Forest-based bio-products: Biofuels pathways for the City of Quesnel in a carbon-constrained world

Prepared by Tom Browne

Final version 2021-09-29

Thomas C. Browne, ing., Ph. D.
https://ca.linkedin.com/in/tcbrowne
+1 514.523.9508
tom@tcbrowne.ca

Contents

1. Executive Summary: Biofuel opportunities for Quesnel

1.1. Background: Climate Change is a major new driver

In early 2020, the author contracted with the City of Quesnel to deliver an outline of forest-based biorefinery pathways that might fit the context of the City. The draft final report was delivered on March 13, 2020. (The final approved version, which was unchanged from the final draft, was delivered on June 14, 2021.)

That report downplayed opportunities for biofuels projects given that there were no obvious signs of impending government action sufficiently robust to make these pathways economic in a world of cheap oil and natural gas. With record heat waves in Western Canada early in the summer of 2021, that situation is likely to change quickly; aggressive action by the US and the EU, both including plans for a carbon border tax[1,2] on goods from countries with less strict carbon policies, is likely to put additional pressure on Canadian governments to act quickly.

The City of Quesnel is well placed to show leadership in this new carbon-aware context. While wood supply is under stress, the community nonetheless has the opportunity to significantly reduce its own carbon footprint, and to serve as a showcase by supporting other novel approaches. Advantages include a well-established global forestry industry drawing on well-managed resources, growing involvement by First Nations groups, and a municipal government that is aware of the opportunities and eager to exploit them.

Natural gas use in BC in 2018 was 728,000 Gigajoules per day (0.69 billion cubic feet per day)[3], of which 401,000 GJ/d (0.38 Bcf/d) was industrial. The BC government has implemented policies to drive substitution of 15% of natural gas use in BC with renewable options, corresponding to a demand of 109,000 GJ/d of Renewable Natural Gas (RNG) or substitutes. To incent this, FortisBC has been authorised by the BC Utilities Commission to pay up to $35/GJ for a pipeline-ready RNG. (Unless otherwise noted, all currency is given in 2021 Canadian dollars.) This compares with current industrial rates for gas that are well under $5/GJ, including pipeline charges. FortisBC is also offering to buy back, at a lower rate, natural gas that has been displaced by a lower-grade bio-based gas that may not be of pipeline-grade; a classic example, in use today in Finland and elsewhere, is to gasify wood residues for use in a pulp mill lime kiln.

This short update to Section 4.2 of the earlier report seeks to identify biofuels pathways that are technically close to commercial in scale, that are a good fit for Quesnel, and where the economics would benefit from government action, such as FortisBC support for RNG, on climate change. Specific approaches proposed by the IEA Net Zero by 2050[4] scenario, and which could be a good fit in Quesnel, include the following:

- Solid fuels:
  - Pellets would replace coal in newer Asian coal-fired generating stations that risk being stranded in a carbon-constrained world;
  - Pellets for export are a well understood, low-value product running on sawmill residues, and will be economic if buyers overseas are prepared to pay a carbon premium.

---

[1] "Europe Is Proposing a Border Carbon Tax. What Is It and How Will It Work?". https://www.nytimes.com/2021/07/14/climate/carbon-border-tax.html, viewed 2021-07-17.
[2] "Democrats Propose a Border Tax Based on Countries' Greenhouse Gas Emissions". https://www.nytimes.com/2021/07/19/climate/democrats-border-carbon-tax.html, viewed 2021-07-23.
[3] https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-british-columbia.html, viewed 2021-07-23.
[4] International Energy Agency (2021), Net Zero by 2050, IEA, Paris. https://www.iea.org/reports/net-zero-by-2050, viewed 2021-05-20. See also https://bio-economy-tbrowne.blogspot.com/2021/06/the-iea-roadmap-to-net-zero-critical.html

- Liquid fuels:
  - Biofuels would displace petroleum-based transportation fuels, in particular for aviation or for long-distance or off-road vehicle use;
  - Canfor's biofuel project with Licella provides an example for any subsequent biofuels projects aimed at local markets in the Central Interior.
- District heating, possibly combined with off-grid power generation:
  - This includes city facilities heated with mill waste heat, biomass combustion or gasification, as well as heat, possibly combined with off-grid power, for First Nations;
  - These are local challenges with local solutions that can serve as flagships.
- Gaseous fuels to displace natural gas directly at the point of combustion:
  - Displacing natural gas use in lumber kilns or in Cariboo's lime kiln is an obvious opportunity;
  - Industrial pathways using existing technologies are available from Nexterra or pulp mill equipment vendors. Integrated, modular CHP plants are also available from European suppliers.
- Gaseous fuels for direct injection into pipelines:
  - An RNG plant using technology that has been trialled at the demonstration scale can supply pipeline-ready RNG to the grid;
  - The leading technology is expensive, not quite commercial, and requires a lot of wood. Separately, Nexterra claims to be making progress in making a pipeline-ready RNG. But a large commercial plant could displace 2% of BC's 2018 gas use and meet over 13% of the BC government target for RNG substitution in natural gas pipelines.

1.2. Role of the City

Several of these solutions involve the City directly, others require investment decisions by others. Key strengths include the fibre resource; the presence of a major forest industry company and several smaller ones; a range of government policies which are generally favourable to more effective use of biomass; and proximity to major networks for moving product (rail, road, pipeline).

A key factor in the success of an RNG project will be the successful implementation of new BC government policies around forest management, as long as these policies have the potential to create a sustainable supply of fuel-grade wood that would not compete with existing higher value uses for fibre. Without adequate new fibre supplies, the RNG project proposed here will not succeed.

1.3. Next steps

- More detailed analysis of RNG options requires site-specific engineering studies. The BC BioAlliance has proposed to undertake such studies, but it is not known if the funding has been secured.
- Nexterra, as a BC-based commercial provider of gasifiers, could be approached:
  - To determine the status of their pipeline-ready RNG development process;
  - More immediately for the City, to evaluate City heating options where a Nexterra gasifier or similar technology might displace existing natural gas use within City infrastructure, and thus benefit from FortisBC support. European suppliers also provide modular gasifier-based CHP systems.
- Approaches to potential RNG equipment vendors and investors should be considered and planned.
- In the context of the BC Government's new forestry policies, the potential for new forest management processes to supply 500 to 1100 odt/d to a hypothetical new biofuels plant, while not impacting existing fibre users, would need to be evaluated in extensive detail by a group including foresters, First Nations, existing fibre users and BC government policy experts.

2. Pathways to biofuels

2.1. Necessary climate change action in a forestry context

Quesnel is at the centre of a biomass basket that will be critical to the global move to carbon neutrality. Challenges will include managing that basket in the face of climate-driven risks due to insect infestation, heat stress, drought and fire while continuing to meet the needs of the existing forest sector. But there are options to build on that resource, in partnership with the well-established existing forest industry, to make Quesnel a centre of biomass-driven carbon neutrality.

The IEA roadmap and other similar scenarios leading to a net zero future identify transportation and power generation as the two largest contributors to climate change. In any net zero scenario, these are linked. Wholesale switching from gasoline-powered vehicles to electric vehicles will eliminate roughly half of the end-uses of petroleum; but this will require significantly more power generation which must, in turn, come from carbon-neutral sources. Biomass will play a role in both transportation and power generation.

2.2. Wood supply: a critical consideration

Wood volumes in the Central Interior are under pressure due to insect infestation and fire. Existing forestry companies in Quesnel see challenges in ongoing wood procurement. Any project to develop large-scale biofuels will need to take into account the needs of the existing forest sector, which remains critical through its production of value-added products such as solid wood or pulp. But beehive burners remain, and forest stewardship going forward should include better management of thinnings and deadfall to reduce the risk of catastrophic fires. The available volumes of low-grade residual materials of this type are not well understood, but are among the resources that could become available, along with new fibre available through new BC government policies around forest management. These resources will not be cheap, however, and are not economic raw materials for biofuels today, but climate change action by future governments may alter this: the IEA suggests carbon taxes will need to reach $US 250/t CO_{2EQ} by 2050.

2.3. Solid, liquid and gaseous biofuels

An overview follows; for additional details see Section 3.

2.3.1. Solid fuels

The IEA predicts solid biofuels will be needed to displace coal in newer coal-fired generating stations. When equipped with carbon capture, use and storage (CCUS), such plants would benefit from a double benefit: not only is the carbon emitted of biogenic origin, but capturing it means that new growing biomass will be pulling other carbon from the atmosphere.

The long-term market for these pellets is likely to be in Asia. The EU is increasingly reluctant to burn biomass solely for power, preferring to limit biomass to combined heat and power applications. In North America, the average coal generating station is 40 years old and will reach the end of its useful life in the next decade; at that point, the IEA roadmap suggests it should be retired. The North American market for pellets in this context is likely to decrease at that point. However, the average Asian coal-fired plant is 16 years old at the time of writing (13 years in China alone), and these plants will be expensive to shut before their expected lifetime of 50 years. Pellets combined with CCUS would keep these plants running without the climate impact of burning coal.

2.3.2. Liquid fuels

Liquid biofuels will be needed in situations, such as aviation or long-distance trucking, where alternatives such as electricity or hydrogen are not feasible. The joint venture between Canfor and Licella[5] addresses this opportunity. Licella's process converts wet biomass into a bio-crude[6] for low-grade heating applications, and for upgrading to a true diesel substitute[7] in existing petrochemical refineries. The scale likely matches diesel demand within Canfor's operations in the Central Interior.

Other firms are developing similar processes; Finnish forestry company UPM markets a bio-diesel[8] from crude tall oil, although the volumes produced imply additional sources of biomass, such as imported canola or palm oil, are being used. The proprietary process was developed at UPM's research centre in Kaukas and is produced within the adjoining mill in Lappeenranta.

The opportunity for Quesnel would be a biofuel for local consumption, perhaps in partnership with Canfor and Licella for an additional plant[9]. The former Husky refinery in Prince George would be an obvious partner.

Fermentation pathways from wood to ethanol have been extensively explored but yields on wood remain challenging; and expensive, clean, screened white wood chips are required.

2.3.3. Renewable Natural Gas (RNG)

Several options exist for RNG in Quesnel.

Relatively small amounts of methane can be made in anaerobic digesters running on manure, municipal solid waste streams or landfill gas. The gas can be burned onsite to make small-scale heat, for instance for farm buildings. Connection to a gas pipeline only works if there is a pipeline nearby, and if the gas is processed to remove impurities; volumes from any given source are likely to be small.

Another option is to generate a gas of sufficient quality to displace most of the natural gas used in the lime kiln at the Cariboo pulp mill, in local sawmills for drying lumber, or in institutional facilities in the City that are currently heated with gas. The quality requirements are significantly lower than for pipeline-ready RNG; the biomass required would be only enough to satisfy heating needs, as any excess gas would not be of pipeline grade. The most challenging such application is the lime kiln. Several kilns are supplied by commercial wood-fired gasifiers, in Finland and elsewhere. These plants can be purchased from existing equipment vendors. Gas for lumber kilns and building heat can be met with solutions provided by Nexterra, a BC manufacturer of commercial modular gasification systems running on wood.

Last, and most challenging, would be to produce large-volumes of a pipeline-ready RNG, from wood or residues, for direct injection into the pipeline system. Quality requirements in terms of allowable contaminants are stringent, and this is therefore the costliest approach; as a result, economies of scale mean that the plant will have to be sized to take up all available biomass. The GoBiGas and GTI RNG projects, and the volumes of fibre required to supply them, are described in Section 3.

---

[5] https://www.licella.com.au/news/licella-enter-into-new-joint-venture-with-canfor-to-form-arbios-biotech/, visited 2021-07-20.
[6] https://www.licella.com.au/our-story/, viewed 2021-07-31.
[7] So-called FAME Bio-Diesel fuel made from restaurant fats and oil crops is not a true diesel, although it burns like one; the main disadvantage in the Canadian context is poor performance at low temperatures, limiting the substitution rate to 2%.
[8] https://www.upmbiofuels.com/traffic-fuels/upm-bioverno-diesel-for-fuels/, viewed 2021-07-21.
[9] https://www.licella.com.au/pulp-paper/, viewed 2021-07-31.

2.3.4. District heating for Quesnel

Biomass-based district heating in Quesnel would serve to highlight the community's commitment to carbon-neutral solutions. District heating is not economic where the housing stock is spread out, or where the typical home heating system does not involve forced air or a central hot water system; retrofitting homes for central heating is expensive and disruptive[10]. But major institutional infrastructure may be candidates for elimination of fossil fuels. Pulp mill waste heat or bark-fired systems such as the Nexterra gasifier can provide heat. Facilities currently burning natural gas will also have the option of switching to pipeline-supplied RNG, should this become available, rather than connecting to a district heating grid.

2.3.5. Combined heat and power for First Nations communities

Remote communities that do not have access to three-phase power for industrial use, or who rely on diesel-fired generators, are prime candidates for bio-power, and, where feasible, district heating. But advantages to First Nations go well beyond the simple carbon-neutrality benefits: money spent to buy and import fuel can be kept in the community to pay for collection of thinnings and slash, and to operate the plant and grid. The obvious technology is the Organic Rankine Cycle, flagged in the CEC report[11], which has the advantage of not requiring certified steam plant engineers and operators on duty 24/7. Other options include gasification-based CHP plants provided by European vendors; at least one of these[12] is installed at the Alkali Lake First Nations and is provided in the form of a container-based modular system that can be dropped off the back of a truck and plugged in.

2.3.6. Role of the City

Pellets: From the City's perspective, pellets are a low-grade, low-tech product that requires a large gap between the cost of the raw material and the price available at the mill gate before shipping. That gap shrinks considerably the minute there are no residual materials available of sufficient quality to meet German or other standards for pellet quality; these standards usually require a feed made up of clean white sawdust or chips with low levels of bark. Economics typically shift dramatically once whole logs are needed to supplement available sawdust. Local players will make the decision to invest, or not, based on market dynamics and carbon pricing mechanisms.

Liquid biofuels: From the City's perspective, encouraging investment in liquid fuels should be a higher priority than pellets. There are existing and new green policies that will incent this sort of project, and the world market will take every drop Canada can make. But the issues need to be kept in mind: technologies are still in development, and not all technology providers have a good grasp of what is needed for success. The joint venture between Canfor and Licella is a good example of what is possible.

Renewable Natural Gas (RNG): From the City's perspective, encouraging investment in RNG should be a priority, whether a pipeline-ready RNG or a lower-quality gas for use in industrial, municipal or institutional infrastructure.

Gasifiers for lime kilns and lumber kilns have been built at commercial scale, and the decision to invest would belong to the existing forest sector players. But the City can evaluate the applicability of the Nexterra gasifier for municipal or institutional heating needs in cases where the heating is currently with natural gas.

---

[10] Marinova, M., et al., "Economic assessment of rural district heating by bio-steam supplied by a paper mill in Canada ", Bulletin of Science, Technology & Society, 28(2), p.159-173, 2008. doi:10.1177/0270467607313953.

[11] Clean Energy Consulting Inc., "Quesnel Biomass Utilisation, Biopathways Scoping Study", 2021.

[12] https://www.holz-kraft.com/en/products/energyblock.html, viewed 2021-08-16. Note this system is in service at Alkali Lake First Nations.

As for pipeline-ready RNG, the technology has been proven at a commercial demonstration scale in Göteborg, Sweden. Details are given in Section 3.1. One important outcome of that project was the publication of detailed information about the technology: what worked, what didn't, and what should be done next time. It is indeed rare for detailed post-mortems of this type to be published, and the people involved are available for consultation going forward. So while the technology risk is not zero, there is a wealth of information to draw on for the next plant.

A full-scale RNG plant would require a very large amount of wood, and the availability of wood will be the very first question asked by an investor. The concept of the "converted forest" as described on page 51 of the BC Government Old Growth Strategy[13] could be a useful approach to generating that wood supply on a continuous basis, without unduly impacting existing users. A narrow band of fast-growing aspen surrounding Quesnel, with cutting at 20 or 25-year intervals, might be sufficient, and would provide other benefits such as acting as a fire break. With construction of such a plant likely to take at least 5 years, the initial 15 years of wood supply would have to come from elsewhere until this new resource becomes available.

Support for RNG from the BC government is solid; and there is no need to worry about transporting the finished product as long as the pipeline network through town is in place. A solid push from the City to encourage the BC government to move on a converted forest in the Quesnel area, combined with existing support for RNG, could serve to attract large investors, such as existing oil and gas companies seeking to green their portfolio, without unduly impacting the fibre supply currently going to other players in the area. See Section 3 for more information.

Other opportunities: District heating and CHP for the City and First Nations need to be explored in greater detail, but these are relatively simple projects with quantifiable gains in energy efficiency, carbon impact and First Nations self-sufficiency.

[13] "A new future for old forests: a strategic review of how British Columbia Manages for old forests within its ancient ecosystems", April 2020. https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/old-growth-forests, viewed 2021-7-23.

3. Background: detailed economics for RNG in Quesnel

3.1. Economies of scale and supply of biomass

Local energy needs, such as for district heating, can be met with local biomass supplies, with the demand for biomass being limited by the local heating demand.

The demand for biofuels, which is global rather than local, is significantly larger than just the fuel requirements of the North Cariboo region. The conflicting economic drivers of these plants are, on the one hand, economies of scale: All else being equal, a larger plant will be cheaper, per unit of production, to build and run. But on the other hand, a larger plant requires more biomass, in turn requiring longer haul distances; this in turn drives up the cost of biomass which is usually the largest single operating cost. One way to look at this is in terms of the energy content of the wood entering a plant per unit time, in GW: Canada's largest pulp mill produces about 2250 dry tonnes of pulp per day, requiring about 5600 dry tonnes of wood per day. At 18 GJ/t, this is a scale, based on feedstock energy content, of about 1.2 GW. The largest pulp mills in the US South are a bit larger, because southern pine grows more quickly and can be harvested more frequently; Brazilian mills are of the order of 3 to 5 GW because of fast growing eucalyptus. But a small petrochemical refinery is typically 10 GW in scale (150,000 barrels per day at 6.1 GJ/bbl); by comparison the Port of Rotterdam hosts 5 refineries processing oil at a combined rate of about 80 GW, with enough oil flowing through the port to feed 5 more refineries upstream in Belgium, Holland and Germany.

Wood-based biorefineries, especially in Northern climates with slow-growing wood, will therefore always be at an economic disadvantage compared to petroleum refineries. This is due to the distributed nature of biomass compared to concentrated oil and gas supplies and leads to much poorer economies of scale.

IEA and IPCC scenarios make a very strong case that the climate change imperative will require moving very quickly in this area. Business as usual assumptions around economic feasibility of these projects may change rapidly in response to actions by governments, both within Canada and elsewhere. With the essentially bottomless world market for biofuels required by IEA and IPCC scenarios, and given the economic disadvantages of smaller plants, biofuels plants are likely to need to be as large as possible, given available biomass, once the technologies are fully commercial.

3.2. The GoBiGas project

The GoBiGas project aimed to demonstrate RNG from wood waste at a small commercial scale, and was built by the energy utility in Göteborg, Sweden, with Swedish government support. The feed rate was 110 oven-dried tonnes of wood per day (odt/d). This is, to the author's knowledge, the largest attempt so far at generating RNG from wood residues. The process, developed by Danish firm Haldor Topsoe and Chalmers University, was a technical success but was shut for economic reasons. The economics of the GoBiGas plant and two projected larger plants are summarised in the table below[14, 15]. As well, a wealth of information is available on the technical challenges encountered, and this background would be most useful in scaling the process up.

---

[14] Larsson, A., Gunnarsson, I, and Tengberg, F., "The GoBiGas Project: Demonstration of the production of biomethane from biomass via gasification", Göteborg Energi.

[15] Thunman, H. (ed.), "GoBiGas demonstration – a vital step for a large-scale transition from fossil fuels to advanced biofuels and electrofuels", ISBN 978-91-88041-15-9

2021 CDN $	Reference plant 20 MW, CDN $/GJ	Commercial plant 100 MW, CDN $/GJ	Commercial plant 200 MW, CDN $/GJ
Capital cost, depreciation	$19.39	$8.97	$6.54
Capital cost, interest (5%)	$11.63	$5.41	$3.92
Development costs	$1.94	$0.90	$0.68
Operation costs, excluding feedstock	$15.87	$7.49	$5.95
Feedstock cost	$9.79	$9.79	$9.79
Total cost	$58.62	$32.56	$26.88
Wood consumption, odt/d	110	550	1100
Gas production, GJ/d	1450	7250	14,500

The table is based on 2018 Swedish data converted to 2021 $CAD using US inflation data to June 2021[16], assuming inflation for the second half of the year remains constant, and with a currency conversion rate of 1 SEK = $CAD 0.145. Capital costs for the 20 MW plant are given as €119.3M (2021 $CAD 202M) in a separate 2017 report[17], from which costs for 100 MW and 200 MW plants can be estimated at $525M and $800M, respectively. Note that site-specific engineering studies would be necessary to verify these numbers, which are nonetheless consistent with other available information and are likely correct at least at the level of order of magnitude.

3.3. The GTI study: RNG in Stockton, CA

The Gas Technology Institute (GTI) prepared a report[18] outlining the capital and operating costs to build and operate an RNG plant on the site of a wood-fired power plant in Stockton, CA. The economics of this plant, based on a +/-30% engineering study, are summarised in the tables below, where conversion to 2021 $CAD included inflation adjustment as above and an exchange rate of $CAD 1.00 = $US 0.75.

Capital costs are of the order of $500 million. Biomass is assumed available at an average $60/odt (2019 $US 30 per wet short ton at 17% moisture), which may be low. With revenues of $35/GJ, simple payback is 10.5 years before depreciation and taxes; including 20-year straight-line depreciation and a 30% tax rate, the simple payback increases to 32 years. While this is long for an industrial investor, it may well be acceptable for a utility. The study did not include wood-handling equipment, which was assumed repurposed from the existing generating station, or the pipeline and compressors needed for connection to the gas grid.

---

[16] https://www.usinflationcalculator.com/inflation/current-inflation-rates/, viewed 2021-07-22.

[17] Alamia, A., Larsson, A., Breitholtz, C. and Thunman, H., "Performance of large-scale biomass gasifiers in a biorefinery, a state-of-the-art reference", Int. J. Energy Res. 2017; 41:2001–2019, Published online 29 May 2017. https://onlinelibrary.wiley.com/doi/epdf/10.1002/er.3758, viewed 2021-07-28.

[18] "Low-carbon renewable natural gas (RNG) from wood wastes", Gas Technology Institute, February 2019.

	GTI Stockton project Capex	Millions of dollars		
Capital		USD (2019)	CAD (2021)	Percent
	Gasification island	$88	$128	26%
	Cleanup and methanation island	$64	$93	19%
	Direct and indirect construction	$138	$201	41%
	EPC fee	$12	$17	3%
	Contingency	$14	$20	4%
Total Depreciable Capex		$315	$459	93%
	Engineering (FEL 2)	$2.00	$2.92	0.59%
	Engineering (FEL 3)	$4.00	$5.83	1.18%
	Permiting & consulting	$3.00	$4.37	0.88%
	Commission & startup	$12.60	$18.37	3.71%
	G&A (ProjectDevCo)	$3.50	$5.10	1.03%
All-in capital cost		$340	$496	100%

	GTI Stockton project Opex	MM$/y		$/GJ	
Variable costs		USD (2019)	CAD (2021)	USD (2019)	CAD (2021)
	Electricity	$8.31	$12.11	$2.78	$4.06
	Other variable costs	$5.12	$7.46	$1.72	$2.50
	Operations and management	$7.67	$11.18	$2.57	$3.75
Total variable costs, excluding wood		$21.10	$33.63	$7.07	$10.31
	Wood at $30 per short ton, 17% M.C.	$9.32	$13.59	$3.12	$4.55
Total variable costs, including wood		$30.42	$44.35	$10.19	$14.86
	Fixed costs	$8.91	$12.99	$2.99	$4.35
Total operating costs		$39.33	$57.33	$13.18	$19.21

3.4. Nexterra

Vancouver company Nexterra makes a modular gasifier that is relatively inexpensive and easy to operate. Gas quality from the basic unit is sufficient for displacing natural gas or heating oil in heating applications, and units have been sold to universities, lumber mills and others. In particular a pair of Nexterra units were sold to the Tolko mill in Heffley Creek for lumber drying, and this opportunity is still available for Quesnel-based sawmills. Nexterra has also provided two units to the Kruger Products tissue mill in New Westminster, where the gas is used to operate the dryers.

A more expensive version of the base unit is said to produce higher gas quality suitable for use in pulp mill lime kilns, but this has not, to the author's knowledge, been implemented commercially. Finally, Nexterra claims to be able to generate a pipeline-ready RNG, using their modular system and added gas cleanup equipment, but this has not yet been proven at demonstration scale.

3.5. Comparison of full-scale technologies

Both the GTI and GoBiGas approaches may be economic in a $35/GJ environment, at least for utility costing approaches and at the level of accuracy of the estimates in the studies. Site-specific studies would clarify this; for instance, the cost of connecting to the grid (compressors and pipelines) is not included in these estimates. Wood handling equipment was assumed available in the GTI study, and this would also need to be evaluated locally.

A quick overview of the two processes is provided in the table below. A 200 MW GoBiGas plant would generate 14,500 GJ/d, or 2% of BC gas use in 2018; and meet over 13% of the BC government target for RNG displacement or substitution.

The margin of error in these estimates is large. While the 140 MW GTI capital cost estimate appears lower than the 100 MW GoBiGas estimate, these estimates come from different sources and are not directly comparable. Wood handling, pipeline compressors and piping and other auxiliary equipment is likely treated differently in the two estimates. All that can be deduced from the table at this stage is that a 100 to 140 MW plant is likely to cost of the order of $500M, and a 200 MW plant $1,000M. Site specific engineering studies would be needed to validate these numbers.

	GoBiGas 20 MW	GoBiGas 100 MW	GoBiGas 200 MW	GTI Stockton 140 MW
Wood consumed, odt/d	110	550	1,100	650
Wood consumed, MW	24	121	242	143
Gas produced, GJ/d	1,450	7,250	14,500	8,291
Gas produced, MW	17	84	168	96
Efficiency, GJ gas/GJ wood	69%			67%
Yield, GJ/odt	13.18			12.76
Efficiency (GJ gas/GJ wood)	69%			67%
Capital cost, budget estimate (2021 $M CAD)	$200	$525	$800	$500
Minimum pricing, $/GJ	$58.62	$32.56	$26.88	
Simple payback, years, at $35/GJ				31.7
Percent of total 2018 BC gas use	0.20%	1.00%	1.99%	1.14%

3.6. Getting to RNG

3.6.1. Investment sources

Capital costs of a 200 MW plant will be of the order of $1 billion. The capacity and willingness of the forest sector to take on a project of this scale and level of risk is likely low. As well, the RNG process is not familiar to the pulp and paper industry. Pulp mills in Finland and elsewhere run small low-pressure gasifiers to feed lime kilns; but large high-pressure gasifiers, gas-cleanup technologies and high-pressure catalytic reactors necessary to make RNG are well outside the experience of the forest sector.

The oil and gas majors will face a steep decrease in demand for their products if the world is to get to Net Zero by 2050. For example, about half of all petroleum production becomes gasoline, and another quarter goes to diesel.

Converting all automobiles to electric and all long-distance transport to biofuels will cut demand for oil at least in half. On the other hand, these companies are familiar with gasification, gas cleanup and high temperature, high pressure catalytic synthesis processes; they are capable of mobilising large amounts of cash for investment purposes; they are familiar with large-scale energy systems; and they will be looking for new markets for their survival. For all of these reasons, a partnership between the forest sector, which understands harvesting, logistics, pretreatment processes and a host of other aspects of using biomass, and an oil or gas company would be a winning combination. As an example, the French oil company Total, which has in recent years sold its oil sands stakes, has been working with German gasifier provider Thyssen Krupp[19] on a bio-Diesel project. Separately Danish firm Haldor Topsoe, whose main product line is catalysts for high-temperature thermo-chemical processes, worked on the GoBiGas project and is well equipped to provide equipment, in partnership with an appropriate gasifier supplier, to the appropriate investor.

3.6.2. Fibre supply

The first question any investor is going to have is the source, type and cost of the fibre supply. Interviews with industry players in the Quesnel area have flagged ongoing concerns about the declining resource, especially in the aftermath of the mountain pine beetle epidemic and several bad forest fire seasons. As well, the prospect of increasingly dry conditions in the future must be considered.

A hypothetical 200 MW RNG plant will require a wood supply of about 1100 odt/d. While gasification processes can handle bark, all of these processes run better on clean white wood. (Most GoBiGas runs were made with pellets in order to debug the system without feedstock worries; bark proved to be more challenging, in part because long stringy bark pieces tended to plug feeding systems designed for pellets.)

The BC government old growth policy has proposed the concept of a "converted" forest. A ring of aspen plantation around Quesnel, perhaps under joint First Nations management, could feed whole logs to a 200 MW RNG plant. Assuming the density of aspen is 0.450 odt/m^3, 1100 odt/d requires 880,000 m^3/y. At a rough estimate of 200 m^3/ha, this requires 4400 hectares per year, or about 100,000 hectares in total if harvests take place every 25 years. (Estimates were taken from published estimates of North-Eastern BC fibre supply[20] and TSA[21] analysis by FPInnovations; obtaining better data would be critical.)

A similar approach has been described by FPInnovations[22] in the context of a First Nations community, where a circular area of about 30,000 hectares would be sufficient to fuel a local combined heat and power plant, as well as providing a fire break. It is likely, however, that this area assumes lower yields in terms of cubic metres of wood per hectare.

---

[19] ThyssenKrupp activities with Total are described in a few online locations: Radtke, K., "Syngas Technologies at ThyssenKrupp: from Biomass to Jet fuel to Propane to Acrylonitrile", 2017 Syngas Technologies Conference, Colorado Springs, CO. October 15-18, 2017. https://www.globalsyngas.org/uploads/downloads/S3-1-Thyssenkrupp-%20KarstenRadtke.pdf, viewed 2019-08-07 (link is no longer active, 2021-07-28). https://totalenergies.com/energy-expertise/projects/bioenergies/biotfuel-converting-plant-wastes-into-fuel, viewed 2021-07-28.

[20] Industrial Forestry Service Ltd., "A Review of Aspen/Hardwood Resources in Northeast British Columbia", April 2018. https://nr.civicweb.net/document/144452, viewed 2021-07-23.

[21] Quesnel TSA, AAC for 2017. https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/timber-supply-review-and-allowable-annual-cut/allowable-annual-cut-timber-supply-areas/quesnel-tsa, visited 2021-07-23.

[22] https://www.youtube.com/watch?v=EHe_j4TV6Qk, viewed 2021-08-16.

Another option would be to start at 100 MW, as proposed by the GoBiGas reports, instead of going directly to 200 MW; this would be a scale up of 5 times the 20 MW demonstration plant rather than a more ambitious 10X factor.

Separately a well-managed fast-growing forest can serve as a fire-break. And it is possible to consider this forest in the context of a biorefinery, i.e. pulling out more valuable products (peeler logs for veneer, material for LVL or OSB, pulpwood for QRP) before devoting residues to the lowest value product (energy, in this context). If aspen is not drought-tolerant enough, other energy crops may be considered, but the impact on other biorefinery options would need to be considered.

It is clear, though, that this new fibre resource must not come at a cost to the existing forest sector industries already in operation in Quesnel. It is also clear that a new entrant making a biofuel, of whatever type, stands to gain by working with the existing forest sector, through joint ventures, wood supply agreements, or other business arrangements that might make sense.

4. Conclusions and next steps

4.1. Conclusions

In light of the IEA Roadmap to 2050, a range of energy opportunities should be added to the list of options for Quesnel. Relatively easy pathways based on technologies that exist today include the following:

- Solid fuels (i.e. pellets) can displace coal in generating stations, specifically newer ones that risk being stranded in a carbon-constrained world; these are a well understood, low-value product, and will be economic if buyers overseas are prepared to pay a carbon premium.
- Liquid fuels can displace petroleum-based transportation fuels, in particular aviation fuels or diesel fuels for long-distance or off-road use in the Central Interior; the Canfor-Licella project sets an example.
- District heating can be combined with off-grid power generation, for City infrastructure and First Nations communities; the Organic Rankine Cycle process would be one approach for off-grid applications.
- Gaseous fuels can displace natural gas directly at the point of combustion; Nexterra systems can fuel lumber kilns or City infrastructure, and pulp mill equipment vendors offer gasifier for the lime kiln.

But the RNG pathway represents a real opportunity for Quesnel as governments begin to move more quickly on carbon pricing. A plant consuming 1100 odt/d of wood can, in theory, generate up to 5 million GJ/y, displacing 2% of BC's 2017 gas use and meeting over 13% of the BC government target for RNG substitution in gas pipelines. Some very interesting advantages to the City of Quesnel include:

- Allowing the City to serve as a test bed for BC government forest management policies;
- Potentially making new fibre available for technologies that are crucial for battling climate change without unduly impacting existing users;
- Providing employment opportunities for First Nations in forest stewardship and CHP roles;
- Provide opportunities to attract highly trained petrochemical industry experts to the area.

4.2. Next steps

The climate change imperative will imply moving very quickly. Parallel pathways may need to be undertaken.

- Arguably, it is not too early to start talking to equipment vendors and potential investors:
    - ThyssenKrupp and Haldor Topsoe are leaders in the field, and the Chicago-based Gas Technology Institute (GTI) is well-placed to provide advice.
    - Potential investors include West Fraser but also current players in the Calgary oil and gas industry. Total, in France, is a former investor in the oil sands and has been working in this field.
- More detailed analysis for an RNG plant requires a site-specific engineering study. Cost of such a study is likely in the $100,000 range.
- Nexterra offers an inexpensive, modular RNG system, and can also evaluate heating applications in City institutional infrastructure. Nexterra has likely approached operators of lumber kilns in Quesnel in the past.
- The potential fibre to supply 500 to 1100 odt/d, while not impacting existing fibre users, would need to be evaluated in extensive detail by a group including foresters, First Nations, existing fibre users and BC government policy experts. Without novel fibre supply options, the fibre-constrained Central Interior will have trouble supporting this opportunity without impacting the existing forest sector.