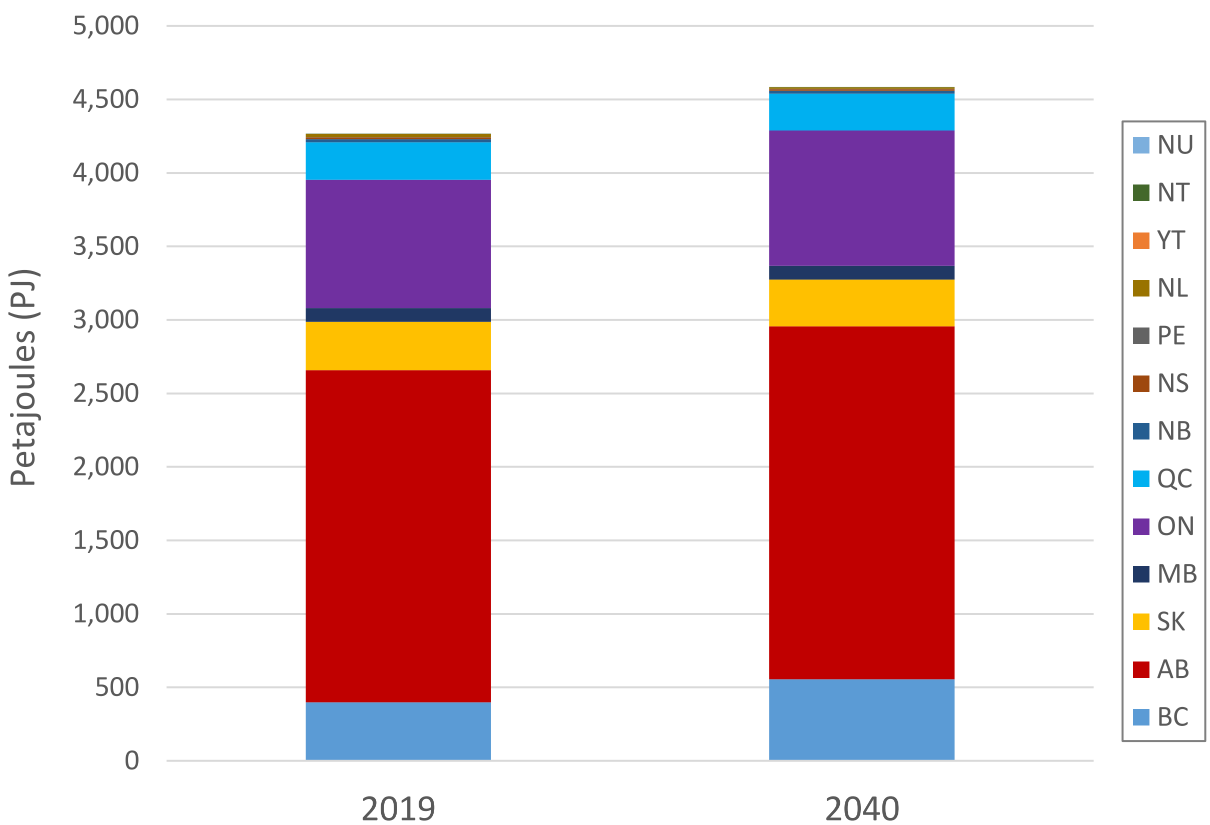


Figure 28. Building Natural Gas Demand in Canada, 2019 & 2040 Projection

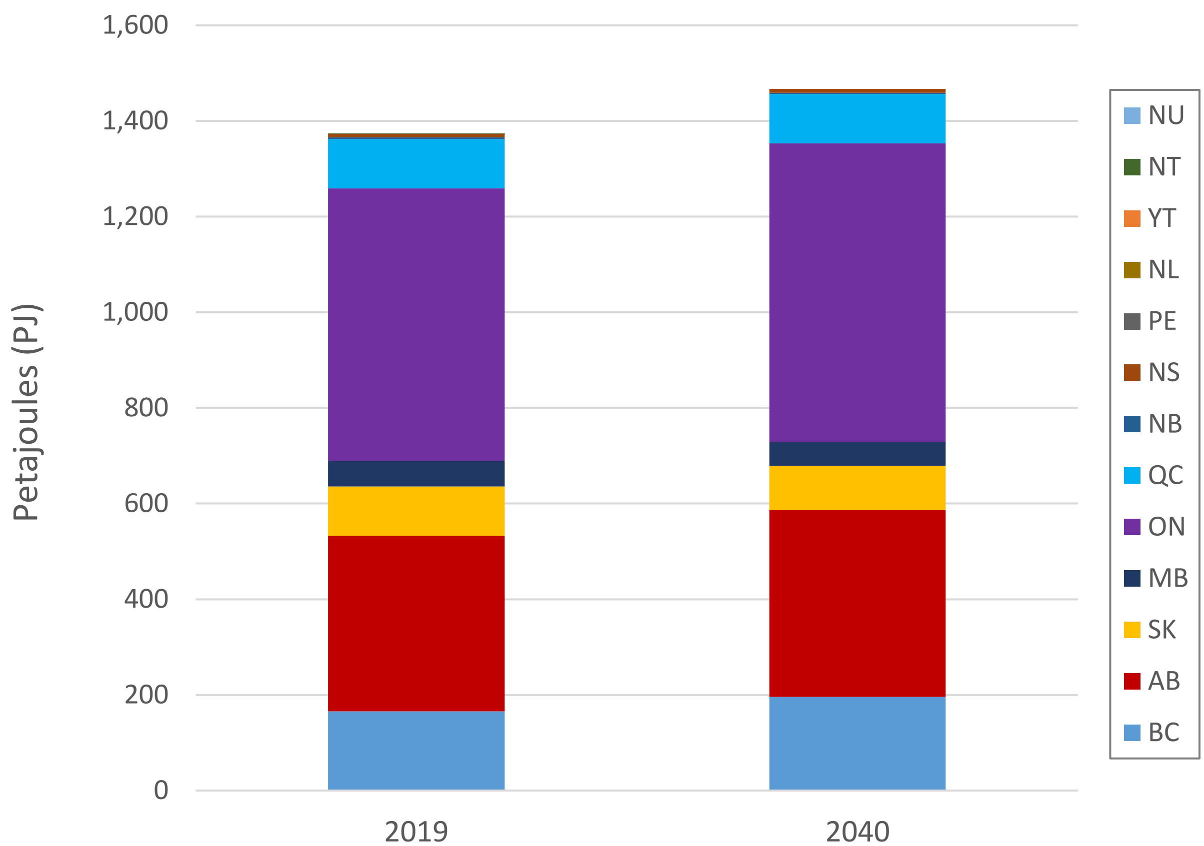


Figure 29. RNG Demand by Natural Gas and Diesel Displacement Rate (PJ)

Prov./ Terr.	2019					2040				
	1% Natural Gas	5% Natural Gas	10% Natural Gas	15% Diesel	10% Natural Gas + 15% Diesel	1% Natural Gas	5% Natural Gas	10% Natural Gas	15% Diesel*	10% Natural Gas + 15% Diesel
BC	4	20	40	12	52	6	28	55	12	67
AB	23	113	226	26	252	24	120	240	25	265
SK	3	16	33	8	41	3	16	32	8	40
MB	1	5	9	5	14	1	5	9	5	14
ON	9	44	87	35	122	9	46	92	33	125
QC	3	13	25	20	45	2	12	25	19	44
NB	0	1	2	3	5	0	1	2	2	5
NS	0	1	1	3	4	0	1	1	3	4
PE	0	0	0	0	0	0	0	0	0	0
NL	0	1	2	1	3	0	1	1	1	2
YT	0	0	0	0	0	0	0	0	0	0
NT	0	0	0	1	1	0	0	0	1	1
NU	0	0	0	0	0	0	0	0	0	0
CA	**43**	**213**	**427**	**114**	**541**	**46**	**229**	**458**	**109**	**567**

*Assumes 6% reduction in diesel demand. CER projects 6% reduction in oil products demand by 2040, but reduction may not be consistent across oil products[2]

5.4 Provincial Supply and Demand

RNG feedstocks are not evenly distributed across Canada and natural gas demand is highly concentrated in Alberta and Ontario, with these provinces representing almost three quarters of total demand. Inevitably, the pathways that provinces and territories will use to meet specific volumetric or CI-based targets using feedstocks from within their jurisdiction will vary significantly. It is likely that cross-border transmission or transport of RNG will be required for several provinces to comply proportionately relative to demand if provincial-level blend requirements are established. Although the CFS is a federal policy, natural gas distribution is under the jurisdiction of the provinces and most natural gas distribution utilities, which will be required to comply with CFS regulations, only supply natural gas in a single province. Therefore, it is critical to understand the ability of a province and its primary natural gas distribution utilities to produce RNG using local feedstocks to meet potential provincial demand.

Section 2 quantified RNG potential at a census division level of detail for key feedstocks. Section 5.3 quantified potential RNG demand. Figure 30 compares RNG supply and demand at a provincial level and identifies whether potential supply is sufficient to meet demand for 5% natural gas blending and 15% of diesel fuel displacement. Two RNG supply options are identified: Scenario 1) conventional RNG excluding corn silage and crop residues; and Scenario 2) conventional RNG including corn (grain and feed corn as silage) and crop residues. In both cases, wood-to-RNG (unconventional) is excluded due to the pre-commercial status of the technology. RNG demand is subtracted from supply, including RNG derived from the corn crop and crop residues, for each province. It should be noted that for all provinces except Quebec, RNG demand exceeds supply if crop residues and corn feedstocks (as silage) are not considered viable feedstocks (Scenario 1). This can be significant; for example, Alberta would require over 120 PJ of RNG imports to meet the modelled blend/displacement volumes if crop residues and corn crops are excluded. The last column in the table indicates whether a province is likely to be a net exporter or importer under Scenario 2. It should be noted RNG supply Scenario 1 is much more likely than RNG Scenario 2 due to the previously discussed constraints on corn-based feedstocks and crop residues.

As is evident from Figure 30, Alberta would become the largest importer of RNG nationally if a 5% volumetric RNG blend requirement, alongside a diesel displacement requirement (e.g., CFS Liquid Class), was implemented. British Columbia would become the second largest importer. This would be a dramatic change from the current natural gas supply situation, in which Alberta and British Columbia account for 98% of Canada's marketable natural gas production. The reason these two provinces would become major importers differs; Alberta has a significant RNG production potential if crop residues are included as a feedstock, but the RNG demand is dramatically higher than any other province, while British Columbia has relatively limited conventional RNG supply potential. Alberta's large natural gas demand is a function of its large industrial thermal energy demand. If heavy industry was excluded from demand, Alberta could be a net exporter of RNG. In reality, Canada's 2050 Net Zero target would also require a dramatically greater reduction in oil products consumption, thereby requiring much larger RNG volumes for transportation.

Figure 30. Theoretical RNG Supply Vs. Demand, by Province

Province	5% Natural Gas Blend (PJ)	15% Diesel Displacement (PJ)	5% Natural Gas Blend + 15% Diesel Displacement (PJ)	RNG Supply 1[a]	RNG Supply 2[b]	Supply 2 - Demand	Import/ Export
BC	20	12	32	16	20	-12	Import
AB	113	26	139	15	105	-34	Import
SK	16	8	24	3	112	88	Export
MB	5	5	10	4	70	60	Export
ON	44	35	79	41	224	146	Export
QC	13	20	33	38	116	83	Export
NB	1	3	4	4	5	2	Export
NS	1	3	4	2	4	1	Export
PE	0	0	0	0	2	2	Export
NL	1	1	2	1	1	-1	Import
CA	**213**	**113**	**327**	**123**	**660**	**327**	**Export**

*Oil Products for energy
[a]Excludes RNG derived from corn silage, crop residues, and wood-to-gas
[b]Includes RNG derived from corn silage and crop residues, but excludes wood-to-gas

Although identified as a net RNG exporter in Figure 30, Ontario would need to redirect corn production from current markets for ethanol production and animal feed, in order to avoid imports. Given current ethanol blend requirements and animal feed markets, this is an unlikely situation in the near to medium term (not considering U.S. trade). In the longer term, light duty liquid transportation fuel demand destruction, driven by electrification of light duty transportation, may limit the market for ethanol. If this were to occur, RNG may be viewed as an alternative market for Ontario and Quebec's corn grain crop. Evidence from Germany, where half of all biogas production is from corn (maize) silage, suggests this can be an economically viable option for producers when enabled by supportive policies. However, ethanol demand is not anticipated to decrease in Canada in the near-medium term.

Demand for natural gas, and by extension, blended RNG, is relatively modest in Atlantic Canada and Manitoba. However, while Manitoba could be a net exporter if modest amounts of crop residues and corn silage are utilized, Atlantic Canada's small natural gas consumption means the region would likely be relatively balanced between RNG supply and demand.

In all cases, it is critical to consider the proportion of theoretical provincial feedstock supply that would actually be used for RNG production. As noted in Section 3, there is significant annual variability in crop residue availability and notable competition from animal markets, particularly in Alberta. Corn crop, including current grain and silage products, use for RNG production would require an unlikely reallocation of Ontario and Quebec's corn industry production. Existing biogas and landfill gas plants generating electricity in Ontario mean that these feedstocks are likely currently unavailable for RNG production, although could present opportunities from 2030 onwards as power purchase contracts expire. Canada has 37 operating digesters that co-digest livestock manure with off-farm organic waste, such as oils, fats, and industrial food residues, with the majority of these located on dairy farms in Ontario. Many feedstock opportunities across the country will be dependent upon RNG prices exceeding $25 per GJ. While competition with diesel fuel may be possible if sufficient demand is present, targeted policies will be required for RNG to compete with natural gas.

6 DISCUSSION AND RECOMMENDATIONS

6.1 Potential RNG Contribution to Canada's Energy Supply

This bottom-up resource analysis has shown the theoretical potential for RNG production in Canada is approximately 809 PJ per year, which is equal to 17% of Canada's current natural gas consumption. However, it is unrealistic for RNG production to reach this level due to competing uses for feedstock, seasonal feedstock supply risk, logistical constraints including the distance between many feedstocks and the closest natural gas pipeline, precommercial technologies for wood-based production, and the high cost of RNG production from most pathways. Of this 809 PJ, 660 PJ is the theoretical potential for conventional RNG. This excludes precommercial wood-to-gas pathways of gasification and methanation, and pyrocatalytic hydrogenation (150 PJ). As identified in Section 4.3 and as stated by stakeholders in a recent national survey, these technologies face major scale-up hurdles.[47,59] In addition, if RNG from wood is used for building or process heat, the production pathway will be notably lower efficiency and higher capital cost than direct combustion of solid wood fuel. This suggests wood-to-gas should not be considered a significant contributor to RNG volume by 2030 and perhaps not by 2040, due to technological limitations and the superior performance of other wood-to-energy approaches.[42]

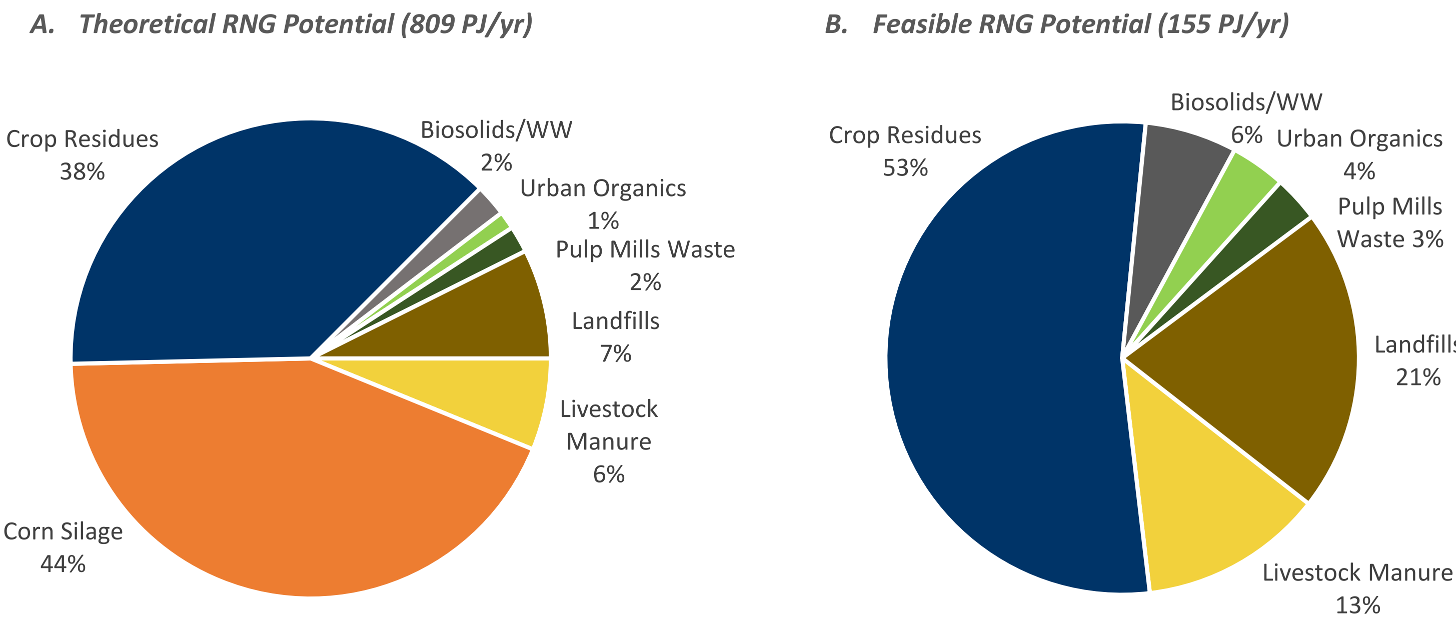
Of the 660 PJ of theoretical conventional RNG potential, 537 PJ is derived from biogas that is produced from grain and feed corn (as silage) and straw (Figure 31A). Utilization of these feedstocks for RNG production can be accomplished using commercial technology and corn silage is the largest contributor to biogas volume in world-leader Germany. However, capturing this potential would require reallocation of feed and industrial grain corn acreage to 'energy crop' (corn silage) production, which is deemed unlikely in the near term. A more likely feedstock is corn stover, which is widely available in Canada's primary corn growing regions of southwestern Ontario and southern Quebec. In fact, a lack of stover markets is a major challenge for some growers. In comparison, the farms in the prairie provinces do not face the same issue of having too much crop residue following harvest. There are large amounts of straw potentially available, but the same need to remove excess residues does not exist in the Prairies. Average annual production of straw in Saskatchewan, Alberta, and Manitoba is very large, but the year-to-year variability can be substantial. In some dry years, and in some regions, very little to no straw is available after accounting for field retention sustainability requirements (e.g., moisture, soil carbon). As noted in Sections 3.1 and 3.2, it is more likely that corn stover and other crop residues could contribute 70-100 PJ of RNG, rather than the theoretical 537 PJ, on an annual basis.

The remaining 123 PJ of theoretical conventional RNG includes landfill gas, livestock manure, urban organics, pulp mills, and biosolids/wastewater. Of this, approximately 50 PJ, or 40%, is landfill gas. However, not all landfill gas will be available for RNG production due to economic constraints – namely small scale and long distance from natural gas pipelines for some landfills. As noted in Section 4.4, economies-of-scale for gas upgrading technologies mean small (e.g., <20,000 GJ/yr) landfill or AD projects may find RNG production and pipeline injection uneconomical. In addition, it is anticipated many landfills do not currently have natural gas distribution system access and extension of the distribution system may further challenge the economics of development. The limited publicly-available information on natural gas distribution lines made it challenging to determine the proximity of gas lines to landfills. Data provided by ECCC on potential landfill gas production focused on landfills that were of significant scale. Assuming 75% of landfill gas can be captured at larger landfills and landfills with a 2030 output less than 20,000 GJ of landfill gas are excluded, a realistic 2030 landfill RNG potential in Canada is 33 PJ. If landfilling of organics is banned, as was recently announced by Quebec, this volume would be projected to decrease over time but offset by increased urban organics availability for RNG.

The remaining RNG feedstocks can be generally grouped into livestock manure, urban waste (biosolids, wastewater, and urban organics), and pulp mill wastes. The potential of livestock manure is roughly equal to urban waste and pulp mills combined. However, livestock manure is used as a key source of fertilizer for many farms in Canada and should not be considered a 'waste'. There is an opportunity to recover energy from this material prior to digestate land application, but implications for soil nutrients and organic matter need to be considered. In most cases, manure is co-digested with off-farm materials, such as waste from abattoirs, food processing plants, urban organics, and local biosolids. The ability of these off-farm feedstocks to provide supplemental nutrients must also be included in the project economics. As the livestock manure quantities included in this report are already discounted for their ability to be collected, it is realistic to assume 50%, or 20 PJ, could be feasible AD feedstocks. The percentage of feedstock actually converted to RNG will be strongly impacted by pricing and availability of complementary co-digestion feedstocks since 100% manure digestion often has an RNG cost exceeding \$50/GJ. Of the urban wastes, including organics, biosolids, and wastewater, 70% or 15 PJ, is assumed to be available. This is the proportion of Canada's population that lives in Census Metropolitan Areas (CMAs): centres with a population greater than 100,000. Large population centres permit RNG project economies-of-scale, which are particularly critical for high CapEx urban waste projects. Finally, a rough assumption of 50% of pulp mills could implement RNG production, adding 5 PJ to the total. Canada's pulp sector has struggled over the past two decades and it is difficult to predict whether all existing mills will be operational 10 or 20 years from now.

After discounting each resource, Canada's RNG potential is estimated to be 140 – 170 PJ, with a mean estimate of 155 PJ. This should be considered an approximation and not a definitive finding. This mean 155 PJ figure is equal to 3.3% of Canada's current natural gas consumption and 1.3% of Canada's energy consumption. The estimated feasible RNG supply breakdown by resource is presented in Figure 31B.

Figure 31. Theoretical and Feasible RNG Potential in Canada



6.2 RNG within Canada's Climate Strategy

RNG production has the potential to make an important contribution to Canada's 2050 Net Zero climate strategy. This contribution is in the form of fuel switching from diesel and natural gas to RNG, but also in the form of avoided methane emissions from key landfill gas, urban waste, and livestock manure feedstocks. Canadian landfills alone were the source of 13.25 Mt CO_2e in methane emissions in 2017, which is equal to the national emissions of Costa Rica or Latvia.[60] When considered on a 20-year global warming potential (GWP-20) basis, these emissions are similar to the national emissions of Norway or Switzerland. If RNG can provide a market for waste feedstocks and landfill gas, it can contribute to reducing emissions.

Avoidance of methane emissions is likely to be the largest contributor of RNG to Canada's climate strategy. As identified in this report, RNG volumes are likely to be limited, particularly when relative GHG reduction costs are considered. Excluding crop residues – namely straw and corn stover – the estimated feasible RNG volume in Canada is 70 PJ. When viewed from a developer perspective, this is a huge opportunity. With a project size of 100,000 GJ per year, this is 700 projects. However, from a national energy policy perspective, 70 PJ is only 0.6% of Canada's current energy consumption. This limited volume means RNG will not be able to displace a large quantity of fossil fuels for GHG reductions. Assuming an average carbon intensity 65% lower than natural gas, the RNG volume estimated in this report could reduce Canada's GHG emissions by 2.8 Mt CO_2e per year. This is 1.4% of Canada's required GHG reduction to meet its Paris Agreement commitment and less than 0.4% of Canada's national emissions. Clearly, federal, provincial, or municipal climate policy cannot rely heavily on RNG to meet GHG goals due to the anticipated limited supply. With RNG as the projected largest volume renewable gas in 2030 and beyond,[59] this has significant implications for the continued operation of natural gas infrastructure under a Net Zero federal climate policy. The Netherlands, which has a natural gas building heat market penetration rate of over 95% (Canada is approximately 55%), has committed to disconnect all buildings from natural gas lines by 2050, with 1.5 M disconnects planned by 2030.[61]

While crop residues can certainly contribute to the RNG total, the reality is that surplus crop residues can be converted to thermal energy (building heat, process heat) at a higher efficiency and with lower costs using combustion technology. This is practiced extensively in countries such as Denmark, where large, low emissions straw plants heat the country's largest cities of Copenhagen and Aarhus. With this considered, RNG from crop residues may still have important role if decarbonization alternatives for heavy duty ground, in-land marine, or rail transportation are limited.

6.3 Growing Canada's RNG Production

The price of natural gas in western Canada, Ontario, and Quebec is extremely low by international energy standards. As an example, the commodity price for gas in Ontario is currently \$2.50/GJ and less than \$2.00/GJ in Alberta. Even with carbon pricing at \$200/t CO_2e, RNG is uncompetitive with natural gas. It will take a blend requirement or a CI-based compliance policy, like the CFS, to drive significant RNG production increases. However, given the higher price for RNG compared to natural gas, provincial governments will need to modify provincial utility regulations to permit natural gas distribution companies to blend RNG and distribute the higher cost across the customer base. Only British Columbia and Quebec have done this to date. Canada's two largest natural gas consumers – Alberta and Ontario – have not yet signalled intent to change the utility regulations if the result is a higher delivered cost of energy. This analysis found RNG could cost up to \$55/GJ to produce, with most volume available in the

$25-55/GJ range. This is 10-22 times the natural gas at $2.50/GJ and, assuming a 65% life cycle GHG reduction relative to natural gas, results in a GHG reduction cost of $558-1,303/ t CO_2e. It will be difficult to argue that RNG is a low cost GHG reduction approach when displacing natural gas.

Conversely, diesel fuel at $1.00/L has an energy cost of approximately $28/GJ. After a 10% efficiency discount for a methane-fuelled engine, the comparable fuel cost of diesel is $25/GJ. This indicates that, on a fuel cost basis, RNG can be competitive with diesel fuel – particularly in the presence of carbon pricing. With the difference in RNG cost competitiveness when compared to natural gas versus diesel, the lack of utility regulation changes may not actually impede growth of the sector. In the absence of prescriptive policy and at similar relative prices, RNG is more likely to be used to displace diesel than natural gas under the CFS.

Based upon the analysis presented here, there is significant opportunity to grow Canada's RNG industry, even if its ultimate contribution to Canada's energy supply is limited. Given the potential to avoid landfill gas emissions and the relative low cost of landfill gas-based RNG compared to most biogas-based RNG production, it is logical to focus RNG production efforts on Canada's landfills. There are numerous municipal landfills that capture landfill gas but flare it due to lack of a market or ability to develop an energy project. These should be an RNG industry development priority. Also high on the list of priorities should be AD projects that utilize feedstocks with negative value and/or have a negative carbon intensity. These feedstocks include manure, urban organics, and biosolids. While the capital cost of these projects is typically high, the avoided methane emissions from landfilling or composting should be recognized in the value of the RNG. If agricultural crop or crop residue feedstocks are to be pursued, the priority should be placed on corn stover in Ontario and Quebec. Corn stover is readily available and is causing operational challenges for some farmers due to high biomass yields.

6.4 Government of Canada Policy Recommendations

This analysis has determined that RNG can make an important contribution to decarbonization in Canada, but that the quantity of fossil fuels that can be displaced with conventional RNG is quite limited. As a result, the Government of Canada must seek to optimize the decarbonization role of RNG, direct biogas use, and biogas/landfill gas-based renewable electricity generation as part of Canada's Net Zero commitment. With the 2050 Net Zero goal in mind, the following recommendations are provided:

1. **Significantly Increase Landfill Gas Capture and Utilization**

   Canada's landfills are a major source of GHG emissions. Municipalities need to be supported and encouraged to implement projects that dramatically curtail methane emissions while a market for RNG (and direct biogas use and electricity from landfill gas, when RNG is not viable) must be established to provide economic value for the resource. Ultimately, requirements on all municipalities of reasonable size to capture and utilize landfill gas should be enacted.

2. **Support Municipalities to Increase Urban Resource Conversion to RNG**

   Quebec and Ontario are implementing organics landfilling bans but the latter has not enabled a market for the resources. Banning landfilling of organics creates significant resource management challenges if there is no economical use of the material. While large population centres, such as Toronto, can develop organics-to-RNG infrastructure and serve as their own market by fuelling municipal vehicles, smaller population centres are more challenged. Support for municipalities to derive value from their organics, biosolids, and wastewater resources is required. Permitting farms to accept more off-farm material, such as urban organics, should enable project economies-of-scale to be realized and more biogas/RNG development to occur.

3. **RNG Fuelling Infrastructure Build-Out**

   RNG is more fuel cost competitive with diesel than with natural gas. However, displacement of diesel is more difficult logistically than displacement of natural gas due to fuel property differences. Addition of, or modifications to, fuelling infrastructure and vehicle engines is required. The Government of Canada should investigate options to support and/or encourage the build-out of RNG fuelling infrastructure for ground, rail, and/or marine vehicles, after determining priority RNG transportation market(s).

4. **Create a Public Database and Mapping System of Waste Opportunities**

   One of the major data gaps in this analysis was the lack of information on Canada's food and beverage manufacturing industry's residue and waste streams. The United States Environmental Protection Agency created and hosts a public database and map of waste food opportunities in the country. Canada should seek to establish a similar database and online portal to enable project development by linking potential feedstock suppliers with project developers. This will require participation of the industry and, potentially, provincial governments.

5. Survey Farmers for Crop Residue Availability and Fate

A second significant identified data gap is the lack of up-to-date information on crop residue production and fate in Canada. The most recent survey of farmers was conducted in 2001 and the survey questions have been discontinued by Statistics Canada. As this feedstock is often identified as 'available' for bioenergy and bioproducts, it is essential to have a better understanding of the volumes that are produced and can be sustainably removed on a year-to-year basis. A survey of farmers would provide great value to development of the bioeconomy.

6. Value Water Quality and Nutrient Management

By increasing the value to the producer of manure through the addition of RNG production, any potential for nutrient run-off, N_2O emissions and subsequent bacterial water contamination is reduced. In general, anaerobic digestion of livestock manure, coverage of digestate storage, followed by land application of digestate, generates fewer methane and nitrous oxide (N_20) emissions than direct application of the manure. Avoidance of these potent GHG emissions, along with water quality benefits from best practices, should be valued economically.

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APPENDIX 1: RESOURCE POTENTIAL BY CENSUS DIVISION

Census Division Unique Identifier (CDUID)	Province/ Territory	Census Division Name	Resource Potential (TJ)											
			Livestock Manure				Crop-Based		Urban			Forest-Based		Total
			Dairy Cows	Beef Cattle	Hogs	Poultry	Corn Silage	Other Crop Residues	Biosolids & WW	Urban Organics	Landfills	Pulp Mill Sludge	Wood	
1001	NL	Division No. 1	0	0	0	81	0	0	105	60	386	0	0	633
1002	NL	Division No. 2	21	0	0	0	0	0	0	0	19	0	0	40
1003	NL	Division No. 3	0	0	0	0	0	0	0	0	0	0	0	-
1004	NL	Division No. 4	0	0	0	0	0	0	0	0	34	0	0	34
1005	NL	Division No. 5	0	0	108	0	0	0	0	0	0	200	0	308
1006	NL	Division No. 6	0	0	0	0	0	0	0	0	31	0	0	31
1007	NL	Division No. 7	0	0	0	0	0	0	0	0	0	0	0	-
1008	NL	Division No. 8	0	0	0	0	0	0	0	0	0	0	0	-
1009	NL	Division No. 9	0	0	0	0	0	0	0	0	0	0	0	-
1010	NL	Division No. 10	0	0	0	0	0	0	0	0	0	0	0	-
1010	NL	Division No. 10	0	0	0	0	0	0	0	0	0	0	0	-
1101	PE	Kings	0	0	0	0	55	136	0	0	0	0	0	191
1102	PE	Queens	31	2	145	0	578	296	35	32	0	0	0	1,118
1103	PE	Prince	0	0	0	0	281	220	0	0	64	0	0	566
1201	NS	Shelburne	0	0	0	0	0	0	0	0	0	0	0	-
1202	NS	Yarmouth	0	0	0	0	0	3	0	0	0	0	0	3
1203	NS	Digby	0	0	0	0	0	2	0	0	0	0	0	2
1204	NS	Queens	0	0	36	0	0	1	0	0	0	0	0	37
1205	NS	Annapolis	0	0	0	8	135	8	0	0	0	0	0	151
1206	NS	Lunenburg	0	4	0	16	0	5	0	0	38	0	0	64
1207	NS	Kings	0	2	0	179	811	26	0	0	0	0	0	1,018
1208	NS	Hants	0	0	0	24	438	23	0	0	71	0	0	557
1209	NS	Halifax	10	0	0	0	0	8	206	119	466	0	0	809
1210	NS	Colchester	83	0	36	0	378	31	0	0	43	0	0	571
1211	NS	Cumberland	42	0	0	0	0	28	0	0	58	0	0	128
1212	NS	Pictou	0	0	0	0	0	18	0	0	0	140	0	158
1213	NS	Guysborough	10	0	181	0	0	3	0	0	73	0	0	267
1214	NS	Antigonish	10	0	0	0	82	12	0	0	0	0	0	104
1215	NS	Inverness	0	0	0	0	0	5	0	0	0	216	0	221
1216	NS	Richmond	0	0	0	0	0	1	0	0	0	0	0	1
1217	NS	Cape Breton	0	0	0	0	0	3	50	21	0	0	0	75
1218	NS	Victoria	10	0	36	0	0	3	0	0	0	0	0	49
1301	NB	Saint John	10	0	108	0	0	2	0	0	142	424	0	686

1302	NB	Charlotte	0	0	0	0	0	8	0	0	140	241	0	389
1303	NB	Sunbury	0	0	0	0	0	7	0	0	0	0	0	7
1304	NB	Queens	0	0	108	0	0	20	0	25	0	0	0	154
1305	NB	Kings	73	0	36	0	174	47	64	28	0	0	0	423
1306	NB	Albert	10	0	0	0	0	15	74	0	0	0	0	99
1307	NB	Westmorland	31	5	181	0	156	67	0	48	349	0	0	837
1308	NB	Kent	0	0	0	0	0	31	0	0	0	0	0	31
1309	NB	Northumberland	10	0	108	0	0	17	0	0	0	0	8,149	8,285
1310	NB	York	0	0	145	16	39	19	52	0	221	87	0	578
1311	NB	Carleton	31	0	0	0	507	59	0	0	0	0	0	598
1312	NB	Victoria	62	0	0	0	33	46	0	0	0	0	0	141
1313	NB	Madawaska	52	0	36	106	0	33	0	0	129	481	0	836
1314	NB	Restigouche	0	0	36	0	0	19	0	0	0	165	17,578	17,798
1315	NB	Gloucester	0	0	0	0	0	30	0	0	201	0	0	231
2401	QC	Les Îles-de-la-Madeleine	0	0	0	0	0	8	0	0	0	0	0	8
2402	QC	Le Rocher-Percé	21	0	72	0	0	15	0	0	0	0	0	108
2403	QC	La Côte-de-Gaspé	10	0	0	0	0	2	0	0	27	0	0	39
2404	QC	La Haute-Gaspésie	42	0	0	0	0	8	0	0	0	0	0	49
2405	QC	Bonaventure	10	0	0	0	0	30	0	0	53	0	0	93
2406	QC	Avignon	0	0	0	0	0	25	0	0	0	0	0	25
2407	QC	La Matapédia	156	0	434	0	40	97	0	0	0	0	0	726
2408	QC	Matane	0	0	0	0	36	43	0	0	32	216	0	327
2409	QC	La Mitis	10	0	0	0	86	93	0	0	0	0	0	189
2410	QC	Rimouski-Neigette	0	0	0	0	113	89	28	0	55	0	0	285
2411	QC	Les Basques	0	0	0	0	67	102	0	0	0	0	0	169
2412	QC	Rivière-du-Loup	42	0	181	0	146	132	0	0	83	212	0	796
2413	QC	Témiscouata	10	0	72	0	36	71	0	0	30	0	0	219
2414	QC	Kamouraska	0	0	0	0	452	121	0	0	0	0	0	573
2415	QC	Charlevoix-Est	10	0	0	8	0	21	0	0	16	180	0	235
2416	QC	Charlevoix	21	0	36	16	4	21	0	0	0	0	0	99
2417	QC	L'Islet	93	0	36	33	222	47	0	0	15	0	0	447
2418	QC	Montmagny	0	0	0	0	294	47	0	0	0	0	0	341
2419	QC	Bellechasse	21	0	325	81	959	101	0	0	142	0	0	1,630
2420	QC	L'Île-d'Orléans	42	0	397	8	93	33	0	0	0	0	0	573
2421	QC	La Côte-de-Beaupré	42	0	72	0	0	19	0	0	332	0	0	465
2422	QC	La Jacques-Cartier	21	0	0	43	0	8	0	0	0	0	0	71
2423	QC	Québec	10	0	0	0	98	24	409	272	0	200	0	1,013
2425	QC	Lévis	0	0	0	0	147	44	0	0	0	0	0	191
2426	QC	La Nouvelle-Beauce	10	0	253	138	1,218	83	0	0	174	0	0	1,877
2427	QC	Robert-Cliche	125	0	470	24	310	59	0	25	0	0	0	1,013
2428	QC	Les Etchemins	0	0	0	0	0	23	0	0	0	0	0	23

2429	QC	Beauce-Sartigan	21	0	0	24	212	54	0	0	64	0	0	375
2430	QC	Le Granit	31	0	253	8	172	22	0	0	0	0	0	487
2431	QC	Les Appalaches	31	0	0	8	0	81	0	0	0	0	0	121
2432	QC	L'Érable	21	0	0	8	688	97	0	0	46	0	0	860
2433	QC	Lotbinière	21	0	217	41	1,427	123	0	0	62	0	0	1,890
2434	QC	Portneuf	260	0	253	8	462	101	0	0	21	0	12,237	13,341
2435	QC	Mékinac	52	0	0	0	0	53	0	0	0	0	0	105
2436	QC	Shawinigan	0	0	0	0	0	22	28	0	0	0	0	49
2437	QC	Francheville	42	0	0	8	1,064	116	0	0	48	463	0	1,741
2438	QC	Bécancour	42	0	0	33	1,338	109	0	0	0	0	0	1,521
2439	QC	Arthabaska	31	0	72	49	2,145	153	25	44	125	0	0	2,645
2440	QC	Les Sources	31	0	0	0	338	49	0	0	16	0	0	434
2441	QC	Le Haut-Saint-François	83	1	0	0	313	28	0	0	0	0	0	425
2442	QC	Le Val-Saint-François	0	0	0	0	454	52	0	0	0	224	0	730
2443	QC	Sherbrooke	10	0	0	0	129	13	108	60	223	160	0	704
2444	QC	Coaticook	62	0	181	8	1,239	32	0	0	44	0	0	1,567
2445	QC	Memphrémagog	10	0	0	8	159	26	0	0	98	0	0	302
2446	QC	Brome-Missisquoi	21	0	0	77	2,799	87	0	0	132	0	0	3,115
2447	QC	La Haute-Yamaska	52	0	36	115	954	43	43	0	390	0	0	1,632
2448	QC	Acton	10	0	0	16	1,642	71	0	0	0	0	0	1,740
2449	QC	Drummond	52	0	181	130	3,080	173	49	0	1,646	0	0	5,310
2450	QC	Nicolet-Yamaska	52	0	0	57	3,384	146	0	0	0	0	0	3,640
2451	QC	Maskinongé	145	0	145	0	1,782	95	0	52	167	0	0	2,385
2452	QC	D'Autray	31	0	108	195	1,583	121	0	0	0	0	0	2,038
2453	QC	Pierre-De Saurel	0	0	0	0	2,750	88	0	0	0	0	0	2,838
2454	QC	Les Maskoutains	0	0	36	326	8,866	193	30	0	0	0	0	9,452
2455	QC	Rouville	0	0	0	121	2,390	74	0	56	0	0	0	2,641
2456	QC	Le Haut-Richelieu	176	0	2,637	20	5,664	118	0	0	0	0	0	8,616
2457	QC	La Vallée-du-Richelieu	0	0	0	24	2,434	116	0	0	0	0	0	2,575
2458	QC	Longueuil	0	0	0	0	207	19	0	0	0	0	0	227
2459	QC	Marguerite-D'Youville	0	0	0	0	1,097	49	0	0	0	0	0	1,146
2460	QC	L'Assomption	114	0	36	16	633	56	0	0	0	0	0	856
2461	QC	Joliette	0	0	0	24	559	92	25	0	1,843	0	0	2,544
2462	QC	Matawinie	0	0	0	147	374	52	0	0	0	0	0	572
2463	QC	Montcalm	353	0	831	73	1,710	86	0	0	0	0	0	3,053
2464	QC	Les Moulins	0	0	0	0	169	56	0	0	2,754	0	0	2,978
2465	QC	Laval	52	0	108	0	0	16	2,094	1,309	0	0	0	3,579
2466	QC	Montréal	10	0	0	0	0	33	0	0	2,707	0	0	2,751
2467	QC	Roussillon	0	0	0	0	1,064	55	0	0	0	0	0	1,119
2468	QC	Les Jardins-de-Napierville	42	0	36	8	2,531	103	0	0	0	0	0	2,720
2469	QC	Le Haut-Saint-Laurent	0	0	0	8	3,863	97	0	0	0	0	0	3,968

2470	QC	Beauharnois-Salaberry	0	0	0	0	2,691	78	0	0	0	0	0	2,769
2471	QC	Vaudreuil-Soulanges	0	0	0	24	2,745	90	0	0	0	0	0	2,859
2472	QC	Deux-Montagnes	0	0	0	16	256	39	0	0	0	0	0	311
2473	QC	Thérèse-De Blainville	0	0	0	0	125	35	0	0	0	0	0	160
2474	QC	Mirabel	31	0	0	0	773	59	0	0	0	0	0	863
2475	QC	La Rivière-du-Nord	0	0	0	8	42	20	0	0	1,690	0	0	1,760
2476	QC	Argenteuil	0	0	145	0	518	27	0	0	1,371	0	0	2,060
2477	QC	Les Pays-d'en-Haut	10	0	0	0	0	2	0	0	0	0	0	12
2478	QC	Les Laurentides	42	0	0	0	21	4	0	0	0	0	0	67
2479	QC	Antoine-Labelle	0	0	0	8	59	14	0	0	104	0	0	185
2480	QC	Papineau	0	0	0	0	183	35	0	0	0	83	0	301
2481	QC	Gatineau	0	0	0	0	0	20	0	397	0	192	0	609
2482	QC	Les Collines-de-l'Outaouais	21	0	0	0	126	39	676	0	0	0	0	862
2483	QC	La Vallée-de-la-Gatineau	21	0	0	0	0	15	0	0	0	0	0	36
2484	QC	Pontiac	10	0	0	0	472	54	0	0	0	0	0	536
2485	QC	Témiscamingue	10	0	0	0	124	57	0	0	0	387	0	578
2486	QC	Rouyn-Noranda	0	0	0	0	0	24	0	0	0	0	0	24
2487	QC	Abitibi-Ouest	10	0	0	0	0	56	0	0	0	0	0	66
2488	QC	Abitibi	10	0	0	0	0	47	0	0	57	157	0	271
2489	QC	La Vallée-de-l'Or	0	0	0	0	0	14	0	0	40	0	0	54
2490	QC	La Tuque	0	0	0	0	0	1	0	0	0	240	0	241
2491	QC	Le Domaine-du-Roy	0	0	0	0	59	133	0	0	0	174	0	365
2492	QC	Maria-Chapdelaine	488	0	108	0	60	160	0	0	0	114	0	931
2493	QC	Lac-Saint-Jean-Est	0	0	0	33	245	139	0	0	152	288	0	856
2494	QC	Le Saguenay-et-son-Fjord	0	1	0	0	54	98	82	50	216	106	7,781	8,389
2495	QC	La Haute-Côte-Nord	0	0	0	0	0	10	0	0	0	0	0	10
2496	QC	Manicouagan	0	0	0	0	0	5	0	0	30	258	0	294
2497	QC	Sept-Rivières--Caniapiscau	0	0	0	0	0	0	0	0	87	0	0	87
2498	QC	Minganie--Le Golfe-du-Saint-Laurent	0	0	0	0	0	0	0	0	40	0	0	40
2499	QC	Nord-du-Québec	0	0	0	0	0	7	0	0	231	0	8,064	8,302
3501	ON	Stormont, Dundas and Glengarry	0	0	0	57	10,371	207	30	0	914	0	8,064	19,644
3502	ON	Prescott and Russell	0	0	0	90	5,727	155	0	0	0	0	0	5,971
3506	ON	Ottawa	31	0	0	16	4,533	141	676	0	1,878	0	0	7,276
3507	ON	Leeds and Grenville	0	0	0	57	2,358	93	0	0	0	0	0	2,509
3509	ON	Lanark	0	0	0	0	842	64	0	0	0	0	0	907
3510	ON	Frontenac	0	0	0	0	646	53	82	43	0	0	0	824
3511	ON	Lennox and Addington	0	0	0	41	834	72	0	0	190	0	0	1,136
3512	ON	Hastings	31	0	0	8	1,495	173	53	28	19	0	0	1,807
3513	ON	Prince Edward	21	0	0	16	1,004	92	0	0	0	0	0	1,133

3514	ON	Northumberland	42	0	36	24	2,343	201	0	0	61	0	0	2,707
3515	ON	Peterborough	52	0	36	16	962	203	62	28	214	0	0	1,573
3516	ON	Kawartha Lakes	31	0	36	8	1,719	251	39	0	64	0	0	2,148
3518	ON	Durham	52	0	0	57	3,841	281	194	113	1,744	0	0	6,282
3519	ON	York	0	0	0	16	1,355	223	3,028	54	1,706	0	0	6,381
3520	ON	Toronto	31	0	0	0	19	18	0	1,559	387	0	0	2,015
3521	ON	Peel	114	0	217	8	903	237	0	0	935	0	0	2,414
3522	ON	Dufferin	0	0	0	16	1,263	465	0	0	0	0	0	1,745
3523	ON	Wellington	0	2	0	400	7,403	848	78	0	163	0	0	8,894
3524	ON	Halton	0	0	36	8	791	183	0	74	255	0	0	1,347
3525	ON	Hamilton	10	0	36	41	1,774	336	382	0	542	0	0	3,121
3526	ON	Niagara	0	0	0	273	1,632	352	207	333	3,913	0	0	6,711
3528	ON	Haldimand-Norfolk	176	0	975	227	5,446	776	33	52	92	0	0	7,778
3529	ON	Brant	21	0	0	41	3,330	482	69	0	310	0	0	4,252
3530	ON	Waterloo	363	0	723	220	4,156	533	268	170	531	0	0	6,964
3531	ON	Perth	10	4	36	301	10,851	951	0	0	123	0	0	12,275
3532	ON	Oxford	10	2	36	300	11,872	841	0	0	145	0	0	13,206
3534	ON	Elgin	114	0	145	79	9,076	695	0	0	776	0	0	10,884
3536	ON	Chatham-Kent	93	0	72	16	13,413	849	52	0	1,769	0	0	16,264
3537	ON	Essex	52	0	36	14	4,303	474	25	95	770	0	0	5,769
3538	ON	Lambton	10	0	289	140	8,503	998	49	29	883	0	0	10,901
3539	ON	Middlesex	21	2	253	261	13,957	1,244	252	158	751	0	0	16,899
3540	ON	Huron	42	0	145	426	14,561	1,097	0	0	35	0	0	16,305
3541	ON	Bruce	83	0	181	81	5,945	733	0	0	0	0	0	7,023
3542	ON	Grey	0	0	0	87	3,324	936	0	0	0	0	0	4,348
3543	ON	Simcoe	249	0	72	55	4,533	715	101	63	260	0	0	6,047
3544	ON	Muskoka	10	0	0	0	0	22	0	0	199	0	0	231
3546	ON	Haliburton	0	0	0	0	0	3	0	0	0	0	0	3
3547	ON	Renfrew	0	0	0	0	1,662	91	0	0	105	0	6,801	8,659
3548	ON	Nipissing	52	0	72	0	6	32	36	0	194	0	0	392
3549	ON	Parry Sound	0	0	0	0	0	28	0	0	0	0	0	28
3551	ON	Manitoulin	166	0	397	0	42	52	0	0	0	0	0	658
3552	ON	Sudbury	10	0	0	0	25	23	0	0	0	164	0	222
3553	ON	Greater Sudbury / Grand Sudbury	10	0	0	0	0	10	84	44	256	0	0	405
3554	ON	Timiskaming	0	0	0	0	215	70	0	0	92	0	0	377
3556	ON	Cochrane	0	0	0	0	10	50	0	0	194	176	8,347	8,776
3557	ON	Algoma	0	0	0	0	56	27	0	25	168	0	0	275
3558	ON	Thunder Bay	10	0	0	0	161	18	62	32	297	436	10,186	11,202
3559	ON	Rainy River	10	0	0	0	52	62	0	0	0	0	0	124
3560	ON	Kenora	114	0	578	0	0	10	0	0	29	164	0	895

4601	MB	Division No. 1	31	0	0	24	473	604	0	0	0	0	0	1,133
4602	MB	Division No. 2	10	1	108	212	4,467	1,978	0	0	63	0	0	6,840
4603	MB	Division No. 3	0	2	108	16	6,682	3,518	0	0	0	0	0	10,327
4604	MB	Division No. 4	0	0	0	41	816	2,629	0	0	0	0	0	3,485
4605	MB	Division No. 5	10	8	0	0	2,610	3,801	0	0	0	0	0	6,430
4606	MB	Division No. 6	208	4	36	0	599	2,061	0	0	0	0	0	2,908
4607	MB	Division No. 7	93	0	0	33	2,155	3,020	30	0	85	0	0	5,416
4608	MB	Division No. 8	42	51	0	30	2,721	1,999	0	0	0	0	0	4,842
4609	MB	Division No. 9	52	7	72	33	1,482	1,854	0	0	25	0	0	3,525
4610	MB	Division No. 10	0	0	0	55	798	1,742	0	0	0	0	0	2,595
4611	MB	Division No. 11	0	0	0	16	249	438	398	0	914	0	0	2,016
4612	MB	Division No. 12	0	0	0	0	394	802	0	244	0	0	0	1,439
4613	MB	Division No. 13	0	0	0	0	222	914	0	0	50	0	0	1,186
4614	MB	Division No. 14	10	0	181	8	777	1,554	0	0	347	0	0	2,877
4615	MB	Division No. 15	42	59	0	8	866	4,683	0	0	9	0	0	5,667
4616	MB	Division No. 16	73	0	0	0	0	1,840	0	0	0	0	0	1,913
4617	MB	Division No. 17	31	12	0	0	941	2,353	0	0	41	0	0	3,378
4618	MB	Division No. 18	73	8	0	0	96	1,212	0	0	0	0	0	1,388
4619	MB	Division No. 19	10	0	0	0	0	464	0	0	0	0	0	474
4620	MB	Division No. 20	0	0	0	0	0	1,361	0	0	0	0	0	1,361
4621	MB	Division No. 21	0	0	0	0	0	86	0	0	10	90	0	187
4622	MB	Division No. 22	73	0	181	0	0	0	0	0	0	0	0	253
4623	MB	Division No. 23	0	0	0	0	0	0	0	0	0	0	0	-
4701	SK	Division No. 1	0	13	0	0	496	6,595	0	0	0	0	0	7,104
4702	SK	Division No. 2	0	48	0	0	637	5,184	0	0	10	0	0	5,880
4703	SK	Division No. 3	10	88	0	8	261	1,532	0	0	0	0	0	1,900
4704	SK	Division No. 4	0	6	0	16	0	1,475	0	0	0	0	0	1,497
4705	SK	Division No. 5	10	57	72	33	412	7,507	0	0	0	0	0	8,091
4706	SK	Division No. 6	10	17	0	16	250	9,654	121	77	73	0	0	10,218
4707	SK	Division No. 7	21	14	0	8	0	4,351	0	0	248	0	0	4,642
4708	SK	Division No. 8	21	21	0	8	109	5,125	0	0	14	0	0	5,297
4709	SK	Division No. 9	0	39	0	0	0	6,079	0	0	67	0	0	6,185
4710	SK	Division No. 10	0	115	0	0	0	7,001	0	0	0	0	0	7,116
4711	SK	Division No. 11	0	0	0	74	474	7,803	151	88	239	0	0	8,829
4712	SK	Division No. 12	0	27	0	81	156	6,519	0	0	0	0	0	6,784
4713	SK	Division No. 13	21	0	0	8	275	7,934	0	0	0	0	0	8,237
4714	SK	Division No. 14	10	0	0	0	107	8,311	0	0	0	0	0	8,428
4715	SK	Division No. 15	0	18	0	74	0	9,481	0	0	91	0	8,736	18,400
4716	SK	Division No. 16	10	18	0	0	0	6,232	0	0	22	0	0	6,283
4717	SK	Division No. 17	0	0	0	0	485	4,860	0	0	18	320	0	5,683
4718	SK	Division No. 18	62	0	72	0	0	18	0	0	0	0	0	152

4801	AB	Division No. 1	93	26	0	24	683	3,799	39	0	116	0	0	4,782
4802	AB	Division No. 2	10	1,626	72	183	4,113	6,601	60	40	289	0	0	12,995
4803	AB	Division No. 3	62	141	0	24	0	1,371	0	0	50	0	0	1,649
4804	AB	Division No. 4	21	4	0	16	671	3,902	0	0	0	0	0	4,613
4805	AB	Division No. 5	0	385	72	112	591	10,661	0	0	12	0	0	11,833
4806	AB	Division No. 6	21	253	0	57	0	5,962	711	428	2,060	0	0	9,491
4807	AB	Division No. 7	10	73	0	30	769	8,067	0	0	180	0	0	9,129
4808	AB	Division No. 8	21	53	0	128	1,002	4,005	51	49	115	0	0	5,423
4809	AB	Division No. 9	52	0	0	0	0	935	0	0	0	0	0	987
4810	AB	Division No. 10	31	179	36	112	1,115	11,883	0	0	249	0	0	13,606
4811	AB	Division No. 11	10	0	0	140	0	5,309	675	391	879	0	0	7,404
4812	AB	Division No. 12	73	9	108	0	443	2,663	0	0	9	0	0	3,305
4813	AB	Division No. 13	280	32	325	33	0	3,603	0	0	76	805	0	5,155
4814	AB	Division No. 14	93	0	145	0	0	497	0	0	35	190	0	959
4815	AB	Division No. 15	145	0	397	0	0	89	0	0	0	0	0	632
4816	AB	Division No. 16	62	0	0	0	0	0	37	0	56	0	0	156
4817	AB	Division No. 17	21	0	36	0	0	4,259	0	0	28	200	0	4,545
4818	AB	Division No. 18	0	0	0	0	37	1,204	0	0	0	0	0	1,241
4819	AB	Division No. 19	52	13	397	8	0	5,563	32	25	145	428	0	6,662
5901	BC	East Kootenay	0	0	72	0	0	7	0	0	35	119	0	232
5903	BC	Central Kootenay	83	0	108	0	0	12	0	0	59	260	0	522
5905	BC	Kootenay Boundary	208	0	145	0	0	6	0	0	23	0	0	381
5907	BC	Okanagan-Similkameen	42	24	36	0	0	12	0	62	37	0	0	212
5909	BC	Fraser Valley	0	0	0	843	2,139	26	52	65	143	0	0	3,268
5915	BC	Greater Vancouver	31	0	72	301	438	22	1,258	747	1,738	0	0	4,608
5917	BC	Capital	62	0	217	8	0	2	188	120	347	0	0	944
5919	BC	Cowichan Valley	10	0	0	16	116	4	0	50	0	350	0	546
5921	BC	Nanaimo	166	0	145	8	0	3	54	0	98	183	0	655
5923	BC	Alberni-Clayoquot	0	0	0	0	0	1	0	0	48	272	0	321
5924	BC	Strathcona	10	0	36	0	0	1	0	0	26	0	28,063	28,136
5926	BC	Comox Valley	83	0	108	0	73	4	28	0	48	0	0	344
5927	BC	Powell River	42	0	145	0	0	0	0	0	0	280	0	466
5929	BC	Sunshine Coast	73	0	253	0	0	0	0	0	37	328	0	690
5931	BC	Squamish-Lillooet	83	0	542	0	0	4	0	0	50	0	0	679
5933	BC	Thompson-Nicola	114	0	108	8	0	30	53	27	22	178	0	540
5935	BC	Central Okanagan	0	0	145	0	0	5	100	0	102	0	0	352
5937	BC	North Okanagan	42	3	0	49	722	23	31	0	48	0	0	917
5939	BC	Columbia-Shuswap	31	0	72	24	198	19	0	22	44	0	0	410
5941	BC	Cariboo	104	0	686	0	0	56	0	0	22	405	0	1,273
5943	BC	Mount Waddington	42	0	253	0	0	0	0	0	22	0	0	316
5945	BC	Central Coast	0	0	0	0	0	0	0	0	0	0	0	0

5947	BC	Skeena-Queen Charlotte	83	0	361	0	0	0	0	0	39	0	13,440	13,923
5949	BC	Kitimat-Stikine	31	0	0	0	0	2	0	0	48	0	12,096	12,177
5951	BC	Bulkley-Nechako	0	0	0	0	13	60	0	0	35	0	0	108
5953	BC	Fraser-Fort George	10	0	0	0	0	33	44	0	193	655	0	936
5955	BC	Peace River	10	0	0	0	0	741	0	0	16	176	0	943
5957	BC	Stikine	0	0	0	0	0	0	0	0	0	0	0	0
5959	BC	Northern Rockies	21	0	36	0	0	5	0	0	10	0	0	72
6001	YK	Yukon	10	0	0	0	0	0	0	0	0	0	0	10
6101	NT	Region 1	0	0	0	0	0	0	0	0	0	0	0	0
6102	NT	Region 2	0	0	0	0	0	0	0	0	0	0	0	0
6103	NT	Region 3	0	0	0	0	0	0	0	0	0	0	0	0
6104	NT	Region 4	0	0	0	0	0	0	0	0	0	0	0	0
6105	NT	Region 5	0	0	0	0	0	0	0	0	0	0	0	0
6106	NT	Region 6	0	0	0	0	0	0	0	0	0	0	0	0
6204	NU	Baffin	0	0	0	0	0	0	0	0	0	0	0	0
6205	NU	Keewatin	0	0	0	0	0	0	0	0	0	0	0	0
6208	NU	Kitikmeot	0	0	0	0	0	0	0	0	0	0	0	0
Total			**9,136**	**3,479**	**19,401**	**8,767**	**286,659**	**249,571**	**14,159**	**7,933**	**48,706**	**11,782**	**149,542**	**809,135**