# Resource Supply Potential for Renewable Natural Gas in B.C.

## PUBLIC VERSION

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## Abbreviations and Acronyms

| | |
|---|---|
| **AD** | Anaerobic Digestion |
| **B.C.** | British Columbia |
| **BOD** | Biochemical Oxygen Demand |
| **CCS** | Census Consolidated Subdivision |
| **$CH_4$** | Methane |
| **DLC** | Demolition, Land-clearing and Construction |
| **GHG** | Greenhouse Gas |
| **GJ** | Gigajoule |
| **ICI** | Industrial, Commercial and Institutional |
| **Kg** | Kilogram |
| **Km** | Kilometer |
| **l** | Litre |
| **LFG** | Landfill gas |
| **$Nm^3$** | Cubic metre |
| **NRCan** | Natural Resources Canada |
| **ODT** | Oven Dry Tonnes |
| **PJ** | Petajoule (one million GJs) |
| **RI.SE** | Research Institute of Sweden |
| **RNG** | Renewable Natural Gas |
| **SSO** | Source Separated Organic |
| **TSA** | Timber Supply Area |
| **WAS** | Waste Activated Sludge |
| **WWTP** | Wastewater Treatment Plant |

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## 1. Executive Summary

Renewable Natural Gas (RNG) production potential in B.C. was assessed under short and long-term scenarios. The short-term scenario is defined as the next few years in which little change is expected regarding RNG feedstock and technology. The long-term scenario is defined as a date in the future where significant changes in RNG feedstock and technology are expected (the year 2035 was chosen). For the long-term scenario RNG production was assessed twice; first using only projected increased feedstock availability, second using projected increased feedstock availability and assuming significant advancements in wood RNG technology.

Within the short-term, theoretical RNG production potential is estimated to be up to 7.6 PJ/year. However, theoretical RNG production potential is the maximum amount of RNG that could be produced using the most favourable assumptions. Theoretical RNG production potential doesn't take into account certain realities, such as potential feedstock unavailability, or less than 100% capacity production at AD plants. Achievable RNG production potential is the amount of RNG that could be produced using realistic assumptions. In the short-term, achievable RNG production potential is estimated to be up to 4.4 PJ/year.

Long-term achievable RNG production potential, using projected increased feedstock availability and assuming no significant technology advancements, is estimated to be up to 11.9 PJ/year. Long-term achievable RNG production potential, using increased projected feedstock availability and assuming significant advancements in wood RNG technology, is estimated to be up to 93.6 PJ/year; this estimation depends heavily upon the assumed availability of forestry feedstock.

It should be noted that short and long-term RNG production potentials are total amounts of RNG that could be produced based on available feedstocks and RNG technology, and assuming a maximum RNG purchase price of $28/GJ. RNG production potentials therefore do not estimate total amount of RNG that could be produced at lower price points (i.e., $16/GJ or $20/GJ). As such, actual RNG production in B.C., which will depend heavily upon the market price for RNG, may be lower.

***Figure 1: RNG Production Potential without Technology Advancements at $28/GJ***

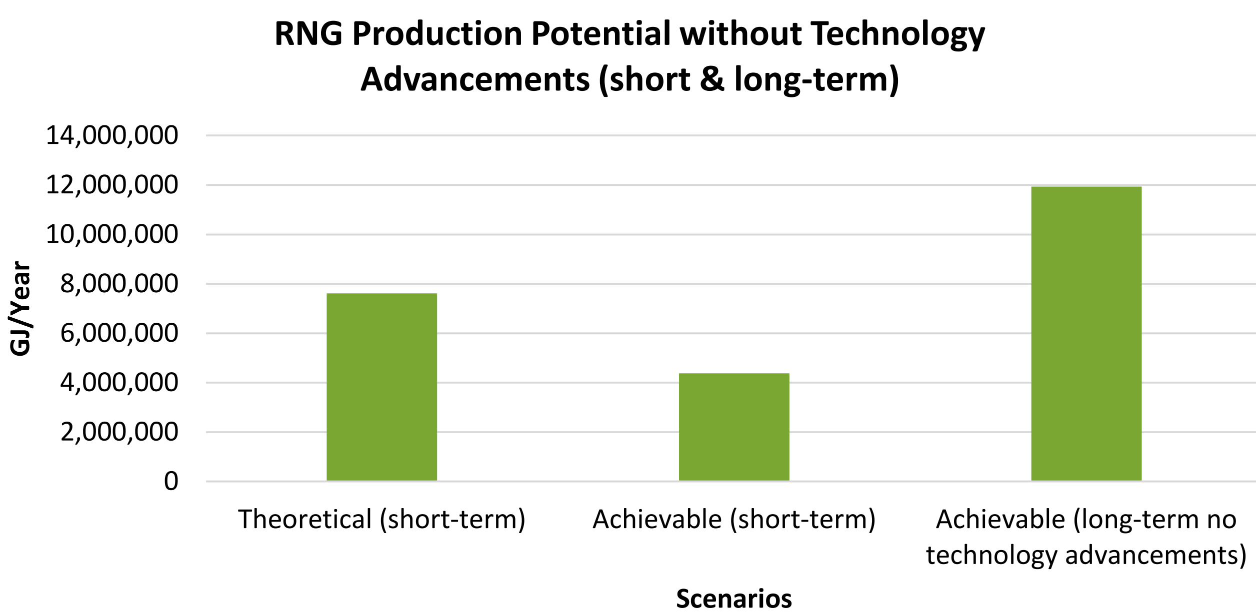
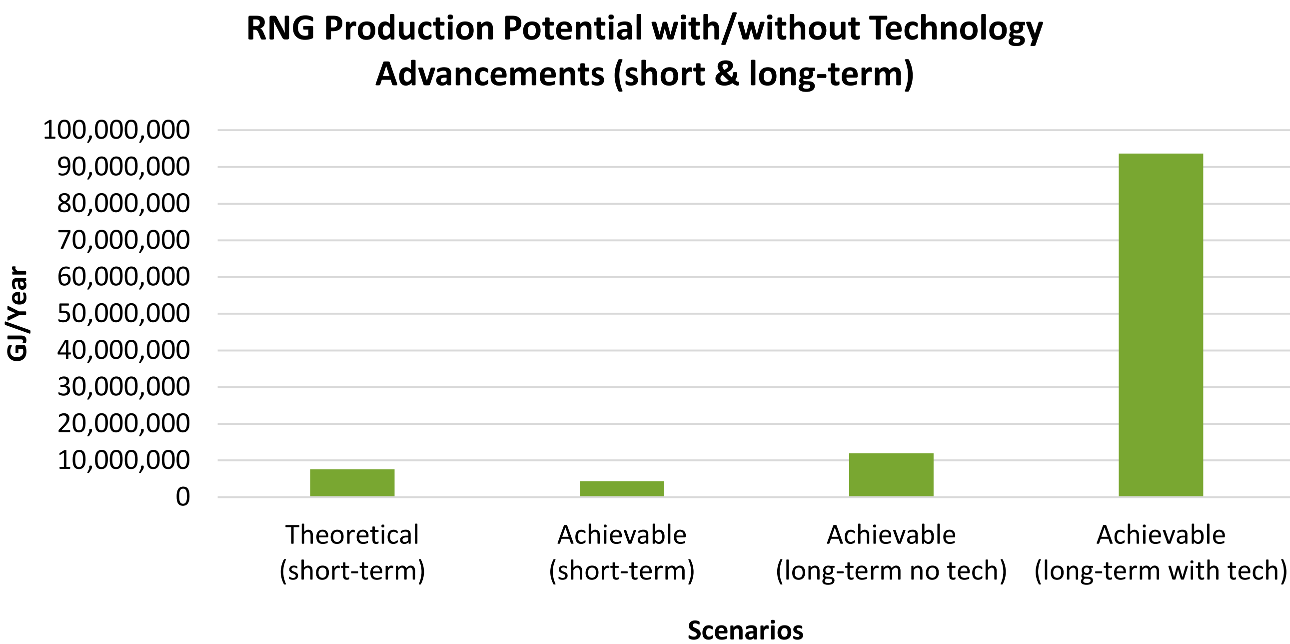


**Figure 2: RNG Production Potential with/without Technology Advancements at $28/GJ**



## 2. Introduction

Production of Renewable Natural Gas (RNG) can currently be achieved by two general methods. Biogas can be produced within anaerobic digestion (AD) plants, or it can occur within landfills and be collected using wells and pipes; biogas produced in landfills is known as landfill gas (LFG). Once captured, biogas or LFG can be upgraded to RNG. This process involves cleaning and refining the biogas or LFG to remove carbon dioxide and other contaminates so that it meets natural gas pipeline specifications.

Currently, a third method for producing biogas from wood biomass is also being developed. This thermochemical method uses technology to first convert wood feedstock into synthetic gas, before transforming the synthetic gas into RNG. In 2013, Göteborg Energi successfully opened the first large-scale thermochemical plant for producing RNG from wood feedstock in Gothenburg, Sweden. Gaz Métro recently announced success with a similar demonstration project in Boucherville, Québec.

The objective of this study was to determine theoretical and achievable RNG production potential within B.C. based on available agricultural, commercial, municipal, wastewater, and forestry waste feedstock (herein referred to as feedstocks), and LFG. Achievable RNG production potential was assessed under two different scenarios; a short-term scenario using currently available feedstocks and technologies, and a long-term scenario using projected increased feedstock availability in 2035 and assuming advancements in wood RNG technology.

## 3. RNG Feedstocks

Feedstocks used to produce RNG can be grouped into six broad categories. These six categories are:

- Agricultural: manure and bedding from livestock operations, and crop residues;
- Commercial: industrial, commercial, and institutional source-separated organics, and wood waste from demolition, land-clearing, and construction;
- Municipal: residential source-separated organics;
- Wastewater: sludge from wastewater treatment plants and pulp mills;
- Landfills: waste buried in landfills; and
- Forestry: by-products from industrial forest processes.

When assessing B.C.'s RNG production potential, feedstock data is required. Where this data was missing or wasn't detailed enough for this study, assumptions were made. Whenever these assumptions were made, every effort was taken to ensure they were as realistic as possible.

### 3.1 Agricultural Feedstock

Most agricultural AD plants will be designed for dairy or hog manure from a single farm, and possibly if available, some chicken layer manure and/or chicken broiler or turkey litter. Beef cattle AD plants will be designed for cattle manure from a single farm or several farms in close proximity. Agricultural AD plants, as defined by provincial regulations, are allowed to accept up to 49% Industrial, Commercial, and Institutional (ICI) source-separated organic (SSOs) feedstock. ICI SSO feedstock is hugely beneficial to agricultural AD plants because it has a much higher biogas production potential than manure and bedding.

The following is an assessment of the different types of agricultural feedstock in B.C. suitable for RNG production.[1] Where available, data for livestock populations was taken from Statistics Canada's 2011 Agricultural Census and industry publications. Feedstock estimates were taken from the B.C. Ministry of Agriculture's Agricultural Composting Handbook, and the Canada – British Columbia Environmental Farm Plan Program Reference Guide.

**Dairy Manure**

In B.C., > 90% of dairy cattle are currently raised in the regional districts of the Cowichan Valley, Comox Valley, Fraser Valley, Greater Vancouver, North Okanagan, and Columbia-Shuswap. Dairy manure produced in other regional districts wasn't considered in this study as the volume of feedstock is too small to have a noticeable impact on RNG production potential.

Estimated manure production per milking dairy cow and associated livestock is 38 $m^3$/year. Dairy manure has an average bulk density of 990 kg/$m^3$ and a 6% average dry matter content. Considered an excellent feedstock, when digested in a complete mix AD plant dairy manure is assumed to have an average methane ($CH_4$) production potential of 15 $Nm^3$/tonne.[2] It was assumed that due to dairy manure's low dry matter content, this feedstock will not be transported from farm to farm. As such, only dairy farms within close proximity to the natural gas pipeline were assumed able to produce RNG.

According to B.C. Agrifood Industry Year in Review reports from the B.C. Ministry of Agriculture, milk production by B.C. dairy farmers increased by ~1%/year since 2008. As such, it was assumed that the number of dairy cows in B.C. will continue to grow by 1%/year until 2035.

**Pig Manure**

In B.C., > 84% of pigs are currently raised in the Fraser Valley. Pig manure produced in other regional districts wasn't considered in this study as the volume of feedstock is too small to have a noticeable impact on RNG production potential.

Estimated manure production per pig (from grower to finisher) is 4 $m^3$/year. Pig manure has an average bulk density of 1,000 kg/$m^3$ and a 5% average dry matter content. Considered an excellent feedstock, when digested in a complete mix AD plant pig manure is assumed to have an average $CH_4$ production potential of 19 $Nm^3$/tonne.[3] It was assumed that due to pig manure's low dry matter content, this feedstock will not be transported from farm to farm. As such, only pig farms within close proximity to the natural gas pipeline were assumed able to produce RNG.

According to B.C. Agrifood Industry Year in Review reports from the B.C. Ministry of Agriculture, pork production by B.C. pig farmers increased by ~2%/year since 2012. As such, it was assumed that the number of pigs in B.C. will continue to grow by 2%/year until 2035.

**Layer Manure**

In B.C., > 90% of laying hens currently live in the regional districts of Cowichan Valley, Fraser Valley, Greater Vancouver, and Columbia-Shuswap. Layer manure produced in other regional districts wasn't considered in this study as the volume of feedstock is either too small to have a noticeable impact on RNG production

[1] Manure and bedding from geese, ducks, pheasants, sheep, emus, and other less-common livestock has not been included in this study as the population of these animals in B.C. is very small.

[2] Estimate using data from Swedish Waste Management, Swedish Gas Technology Center, and contact with Mats Edström (RISE).

[3] *Ibid.*

potential, or the geographical distribution of hens is too large to enable sufficient volumes of layer manure to be collected.

Estimated manure production for pullets (layers under 19 weeks of age) is $0.014 m^3$/year/bird, and for layers is $0.05 m^3$/year/bird. Layer manure has an average bulk density of 470 $kg/m^3$ and a 55% average dry matter content. Considered a suitable feedstock, layer manure's high nitrogen content can inhibit biogas production. As such, this feedstock shouldn't account for more than 20%[4] of an AD plant's total feedstock, and therefore layer manure will most likely be digested in dairy or hog manure AD plants. When digested in a complete mix AD plant layer manure is assumed to have an average $CH_4$ production potential of 69 $Nm^3$/tonne.[5] It was assumed that due to layer manure's high dry matter content, this feedstock could be transported to AD plants within the regional district in which it is produced.

According to B.C. Agrifood Industry Year in Review reports from the B.C. Ministry of Agriculture, egg production by B.C. layer farmers increased by ~2%/year since 2012. As such, it was assumed that the number of layers in B.C. will continue to grow by 2%/year until 2035.

**Beef Cattle Manure**

In B.C., > 80% of beef cattle are currently raised in the regional districts of Thompson-Nicola, Cariboo, Fraser-Fort George, Bulkley-Nechako, and Peace River. Cattle manure produced in other regional districts wasn't considered in this study as the volume of feedstock is either too small to have a noticeable impact on RNG production potential, or the geographical distribution of cattle is too large to enable sufficient volumes of this feedstock to be collected.

Estimated manure production per beef cow and associated livestock is 12 $m^3$/year. However, because cattle spend roughly half their time in fields, and because some cattle farms are far from the natural gas pipeline, only ¼ of the cattle manure produced was assumed potentially available for RNG production. Cattle manure has an average bulk density of 710 $kg/m^3$ and a 30% average dry matter content. Considered a suitable feedstock, cattle manure must be diluted with water/wet feedstocks for complete mix AD plants.

When digested in a complete mix AD plant cattle manure is assumed to have an average $CH_4$ production potential of 50 $Nm^3$/tonne.[6] It was assumed that water/wet feedstocks are available for diluting cattle manure, and that due to its moderate dry matter content, this feedstock could be transported to AD plants within the Census Consolidated Subdivision (CCS) in which it is produced.

According to B.C. Agrifood Industry Year in Review reports from the B.C. Ministry of Agriculture, beef production by B.C. cattle farmers decreased by ~5%/year between 2007 and 2012, before stabilising over the past few years. As such, it was assumed that the number of cattle in B.C. will stay the same until 2035.

**Broiler & Turkey Litter**

In B.C., > 98% of broiler hens are currently raised in the regional districts of Fraser Valley, Greater Vancouver, and North Okanagan, and > 93% of turkey are currently raised in the Fraser Valley and Greater Vancouver. Broiler and turkey litter produced in other regional districts wasn't considered in this study as the volume of feedstock is either too small to have a noticeable impact on RNG production potential, or the

[4] Edström et.al., 2013

[5] Estimate using data from Swedish Waste Management, Swedish Gas Technology Center and contact with Mats Edström (RISE).

[6] *Ibid.*

geographical distribution of birds is too large to enable sufficient volumes of broiler and turkey litter to be collected.

Estimated broiler and turkey litter production is 0.035 $m^3$/year/bird and 0.13 $m^3$/year/bird respectively. Broiler and turkey litter have average bulk densities of 330 kg/$m^3$ and 380 kg/$m^3$, and average dry matter contents of 75% and 70% respectively. Considered suitable feedstocks, broiler and turkey litter's high nitrogen contents can inhibit biogas production. Therefore these feedstock shouldn't account for more than 10%[7] of an AD plant's total feedstock, and as such all broiler and turkey litter will most likely be digested in dairy or hog manure AD plants.

When digested in a complete mix AD plant, broiler and turkey litter are assumed to have an average $CH_4$ production potential of 69 $Nm^3$/tonne.[8] Due to their high wood content (most farmers bed on wood shavings), broiler and turkey litter are also suitable for gasification or pyrolysis. When used for gasification or pyrolysis, broiler and turkey litter have a much higher estimated $CH_4$ production potential of 208 $Nm^3$/tonne.[9] It was assumed that due to broiler and turkey litter's high dry matter content, these feedstocks could be transported to AD plants within the regional district in which they are produced.

According to B.C. Agrifood Industry Year in Review reports from the B.C. Ministry of Agriculture, broiler production by B.C. broiler farmers has increased by ~1%/year since 2007, while turkey production has hardly changed. As such, it was assumed that the number of broilers and turkeys in B.C. will grow by 1%/year and 0.5%/year until 2035 respectively.

**Horse Bedding**

In B.C., while horses are currently present in every regional district, most regional districts have horse populations that are either too small to have a noticeable impact on RNG production potential, or the geographical distribution of horses is too large to enable sufficient volumes of horse bedding to be collected. Due to this, only bedding from the Capital Region, Fraser Valley, Greater Vancouver, Okanagan-Similkameen, Central, and North Okanagan was considered.

Estimated bedding production per horse is 21 $m^3$/year. Horse bedding has an average bulk density of 850 kg/$m^3$ and a 35% average dry matter content. Due to its high wood content (most equine facilities bed on wood shavings), horse bedding was assumed unsuitable for complete mix AD plants. Instead, horse bedding was assumed suitable for gasification or pyrolysis. When used for gasification or pyrolysis, horse bedding is assumed to have an average $CH_4$ production potential of 89 $Nm^3$/tonne[10]. It was assumed that due to horse bedding's moderate dry matter content, this feedstock could be transported to gasification or pyrolysis plants within the CCS in which it is produced.

According to Horse Council B.C.'s Equine Industry Study, horse numbers in B.C. have remained fairly stable for the past ten years, while expectation is that this number will remain fairly consistent as the industry stabilises. As such, it was assumed that the number of horses in B.C. will stay the same until 2035.

[7] Edström et. al., 2013.
[8] Estimate using data from Swedish Waste Management, Swedish Gas Technology Center and contact with Mats Edström (RISE).
[9] Värmeforsk, 2012.
[10] *Ibid.*

**Crop Residue**

Crop residues are the small amount of vegetative material left on fields after harvest; farmers generally take as much from the field during harvest as possible, leaving as little as possible. After harvest, and to reduce soil erosion, crop residues are often incorporated into the soil or they are left on the soil over winter before incorporation the following spring. Spoiled harvest are any crops that have deteriorated to the point in which they are no longer edible.

For the purposes of this study, crop residues and spoiled harvests were not included as feedstocks for RNG production. The reasons for this are threefold. First, crop residues often have a high fiber content, meaning they take a long time to breakdown inside AD plants and are therefore not a favoured feedstock. Second, crop residues and spoiled harvests have seasonal variation (i.e., they are usually available only once or at certain times of the year), making it difficult to incorporate these into AD plants that prefer year-round feedstock supply contracts without needing expensive storage. Third, the volume of agricultural residues in B.C. compared to other feedstocks (such as manure, food processing waste, etc.) is very small, and as such it is unlikely these residues will have any noticeable impact on RNG production potential.

**Energy Crops**

Growing dedicated plant biomass, so called "energy crops", for biogas production is not new. In Germany and Austria for example, the number of AD plants using energy crops is estimated to be in the thousands. Despite widespread use, energy crops were not considered in this study as a feedstock for RNG production. The reason for this is that this study is solely focused on using waste feedstocks to produce RNG.

***Table 1: Summary of Manure and Bedding Feedstocks***

| Feedstock | Bulk Density | Dry Matter | $CH_4$ Potential (per tonne) | Location | Volume (per animal) | Cost | Availability |
|---|---|---|---|---|---|---|---|
| Dairy Manure | 990kg/$m^3$ | 6% | 15 $m^3$ | CWV, CV, FV, GV, NO, CS | 38 $m^3$/year | None | On-farm only |
| Pig Manure | 1,000/$m^3$ | 5% | 19 $m^3$ | FV | 4 $m^3$/year | None | On-farm only |
| Layer Manure | 470/$m^3$ | 55% | 69 $m^3$ | CWV, FV, GR, CS | .014 and .05 $m^3$/year | $10/tonne | Within RD |
| Beef Cattle Manure | 710/$m^3$ | 30% | 50 $m^3$ | TN, C, FG, BN, PR | 12 $m^3$/year | None | Within CCS |
| Broiler Litter | 330/$m^3$ | 75% | 69 or 208 $m^3$ | FV, GV, NO | .035 $m^3$/year | $10/tonne | Within RD |
| Turkey Litter | 380/$m^3$ | 70% | 69 or 208 $m^3$ | FV, GV | .013 $m^3$/year | $10/tonne | Within RD |
| Horse Bedding | 850/$m^3$ | 35% | 89 $m^3$ | CR, FV, GV, OS, CO, NO | 21 $m^3$/year | None | Within CCS |

*Key: Bulkley-Nechako (BN), Capital Region (CR), Cariboo (C), Central Okanagan (CO), Columbia-Shuswap (CS), Comox Valley (CV), Cowichan Valley (CWV), Fraser-Fort George (FG), Fraser Valley (FV), Greater Vancouver (GV), North Okanagan (NO), Okanagan-Similkameen (OS), Peace River (PR) and Thompson-Nicola (TN).*

**Summary of Assumptions for Agriculture**

When assessing the RNG production potential of agricultural feedstocks in B.C. some assumptions were made. These assumptions included the following:

- Dairy and pig manure will not be transported between farms;
- Only dairy and pig farms close to the natural gas pipeline (< 1km) will build AD plants;
- Cattle farms will have sufficient water/wet feedstock required for dilution of their manure;

- Cattle manure and horse bedding can be transported within the Census Consolidated Subdivision (CCS) in which they are produced;
- Layer manure, broiler, and turkey litter can be transported within the regional district in which they are produced;
- Layer manure, broiler and turkey litter will only be digested to a maximum of 20% and 10% respectively in dairy or hog manure AD plants; and
- Agricultural AD plants will accept up to 49% ICI SSO (if available).

### 3.2 Commercial Feedstock

Commercial source separated organics (SSOs) is organic waste produced from industrial, commercial, and institutional (ICI) activities, such as food processing, restaurants, and accommodation. Due to large variations in ICI activities, estimating available volumes and composition of this feedstock was very challenging.

Firstly, the cost and effort required by ICI facilities to separate organic waste from other waste streams will vary. Some facilities, such as supermarkets and food processors, who produce large volumes of organic waste and have staff responsible for disposal, will likely separate organic waste more easily and successfully than facilities that produce small volumes, or who rely on others to separate their waste streams (such as office buildings). Secondly, securing ICI SSOs for RNG production can be challenging, as this feedstock may already be processed on-site, sold, or given away for other purposes, such as animal feed.

While AD plants can be built specifically to process ICI SSOs, there are very few such plants in Canada. As such, it was assumed this feedstock will be delivered to agricultural or municipal AD plants. This assumption is important as ICI SSOs can be classed as 'pre-consumer' (coming from manufactures, wholesale and retail trade, etc.) or 'post-consumer' (originating from accommodation, food services, offices, etc.). In B.C., and based on current provincial regulations, only pre-consumer SSOs is allowed into agricultural AD plants.

Demolition, land-clearing, and construction (DLC) waste consists largely of inert solid waste resulting from construction, remodelling, and demolition projects. Examples of DLC waste include wood, soft construction materials such as plastic, carpet, and insulation, and land clearing waste. Highly unsuitable for AD plants, DLC wood waste is a suitable feedstock for gasification or pyrolysis.

According to Metro Vancouver's 2013 Recycling and Solid Waste Management Report, per capita disposal rate for the region was 0.55 tonnes/year. Of this, ICI and DLC waste accounted for 0.17 and 0.16 tonnes respectively. Similar per capita disposal rate estimations are also provided by the B.C. Government, who in their 1990 – 2014 Municipal Solid Waste Disposal Report estimated that in 2014 each British Columbian disposed of 0.52 tonnes of solid waste.

Disposal rates do not include waste that is reused or recycled. According to Metro Vancouver's 2013 Recycling and Solid Waste Management Report, per capita ICI and DLC recycling rates were 0.11 and 0.5 tonnes/year respectively. Based on this information, it was assumed per capita ICI and DLC waste production rates (both disposed and recycled) in B.C. are 0.28 and 0.66 tonnes/year respectively. Metro Vancouver's 2013 Recycling & Solid Waste Management Report shows per capita waste production rates remained fairly stable from 1994 – 2013. As such, it was assumed that per capita disposal rates will remain stable until 2035.

Metro Vancouver's 2014 ICI Waste Characterization Program found that 35% of ICI waste being landfilled is compostable organics. A 2011 Solid Waste Stream Composition Study by the Capital Regional District found landfilled ICI SSOs consisted of 32% compostable organics. However, these studies only captured the percentage of compostable organics in ICI waste being landfilled. It is highly likely that the percentage of compostable organics in ICI waste not being landfilled but composted or used for other purposes is much higher. As such it was assumed 50% of ICI waste in B.C. is compostable organics suitable for AD plants.

The Capital Regional District's study found that 63% of DLC waste consisted of wood or wood products (the remaining 36% being construction and demolition material). Metro Vancouver's 2011 Demolition, Land-clearing, and Construction Waste Composition Monitoring Report found that 54% of DLC waste consisted of wood. As with ICI waste, these studies only captured the percentage being landfilled. It is highly likely that the percentage of wood in DLC waste not being landfilled but used for other purposes is higher. As such it was assumed 60% of DLC waste is suitable for gasification or pyrolysis.

No study could be found showing the percentage of ICI waste from pre-consumer and post-consumer sources. Metro Vancouver's 2014 ICI Waste Characterization Study found accommodation/food and business services (post-consumer) accounted for 9% and 7% of ICI waste respectively, while manufacturing and retail (pre-consumer) accounted for 10% and 4% respectively. The City of Calgary's Industrial Commercial Institutional Waste Diversion Progress Update found accommodation/food and business commercial services (post-consumer) accounted for 17% and 16% of ICI waste respectively, while retail and wholesale trade, manufacturing and warehousing (pre-consumer) accounted for 15%, 4%, and 6% respectively.

As with the percentage of compostable organics in ICI waste, these studies only captured the percentage of pre and post-consumer waste being landfilled. Due to the likely lower cost and effort required by pre-consumer ICI facilities to separate their organic waste from other waste streams, it is highly likely that the percentage of pre-consumer waste being produced is higher than that being landfilled. As such, it was assumed that 50% of ICI SSOs is pre-consumer and therefore suitable for agricultural AD plants.

The $CH_4$ production potential of ICI SSOs can vary greatly, from as little as 67 $Nm^3$/tonne to as much as 383 $Nm^3$/tonne. Despite this, when digested in a complete mix AD plant ICI SSOs was assumed to have a $CH_4$ production potential of 140 $m^3$/tonne.[11] It was assumed that ICI SSOs can be transported to AD plants within the regional district in which it is produced. When used for gasification or pyrolysis, DLC waste has an assumed average $CH_4$ production potential of 198 $Nm^3$/tonne.[12] It was assumed that DLC wood waste can also be transported to gasification or pyrolysis plants within the regional district in which it is produced.

**Summary of Assumptions**

When assessing the RNG production potential of ICI SSO and DLC waste in B.C. some assumptions were made. These assumptions include the following:

- ICI SSOs is delivered to either agricultural or municipal AD plants;
- ICI SSOs per capita production rate is 0.28 tonnes/year;
- DLC waste per capital production rate is 0.66 tonnes/year;

[11] Estimate using data from Swedish Waste Management, Swedish Gas Technology Center and contact with Mats Edström (RISE).
[12] Värmeforsk, 2012.

- 50% of ICI waste is organic waste suitable for AD plants, and 50% of this is pre-consumer waste suitable for agricultural AD plants;
- 60% of DLC waste is wood waste suitable for gasification or pyrolysis plants;
- DLC wood waste has an average moisture content of 23%;
- ICI SSOs and DLC wood waste can be transported within the regional district they are produced;
- ICI SSOs has an average $CH_4$ production potential of 140 $Nm^3$/tonne;
- DLC wood waste has an average $CH_4$ production potential of 198 $Nm^3$/tonne; and
- ICI SSOs and DLC waste per capita production rates will be 0.28 tonnes/year and 0.66 tonnes/year in 2035 respectively.

### 3.3 Municipal Feedstock

Residential Source Separated Organics (SSOs) refers to organic waste that has been separated from the residential garbage stream. Within Canada there are examples of residential SSOs being co-digested at wastewater treatment plants. Despite this, residential SSOs is most often digested at municipal AD plants, either alone, or with ICI SSOs, and/or wastewater treatment plant sludge. As such, it was assumed this feedstock will only be digested in municipal AD plants.

Residential SSOs is suitable for wet or dry AD plants.[13] Wet (liquid) AD plants require feedstock with <15% average dry matter content. For feedstock with higher dry matter content, such as residential SSOs, water or other wet feedstocks can be added. While wet AD plants generally have larger footprints and higher feedstock and digestate treatment costs than dry AD plants, they generally produce 3 – 4 times more biogas per tonne of feedstock. Because the aim is to produce as much RNG as possible, it was assumed all residential SSOs will be digested in wet AD plants.

According to Metro Vancouver's 2013 Recycling and Solid Waste Management Report, per capita disposal rate for the region was 0.55 tonnes/year. Of this, residential waste accounted for 0.21 tonnes. Disposal rates do not include waste that is reused or recycled. According to Metro Vancouver's 2013 Recycling and Solid Waste Management Report, per capita residential recycling rates were 0.22 tonnes/year. Based on this information, it was assumed the per capita residential waste production rate (both disposed and recycled) in B.C. is 0.44 tonnes/year. Metro Vancouver's 2013 Recycling and Solid Waste Management Report shows that per capita waste production rates have remained fairly stable from 1994 to 2013. As such it was assumed that this per capita disposal rate will remain consistent until 2035.

Environment Canada's 2013 Technical Document on Municipal Solid Waste Organics Processing shows that biodegradable material, typically food waste and leaf and yard waste, constitutes approximately 40% of the residential waste stream. A 2011 Capital Regional District Solid Waste Stream Composition Study shows that on average 35% of residential waste is organic, while Metro Vancouver's 2015 Waste Composition monitoring program found that compostable organics accounted for 35% of the waste from single and multifamily residential.

Determining how much of the organic waste in residential SSOs has good biogas potential (i.e., food waste), and how much has poor biogas potential (i.e., yard waste) is difficult. Most waste composition studies do not provide the required level of detail, while those that do only capture the organic waste being thrown away (i.e., they do not capture the organic waste being recycled through commercial and

[13] While the AD plants in B.C. digesting residential SSOs are dry, most residential SSOs AD plants in Canada and globally are wet.

household composting).[14] Based on the information available, it was assumed that 40% of residential waste is organic, and that 75% of this organic waste will produce biogas in AD plants (the remaining 25% being yard waste).

Residential SSOs is produced where people live. As such, residential SSOs will be produced in cities, towns, municipalities, and small rural communities. While the majority of residential organic waste in B.C. is currently collected and transported to landfills or compost facilities, collection becomes difficult in sparsely populated areas. Therefore it was assumed that residential SSOs is only collected for AD plants in areas of B.C. where the population density is > 20/km$^2$.

The $CH_4$ production potential of residential SSOs can vary greatly, from as little as 78 Nm$^3$/tonne to as much as 129 Nm$^3$/tonne. Despite this, when digested in a complete mix AD plant, residential SSOs was assumed to have an average $CH_4$ production potential of 100 Nm$^3$/tonne.[15] It was assumed that residential SSOs can be transported to AD plants within the regional district in which it is produced.

**Summary of Assumptions**
When assessing the RNG production potential of residential SSOs in B.C. some assumptions were made. These assumptions include the following:

- All residential SSOs is delivered to municipal AD plants;
- Residential SSOs per capita production rate is 0.44 tonnes/year;
- 30% of residential waste is suitable for AD plants;
- Only residential SSOs produced in areas with a population density of >20 people/km$^2$ is available for RNG production;
- Residential SSOs can be transported to plants within the regional district in which it is produced;
- $CH_4$ production potential is 100 Nm$^3$/tonne; and
- Per capita production rates will be 0.44 tonnes/year in 2035.

## 3.4 Wastewater Feedstock

At Wastewater Treatment Plants (WWTPs) wastewater flushed down the toilet or washed down the drain is treated using primary or secondary treatment. Primary treatment generally involves screens and/or settling tanks. Secondary treatment generally involves aerobic biological processes. Sludge from WWTPs is a suitable feedstock for AD plants. The production of pulp is associated with the generation of large quantities of wastewater. Treatment of pulp mill wastewater using activated sludge systems can result in production of Waste Activated Sludge (WAS). WAS is a suitable feedstock for AD plants.

All B.C. WWTPs require authorization permits. These permits show a WWTP's maximum daily discharge rate and daily biochemical oxygen demand (BOD) concentration levels, and sometimes annual average daily discharge rates. Some WWTPs also publish actual daily discharge rates. Based on this information it is estimated that thirteen WWTPs account for > 90% of wastewater treated in B.C. (Table 2).

Of the thirteen WWTPs, nine currently produce biogas through AD that is either combusted to produce heat and/or electricity (as at five WWTPs), or it is flared (as at four WWTPS). The remaining WWTPs don't

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[14] According to Stats Canada, in 2011 over half of Canadian households (61%) participated in some form of composting (www.statcan.gc.ca/pub/16-002-x/2013001/article/11848-eng.htm).
[15] Estimate using data from Swedish Waste Management, Swedish Gas Technology Center and contact with Mats Edström (RISE).

produce biogas. Due to the technology and infrastructure investments required to produce heat and/or electricity from biogas, it was assumed that only WWTPs currently flaring biogas are able to produce RNG in the short-term. It was also assumed that Langley and Duncan WWTPs send their sludge to nearby municipal AD plants, while Clover Point and Macaulay WWTPs do not produce sludge suitable for RNG production.

For 2035, it was assumed that sludge production will increase with projected population growth, and that all WWTPs that currently produce biogas will be able to produce RNG. It was also assumed that by 2035 a WWTP built on Vancouver Island will produce RNG. When digested in a complete mix AD plant, WWTP sludge was assumed to have an average $CH_4$ production potential of 502 $Nm^3$/tonne BOD.[16]

***Table 2: Largest WWTPs in B.C.***

| Name | Muni | Discharge ($m^3$/day) | | | Maximum Daily BOD (mg/l) | Current Operation |
|---|---|---|---|---|---|---|
| | | Maximum | Actually | Average | | |
| Iona Island | Richmond | 1,530,000 | 600,000 | N/A | 130 | Biogas for heat/electricity |
| Annacis Island | Delta | 1,050,000 | 500,000 | N/A | 45 | Biogas for heat/ electricity |
| Lion's Gate | North Vancouver | 318,000 | 90,000 | N/A | 130 | Biogas for heat and engines |
| Lulu Island | Richmond | 233,000 | 80,000 | N/A | 45 | Biogas for heat |
| Clover Point | Nanaimo | 185,000 | N/A | 82,000 | 45 | No biogas produced |
| Macaulay | Nanaimo | 150,000 | N/A | 50,000 | 45 | No biogas produced |
| GNPCC | Nanaimo | 80,870 | N/A | 40,950 | 130 | Biogas for heat/ electricity |
| J.A.M.E.S | Abbotsford | 70,000 | N/A | 48,000 | 45 | Biogas flared |
| Kamloops | Kamloops | 55,000 | 40,000 | N/A | 30 | Biogas flared |
| Duncan | Nanaimo | 49,000 | N/A | N/A | 30 | No biogas produced |
| Chilliwack | Chilliwack | 45,000 | N/A | N/A | 45 | Biogas flared |
| Landsdowne Road | Prince George | 45,000 | N/A | N/A | 30 | Biogas flared |
| Langley | Langley | 42,000 | 12,500 | N/A | 45 | No biogas produced |

Within B.C., 17 pulp mills are close to the natural gas pipeline (Table 3).[17] Of these mills, eight were assumed to have activated sludge systems that produce WAS.[18] Because information regarding WAS production volumes at pulp mills couldn't be found, it was assumed that these eight pulp mills produce an average of 1,500 kg WAS with 1.5% average dry matter content for every one tonne of pulp.[19] It was also assumed that the capacity utilization of these eight pulp mills is 100%.[20] When digested in a complete mix AD plant WAS was assumed to have an average $CH_4$ production potential of 1.8 $Nm^3$/tonne.[21]

[16] Swedish Institute of Agricultural and Environmental Engineering (JTI), 1988.
[17] Neucel Specialty Cellulose in Port Alice is the only pulp mill considered too far from the natural gas pipeline.
[18] The other pulp mills were assumed to use aerated stabilization basins which do not produce feedstock suitable for AD plants.
[19] Elliott A, Mahmood T (2005) Survey Benchmarks Generation, Management of Solid Residues. Pulp Pap 79(12):49–55.
[20] A 2011 B.C. Ministry of Forests, Lands and Natural Resource Operations report titled Major Primary Timber Processing Facilities in B.C. found that capacity utilization of pulp mills in B.C was only slightly below 100%.
[21] JTI, 1988.

According to a 2011 study by the B.C. Ministry of Forestry, Lands and Natural Resource Operations, total output by B.C. pulp mills saw a 15% decline from 1991 to 2011.[22] Despite this, and due to the difficulties in forecasting the future of B.C.'s pulp mills, it was assumed that pulp mill output in B.C., and therefore WAS production, will remain stable to 2035.

***Table 3: B.C. Pulp Mills Close to the Natural Gas Pipeline***

| Name | Municipality | Capacity (t/year) | WAS Production (t/year) |
|---|---|---|---|
| Canfor | Prince George | 313,000 | N/A |
| | Prince George | 140,000 | N/A |
| | Prince George* | 568,000 | 852,000 |
| | Taylor | 210,000 | N/A |
| Cariboo Pulp and Paper | Quesnel | 331,000 | N/A |
| Catalyst Paper | Crofton* | 373,000 | 559,500 |
| | Port Alberni | 186,000 | N/A |
| | Power River* | 354,000 | 531,000 |
| Celgas Pulp Co | Castlegar | 503,000 | N/A |
| Chetwynd Mechanical Pulp | Chetwynd* | 205,000 | 307,500 |
| Domtar Pulp | Kamloops* | 460,000 | 690,000 |
| Howe Sound Pulp & Paper | Port Mellon* | 725,000 | 1,087,500 |
| MacKenzie Pulp Mill Corp | Mackenzie | 224,000 | N/A |
| Nanaimo Forest Products | Nanaimo* | 327,000 | 490,500 |
| Paper Excellence | Skookumchuck | 248,000 | N/A |
| | New Westminster | 31,000 | N/A |
| Quesnel River Pulp | Quesnel* | 370,000 | 555,000 |

*Note: * Pulp mills thought to produce WAS.*

**Summary of Assumptions**

When assessing the RNG production potential of feedstocks from WWTPs and pulp mills in B.C. some assumptions were made. These assumptions included the following:

- Only WWTPs currently producing biogas that isn't combusted for heat and/or electricity have the potential to produce RNG in the short-term;
- Langley and Duncan WWTPs will send their sludge to nearby municipal AD plants while Clover Point and Macaulay WWTPs produce no useable sludge;
- $CH_4$ production potential of WWTP sludge is 502 $Nm^3$/tonne BOD;
- WWTP sludge production will increase in line with estimated population growth to 2035;
- A WWTP will be built on Vancouver Island capable of producing RNG by 2035;
- Pulp mills with activated sludge systems produce 1,500 kg WAS with a dry matter content of 1.5% for every tonne of pulp produced;
- The capacity utilization of B.C.'s pulp mills is 100% and the size/number of pulp mills in 2035 will be the same as today; and
- $CH_4$ production potential of WAS is 1.8 $Nm^3$/tonne.

[22] Major Primary Timber Processing Facilities in British Columbia 2011
www.for.gov.bc.ca/ftp/het/external/!publish/web/mill%20list/Mill%20List%20Public%20Report%202011.pdf

## 3.5 Landfill Gas

Landfill gas (LFG) is a by-product from the decomposition of organic waste buried in landfills. LFG is captured through a system of vertical or horizontal perforated pipes drilled into the landfill at regular intervals. A vacuum in the pipes, created using blowers or compressors, is used to draw LFG into the pipe where it is sent to a central location for flaring or use.

B.C.'s Landfill Gas Management Regulation[23] establishes province-wide criteria for LFG capture from municipal landfills. Under this Regulation any landfill estimated to generate > 1,000 tonnes $CH_4$/year is required to install a LFG capture system. While the efficiency of a LFG capture system depends upon various factors, including pipe placement, waste permeability, and landfill operations, B.C.'s regulation sets a capture rate performance objective of 75%.

Due to the Landfill Gas Management Regulation, it was assumed only landfills that generate > 1,000 tonnes $CH_4$/year will install LFG capture systems. It was also assumed that these landfills are within close proximity to the Fortis or PNG natural gas pipeline. Smaller landfills, with the exception of those already capturing LFG, are assumed not to install LFG capture systems as cost to do so is prohibitive. It was also assumed that all LFG capture systems in B.C. achieve a 75% capture rate.

Currently, the availability of information regarding LFG production in B.C. is extremely limited. In 2008 the B.C. Ministry of Environment undertook an inventory of GHG generation from landfills in B.C.[24] This inventory, commissioned as a first-step estimating report to provide an overall high-level perspective on $CH_4$ generation from B.C. landfills, estimated $CH_4$ generation from 2005 – 2030 for all municipal landfills with a disposal rate > 10,000 tonnes/year; therefore accounting for ~90% of total municipal solid waste disposed of at provincially regulated landfills in B.C.

Since completion of this inventory, several B.C. landfills have submitted LFG Assessment Reports. Some of these Assessment Reports show similar $CH_4$ generation estimates to those in the Ministry's 2008 inventory, others are less similar.[25] Where the Ministry of Environment's $CH_4$ estimates are similar to those provided in the landfill's Assessment Reports, these estimates have been used to calculate the landfill's $CH_4$ potential for 2035. Where the Ministry's $CH_4$ generation estimates differ significantly from those provided in the landfill's Assessment Reports, these estimates have been recalibrated using the landfill's own assessment report to calculate $CH_4$ potential for 2035 (Table 4).

The Ministry of Environment's inventory was completed in 2008. Since 2008 and over the coming years B.C. municipalities have or will introduce organic waste diversion programs. Since it is the decomposition of organic waste that produces LFG, these diversion programs will ultimately decrease LFG production. Despite this, organic waste takes a long time to decompose in landfills. As such, it was assumed that organic waste diversion programs will have minimal impact on LFG generation over the next twenty years.

Currently, three of the landfills estimated to generate > 1,000 tonnes $CH_4$/year (Hartland, Cache Creek, and Nanaimo) combust LFG to produce heat and electricity, while at a fourth (Vancouver) roughly ½ of the LFG is currently combusted to produce heat and electricity. Due to the technology and infrastructure investments to produce heat and electricity from combusted LFG, it was assumed that only LFG currently being flared will be used to produce RNG in the short-term.

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[23] www.env.gov.bc.ca/epd/codes/landfill_gas/

[24] www.env.gov.bc.ca/epd/codes/landfill_gas/pdf/inventory_ggg_landfills.pdf

[25] One reason for this could be that the LFG Assessment Reports were completed using a different LFG generation model.

***Table 4: Estimated $CH_4$ Production & Capture from B.C.'s Largest Landfills***

| Regional District | Landfill | 2016 | | 2035 | |
|---|---|---|---|---|---|
| | | $CH_4$ Product (t/yr) | $CH_4$ Capture (t/yr) | $CH_4$ Product (t/yr) | $CH_4$ Capture (t/yr) |
| Alberni-Clayoquot | Alberni Valley | 1,077 | 808 | 920 | 690 |
| Capital Region | Hartland | N/A | N/A | 12,366 | 9,252 |
| Central Okanagan | Glenmore | 4,411 | 3,308 | 8,017 | 6,013 |
| Columbia Shuswap | Salmon Arm | 730 | 548 | 1,024 | 768 |
| Comox-Strathcona | Comox Valley | 2,718 | 2,039 | 2,852 | 2,139 |
| | Campbell River | 1,029 | 772 | N/A | N/A |
| East Kootenay | Central Cranbrook | N/A | N/A | 1,401 | 1,051 |
| Fraser-Fort George | Foothills | 4,323 | 3,242 | 5,223 | 3,918 |
| Fraser Valley | Bailey | 3,447 | 2,585 | 4,919 | 3,689 |
| | Minnie's Pit | 2,323 | 1,742 | 3,412 | 2,559 |
| Greater Vancouver | Vancouver | 15,151 | 11,363 | 34,618 | 25,964 |
| | Cache Creek | N/A | N/A | 6,573 | 4,930 |
| | Ecowaste | 4,255 | 3,191 | 3,672 | 2,754 |
| Nanaimo | Nanaimo | N/A | N/A | 1,260 | 945 |
| North Okanagan | Vernon | 1,967 | 1,475 | 3,878 | 2,909 |
| Okanagan-Similkameen | Campbell Mtn | 1,513 | 1,135 | 2,397 | 1,797 |
| Peace River | Ft. St. John | 2,143 | 1,607 | 975 | 732 |
| | Bessborough | N/A | N/A | 1,728 | 1,296 |
| Sunshine Coast | Sechelt | 1,190 | 893 | 1,686 | 1,264 |
| Thompson-Nicola | Mission Flats | 1,639 | 1,229 | 2,591 | 1,943 |

**Summary of Assumptions**

When assessing the RNG production potential of LFG in B.C. some assumptions were made. These assumptions include the following:

- Only landfills estimated to produce > 1,000 tonnes $CH_4$/year will capture LFG;
- For landfills estimated to generate < 1,000 tonnes $CH_4$/year, the cost to install LFG capture systems is prohibitive;
- LFG capture systems have a capture efficiency of 75%;
- LFG production will not be significantly impacted by waste diversion programs by 2035;
- Only LFG not combusted for heat and electricity will be used to produce RNG in the short-term; and
- All landfills estimated to generate > 1,000 tonnes $CH_4$/year are within close proximity to the Fortis or PNG natural gas pipeline.

## 3.6 Forestry Feedstock

Forest feedstock is defined as by-product from industrial forest processes and can be composed of all parts of the tree, including the trunk, bark, branches, or roots. While this by-product can and often is used by other industries, such as for pulp and paper production, pellets, particle board, and by the agriculture sector, when there is excess supply this feedstock is often considered a waste product and therefore could be used for RNG production.

As with some agricultural feedstocks, such as horse bedding, forestry feedstock isn't suitable for AD plants. The reason for this is that forestry feedstock is rich in fibre, and fibre is very difficult to breakdown to produce biogas. As such, very little biogas can be produced from forestry feedstock. Instead, forestry feedstock must be thermally processed in gasification or pyrolysis plants. Once thermally processed, the syngas from these plants can be converted to RNG using some type of methanization technology.

In 2015, B.C. Hydro undertook an assessment of available wood biomass in the province.[26] As part of this study, the availability of biomass considered 'surplus' to the demands of B.C.'s forest industry, and therefore potentially available for energy generation, was estimated. In total, four sources of forestry biomass were identified. These were sawmill wood waste (including residual wood chips, sawdust, shavings, and bark), roadside logging residues (including tree tops, branches, and other non-saw log material derived during logging operations), pulp logs (the by-product created from the harvest of saw logs not suitable for lumber), and standing timber (non-harvested trees).

The objective of this study was to consider potential RNG production using waste feedstocks. As such, only by-products from the forestry sector were considered. Based on this, and assuming pulp logs surplus to the requirement of the pulp and paper industry have no other use, sawmill wood waste, roadside logging residues, and pulp logs were considered.[27] Furthermore, and due to the lack of commercial methanization technology, only forestry feedstock available in 2035 was considered. According to B.C. Hydro's study, by 2035 stable mid-term forestry harvest is forecast to occur (i.e., after supply of dead pine from the Mountain Pine Beetle epidemic is expected to be largely extinguished).

Table 5 shows B.C Hydro's estimates for the availability of sawmill waste, roadside logging residue, and pulp logs in Oven Dry Tonnes (ODT) for several regions of the province. Kamloops/Okanagan, Prince George, North-East, and North-West B.C. aren't included in the table as according to B.C Hydro's study, these areas aren't estimated to have available surplus forestry feedstock in 2035.

***Table 5: Estimated Forestry Feedstock Availability (B.C. Hydro estimates)***

| Delivery Location | Estimated Availability (ODT/year) | | | |
|---|---|---|---|---|
| | Sawmill Waste | Roadside Residue | Pulp Log | Total |
| Parksville or Aldergrove | 26,640 | 376,560 | - | 403,200 |
| Canal Flats | - | 69,840 | - | 69,840 |
| Castlegar | 158,400 | 134,640 | - | 293,040 |
| Hanceville | - | 12,240 | - | 12,240 |
| Mackenzie | - | 20,880 | - | 20,880 |
| Chetwynd | 6,480 | 117,360 | 71,280 | 195,120 |
| Houston | 6,480 | 720 | 143,280 | 150,480 |
| Kitimat | 15,120 | 12,240 | 46,800 | 74,160 |

B.C. Hydro's study of wood biomass is seen by some as being overly conservative in its estimates, particularly with regard to roadside logging residues. One reason for this could be that B.C. Hydro's study only forecasts the biomass that might be available for new electricity generation projects and that is

[26] www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/regulatory-planning-documents/integrated-resource-plans/current-plan/rou-characterization-wood-based-biomass-report-201507-industrial-forestry-service.pdf

[27] Harvesting standing timber to produce RNG would also raise questions related to carbon dioxide. Does it make sense to harvest trees, thereby returning sequestered carbon dioxide to the atmosphere, to produce low carbon fuel?

surplus to requirements. Because of this, work was undertaken by Brian Titus, Research Scientist at the Pacific Forestry Centre of Natural Resources Canada (NRCan), to estimate total maximum theoretical roadside logging residue that could be available based on estimated wood harvested in 2035 within different radii from natural gas compressor stations throughout B.C.

Based on the B.C. Hydro report and work carried out by NRCan, Table 6 was created to show estimated available sawmill waste and pulp logs for Timber Supply Areas (TSAs) using data from B.C. Hydro's report for sawmill waste and pulp logs, and estimated maximum theoretical roadside logging residues from NRCan for each TSA within 50km and 75km radii of natural gas compression stations.

***Table 6: Estimated Forestry Feedstock Availability (NRCan estimates)***

| **Timber Supply Area** | **Estimated Availability (ODT/year)** | | | | | |
|---|---|---|---|---|---|---|
| | **Sawmill Waste*** | **Roadside Residue (50km radius)** | **Roadside Residue (75km radius)** | **Pulp Log*** | **Total (50km radius)** | **Total (75km radius)** |
| Arrowsmith | - | - | 1,325 | - | - | 1,325 |
| Bulkley | 6,480 | 22,013 | 24,592 | 143,280 | 171,773 | 174,352 |
| Cascadia | - | 3,020 | 3,368 | - | 3,020 | 3,368 |
| Cranbrook | - | 61,169 | 65,466 | - | 61,169 | 65,466 |
| Dawson Creek | 6,480 | 138,254 | 175,012 | 71,280 | 216,014 | 252,772 |
| Fraser | 26,640 | 116,517 | 109,524 | - | 143,157 | 136,164 |
| Fort Nelson | - | 523,273 | 732,517 | - | 523,273 | 732,517 |
| Fort St. John | - | 598,303 | 643,510 | - | 598,303 | 643,510 |
| Invermere | - | - | 3,433 | - | - | 3,433 |
| Kalum | 15,120 | 18,247 | 24,608 | 46,800 | 80,167 | 86,528 |
| Kamloops | - | 81,269 | 113,384 | - | 81,269 | 113,384 |
| Kispiox | - | 2,262 | 12,395 | - | 2,262 | 12,395 |
| Kootenay Lake | 158,400 | 8,343 | 12,005 | - | 166,743 | 170,405 |
| Lakes | - | 22,281 | 26,972 | - | 22,281 | 26,972 |
| Lillooet | - | 1,385 | 7,373 | - | 1,385 | 7,373 |
| MacKenzie | - | 86,312 | 131,491 | - | 86,312 | 131,491 |
| Merritt | - | 59,307 | 69,263 | - | 59,307 | 69,263 |
| 100 Mile House | - | 55,290 | 58,787 | - | 55,290 | 58,787 |
| Morice | - | 43,374 | 84,304 | - | 43,374 | 84,304 |
| North Coast | - | - | 1,211 | - | - | 1,211 |
| Okanagan | - | - | 13,217 | - | - | 13,217 |
| Pacific | - | - | 3,932 | - | - | 3,932 |
| Prince George | - | 1,217,178 | 1,517,113 | - | 1,217,178 | 1,517,113 |
| Quesnel | - | 85,594 | 105,192 | - | 85,594 | 105,192 |
| Soo | - | 3,184 | 8,110 | - | 3,184 | 8,110 |
| Sunshine Coast | - | 2,556 | 10,927 | - | 2,556 | 10,927 |
| Williams Lake | - | 68,597 | 108,063 | - | 68,597 | 108,063 |
| **Totals** | **213,120** | **3,217,728** | **4,067,094** | **261,360** | **3,692,208** | **4,541,574** |

*Note: * Estimated availability and delivery cost taken from B.C. Hydro report.*

**Summary of Assumptions**

When assessing the RNG production potential of forestry feedstock in B.C. some assumptions were made. These assumptions include the following:

- All biomass considered surplus to the demands of the B.C. forest industry in the B.C. Hydro report or estimated by NRCan can be used for RNG production in 2035;
- Standing timber is not considered a suitable feedstock as harvesting these trees will release sequestered carbon dioxide into the atmosphere; and
- All potential delivery locations identified in the B.C. Hydro report can connect to the FortisBC or PNG natural gas pipeline.

## 4. Short-Term RNG Production Potential

The above information regarding volume, availability, and $CH_4$ production potential of feedstock in B.C. was used to estimate RNG production potential assuming a market price of $28/GJ for the short-term; defined as the next few years in which little is expected to change regarding RNG feedstock availability or technology.

Theoretical short-term RNG production potential was estimated to be 7.6 PJ/year. However, theoretical production potential is the maximum amount of RNG that could be produced using the most favourable assumptions. Theoretical RNG production potential doesn't take into account certain realities, including:

- Plant operating capacity: AD plants are biological systems. If the biology within these systems is disrupted or upset, biogas production falls.[28] While every effort is made to ensure this doesn't happen, in reality few AD plants run at full capacity. It is therefore more realistic to assume an average operating capacity of 80%; and
- Feedstock availability: separating ICI organic waste from other waste streams can be difficult and costly, while some ICI feedstocks may have alternate uses (such as for rendering and animal feed). Collection and separation of residential organic waste requires implementation of 'green bin' collection programs that often only secure ~60% of total organic waste. It is therefore more realistic to assume only 80% of ICI and 60% of residential SSOs are available for RNG production.

Achievable short-term RNG production potential assuming a market price of $28/GJ was estimated to be 4.4 PJ/year. However, achievable RNG production potential doesn't include potential 'human factor'. For example, if a farmer is uninterested in activities beyond farming, or if a municipal manager feels more comfortable with composting organic waste than digesting it, it is unlikely RNG will be produced using the agricultural or SSOs feedstocks, even if the price paid for the RNG is sufficient to be profitable.

While this dynamic could affect RNG supply, it is impossible to predict and therefore was not included in the RNG production potential estimations. Furthermore, the following observations may be offered:

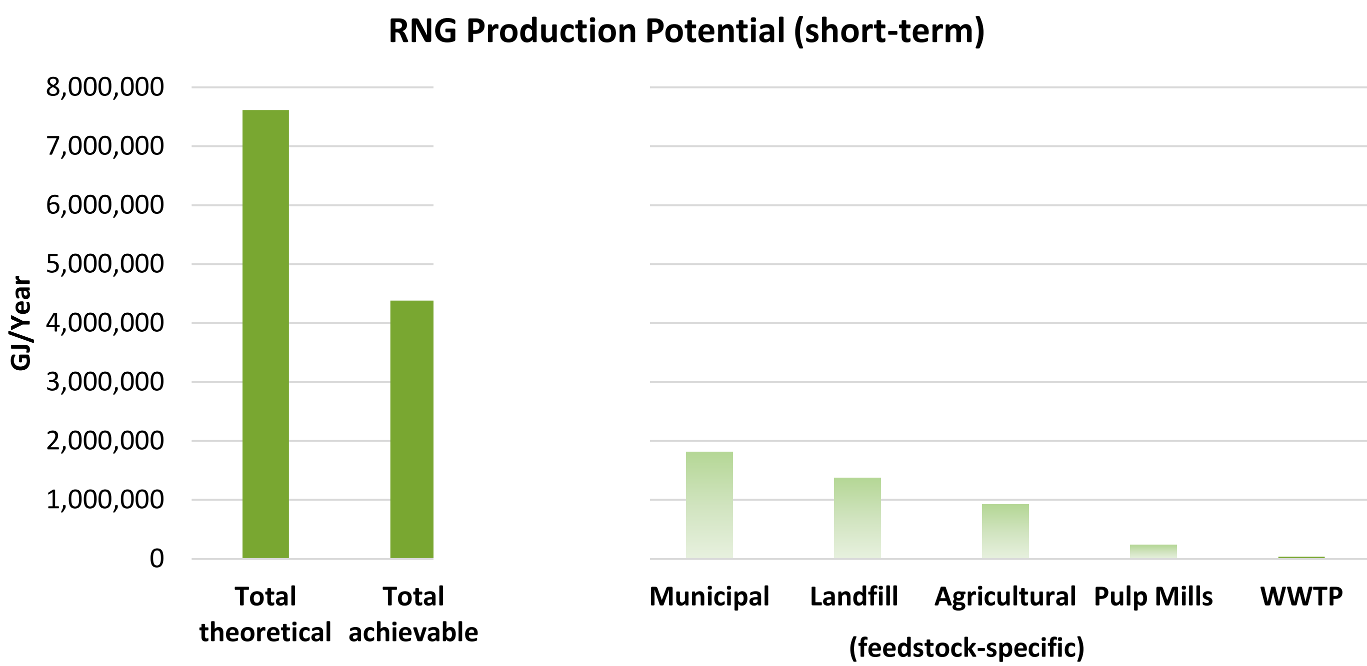
- Larger farms with the majority of the agricultural feedstocks are typically more business orientated and diverse than smaller farms. Furthermore, many on-farm AD plants in the US aren't owned or operated by farmers, but by a third-party. Therefore any 'human factor' will likely have a minimal impact on achievable agricultural RNG production potential; and

[28] This is less of a concern/issue for LFG upgrading, as upgrading technologies generally have ~95% operating capacity.

- As the drive for greenhouse gas (GHG) reductions continue, local government will likely favour AD plants over compost facilities as AD plants result in greater GHG reductions. Therefore any 'human factor' may have a smaller and smaller impact on achievable municipal RNG production potential.

Achievable feedstock-specific RNG production potential in the short-term is greatest for municipal AD plants digesting residential and ICI SSOs, which have potential to produce 1.9 PJ/year. Landfills upgrading LFG to RNG have an achievable short-term RNG production potential of 1.4 PJ/year, while agricultural AD plants digesting manure, litter, and ICI SSOs where available, have an achievable short-term RNG production potential of 0.9 PJ/year. Pulp mill AD plants digesting WAS and WWTPs upgrading biogas to RNG have achievable short-term RNG production potentials of 0.24 and 0.034 PJ/year[29] respectively (Figure 3).

***Figure 3: Short-Term RNG Production Potential at $28/GJ***




## 5. Long-Term RNG Production Potential

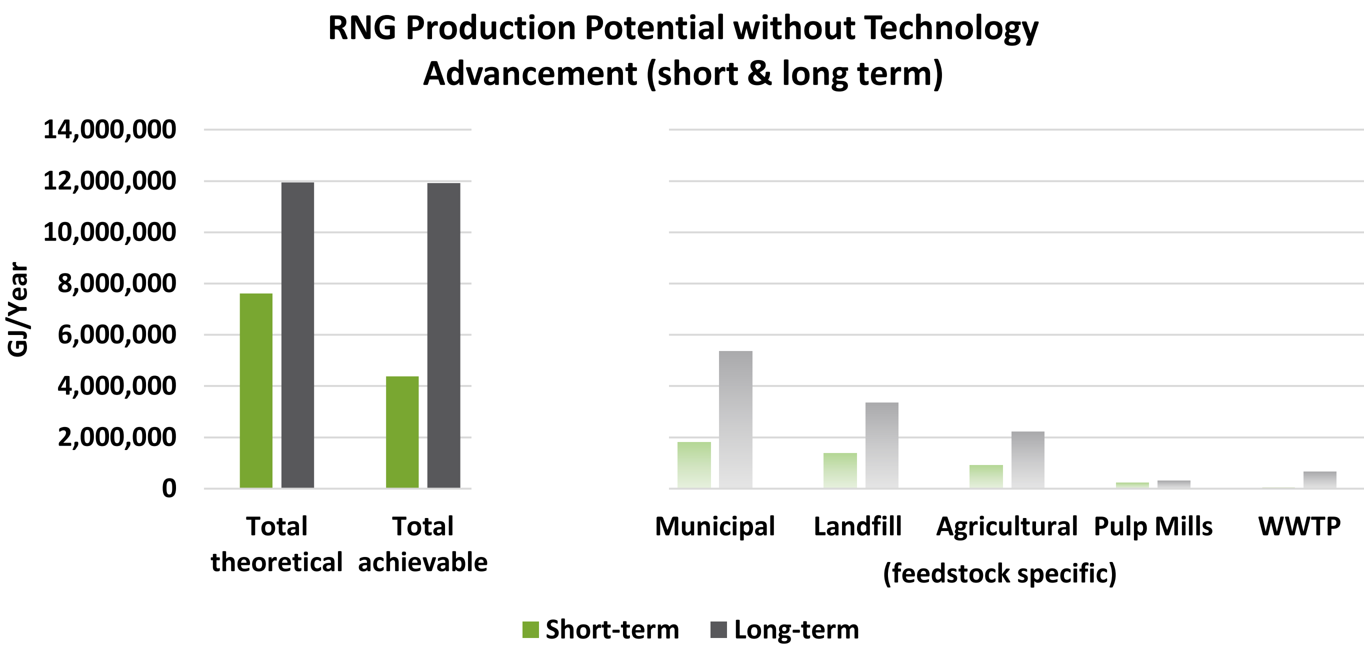
Long-term RNG production potential assuming a market price of $28/GJ was estimated. The long-term was defined as a time in which significant changes in both available RNG feedstocks and wood RNG technology are expected. For the purpose of estimating potential feedstock availability, the year 2035 was chosen.

The first long-term RNG production potential used projected industry and population growth rates to estimate increased feedstock volumes, and assumed no significant advancements in wood RNG technology. It also assumed that WWTPs and landfills currently burning biogas and LFG to produce heat and/or electricity are able to switch to RNG production; as technology and infrastructure originally installed to produce heat and/or electricity was assumed to be close to or beyond retirement age and could therefore be replaced.

[29] The reason for this low RNG production potential is that WWTPs currently burning biogas to produce heat and/or electricity are assumed unable to switch production to RNG in the short-term.

RNG production potential in the long-term assuming a market price of $28/GJ and no significant advancements in wood RNG technology is estimated to be 11.9 PJ/year.[30] The increase in RNG production potential is estimated to occur across all potential sources, with municipal, agricultural, and pulp mill RNG production potential estimated to increase to 5.4, 2.2, and 0.3 PJ/year respectively, and LFG and WWTP RNG production potential estimated to increase to 3.4 and 0.7 PJ/year respectively (Figure 4).

***Figure 4: Short & Long-Term RNG Production Potential without Technology Advancements at $28/GJ***

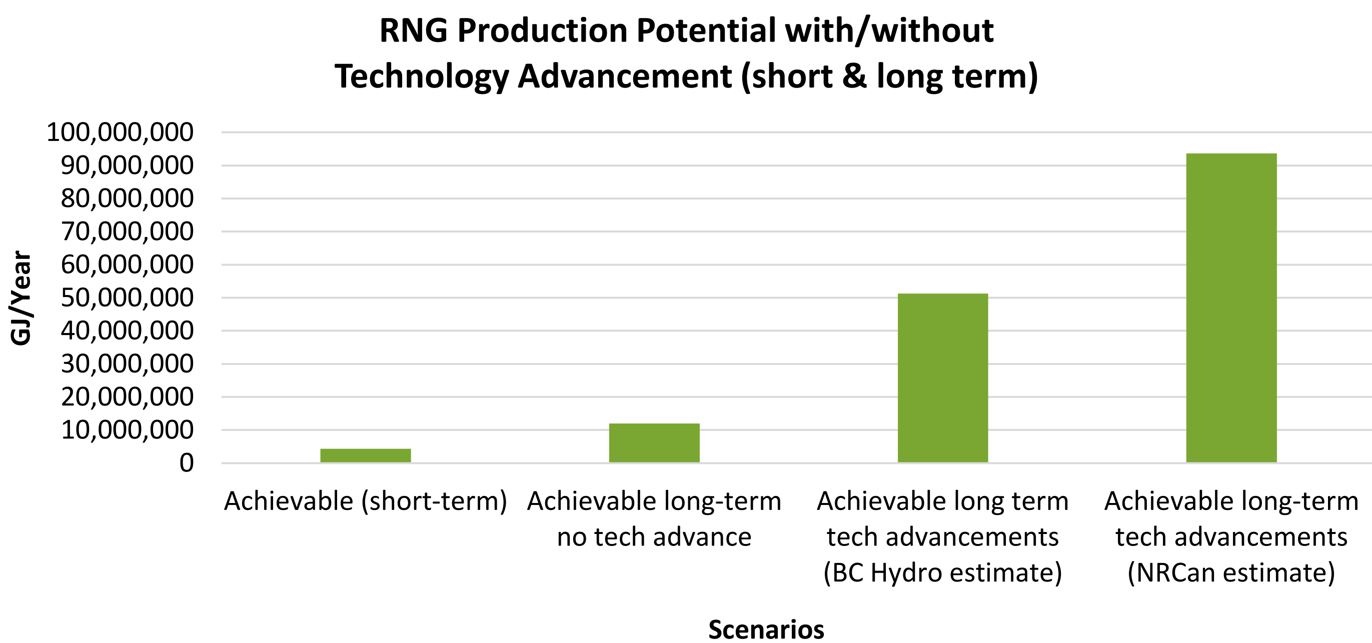



The second long-term RNG production potential used estimated feedstock volumes, and assuming a market price of $28/GJ and significant advancements in wood RNG technology. Development of commercially available technologies[31] to convert wood feedstock to RNG will significantly increase B.C.'s RNG production potential. For example, based on available suitable agricultural feedstocks (i.e., horse bedding, broiler litter, and turkey litter) and B.C. Hydro's forestry feedstock estimations, RNG production potential is estimated to be 51.3 PJ/year. If NRCan's forestry feedstock estimations are used, RNG production potential is estimated to be 93.6 PJ/year (Figure 5).

[30] There is little difference between short and long-term theoretical and achievable RNG production potential because improvements in feedstock pre-treatment (increasing RNG production per unit) and more widely implement organic waste separation (increasing availability of SSOs) are assumed to offset the lower operating capacity and feedstock unavailability assumed in the short-term.

[31] Two promising technologies currently demonstrating conversion of wood feedstock into RNG use thermochemical technology to first convert the feedstock into synthetic gas, before transforming the synthetic gas into RNG. A third approach being developed involves using synthetic gas as a gaseous co-digestion feedstock in AD plants to convert carbon monoxide and hydrogen into $CH_4$. Other technologies being developed include small-scale lignocellulosic pre-treatment technologies, such as catalyzed steam pre-treatment and extrusion technologies, making it possible to use wood feedstock in AD plants.

*Figure 5: Short & Long-Term RNG Production Potential with/without Technology Advancements at $28/GJ*



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