Renewable natural gas production in Québec: A key driver in the energy transition

Assessment of technical and economic potential in Québec (2018–2030)

October 2018

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The study was funded and coordinated by Énergir.

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The fight against climate change is intensifying and a major energy transition has begun. In this context, producing and using renewable natural gas (RNG) as a future-friendly energy source warrants careful consideration, and Québec has to be a part of this shift.

It is critical to understand the province's unique characteristics, technological maturity and distribution of sources of organic matter, to determine how ambitiously Québec can seize this opportunity.

With a technical and economic potential of 144 million gigajoules (GJ) by 2030—nearly two thirds of the current natural gas consumption in Québec—production of RNG in Québec could be a key driver in the energy transition.

Bringing new information to light, this study invites all stakeholders, regardless of their involvement in the sector's development, to clarify Québec's ambitions and what it will need to fulfill them.

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What is RNG?

The *Act respecting the Régie de l'énergie* defines renewable natural gas (RNG) as "methane from renewable sources," which can be produced using various technologies such as biogas capture (at landfill sites), biomethanation, pyro-gasification, pyro-catalytic hydrogenation, and Power-to-Gas.

To replace conventional natural gas and be injected into the natural gas distribution system, the RNG produced must meet renewable natural gas quality specifications (BNQ 3672-100). Once in the system, RNG molecules are used for the same purposes as natural gas.

Advantages of RNG

Renewable

- Produced from organic matter
- Helps achieve GHG reduction targets

Interchangeable

- Can replace conventional natural gas
- Can be used in existing distribution systems

Economic

- Provides revenue to organic matter resource owners
- Contributes to a circular economy by creating wealth from residual materials

Local

- Creates local jobs that cannot be outsourced
- Improves the trade balance by decreasing energy imports

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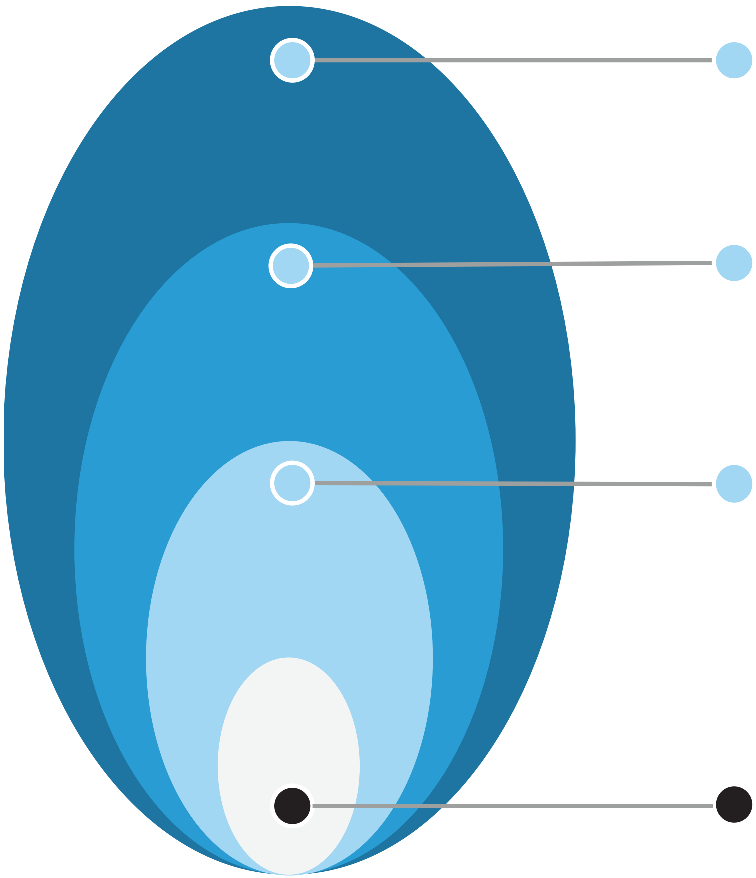
What is a technical and economic potential?



Total potential

- Total potential is based on all feedstock capable of producing RNG, considering applicable technologies. It represents 100% of the resource considered.

Technical potential

- Technical potential is total potential minus the portion that cannot be technically mobilized (collected), for accessibility reasons for instance. It does not take into account costs, adoption or market barriers, or any other constraints.

Technical and economic potential

- Providing an added filter, technical and economic potential incorporates the cost of RNG production for each feedstock technically available given current market conditions. It represents the portion of the technical potential for which RNG operating and production costs make it economically viable for producers in the current landscape, before taking into consideration any adoption or market barriers.

Maximum attainable commercial potential (not included in this study)

- Maximum attainable commercial potential adds a final filter to account for competing uses (conventional or for recovery) of the resources considered. There can be many competing uses for some resources, but it is difficult to determine and document the full range of these and their long-term significance, considering how each market evolves over time.

Figure 1: Potential analyzed

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Background and objective

By adopting the new 2030 Energy Policy,[1] the government of Québec clearly stated its intention to diversify energy sources. In keeping with the Government Sustainable Development Strategy[2] and the targets it adopted to fight climate change, it is seeking to drive the shift toward a low-carbon economy.

To achieve that goal, the government aims to increase renewable energy production by 25% and bioenergy production by 50% within the next 15 years. This specifically includes RNG, as the government deems this alternative energy source imperative for it to meet those targets. In August 2018, the government of Québec published a draft regulation aiming to set the minimum quantity of RNG delivered by natural gas distributors at 5% by 2025.

Currently, only four facilities produce RNG in Québec: two biomethanation sites and two landfills. Six other facilities are in various stages of development. Most of the RNG volume produced in Québec is currently sold to the United States and therefore not accounted for in Québec. It is estimated that the facilities currently in operation contributed less than 1% of the total volume of natural gas in Québec's distribution system in 2017.[3]

To determine how significant a role RNG could play in the transition and how it will fit in the future energy mix, it is critical to **assess the quantity of RNG Québec could potentially produce now and in the years to come**.

[1] Government of Québec. 2016. The 2030 Energy Policy

[2] MDDELCC. 2015. Government Sustainable Development Strategy for 2015–2020.

[3] ÉNERGIR data, 2017.

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Approach and scope of the study

The selected approach centres on the various steps presented in figure 2 and outlined in greater detail in the section of this report that presents the study's assumptions.

1. Identification of anticipated challenges and opportunities in developing the RNG industry in Québec

- Elements of the political, regulatory, environmental, social, economic and regional context
- Challenges and opportunities associated with these contextual components

2. Assessment of usable feedstock and overview of current RNG production technologies

- Potential output and technical accessibility of available feedstock, and estimated growth by 2030
- Availability/maturity of RNG production technologies
- Evaluation of investment and operating costs for these technologies

3. Assessment of total potential, technical potential and technical and economic potential for RNG production in 2018 and 2030, by region

- Conversion of usable resources into technical potential
- Modelling of acquisition costs for inputs for each resource, RNG production costs, as well as injection costs
- Development of cost curve to identify viable resources, based on RNG purchase price
- High-level quantification of the potential GHG reduction as a result of RNG consumption in Québec

Figure 2: Study approach

Summary of the study scope:

- Territory covered: Province of Québec
- Time horizons: 2018 and 2030
- Technologies analyzed: first generation (biogas capture at landfills, biomethanation), second generation (pyro gasification and pyro catalytic hydrogenation) and third generation (Power-to-Gas, qualitative assessment without assessment of technical potential and technical and economic potential)
- Resources: agricultural biomass, organic waste and forest biomass
- RNG use: RNG injected into the natural gas distribution system
- Method of injection into the system: RNG injected directly into the system or transported by truck for injection (transported gas)
- Potential assessed: technical potential, technical and economic potential at $15/GJ, which represents a value that is competitive with electricity in Québec
- Potential not assessed: commercial potential

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Three technological generations and 13 resources were analyzed (Figure 3). The Power-to-Gas technology was excluded from the technical potential and economic potential quantitative analyses, due to the significant uncertainty surrounding the potential future surplus of electricity in Québec.

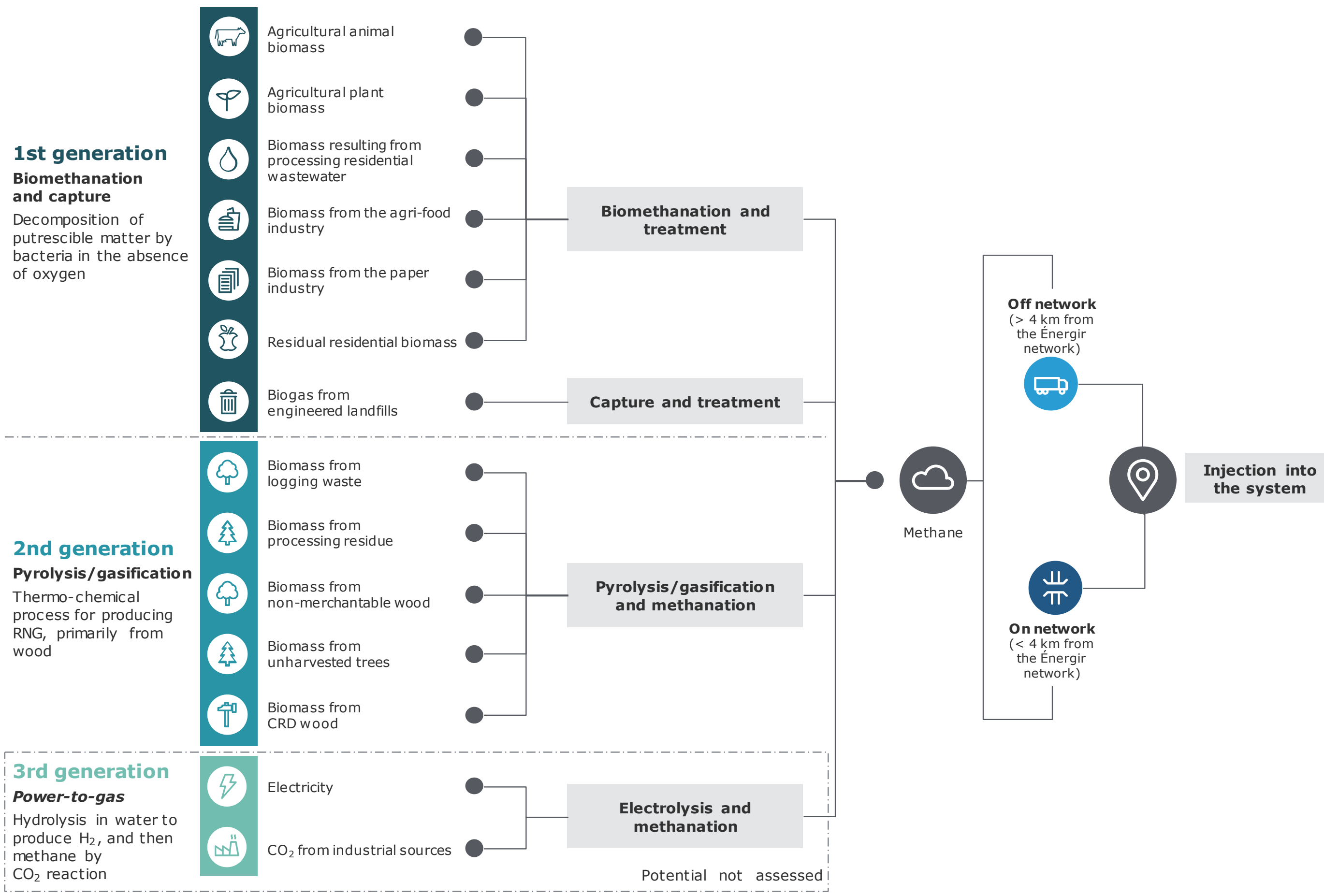

Figure 3: RNG production flow considered in the study

This analysis assessed the levels of potential, from greatest to smallest (Figure 1), based on the total size of the source and the technical or economic constraints considered. Because of the inherent difficulty of factoring in future market variables, the study findings are limited to the technical and economic potential and do not include the maximum attainable commercial potential.

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Results

2018: a technical and economic potential based on first-generation technologies (biomethanation and capture)

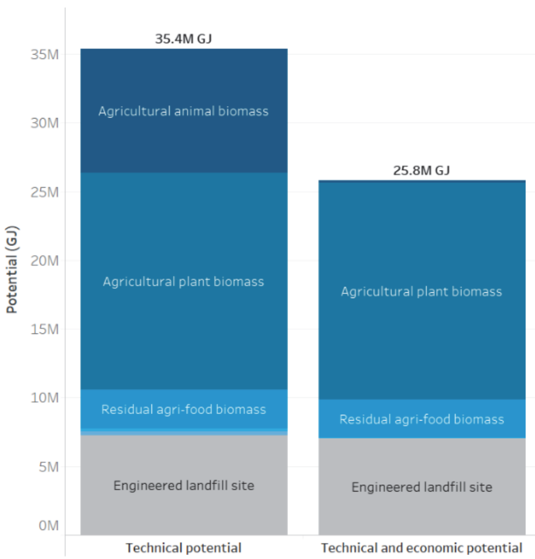
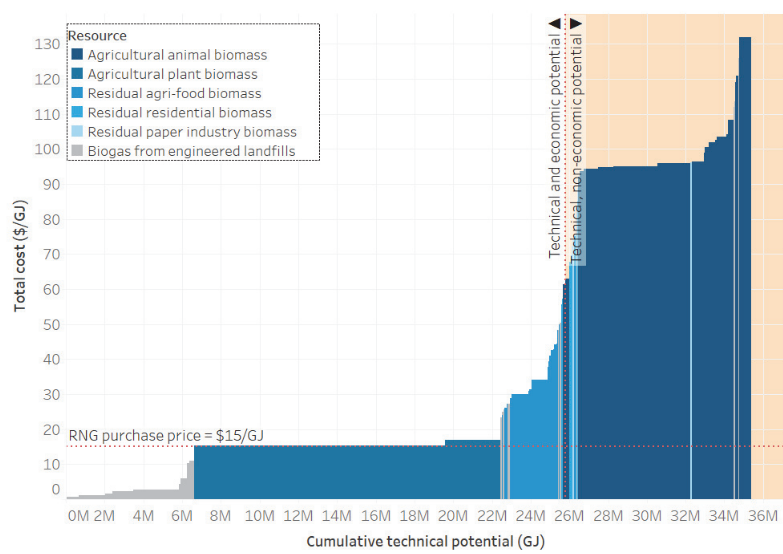


Figure 4: Technical potential and technical and economic potential in 2018

The technical potential amounts to 35.4 million GJ in 2018 (Figure 4). This only includes first-generation resources, primarily from biogas capture from engineered landfills and biomethanation of agricultural and agri-food industry biomass.

The 2018 technical and economic potential amounts to 25.8 million GJ, which corresponds to 12% of the volume of natural gas currently distributed by Énergir in Québec. It is composed of RNG generated from biomethanation of agricultural plant biomass (61%), residual biomass from agri-food industries (11%), and biogas capture from engineered landfills (27%).

As demonstrated by the technical potential cost curve for 2018, the low cost to produce RNG from engineered landfills means that resources costing more than the RNG purchase price used in this study ($15/GJ) can be factored into the technical and economic potential (Figure 5). For the end user, this amount is generally competitive with the price of electricity in Québec.



For 2018, the technical and economic potential does not include RNG production exclusively from agricultural animal biomass sources, since the marginal costs of production are too high. This result is explained by the single-resource approach employed for this study, which does not take into account the fact that resources may be processed along with other feedstock. (Refer to the *Key findings and interpretations* section on page 8 for more details.)

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2030: an increased potential with the widespread use of second-generation technologies (forest biomass)

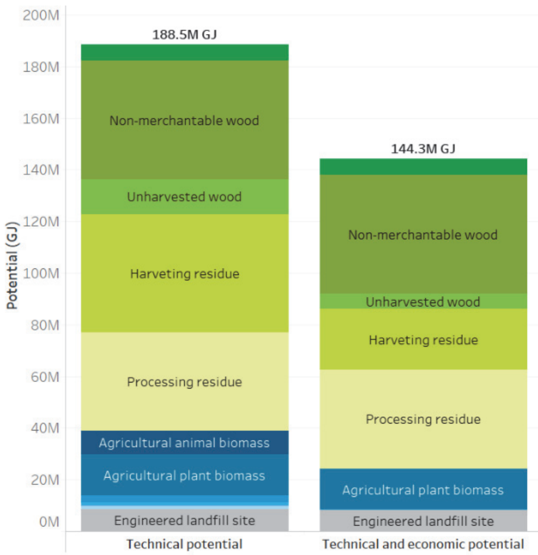
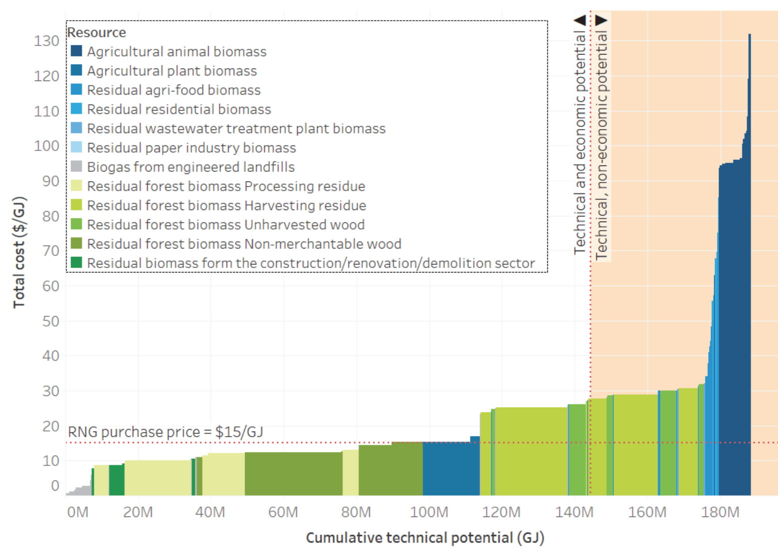


Figure 6: Technical potential and technical and economic potential in 2030

In 2030, the technical potential reaches 188.5 million GJ (Figure 6). This potential includes first-generation resources that were already identified in 2018 (with a slight increase), but mainly reflects the commercial maturity in Québec of pyrolysis/gasification, a second-generation technology that primarily uses forest biomass.

The 2030 technical and economic potential amounts to 144.3 million GJ, which corresponds to 66% of the volume of natural gas currently distributed by Énergir in Québec. It is primarily composed of RNG generated from second-generation technologies (82%), complemented by RNG from biomethanation (13%) and engineered landfills (5%).

The technical potential cost curve for 2030 shows that more than half the technical and economic potential from second-generation technologies could be produced at a cost less than $15/GJ. These technologies are based on processing residue, non-merchantable wood, as well as residual biomass from the construction, renovation and demolition sector. Moreover, 60% of the other two second-generation resources (harvesting residue and unharvested wood) is economically viable when the purchase price is $15/GJ (Figure 7).



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Key findings and interpretations

The technical and economic potential is substantial: by 2030 it could reach two thirds of the current consumption with first- and second-generation technologies

Today, the technical and economic potential of first-generation technologies is already significant, equivalent to 12% of the volume of natural gas consumed in Québec. This potential will continue to increase through 2030 with the widespread emergence of second-generation technologies using forest biomass, rising to 144.3 million GJ, or two thirds of the current natural gas consumption in Québec.

Using this volume of RNG instead of conventional natural gas could prevent the emission of 7.2 Mt of CO_2e: more than the total annual emissions from 1.5 million cars.[4] Avoided emissions could be even higher if RNG were used as a substitute for diesel fuel in heavy transport. However, that value does not take into account the additional emissions associated with the RNG lifecycle, most particularly emissions resulting from transport and production.

[4] US EPA, Greenhouse Gas Equivalencies Calculator

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Potential could grow as of 2030 with the introduction of third-generation technologies (Power-to-Gas), as demonstrated by some European projects

Power-to-Gas is a technology that is rapidly evolving, particularly in Europe where 70 Power-to-Gas projects are either in operation or in development.[5] According to current project data, this technology could represent a very significant additional resource for Québec in the future. However, since its limiting factor is the availability and cost of electricity, this resource could benefit from temporary, seasonal and possibly more long-term electricity surpluses that were not estimated within the framework of this study. Although the cost of RNG production using Power-to-Gas may exclude it from the technical and economic potential (considering current electricity costs), RNG produced in this manner could be treated as a form of energy storage that would otherwise be lost.

Based on the different organic matter resources, all regions have technical and economic potential for RNG production by 2030

The map in Figure 8 shows that all regions in Québec will have technical and economic potential for RNG production. However, these regional potentials are based on a wide variety of resources, the composition of which varies significantly depending on each region's key economic sectors and population.

Resource regions show a strong propensity for RNG produced using residual forest biomass, while RNG produced using biomass derived from agri-food industries and municipalities appear in the more industrial and urbanized regions. Agricultural biomass resources are significant and even dominant in the regions in Québec with significant agricultural activity.

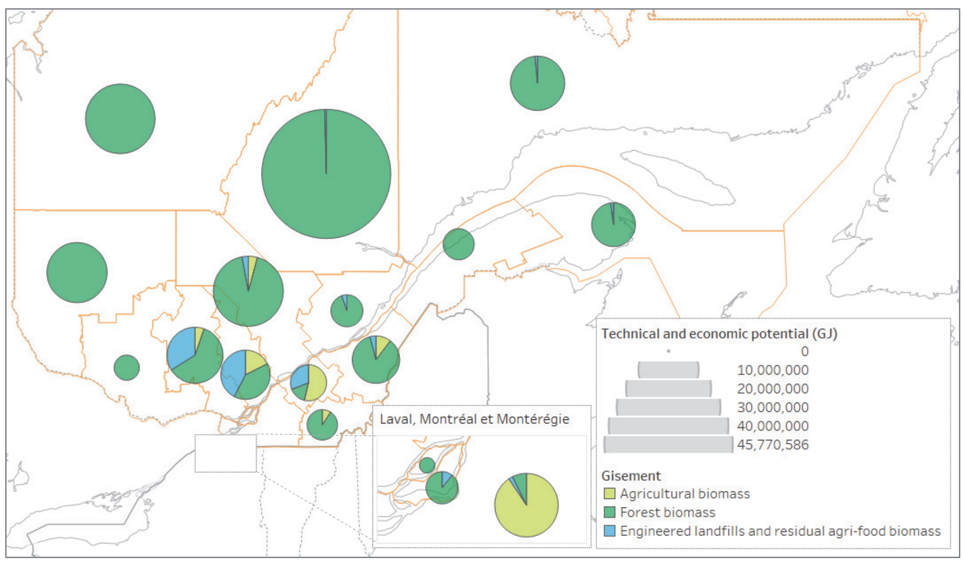

Figure 8: Distribution of technical and economic potential for RNG in all regions of Québec (2030)

[5] European Power-to-Gas. 2017. Power-to-Gas in a Decarbonized European Energy System Based on Renewable Energy Sources

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Achieving the technical and economic potential depends on a number of factors, including recovery of resources using co-processing operations, resource availability, obtaining of a sufficient purchase price, and potential subsidies.

Some resources could be converted with co-processing operations, even though such operations were not included under technical and economic potential

Separate assessment of RNG production costs per resource/region does not necessarily reflect the operational reality of each production site.

For example, agricultural animal biomass is almost always co-processed with other sources, such as agri-food processing waste. Biomethanation plants are often supplied from numerous sources of organic matter in order to take advantage of their physico-chemical complementarity with the best possible economic return.

The “single-resource” approach taken with this study is a simplification of the operational reality; therefore, the results per resource should be considered with caution. In fact, resources will very likely be combined according to the needs and availability in each region. This could lead to the inclusion in economically viable projects, of resources that were not factored into the technical and economic potential here, this study having looked at resources individually.

Market factors will have an impact on the availability of resources included in technical and economic potential

As stipulated in the description of the approach, technical and economic potential does not equal the maximum attainable commercial potential. In fact, this study does not include market or adoption barriers to the technologies, nor does it consider the competing uses that could decrease the availability of certain resources or increase their costs. For example, forest biomass sources could be mobilized by other energy generation technologies, which would affect both the quantity available and the price at which it would be accessible for RNG production in Québec.

Furthermore, potential competitive uses for RNG produced for purposes other than injection into Québec’s natural gas distribution system were not considered in this study. One example to illustrate this point could be the production of RNG from engineered landfills in Québec. Currently, because of regulations favouring the use of RNG (Renewable Fuel Standard, Low-Carbon Fuel Standard), most RNG from engineered landfills is exported to the United States. This situation illustrates the difficulty that Québec could have using the RNG it produces within its own territory, given the free movement in RNG gas markets. This also demonstrates the impact that not taking potential RNG imports/exports into account could have on the technical and economic potential for other resources, if the less expensive resources are exported.

> Thus, if RNG from engineered landfills is not used in Québec in 2018, the technical and economic potential would be nil, considering a purchase price of $15/GJ. Unless regulatory measures are implemented, a purchase price of $38/GJ would be necessary to achieve a technical and economic potential of 25.8 million GJ.

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Technical and economic potential is directly affected by the RNG purchase price and the amount of subsidies

The technical and economic potential indicated in this study was calculated based on a fixed purchase price for RNG of $15/GJ. This could vary depending on a variety of external factors such as the fluctuation in electricity prices or the cost of GHG credits.

The RNG purchase price threshold is key in determining technical and economic potential. In fact, a variation of only a few dollars per GJ can result in a loss or gain of millions of GJ of technical and economic potential, from 51 million GJ at $10/GJ to 182 million GJ at $20/GJ, for example (Figure 9).

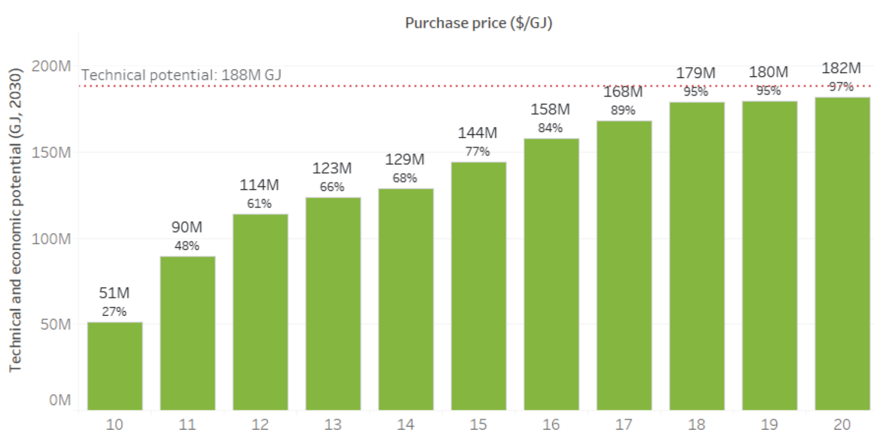

Figure 9: Fluctuation in technical and economic potential, according to purchase price (2030)

Technical and economic potential could increase for specific resources, taking possible subsidies into account

Current and future subsidies are not included in the values presented herein, and could significantly decrease the productions costs, i.e. the highest costs, for first-generation technologies in particular. These subsidies could stem from the *Programme de traitement des matières organiques par biométhanisation et compostage* (PTMOBC) [program for processing organic matter using biomethanation and composting] or be associated with new tools developed as part of the bioenergy development measures in the *Transition énergétique Québec* 2018-2023 master plan, for example.

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Additional information on the approach

Technologies analyzed

Three RNG production industries were investigated in this study, corresponding to each of the three technological generations:

- **First-generation** technologies:
  Biomethanation, or anaerobic fermentation, is the process whereby putrescible matter is decomposed by bacteria in the absence of oxygen. This process produces biogas that is primarily composed of 50–70% methane (CH_4), as well as carbon dioxide (CO_2). The digested matter, called "digestate", is used as fertilizer or can undergo an additional processing step involving composting. The biogas produced by biomethanation must then be refined to reach a quality comparable to natural gas. These different steps have varying degrees of effectiveness, depending on the inputs considered.

  Biogas capture consists in capturing gases emitted naturally by landfilled putrescible matter. The matter undergoes anaerobic fermentation by the microorganisms naturally present in the waste or in the soil. This natural and uncontrolled biomethanation produces methane-rich gas that must then be refined to reach quality comparable to that of natural gas. The quantity of biogas emitted at landfills is proportionate to the annual tonnage received and the organic content of these landfilled materials.

- **Second-generation** technologies:
  Pyro-gasification is a thermal process that produces fuel gas (called synthesis gas or "syngas") through pyrolysis with little or no oxygen, followed by gasification at high temperature. The resulting gas then undergoes methanation to produce methane.

  Pyro-catalytic hydrogenation consists of a first step involving high-temperature pyrolysis in the absence of oxygen, followed by catalytic hydrogenation of the gases. The advantage of this technology is that it yields a higher final energy output as compared with traditional pyro-gasification.

- While there are already commercial pyro-gasification facilities in Europe, pyro catalytic hydrogenation is a relatively recent technology. Québec has a pilot facility that will be operational by 2021 (G4 project). The results in this study are therefore based on the more mature pyro-gasification technology, which should have reached full maturity by 2030.

- **Third-generation** technology:

  Power-to-Gas technology is a process used to combine excess electricity with CO_2 to produce CH_4 through water electrolysis followed by methanation of the resulting hydrogen gas (H_2) in the presence of CO_2. This technology is still being studied with existing prototypes outside of Québec. It is particularly attractive in jurisdictions with low-cost electricity and low GHG emissions like Québec, but the uncertainties surrounding possible long-term electricity surpluses prevented a quantitative analysis of its technical potential.

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Resources analyzed and specific assumptions

Twelve resources were analyzed in detail to assess the technical potential and the technical and economic potential of RNG in Québec. The assumptions used to estimate the available quantities of each resource were based on public data (MFFP, RECYC-QUÉBEC, MDDELCC, ISQ, Chief Forester's Office, etc.), scientific and technical articles, as well as estimates validated by the steering committee. These assumptions were made conservatively, in accordance with the principles of sustainability (e.g. conservation of carbon in the soil).

	Resource	Resource description
Agricultural residue	Crop residue	Corn/grain crop residue (only residue that can be used for RNG production in Québec, since all other crop residue has been earmarked for other use or degraded prior to harvesting).
	Livestock production residue	Residue (manure, liquid manure) from the five main types of livestock production in Québec: beef and dairy cattle, pigs, laying hens and chickens, turkeys and other poultry.
Organic waste	Organic waste (not in engineered landfills)	Organic waste resulting from separation of organic and solid waste by Québec residents, primarily composed of green residue and food residue.
	Sludge from wastewater treatment plants	Sludge (biosolids) from domestic wastewater treatment plants, municipal sewer stations and pond-type treatment stations.
	Landfilled organic waste (open and closed engineered landfills)	Landfilled organic matter in engineered landfills that produce biogas through anaerobic fermentation.
	Organic waste from agri-food industries	Biomethanizable organic waste produced by agri-food industries, characterized by their methanogenic potential, which varies according to the type of industry (does not include residue from stores and institutions due to lack of data).
	Paper waste	Sludge produced by the paper industry in the papermaking or de-inking processes, and currently not incinerated.
Forest biomass	Harvesting residue	Biomass left on site after harvesting, such as small-diameter branches, tree tops and leaves.
	Non-harvested wood	Volume corresponding to the difference between the allowable annual cut, as estimated every five years by the Chief Forester, and the actual volume harvested.
	Non-merchantable wood	Volume of trees available in the forest, but damaged. Within the context of this study, this corresponds to trees left after forest fires and trees killed by the spruce budworm (most devastating epidemic in Québec).
	Processing residue	Residue from wood processing plants, primarily consisting of wood chips, but also including some bark, shavings and sawdust.
	Construction, renovation and demolition (CRD) residue	Wood generated by the construction, renovation and demolition (CRD) industry. Wood represents 56% of CRD materials destined for recycling and energy recovery (RECYC-QUÉBEC, 2015).

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Technical and economic potential modelling

Quantification of the technical potential and technical and economic potential is based on a model consisting of more than 15 key variables, summarized in Figure 10. It is important to note that the effect of inflation was not taken into account in the cost estimate (inputs, production and injection) nor in the thresholds used to determine the economic potential (RNG purchase price) or any other economic component.

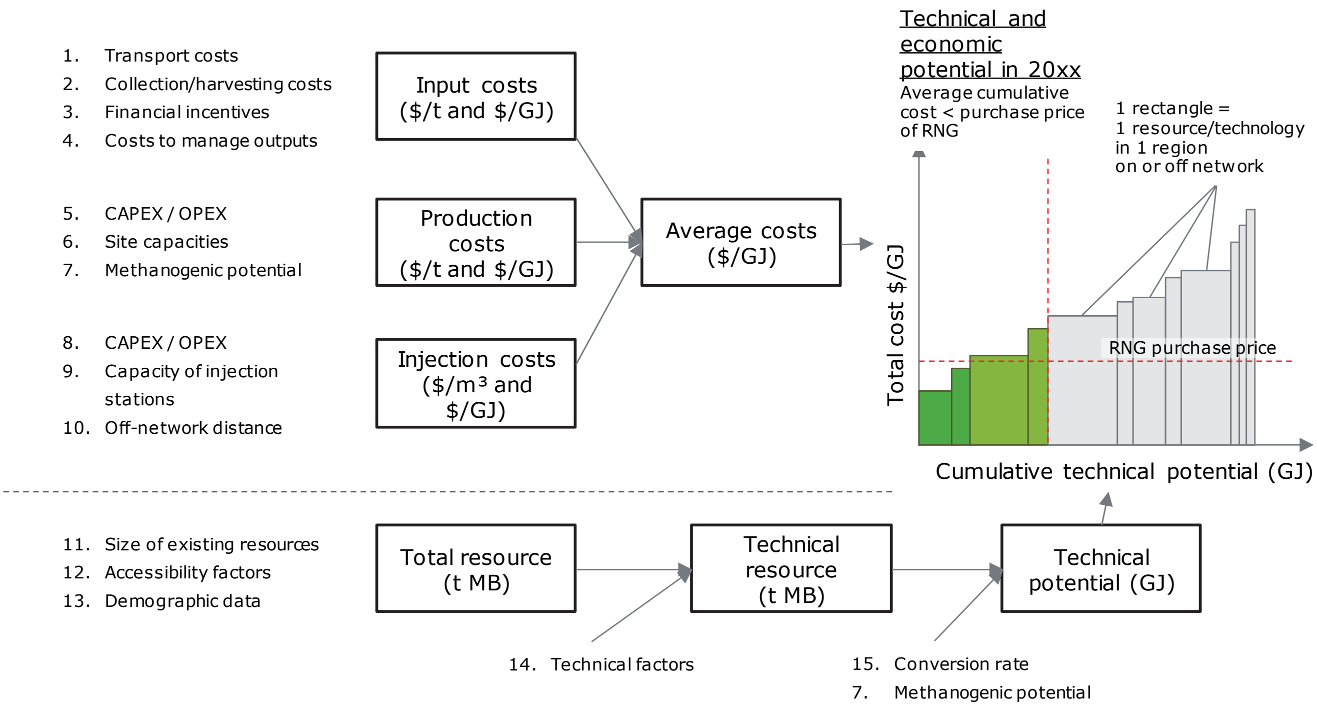

Figure 10: Summary of approach to quantify technical potential and technical and economic potential

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