Discussion Paper

Newfoundland and Labrador Biomass and Low-Carbon Fuels Opportunities

July 2026

econext
Advancing Newfoundland & Labrador's
Green Economy

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Partially Funded by Natural Resources Canada

Financé partiellement par Ressources naturelles Canada

Canada

Version 2.0 – Published July 14, 2026

1. Executive Summary

The objective of this paper is to generate discussion and encourage further exploration of the local production and adoption of biomass-based low-carbon fuels in Newfoundland and Labrador (NL).

It is estimated that the total waste disposed in NL is 351,417 MT annually[1]. Up to 30% of the waste generated in NL is organic[2], and less than one percent of organic waste is being diverted from landfills[3]. Waste management, exclusive of associated transportation, is responsible for 7% of NL's greenhouse gas (GHG) emissions[4]. The vast majority of these GHGs are caused by the decomposition of organic waste that is landfilled. In addition, there are industrial waste streams which are not disposed of in landfills which are having similar environmental impacts.

Using locally available biomass in the production of low-carbon fuels is emerging as a significant opportunity for NL and can have a number of positive benefits: (1) decreased GHG emissions within NL's waste management sector; (2) decreased GHG emissions for the sectors within which the fuels produced are used in NL; (3) reduced air pollutants in the atmosphere; (4) increased energy security; (5) the valorization of under-utilized waste resources; (6) better value for taxpayers who invest in waste management; (7) new solutions for challenging industry byproducts; and (8) economic development for communities.

There are geographic, economic, and logistical challenges to be overcome in pursuing bio-based low-carbon fuels production in NL. However, circumstances are changing at global and national levels which may help make the provincial case stronger. This includes increasing international focus on energy and the pursuit of net zero, technology advancements, and evolving policy and market forces that are creating new incentives. In addition, local expertise is being built through large scale export-oriented low-carbon fuel production projects in NL which are either online or nearing final investment decisions.

NL can advance the production and adoption of biomass-based low-carbon fuels by: (1) defining the best use cases for available biomass in NL and techno-economic feasibility of low-carbon fuels production; (2) aligning provincial climate and energy strategy with domestic production capabilities; (3) establishing workable business models for low-carbon fuels adoption in NL; and (4) investing in fuel blending/testing research and infrastructure.

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[1] https://mmsb.nl.ca/wp-content/uploads/2025/04/2019-Waste-Report-Card.pdf
[2] https://mmsb.nl.ca/education/composting/
[3] https://www.gov.nl.ca/eccc/files/waste-management-final-report-review-pswms.pdf
[4] https://www.gov.nl.ca/ecc/occ/greenhouse-gas-data/

2. Background and Context

2.1 Introduction

Organic waste represents as much as 30% of the waste generated in Newfoundland and Labrador (NL)[5]. Waste management, exclusive of associated transportation, is responsible for 7% of NL's greenhouse gas (GHG) emissions[6]. The vast majority of the emissions associated with waste management are caused by the decomposition of organic waste that is landfilled; the primary gas produced is methane which is a GHG that is 25-28 times more powerful than carbon dioxide.

Organic waste contains valuable nutrients from which value can be extracted. 'Biomass' describes recently living (but now dead) organic matter such as crops, animal residues, and other biological materials. Biomass waste is the by-product or residues from biomass processing, for example food waste, woodchips / bark from forestry operations, fish offal from fishery, or husks from corn production.

Biomass (and its residues) can be used in energy production in the form of electricity, heat, and/or fuels. This opportunity historically has, perhaps, not been as clear for NL. Climate change pressures were not as great; biomass energy technologies were in their infancy; there were few opportunities for domestic use of the energy produced; and export was challenging. However, circumstances are changing which may present a more compelling business case for the province – particularly as it relates to low-carbon fuels production.

In 2025 econext completed a study with KPMG titled "*Opportunities for Domestic Clean Fuels Use in Newfoundland and Labrador*". This study explored potential low-carbon fuel use according to various economic sectors within the province.

The outlook for the future adoption of low-carbon fuels is based on many different variables and is difficult to predict – particularly within a localized geography. However, the research did help to advance discussions and outline some of the opportunities and challenges for low-carbon fuels adoption within specific sectors in NL.

The estimates in this study were made based on high-level assumptions using available greenhouse gas (GHG) data, International Energy Agency (IEA) projections, and practical observations.

Subsequent further investigation by econext into marine transportation, surface transportation, and electricity sectors helped to advance an understanding of the role that

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[5] https://rethinkwastenl.ca/food-waste/
[6] https://www.gov.nl.ca/ecc/occ/greenhouse-gas-data/

low-carbon fuels can play in NL's economy. Increasing clarity on potential domestic low-carbon fuels use demands further analysis on the local feedstocks that could be used to produce them.

2.2 Discussion Paper Purpose

The objective of this discussion paper is to generate discussion and encourage further exploration of valorizing organic waste streams in NL for the purposes of low-carbon fuels production.

Data regarding waste streams in NL (particularly industrial waste streams) is incomplete, while biofuel technologies and their applications are quickly advancing.

While every effort has been made to provide sources for information provided, this discussion paper is not an academic publication and is not intended to be. This is a document produced internally by *econext* staff through secondary research via information known to be available in the public domain.

econext welcomes all feedback that can help improve the quality and usefulness of this discussion paper. Feedback can be sent to info@econext.ca.

2.3 About econext

econext is a not-for-profit industry association dedicated to advancing environmentally sustainable economic growth in Newfoundland and Labrador. With a network of approximately 200 member businesses, research institutions, governments, and organizations, econext serves as a leading voice for the province's green economy.

econext has four key areas of focus:

Member Opportunities
We connect our members with opportunities to grow their businesses in the green economy.

Public Policy & Advocacy
We identify, analyze, and champion policy frameworks that support sustainable economic growth in NL.

Capacity Building
We equip NL's businesses, communities, and workforce with skills, experience, and knowledge needed to contribute to green economic growth.

Innovation
We identify emerging trends and provide insights that inform policy, investment, and innovation that advance clean growth in NL.

Together, we strengthen NL's green economy by supporting our members and help drive sustainable growth and innovation across the province. Learn more at econext.ca.

3. Waste Management in NL and Changing Circumstances

3.1 Current Status and Structures

Estimates of NL's waste stream composition were produced by Environment and Climate Change Canada (ECCC) in 2016.

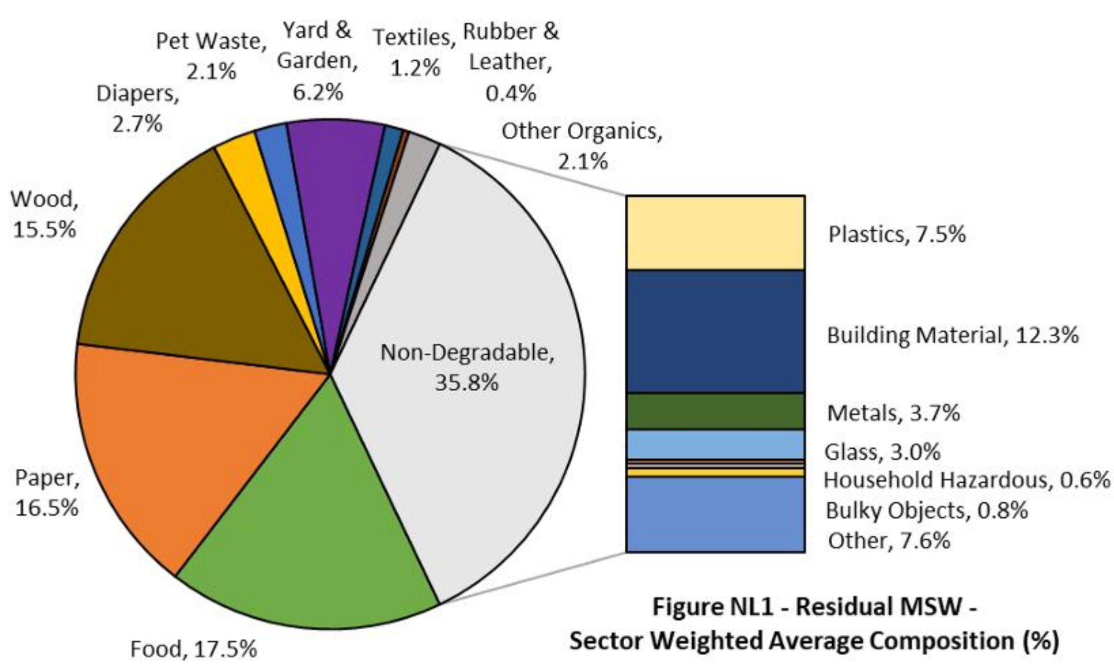

Figure 1: Residual Municipal Solid Waste – Sector Weighted Average Composition[7]

[7] https://publications.gc.ca/collections/collection_2020/eccc/en14/En14-405-2020-eng.pdf

NL generated approximately 520,000 metric tonnes (MT) of waste. Consistent with national trends, the majority of waste generated (57%) came from non-residential sources and 43% from residential sources. The amount of total waste disposed was 390,000 MT and the total diverted from landfills was approximately 130,000 MT or 25%[8].

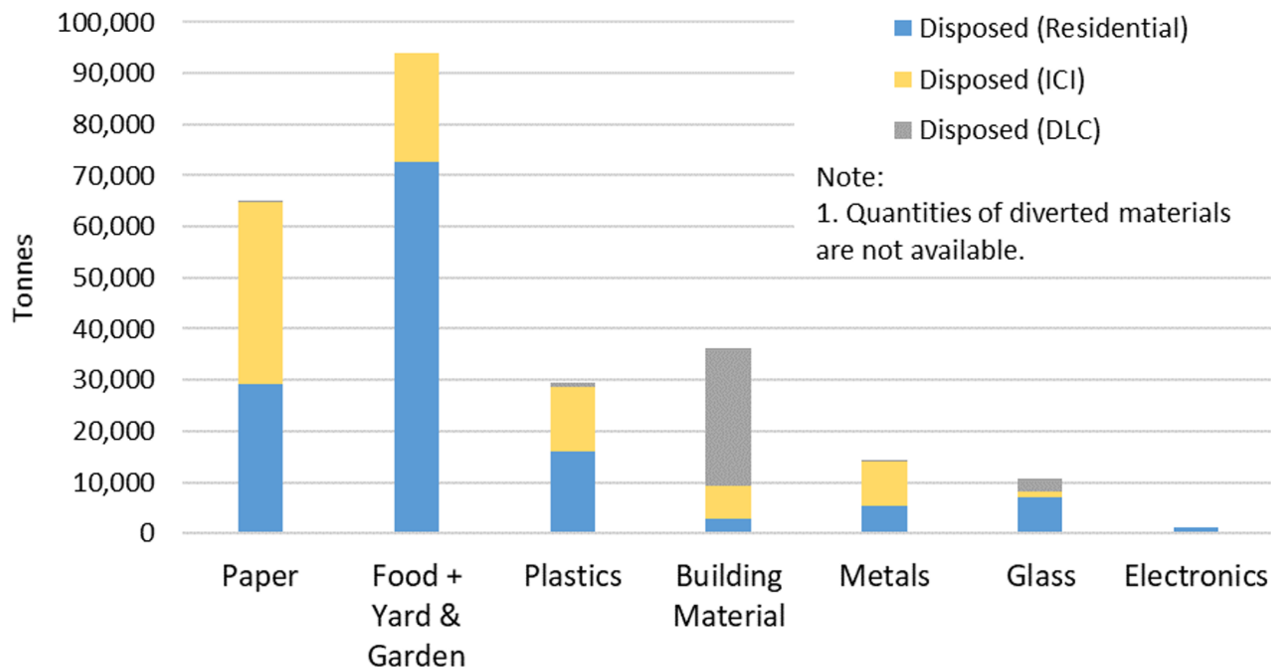

Figure 2: Quantity of select materials in Municipal Solid Waste disposed (by sector) – 2016 (tonnes)[9]

A 2019 report notes that total waste disposed in NL had decreased to 351,417 MT with 122,846 diverted[10].

It is estimated that up to 30% of the waste generated in NL is organic[11]. Current estimated organics diversion represents less than one percent of the total municipal solid waste stream, or 2.5% of the organics waste stream. The remaining organic material is disposed in landfills. Adding to this situation is the fact that all industrial organics waste is being disposed at the one authorized landfill in the province currently, and the landfill is not lined[12].

The responsibility for waste management in NL rests with regional service boards and other local waste management authorities. This includes responsibility for all related operating costs and ongoing system capital requirements (e.g., equipment replacement, new waste containment cells, and site reclamation) to manage waste.

[8] https://www.gov.nl.ca/eccc/files/waste-management-final-report-review-pswms.pdf
[9] https://publications.gc.ca/collections/collection_2020/eccc/en14/En14-405-2020-eng.pdf
[10] https://mmsb.nl.ca/wp-content/uploads/2025/04/2019-Waste-Report-Card.pdf
[11] https://mmsb.nl.ca/education/composting/
[12] https://www.gov.nl.ca/eccc/files/waste-management-final-report-review-pswms.pdf

Eight regional service boards on the island portion of the province are established under the Regional Service Boards Act. Only five boards are active currently:

- Northern Peninsula Regional Service Board (2005)
- Central Regional Service Board (2008)
- Eastern Regional Service Board (2011)
- Western Regional Service Board (2013)
- Burin Peninsula Regional Service Board (2013)

Inactive boards include: Discovery Regional Service Board (2013); Coast of Bays Regional Service Board (2015); and Baie Verte Peninsula-Green Bay Regional Service Board (2018). Labrador comprises the remaining four waste management regions, in Western, Central, Southern, and Northern Labrador.

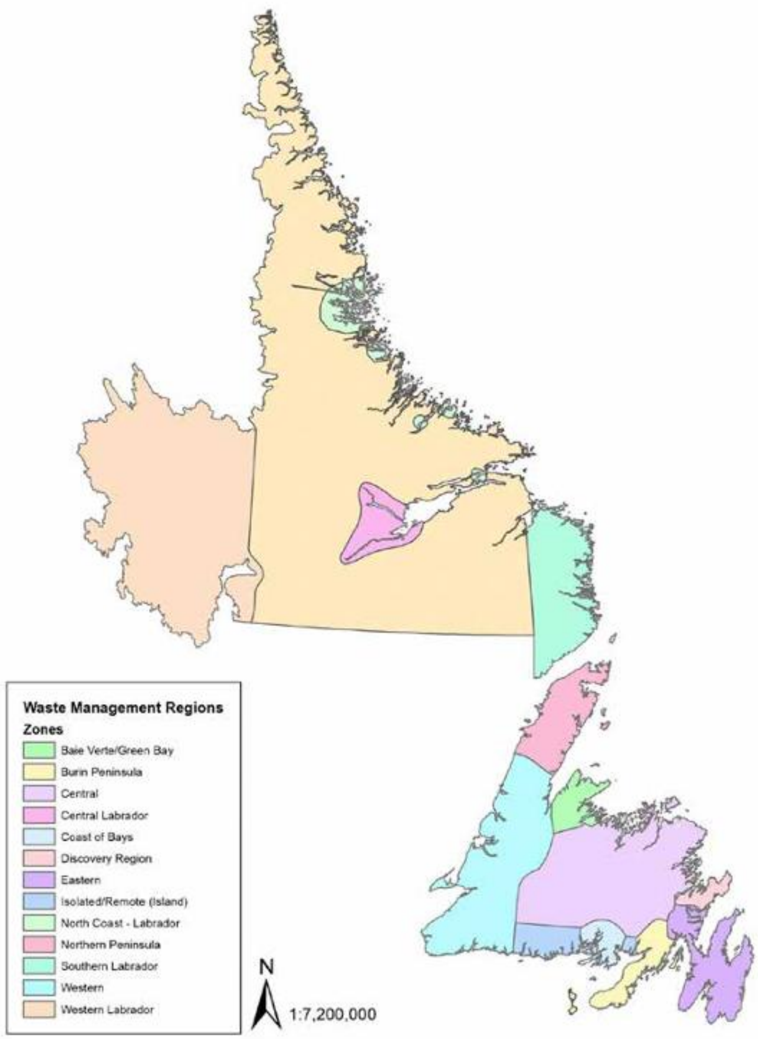

Figure 3: Waste Management Regions / Zones in NL[13]

[13] https://www.gov.nl.ca/eccc/files/waste-management-final-report-review-pswms.pdf

Modern waste disposal facilities now operate at Robin Hood Bay and Norris Arm, and comprehensive waste transfer systems are in place in the three regions on the island (i.e., east, central and west) that are sending waste to the final disposal sites. A new landfill operates in Western Labrador, serving Labrador City and Wabush. As new landfills were constructed or upgraded, old ones, 170 (72%) of them, closed[14].

Regulatory oversight remains within the provincial government. The Department of Environment, Conservation, and Climate Change's Pollution Prevention Division houses the Waste Management Section which is responsible for regulating the collection, transportation, storage, treatment and disposal of municipal solid wastes, hazardous wastes, and special wastes (e.g., asbestos). Major activities include: the development of environmental standards to support the provincial Waste Management Strategy for municipal solid waste; management of the movement of hazardous and special wastes through registration of waste generators and licensing of transporters; management of inventories of PCB wastes throughout the province; regulation of waste management systems for farms and compost operations; and regulation of environmental industries including soil treatment facilities and metal recycling operations[15].

The Multi-Materials Stewardship Board (MMSB) is a provincial crown corporation which exists to advance sustainable waste management in the province with a focus on waste diversion and reduction to protect the long-term health and well-being of NL's environment and communities[16]. The MMSB develops, manages, oversees, and administers provincial waste diversion programs – specifically the province's used beverage containers and used tires programs. It leads and supports public education programs in NL focused on waste management and provides funding for community waste management initiatives and research and development. The MMSB reports to the Minister of Environment, Conservation, and Climate Change.

In its Provincial Solid Waste Management Strategy of 2002, the Government of NL made a commitment to reduce materials going to landfill by 50%. As organic waste represents a third of waste generated in NL, this commitment is difficult to achieve without addressing this waste stream. While significant progress has been made in other areas outlined by the 2002 strategy, decisions have not been made on large-scale solutions for organic waste. Generally, producers of organic waste are not required to separate from other waste streams, and landfill operators are not required to find special solutions.

Historically the diversion of organic waste in NL has been challenging due to its large geography, relatively small and dispersed populations and industrial operations, and the difficult achieving economies of scale for known solutions (processes and technologies).

[14] https://www.gov.nl.ca/eccc/files/waste-management-final-report-review-pswms.pdf
[15] https://www.gov.nl.ca/eccc/env-protection/waste/
[16] https://mmsb.nl.ca/about/

3.2 Changing Circumstances

The most recent review of NL's waste management strategy took place in 2019[17]. The review pointed to the importance of diverting organic waste but focused almost exclusively on composting programs as the probable solution. 2019 research undertaken exploring waste-to-energy potential in NL was referenced which focused on electricity generation; the review's conclusion as it relates to this study was that the province should keep itself apprised of key technology developments. The review recommended that an organics waste management strategy be developed, but this was not actioned.

The 2019 review has quickly become outdated. Developments and evolving circumstances since 2019 provincially, nationally, and globally are creating opportunities for biomass energy – specifically low-carbon fuels production – that have the potential to advance organics waste diversion in NL. These changing circumstances include:

- Increased national focus on **energy security**. Geopolitical events and disruptions are driving a renewed priority on the local production of energy (including fuels) to meet local demands.
- Increased focus on climate change mitigation and **the pursuit of net zero** greenhouse gas emissions. Tackling climate change has become an international, national, and provincial priority with policies and incentives to take action being put in place.
- Biomass energy **technologies have advanced** and are maturing, possibly addressing the geographic and economies-of-scale challenges in NL.
- **Policy and market forces** – within NL and abroad – are creating new demands for low-carbon fuels and are creating new domestic and export opportunities for biomass energy.
- Biofuels are now common alternatives in transport fuels either through full replacement or **blending** with conventional (petroleum-based) fuels.
- **New incentives** (such as investment tax credits) have been put into place to support biomass energy projects.
- Large low-carbon fuels are **online and producing product**[18] or are making their way through regulatory processes towards final investment decisions[19], resulting in new potential synergies with the private sector.

Given the changing circumstances described above, diverting organic waste streams for the purposes of low-carbon fuels production is an opportunity that is worthy of further investigation in NL.

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17 https://www.gov.nl.ca/eccc/files/waste-management-final-report-review-pswms.pdf
18 https://econext.ca/econext-celebrates-first-commercial-production-of-clean-fuels-in-newfoundland-and-labrador/
19 https://northatlantic.ca/green-energy-hub/phase-1/

4. Benefits of Organic Waste Diversion

There are a variety of benefits of organic waste diversion ranging from environmental to economic with positive impact potential for governments, taxpayers, communities, and the private sector.

Environmental Benefits

There are numerous environmental benefits that can be gained through organic waste diversion. Organic waste, when decomposing, creates GHG emissions. In a landfill, methane is the primary GHG produced which has 25-28 times more global warming potential than carbon dioxide over a 100-year period. In NL, emissions from waste account for 7-8%[20] of the province's total GHGs. Diverting organic waste from landfills can help NL to fight climate change and meet its net zero by 2050 commitments. Organic waste disposed of in a landfill also breaks down to create harmful leachate which has the potential to pollute local topography and water bodies. Diverting up to 30% of waste, the portion attributed to organics, will also reduce the amount of NL's pristine land needed to be used for the disposal and burying or garbage. If organic waste is used to produce low-carbon fuel that is consumed domestically, there would also be GHG reductions associated with the displacement of conventional fuel use.

Reduced Operational Costs

A 30% reduction in waste volumes would either reduce the weight of or needed frequency for its transportation (or achieve both). This translates into fuel savings, meaning reduced costs and reduced GHGs. ECCC provides a GHG calculator that estimates the mass of landfill (diverted) organic waste and associated GHG emissions (e.g. landfill use and energy related to fuel and transport to site). A 30wt% reduction to landfills would reduce GHG emissions from ~16,000 tonnes CO_2e/yr to ~11,200 tonnes/yr. A reduction in waste volumes will also have a positive impact on the operating costs of a landfill. While these efficiencies may not correspond exactly to the reduction in waste (i.e., amount to 30% savings), there will be variable operating costs that will see a reduction. Less waste being received and handled will reduce transportation, fuel, electricity, machinery, supplies, labour, and other costs. The potential for savings should be quantified to allow for a full valuation of the benefits of organic waste diversion.

[20] https://www.gov.nl.ca/eccc/occ/greenhouse-gas-data/

Extended Life for Landfills

Landfills are not renewable resources; they have a lifespan. Lifespans vary from location to location depending on available space or other factors. The average landfill can last between 20-50 years[21]. New landfills are expensive, potentially in the scale of tens of millions of dollars to construct and establish – and hundreds of millions of dollars over their operational life. Moreover, retired landfills still need to be monitored and maintained for decades after their closure. Therefore, whatever can be done to extend the life of a landfill can delay significant new costs that society will shoulder. As organic waste represents almost a third of total material being landfilled in NL, its diversion would have a significant impact on the lifespan of existing landfills. Every 3-4 years of diversion would buy landfills an extra year of life as compared to the status quo. Or, if a landfill is expected to close in 20 years, organic waste diversion could extend that life another 5-6 years. The deferral of new landfill financing, new landfill construction, and new landfill maintenance will give decision makers precious extra time to plan and invest.

Reduced Costs for Municipalities and Societal Savings

The landfilling of waste is not free. The most common practice to charge landfill users is through a 'tipping fee' – a cost per tonne of waste charged for disposal at the site. Industrial and commercial operators are well acquainted with tipping fees as they pay them directly. However, residents and small businesses are often unaware that they also pay these costs. Municipalities are subject to the tipping fee; when municipal waste management fleets dump at landfills, their owners pay per tonne of waste disposed of. Municipalities, of course, pass these costs on to their residents through taxes or fees. If organic waste - representing 30% of all waste in - could be diverted from the landfill in a manner which is less costly than the tipping fees charged, this will result in savings for taxpayers. The commercial tipping fees in NL in 2026 range from $94.50 - $164 per tonne of waste disposed.

Regulatory Compliance

The creation of GHGs is already being discouraged in Canada through various federal/provincial carbon pricing frameworks. While landfills (and waste management in general) have not been subject to carbon pricing in the past, it is expected that the sector will be targeted for regulation in the future. For example, in June 2024 the federal government proposed new regulations that would require landfills to control methane emissions and ensure landfill gas-recovery systems capture as much methane as

[21] https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3410024301

possible[22]. The proposed regulations would aim to reduce methane emissions from Canadian landfills by about 50 percent by 2030 (from 2019 levels). The diversion of organic waste from landfills will have a substantive effect on GHGs and therefore help ensure NL landfills (and their owners) are in compliance with the proposed regulations.

Private Sector Benefits

There are a number of possible benefits for businesses through organic waste diversion – particularly for larger commercial / industrial operations which produce significant quantities (e.g. aquaculture, agriculture, forestry industries). First, there is the potential for businesses to reduce their costs by avoiding tipping fees (directly or indirectly through their waste management provider). Second, there is the potential for businesses to generate new revenue streams for their operations if there is value in their waste stream (i.e., there is an off-taker willing to purchase their organic waste, or they themselves engage in extracting this value). Third, better management of waste helps contribute to a business' environmental, social, and governance (ESG) commitments, its corporate social responsibility (CSR) objectives, or its certifications (i.e., BOMA Best, LEED). At present, the limited options for organic waste diversion pose challenges for companies in NL.

There are a variety of benefits that could be realized through organic waste diversion. Specific solutions are most often tied to specific waste streams and their characteristics. Therefore, to explore solutions, it is necessary to have a reasonable understanding of what the sources of organic waste are in NL.

5. Sources of Organic Waste in Newfoundland and Labrador

As with any jurisdiction, NL has its own unique mixture of organic waste streams.

ECCC provides an estimate[23] of landfill composition annually in NL, from which assumptions can be made about tonnage of various streams of interest:

Stream	Percent	Tonnes
Food	17.5%	69,182
Paper	16.5%	65,228
Wood	15.5%	61,275

[22] https://www.canada.ca/en/environment-climate-change/news/2024/06/the-government-of-canada-introduces-new-measures-to-regulate-methane-emissions-from-canadian-landfills.html
[23] https://publications.gc.ca/collections/collection_2020/eccc/en14/En14-405-2020-eng.pdf

Yard & Garden	6.2%	24,510
Other Organics	2.1%	8,302

Figure 4: Estimated Landfill Composition in NL with a Focus on Biomass

Two important qualifications need to be made when considering this data:

1. Of waste streams landfilled in NL, it was estimated in 2022 that 204,906 tonnes of waste (or 56%) came from non-residential or commercial sources[24].
2. Not all industrial waste streams are sent to landfills; this is particularly true for organic waste streams (i.e., agricultural waste).

Information regarding organic waste streams in NL (particularly industrial waste streams) is incomplete. While recent efforts have been undertaken to better quantify these waste streams, more must be done to obtain a fulsome understanding of organic waste in NL.

Below is an overview of the organic waste streams that exist within NL. Each of these waste streams has their own series of details and complexities, and this information should only be used for high-level consideration. One of the purposes of this discussion paper is to promote and facilitate the pursuit of continuous improvement in NL's organic waste data.

5.1 Agriculture

NL is home to over 400 different farms, with its largest commodities being in dairy, chicken, eggs, greenhouse and nursery, and vegetables. There are also pork, sheep, fruits, fur, and beekeeping operations. Organic waste in agricultural operations can vary significantly – from spent crops and crop residues to livestock waste such as manure, offal, and mortalities. Agricultural waste in NL is not well documented or understood, and it is assumed that much of it is not sent to landfills.

5.2 Forestry

Organic waste in the forestry industry comes from a variety of sources. This includes sawmill residues like bark, shavings, sawdust, and trim blocks. In NL there are many seasonal sawmills, however the majority of production comes from three large operations. It is estimated that total production from these sawmills is approximately 356,000 cubic

[24] https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3810003201

metres of wood fibre a year. The exact breakdown of organic waste differs according to the mix of machinery that is employed, but in general bark represents approximately 5-10% of total log volume with sawdust and shavings also amounting up to 10%. Bark retention varies greatly by season, with more bark bale to be retrained during the colder winter months; numbers range from 100% bark retention for logs delivered between November and March – down to 60% in June and July.

The industry is partly driven by the operations of a local pulp and paper mill, which is both a user and producer of organic waste streams. The mill has a biomass cogeneration plant, using industry waste including much that listed above. It is estimated that the mill uses 680,000 cubic metres of wood fibre in its operations annually, which includes contributions from the sawmills stated above. In addition, sludge is the main organic residual generated from the wastewater treatments of the pulp and paper industry. This sludge is also used in the cogeneration plant. While not an organic waste, several of the province's largest forestry operations emit steam as part of their processes which – as it stands – remains a wasted energy source. Forestry waste is relatively evenly geographically distributed across the island, with one of each of the large sawmills located in rural areas of Eastern. Central, and Western Newfoundland.

5.3 Household/Commercial Organics

Household/commercial organics includes biomass waste disposed of or diverted within municipal and/or regional systems. In 2019, it was estimated that 474,263 tonnes of waste was generated in NL[25]. Approximately 155,000 MT of organics waste is generated annually in NL with only a small fraction (2.5%) diverted, representing approximately 30% of all waste[26]. Second Harvest reports[27] that 46.5% of all food in Canada is wasted. Neighbourhood-scale composting has previously been piloted in NL via curbside or community collections, and residents have been encouraged to compost in their backyards for some years. However, for the most part, household / commercial organics are a waste stream for which there is no plan to address at large-scale. In addition, used cooking oil (i.e., from restaurants) is treated as a hazardous waste and businesses are encouraged to arrange for its pickup or drop-off at collection sites.

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[25] https://mmsb.nl.ca/wp-content/uploads/2021/11/2019-Waste-Report-Card.pdf
[26] https://www.gov.nl.ca/releases/2020/mae/0129n08/
[27] https://cdn.prod.website-files.com/6618114bae6895cc12d3dc1d/671695f108d9e689b40723a0_acfw-technical-updated.pdf

5.4 Fishery

In 2022 there were 89 fish processing plants in the NL: 67 primary, 4 secondary, 5 aquaculture, and 13 in-province retail establishments. Processing ranges from shellfish (snow crab, shrimp, lobster, etc.), to groundfish (turbot, halibut, flounders, cod, redfish, etc.), to pelagic fish (capelin, herring, mackerel). Aquaculture processing would include salmonids and shellfish (including mussels). Each of these plants would have organic waste streams, but their volumes are not well known.

Beyond activity in plants, NL is currently exempt from regulations banning fish offal (i.e., heads, viscera, and other parts discarded) from being disposed at sea. It is reasonable to assume that this practice will, in time, be discouraged. This can be a substantive amount of biomass. For example, in NL the total allowable catch of 10,000 tons of cod for 2021 in an area identified as 3J3KL resulted in an estimated 2,000 – 3,000 tonnes of cod liver (and other gut material) that is currently being discarded in the ocean. In addition, there is an undetermined volume of heads and frames from groundfish production, including the recreational cod fishery.[28]

A recent study has shown that alternative fish waste disposal and utilization options remain limited in the province and seem to be declining[29]. This research estimated that 59,158 tonnes of organic waste was discarded from fisheries, with groundfish accounting for 26%, pelagics 14%, shrimp 23%, crab 26%, and other species 12% of the total. The research also made determinations on the 'availability' of each feedstock – of which there is some uncertainty depending on alternative uses, location of discards (at sea), etc.

5.5 Aquaculture

Organic waste stemming from aquaculture varies greatly depending on the species being farmed and the methods used in the farming processes. Commercial aquaculture production in NL is comprised of salmonids (i.e., Atlantic salmon and steelhead trout) and shellfish (i.e., blue mussels and oysters). Salmonid production was 15, 018 tonnes in 2023 with shellfish production being 4,065 tonnes[30].

Salmonid waste occurs at both the farming and processing stages. If fish are processed 'head on gutted' then waste consists of guts/viscera and is about 10% of fish weight. If fish are fully filleted, then the heads, frames, and trims add another 2-5% or so. The observed rate of morts of finish varies by producer, but it is generally in the 5-10% of production

[28] https://www.gov.nl.ca/ffa/files/Seafood-Industry-Year-in-Review-2022.pdf
[29] https://www.mitacs.ca/our-projects/nl-seafood-sector-organic-waste-inventory-assessment/
[30] https://naia.ca/index.php/aquaculture-nl/production-stats

range. Shellfish waste consists of rejects, broken shells, algae and barnacle waste from shells, etc., and represents up to about 10%-15% of total production and can vary by season.

It is understood that most organic aquaculture waste in NL (i.e., from offal and mortalities) are utilized in pet food/meal production locally. Projected industry growth in NL to 50,000 tonnes in annual production may present some challenges in the use of this organic waste. Current producers will be unable to manage that volume of discards and morts with their current capacity[31]. This might be addressed through expansion, but there are opportunities to explore other options for utilization of this waste stream.

There are a variety of challenges to seizing opportunities associated with this waste stream ranging from industry coordination to the shipping, storage and freezing of waste products.

There is an emerging volume of 'sludge' from hatchery production, discharged as part of effluent within wastewater. Sludge composition includes organic material from feed and fish waste. This waste stream is presently dealt with through industrial disposal contractors; however, increasing volumes will increase costs.

5.6 Clearing and Trimming

The trimming of trees and bushes at scale occurs on a regular basis to protect highways, transmission lines, etc. Meanwhile, clearcutting occurs for roads, industrial developments, commercial and residential developments, etc. In addition, the creation of 'firebreaks' are likely to become more common in an effort to help communities protect themselves from increased fire risks that are resulting from climate change. These firebreaks will result in significant clearing. In some cases, biomass clearing (for other purposes) can result in substantive material which could benefit from having a path to disposal which created more value.

5.7 Construction and Demolition Lumber

Considerable lumber enters NL landfills as waste from construction or demolition projects. There is potential for lumber to be used in the same ways as other forestry residues, however it is generally more complex because of contamination. First, lumber is likely to be mixed in with (or even connected to) a wide variety of other different wastes from which it must be separated. Second, lumber may have been treated or glued which presents chemicals which may be harmful when used in biomass to energy processes.

[31] https://econext.ca/wp-content/uploads/2024/07/Key-Findings-Report-Final-July-8%5EJ-2022-1.pdf

5.8 Wastewater Sludge

There are over 700 wastewater outfalls registered in NL. The majority of these outfalls are not treated, leading directly into the ocean or rivers. The vast majority of treated outfalls in NL are done so with septic tanks. Solid organic waste materials separated from water during treatment processes ('sludge') can be a biomass input for various technologies. For scale, using locally manufactured systems[32] consider that 100 homes would be expected to generate 22,299 litres per year of sludge or approximately 25 tonnes. Large-scale wastewater treatment plants (WWTP) such as that which services the St. John's, Mount Pearl, and Paradise have anaerobic digesters on site which produce methane that the facility uses for its own operations. Wastewater sludge is also a byproduct of various industrial processes (i.e., aquaculture, paper mill, and other activities) which have different compositions and qualities than municipal wastewater and are treated differently. If there was value in this sludge which could be harnessed in a biomass energy project, revenues could be generated that may help offset the operational costs of wastewater treatment.

5.9 Landfill Gas

Much of the organic waste identified above ends up at landfills. Landfills are not significant solid waste producers unto themselves, however it is worthwhile considering the gas that is produced as a result of landfill processes. Landfills can be a significant source of GHG emissions, emitting nearly 400 kg CO_2e per tonne of organic waste[33]. Landfills contain the same anaerobic bacteria present in a digester that break down organic materials to produce methane (CH_4). In most cases, including in all cases in NL, this biogas (and other byproducts) escape into the atmosphere. CH_4 is 25-28 times more potent as GHG than CO_2. Instead of allowing CH_4 to escape into the atmosphere, it can be collected and used as energy. The island of Newfoundland has two primary landfills in St. John's (Robin Hood Bay Waste Management Facility) and Norris Arm (Central Waste Management Facility), with approximately 40 other smaller landfills throughout the province. Labrador has small landfills in its Western and Central regions, with localized landfills / dump sites in remote areas. Landfills will emit CH_4 for decades even after they are closed. The Robin Hood Bay facility currently generates about 9,000,000 cubic meters of gas at about 50% methane content[34].

[32] https://bmsna.com/

[33] https://pubmed.ncbi.nlm.nih.gov/32628836/

[34] https://stjohns.bidsandtenders.ca/Module/Tenders/en/Tender/Detail/0d88adb0-055d-47a0-a484-f18ccf814b97

5.10 Cultivating Biomass

While this discussion paper focuses on the management of existing organic waste streams in NL, there is the potential for the farming and harvesting of biomass specifically for energy purposes. For example, common feedstocks grown for biomass energy purposes include agricultural crops and forest fibre (trees). It is possible for such feedstocks to be harvested in a sustainable manner. A key consideration in cultivating biomass is how it could otherwise be used; for example, the use of crops like corn for fuel production is often considered less than ideal as the produce has value as a food. It is worth considering what biomass can be cultivated in NL with a minimal – or positive – impact on the environment. A focus on invasive species, unwanted growth, etc. can help minimize environmental and possibly societal impacts. Engaging in the farming and harvesting of biomass may help achieve the economies of scale required for certain technologies should waste materials not be sufficient. Environmental impacts of cultivating biomass for energy purposes notwithstanding, if cultivated biomass enables the use of otherwise wasted organic waste streams, the net environmental benefit may be positive.

There are many different potential sources of biomass that could be used in low-carbon fuels production. While volumes in NL are relatively low and will present economies-of-scale challenges, with modern technology some sources may be viable technically and economically. To understand the best options to pursue with the biomass that is available, it is important to have a basic understanding of the various low-carbon fuels that could be produced and where they might be demanded.

6. About Low-Carbon Fuels

With various sources of biomass potentially available for low-carbon fuels production in NL, it is instructive to have a baseline understanding of what these fuels are. Different sources of biomass can be best suited for the production of specific fuels – which can be done through a variety of different processes and technologies.

Clean fuels, or 'low-carbon' fuels, are fuels that produce lower GHGs than traditional (or conventional fossil) fuels on a life-cycle basis[35]. Their increased production and use is viewed as being vital in the world's fight against climate change and the pursuit of net zero. What are their benefits within the NL context?

[35] https://natural-resources.canada.ca/energy-sources/clean-fuels/clean-fuels-fueling-future

6.1 Benefits of Low-Carbon Fuels

There are a number of benefits to the adoption of low-carbon fuels.

Decreased GHGs: The use of low-carbon fuels allows for lifecycle GHG reductions. These reductions will either be associated with the direct use of the fuel (e.g., a clean fuel will produce far fewer GHGs) and/or the displacement of conventional fossil fuels. The amount of GHGs replaced will depend on the low-carbon fuel used, how it is produced, and what is displacing.

Reduced air pollutants: The use of low-carbon fuels is often associated with the reduction of other air pollutants such as particulates (tiny particles of solid matter that lodge in the lungs and deposit on buildings), carbon monoxide, sulfur dioxide, hydrocarbon, and other air toxins[36]. Each low-carbon fuel and the process used in their deployment will result in unique reductions. The amount of air pollutants reduced will depend on the low-carbon fuel used, how it is produced, and what it is displacing.

Energy security: Many low-carbon fuels can be produced using local renewable resources (i.e., biomass, electricity, etc.) Even when locally produced fuels are blended with conventional fuels, this: (1) displaces the volume of fuel that must be imported; (2) protects against supply and supply chain disruptions caused by geopolitical events; (3) protects against price volatility of globally traded commodities; and (4) provides for domestic fuel production and supply capabilities that can be called on when needed in an emergency. For example, a diesel fuel blended with 30% locally produced biodiesel and renewable diesel displaces 30% of the required diesel to be imported and the geopolitical impacts on that import which are out of the user's control.

Valorization of wasted resources: Oftentimes organic waste material (e.g., household organic waste, forestry residues, fishing and aquaculture discards, agricultural waste) are sent to landfill. This 'waste' is actually a resource which has value and can be considered as feedstock for low-carbon fuels production. Moreover, the diversion of these waste streams away from landfills reduces the harmful GHGs that are caused by the decomposition of biomass. It is this benefit which this discussion paper primarily explores, within the NL context.

Economic development and growth: The production and distribution of low-carbon fuels (including the diversion of biomass from landfills) creates jobs, wealth, and improved environmental outcomes for communities. Many low-carbon fuels have value and opportunity domestically, while also are tradeable commodities on a regional, national, and global scale. As various biomass-derived fuels are interoperable with their e-fuel

[36] https://advancedbiofuels.ca/net-zero

counterparts, there are opportunities for the scaling of production utilizing electricity as an additional feedstock.

6.2 Categorizing Low-Carbon Fuels

There are many types of low-carbon fuels. Before identifying specific low-carbon fuels that have the potential for production and use in NL, it is beneficial to have an understanding of the relevant types of fuels and how they are generally produced and used.

Low-carbon fuels can be produced from a variety of feedstocks, such as agricultural and forest biomass, waste materials, electricity, and fossil fuels with carbon capture and storage[37].

Some low-carbon fuels can be used to supplement conventional fuels; some can be used as a direct replacement for conventional fuels within existing equipment and infrastructure; while others are replacements that require new equipment and infrastructure.

It is helpful to organize low-carbon fuels into three categories that acknowledge these important differences: (1) biofuels; (2) renewable biofuels; and (3) e-fuels.

Biofuels

Biofuels are fuels made from recently living organic matter (biomass) like plants, agricultural waste, or animal fats, offering alternatives to fossil fuels. There are a wide variety of biofuels depending on the type of biomass used and the processes used in their creation. Biomass can be converted to fuels through different processes including direct combustion, thermochemical and chemical conversion, and biological conversion. A biofuel can be produced with much lower GHGs than their fossil fuel-based counterparts, and when 'burned' can also be less harmful. However, as they are not chemically identical to their conventional fuel counterpart (i.e., biodiesel vs. diesel), most often biofuels cannot directly replace fuels at a 1:1 ratio without affecting equipment. To achieve environmental benefits, biofuels are most often blended with petroleum-based products to reduce the GHG intensity of their use. 'First generation' biofuels are those made from sugar, starch, or vegetable oil. Their feedstocks are those that might have an impact on food supply if used in large quantities. 'Second generation' biofuels are those made from sustainable feedstocks as defined by the feedstock's availability, its impact from a GHG perspective, and land use[38].

[37] https://natural-resources.canada.ca/energy-sources/clean-fuels/clean-fuels-fueling-future
[38] https://econext.ca/wp-content/uploads/2025/06/Biomass-Energy-Potential-NL-Version-1.0-2025-06-11.pdf

Renewable Biofuels

Produced through a different method ('catalytic pyrolysis') than biofuels but with similar feedstocks, 'renewable' biofuels are chemically identical to their petroleum-based counterparts (i.e., diesel and renewable diesel).

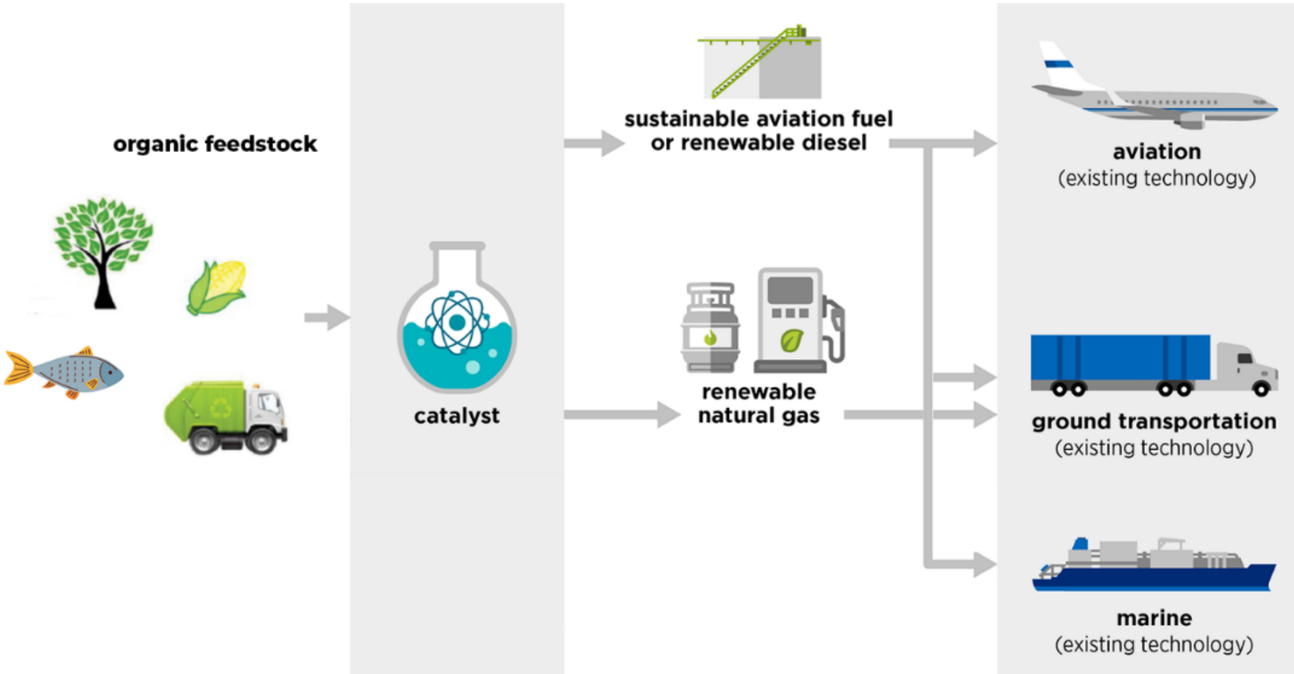

Figure 5: Examples of renewable biofuel pathways

This means that renewable biofuels can potentially be used as a direct replacement (i.e., as a 'drop-in') for conventional fuels in existing technology (i.e., combustion turbines, car/truck/ship engines, other heavy equipment) if not a heavy additive in blending. The concept of blending is defined explored in detail further in the report. This also means that existing transportation, storage, and refueling infrastructure can be used for these fuels – simplifying the logistics of decarbonization.

E-Fuels

E-fuels (electro-fuels) are synthetic fuels produced through electrolysis, which splits water molecules into hydrogen and oxygen using renewable electricity[39]. The most commonly discussed e-fuel is hydrogen, but the category includes fuels that have hydrogen as one of the key components. E-fuels are viewed as being instrumental in the fight against climate change and the global pursuit of net zero as they generally emit significantly less GHGs than fossil fuel alternatives, and their main component – hydrogen – can be produced using clean energy sources.

[39] https://spectra.mhi.com/energy-transition/what-are-e-fuels-and-can-they-help-decarbonization

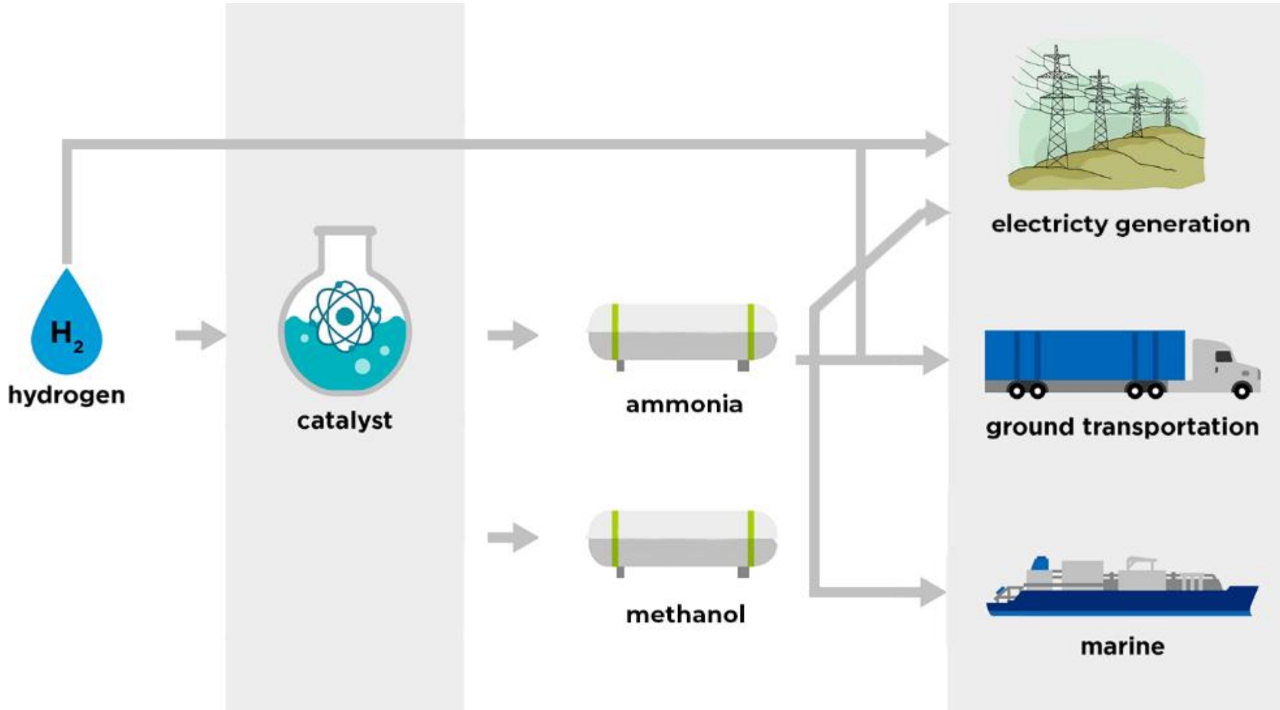

Figure 6: Examples of e-fuel pathways

There are a number of different terms that are being used to describe fuels with a lower carbon intensity that conventional fuels, often used interchangeably and sometimes incorrectly. However, in econext's experience, using these three terms (biofuels, renewable biofuels, and e-fuels) has proven to be the most effective approach to categorizing and communicating these fuels.

'Low-carbon fuels' is a catch-all term describing any fuel with a lower carbon intensity than the status quo fuel.

6.3 Blending Fuels

Fuel types do not necessarily need to be homogeneous or used exclusively. As alluded to above, fuels can often be blended.

Purpose of Blending

Blending allows for the realization – even if in part – of the benefits to low-carbon fuel use as described above. While the blending of fuels does not provide the environmental benefits that the wholesale adoption of low-carbon fuels might, given the prevalence of internal combustion engine technologies in vehicles and the reality that they will exist for many years to come, blending presents an immediate opportunity to achieve GHG emissions reductions.

Fuel blending is likely to become more important over time as (a) pressures continue to mount worldwide to lower the carbon intensity of fuels produced and consumed, while (b) the availability of low-carbon fuels to meet this demand is likely to be in short supply.

Blending of Different Fuels

In some cases, the degree to which fuels can be blended is limited or there is an optimal blending ratio.

For example, ethanol is commonly blended with gasoline but there are limits. The government of Canada currently requires that gasoline at the pump contains an average of five per cent ethanol, with some provinces requiring more[40]. Higher ethanol blends can result in corrosion and performance problems[41], with the emerging E15 (or 15% ethanol blend) only for use in vehicles manufactured after 2001.

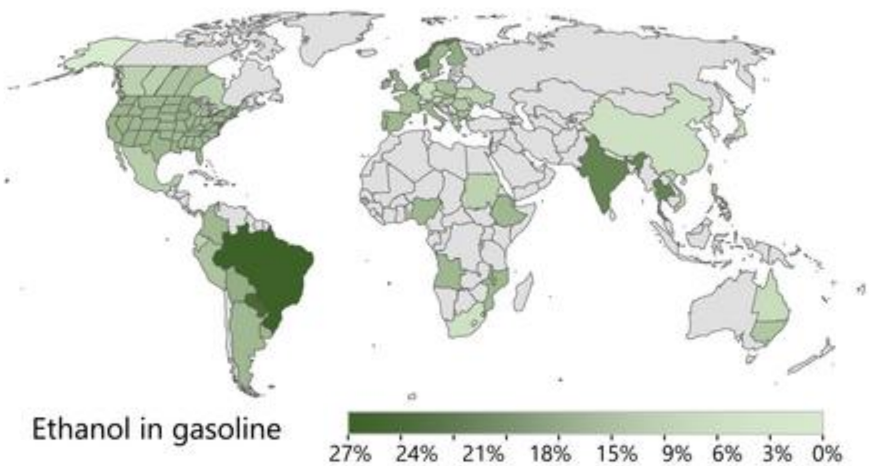

Figure 7: Global Ethanol Blending Mandates[42]

Biodiesel is another example. As biodiesel is not chemically identical to conventional diesel, it is most often an additive in a blend with conventional diesel. A blend classified as B2, for example, is 98% petroleum diesel and 2% biodiesel. B20 is a blend of 80% petroleum diesel and 20% biodiesel. Blending of biodiesel with diesel has become commonplace; the majority of North American engine manufacturers now endorse up to

[40] https://www.canadianfuels.ca/industry-facts/low-carbon-fuels/ethanol/
[41] https://natural-resources.canada.ca/energy-efficiency/transportation-energy-efficiency/ethanol
[42] Biofuel Technologies: Lessons Learned and Pathways to Decarbonization - https://onlinelibrary.wiley.com/doi/10.1111/gcbb.13091

a B5 biodiesel blend[43]. Generally, B20 and lower-level blends can be used in current engines without modifications. In fact, many diesel engine manufacturers approve the use of B20[44].

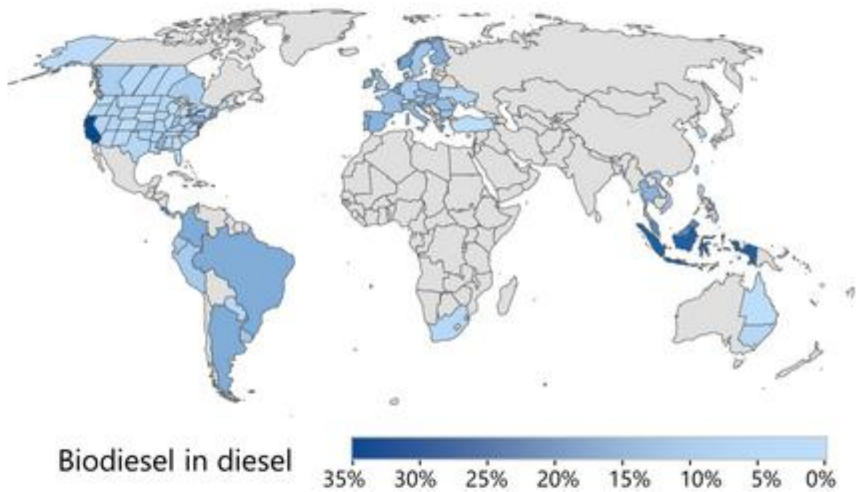

Figure 8: Global Biodiesel Blending Mandates[63]

Another similar case is the potential to blend low-carbon methane with natural gas. While a significant amount of low-carbon methane can be blended due to having the same chemical makeup as the methane component of natural gas, methane totals 90% of the makeup of natural gas so 100% replacement is not possible. Similarly, there is the potential to blend low-carbon hydrogen with natural gas. Hydrogen can be blended with natural gas and delivered through its existing infrastructure for end-use appliances such as stoves, water heaters, generators, etc[45]. Existing natural gas equipment can typically handle a blend of up to 15% hydrogen without compromising performance or safety[46]. Blending natural gas with other fuels is less common than other blends for end-use in surface transportation purposes because natural gas vehicles are not as prevalent as other technologies.

Blending of Same Fuels

In other cases, the low-carbon fuel is chemically identical to its fossil fuel counterpart and can be blended at any ratio at it will not change the composition or characteristics of the original or resulting fuel. This is the case with diesel and renewable diesel.

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[43] https://natural-resources.canada.ca/energy-efficiency/transportation-energy-efficiency/biodiesel
[44] https://afdc.energy.gov/fuels/biodiesel-blends
[45] https://www.cga.ca/natural-gas-101/hydrogen-a-lower-emitting-and-versatile-fuel
[46] https://www.csagroup.org/article/research/appliance-and-equipment-performance-with-hydrogen-enriched-natural-gases

Multi-Fuel Blends

Blending does not necessarily need to be limited to two fuels. For example, the Canadian Coast Guard is testing fuel blends composed of 10% biodiesel, 40% renewable diesel, and 50% conventional diesel[47] in its ships[48]. It is anticipated that multi-fuel diesel blends will become more common for surface transportation over time.

6.4 Low-Carbon Fuels with Potential for Use in NL

Through a series of discussions papers focused on marine transportation, surface transportation, and electricity generation, econext has identified low-carbon fuels which have the potential for application within NL. Below is a summary of this list, beginning with conventional fossil fuels that are lower-carbon, moves into biomass derived fuels, and then e-fuels produced via electricity. While not all fuels are produced via biomass, some have the potential to interact with biomass (i.e., within production processes or as a blend), so a holistic understanding of potential uses for the suite of low-carbon fuels is instructive.

Natural Gas

Conventional natural gas is found in subsurface rock formations and is extracted through a well drilled into that formation. Once extracted, the gas is separated from free liquids, such as crude oil, hydrocarbon condensate, water, and entrained solids – and then processed[49]. While still a fossil fuel, the use of natural gas offers several benefits compared to gasoline or diesel. The primary component (70-95%) of natural gas is methane (one part carbon, four parts hydrogen) with the remainder being a mix of a variety of elements. Burning natural gas for energy results in fewer emissions of nearly all types of air pollutants and carbon dioxide (CO_2) emissions than petroleum products to produce an equal amount of energy[50]. In NL there are possible applications for natural gas within the electricity sector and, to a lesser extent, the surface transportation sector.

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[47] https://www.ccg-gcc.gc.ca/corporation-information-organisation/greening-initiatives-ecologisation-eng.html
[48] https://www.canada.ca/en/canadian-coast-guard/corporate/about-us/greening-initiatives.html
[49] https://afdc.energy.gov/fuels/natural-gas-conventional
[50] https://www.eia.gov/energyexplained/natural-gas/natural-gas-and-the-environment.php

Liquified Natural Gas (LNG)

LNG is natural gas in its liquid form. LNG is produced by purifying natural gas and super-cooling it to -260°F to turn it into a liquid[51]. LNG is more expensive than natural gas due to higher production and storage costs but are valuable in transportation applications that require longer ranges due to its higher density[52]. LNG is being embraced in the marine transportation sector as a potential transitional fuel as the industry looks towards a carbon-neutral future that includes non-fossil fuels[53].

Biomethane / Renewable Natural Gas (RNG, Bio-LNG)

Biogas is a renewable source of methane gas produced when organic matter breaks down without oxygen[54]. Biogas can come from a variety of sources, including municipal solid waste landfills, anaerobic digester plants at water resource recovery facilities (wastewater treatment plants), livestock farms, food production facilities, and organic waste management operations[55] for use in place of (or in tandem with) fossil natural gas. The biological matter that's used to produce biogas will naturally decay anyway, so capturing the gases produced by this decay, and using them as an energy source, causes less harm to the environment than allowing them to escape into the atmosphere[56].

Biomethane – or 'Renewable Natural Gas (RNG)' – refers to biogas that has also been cleaned and conditioned to remove or reduce non-methane elements allowing it to be used as a replacement for (or supplement to) traditional natural gas or LNG[57]. Because of this, RNG has the same potential applications in NL as natural gas or LNG: marine transportation, electricity generation, and (to a lesser extent) surface transportation.

[51] https://afdc.energy.gov/fuels/natural-gas-basics
[52] https://afdc.energy.gov/fuels/natural-gas-basics
[53] https://www.lr.org/en/knowledge/research/fuel-for-thought/lng/
[54] https://biogasassociation.ca/biogas_101/
[55] https://afdc.energy.gov/fuels/natural-gas-renewable
[56] https://www.nationalgrid.com/stories/energy-explained/what-is-biogas
[57] https://afdc.energy.gov/fuels/natural-gas-renewable

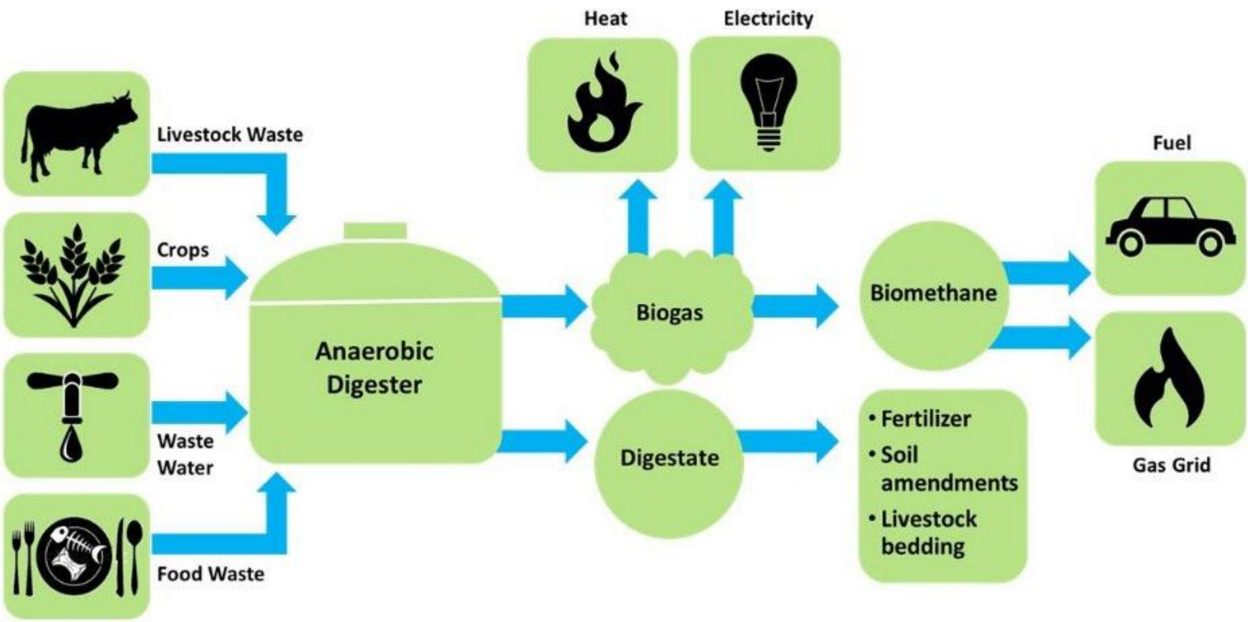

Figure 10: Examples of biomethane pathways[58]

Biohydrogen

Biohydrogen refers to hydrogen obtained from biogenic sources (for example, biogases and biomass) using a variety of technologies including biological, thermochemical, and bioelectrochemical processes[59]. For example, the vast majority of hydrogen used today is produced via natural gas through a process called 'steam methane reforming' (SMR). Consider that RNG is chemically identical to natural gas; a low-carbon hydrogen can be produced with biomass as the original feedstock via SMR using RNG. While biohydrogen itself is not expected to be used in large quantities in NL, it is mentioned here because of the potential uses of green hydrogen and the potential for biohydrogen as a supplement.

Bio-methanol

Biogas can also be refined to produce bio-methanol. Whereas RNG is gaseous, the compound can be further refined into a liquid alcohol (bio-methanol)[60]. Methanol is a light, versatile, colourless and flammable alcohol. Methanol is used as a solvent for lacquers, paints, varnishes, cements, inks, dyes, plastics and various industrial coatings. It is also used in the production of pharmaceuticals, formaldehyde and other chemical products. Methanol appears as an ingredient in many products, from industrial solvents to windshield-washer fluid and nail-polish remover. It can also be used as a fuel and is a viable option for various

58 https://www.eesi.org/papers/view/fact-sheet-biogasconverting-waste-to-energy
59 https://www.europeanbiogas.eu/wp-content/uploads/2025/06/Decarbonising-Europes-hydrogen-production-with-biohydrogen.pdf
60 https://methanol.org/wp-content/uploads/2020/04/IRENA_Innovation_Renewable_Methanol_2021.pdf

applications with increasing interest in its use in power generation and adoption within the marine transportation sector. In an internal combustion engine, methanol reacts with the oxygen in the air to create energy with carbon dioxide and water as the residuals.

Ethanol

Ethanol is a renewable, alcohol-based fuel made primarily from the fermentation of plant materials like corn, sugarcane, wheat, wood fibres, or other biomass feedstocks – potentially even wood waste from the construction and demolition industry. Ethanol is commonly blended with gasoline and blending is required in most jurisdictions in North America. With a higher octane value than gasoline, ethanol improves the effectiveness of the fuel by preventing engine knocking. Typically, gasoline contains E10 (10% ethanol, 90% gasoline), which reduces air pollution[61]. Quebec has recently introduced legislation which will require a 12% ethanol blend by 2026 and 15% by 2030[62], with other provinces already having made these commitments. NL has a permanent exemption from requirements in Canada for ethanol blending, but its use on a voluntary basis presents opportunity for the decarbonization of the surface transportation sector.[63]

Biodiesel

Biodiesel is a diesel fuel substitute made from renewable materials such as: plant oils (canola, soy, flax, etc.), waste cooking oil (yellow or tap grease), other oils (tall, fish, and algae), animal fats (beef or sheep tallow, pork lard, or poultry fat); and potentially from cellulosic feedstock consisting of agriculture and forest biomass. The process to create biodiesel is called 'transesterification.' Made from renewable resources biodiesel has the potential to reduce GHG emissions by over 80% on a lifecycle basis.[64] Biodiesel is most often used blended with conventional diesel (see 'Blending Fuels' above). As such, biodiesel has applications in NL that mirror those of conventional diesel – including use in the marine transportation sector, surface transportation sector, and electricity generation.

[61] https://afdc.energy.gov/fuels/ethanol-fuel-basics
[62] https://www.ctvnews.ca/montreal/article/quebec-rolling-out-higher-ethanol-blend-in-gasoline-starting-this-week/
[63] Biofuel Technologies: Lessons Learned and Pathways to Decarbonization - https://onlinelibrary.wiley.com/doi/10.1111/gcbb.13091
[64] https://natural-resources.canada.ca/energy-efficiency/transportation-energy-efficiency/biodiesel

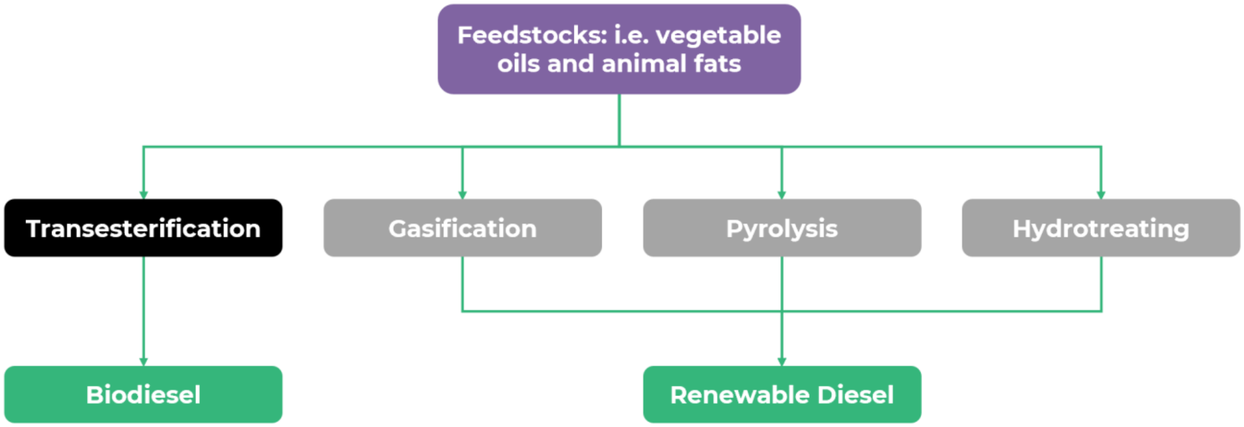

Figure 11: Example of Biodiesel and Renewable Diesel production pathways

Renewable Diesel

Similar to biodiesel in terms of feedstock, renewable diesel is a fuel made from fats and oils, such as soybean oil or canola oil – however the process utilized in fuel production is different. Produced most often by hydrotreating, and also via gasification, pyrolysis, and other biochemical and thermochemical technologies, the resulting fuel is chemically identical to conventional diesel[65] but has a much lower lifecycle carbon footprint. This means that renewable diesel can be used as a direct replacement for conventional diesel (i.e., as a 'drop-in'), if not a heavy additive in blending. While renewable diesel has a similar chemical structure to diesel, it has been shown to produce equal or lower levels of NOx and PM emissions when burned. In addition, traditional diesel contains aromatic compounds present in distillates that contribute to toxicity, whereas renewable diesel does not contain such compounds and as a result, has a decreased environmental toxicity and a higher degradation rate. As such, in the case of a spill, renewable diesel has less short and long-term environmental effects compared to conventional fossil fuels[66]. Renewable diesel is produced in NL; Braya Renewable Fuels has converted the Come by Chance refinery to produce up to 18,000 barrels per day of renewable diesel[67]. Renewable diesel has applications in NL that mirror those of conventional diesel – including use in the marine transportation sector, surface transportation sector, and electricity generation.

Green Hydrogen

Hydrogen is the most abundant element in the universe. When burned, hydrogen produces only water vapour, resulting in zero GHG emissions which makes it an attractive

[65] https://afdc.energy.gov/fuels/renewable-diesel
[66] https://econext.ca/discussion-paper-opportunities-for-domestic-clean-fuels-use-in-newfoundland-and-labrador/
[67] https://brayafuels.com/

fuel source. Hydrogen has been a widely used input in a variety of industries for many years and can be produced through a variety of methods[68]. The vast majority of hydrogen used today is produced via natural gas through a process called 'steam methane reforming' ('grey hydrogen'). This process can be paired with carbon capture and storage (CCS) to produce hydrogen with much fewer resulting GHGs ('blue hydrogen').

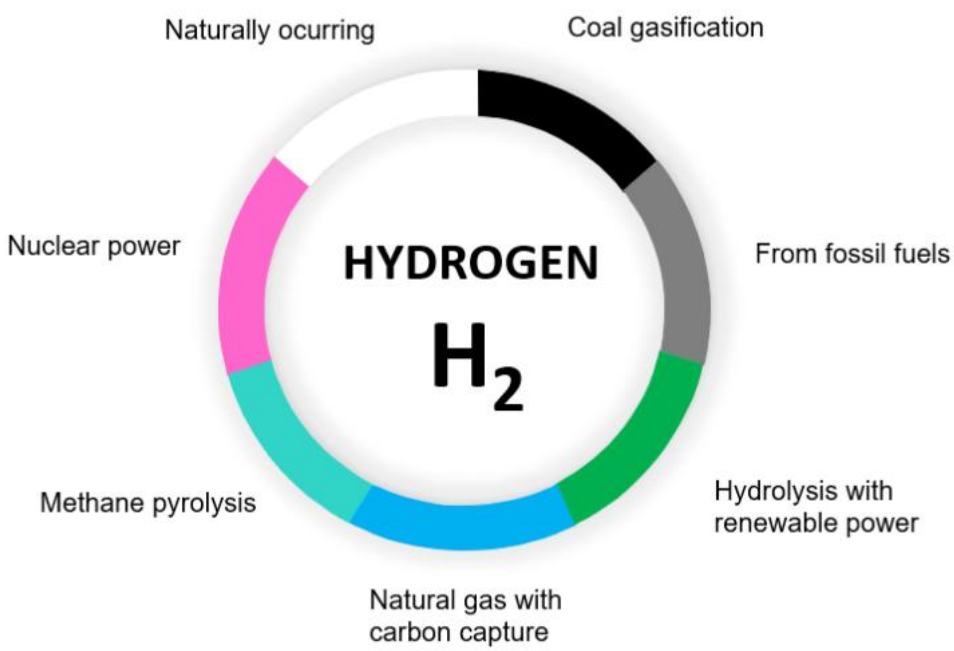

Figure 12: Hydrogen production pathways and colour associations[69]

'Green hydrogen' is when hydrogen is produced through a process called 'electrolysis' utilizing renewable energy. Green hydrogen can be produced with zero GHGs and be 'burned' resulting in zero GHGs – positioning it strongly as an important contributor in the fight against climate change. Green hydrogen is expected to be produced in NL in the early 2030s with a focus on export markets. Domestically, there are potential uses for green hydrogen in the surface transportation and electricity generation sectors. Also important to consider is hydrogen's relationship with other fuels such as methane and natural gas (see below). Hydrogen is also required for the production of renewable diesel, and thus the use of green hydrogen in these processes further decarbonizes that fuel. Moreover, green hydrogen is the key fuel in the production of other e-fuels like green methanol and green ammonia (see below).

[68] https://www.siemens-energy.com/global/en/home/products-services/solutions-usecase/sustainable-fuels.html#Hydrogen-tab-0
[69] https://jpt.spe.org/twa/the-color-palette-of-the-colorless-hydrogen

Liquid Organic Hydrogen Carrier (LOHC)

Hydrogen is light gas with low energy density, making storage and transportation costly. For this reason, a number of different fuels which feature hydrogen as one of the primary elements are being considered as 'hydrogen carriers' as they have more favourable characteristics for transport and storage. LOHC is one of these 'hydrogen derivative' fuels, and allows hydrogen to be chemically bonded to a liquid carrier making it safer and more efficient to handle. LOHCs can be transported easily using existing diesel infrastructure, with the organic compound removed near the point where hydrogen is to be used. These organic compounds are capable of reversible hydrogenation – binding and releasing hydrogen through chemical reactions[70]. Much of the organic compound can be 'recycled' and bonded with hydrogen again many times. Given the potential LOHC has as a hydrogen carrier and the fact it may be produced within NL by the early 2030s[71], it presents opportunities for hydrogen use within the province that are not practical if transporting and storing hydrogen in its pure state.

Green Methane

Methane has been used as a fuel and, later, a chemical feedstock since it was discovered and isolated in the 18th century. It is four parts hydrogen and one part carbon. Methane is a key component of natural gas (90%) and historically has been taken either directly from natural gas fields or as a by-product of other fossil fuel extraction[72]. However, methane can be synthetically created through the combination of hydrogen and carbon dioxide. When green hydrogen is used in this process (along with sustainably sourced carbon dioxide), the resulting fuel is green methane (or 'e-methane'). Similar to biomethane, green methane is chemically identical to conventional methane and thus can be used as a heavy blend (or replacement for) natural gas. Green methane production has been commercialized at a relatively small scale, with most projects tied to existing biogas/biomethane plants; supplying green hydrogen in addition to anaerobic digestion can reportedly increase methane output by 60% compared to typical biogas upgrading[73]. As natural gas is primarily methane, and methane is primarily hydrogen, green hydrogen can be used in the decarbonization of natural gas / LNG / RNG and their applications (marine transportation, electricity generation, and to a lesser extent surface transportation).

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[70] https://www.deassociation.ca/newsfeed/what-is-lohc-liquid-organic-hydrogen-carrier
[71] https://www.greenenergyhub.ca/
[72] https://enapter.com/en/blog/the-promise-of-green-methane/
[73] https://www.idtechex.com/en/research-article/e-fuels-explained-methanol-methane-diesel-and-saf/34444

Green Methanol

Methanol is one part carbon, three parts hydrogen, one part oxygen, and one part methyl group (CH_3OH). Methanol as a fuel has several potential benefits, including low emissions, low cost, and excellent energy density. Methanol is water-soluble and readily biodegradable. With hydrogen being a primary component, the use of green hydrogen in methanol production results in 'green methanol' or 'e-methanol'. Liquid methanol has a higher energy density than gaseous hydrogen, making it practical for transport and storage. Low-carbon methanol (including bio-methanol and green methanol) is increasingly being viewed as a fuel of choice within the international marine transportation sector.

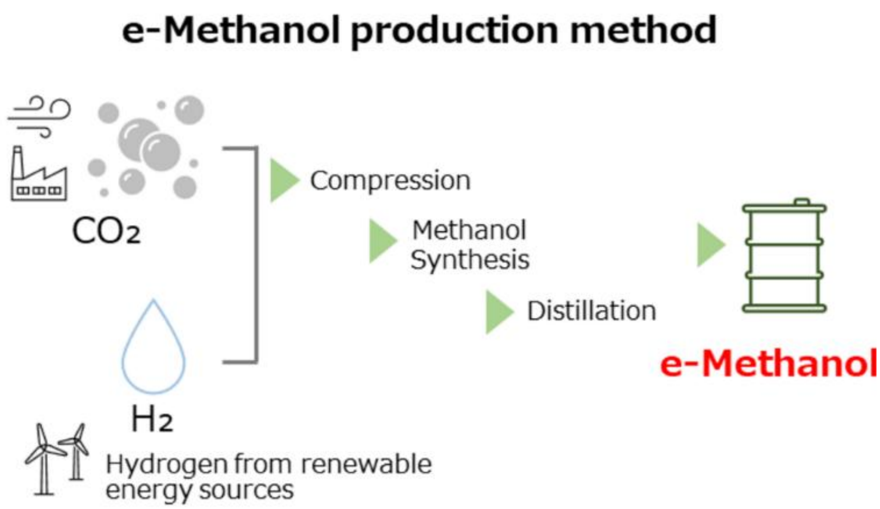


Figure 13: e-methanol production method[74]

Green Ammonia

Ammonia is one part nitrogen and three parts hydrogen (NH_3). Similar to green methanol, ammonia can be produced using green hydrogen resulting in a clean fuel that is commonly referred to as 'green ammonia' or 'e-ammonia'. Ammonia can be used in a variety of applications with an international focus on chemical processing, fertilizer production, marine transportation, and some early work in electricity generation. Its high energy density and low viscosity make it a suitable option as a 'hydrogen carrier' or as a method to transport hydrogen long distances. While significant domestic use of green ammonia is not predicted for NL, a final investment decision is expected to be made on a large green ammonia production in NL before 2030[75] with production being export-focused for international markets.

[74] https://www.idemitsu.com/en/business/oil/lowcarbon/e-methanol_future.html
[75] https://evrec.ca/project/

6.5 Global Demand for Low-Carbon Fuels

The demand for low-carbon fuels is, of course, not only domestic to within NL. Low-carbon fuels are recognized as being a vital contributor to GHG reduction targets worldwide and the achievement of net zero.

As seen in the previous section, there are many different biofuels, renewable biofuels, and e-fuels. This discussion paper will not attempt to project global demand for each of them, but a brief exploration of biofuels and renewable biofuels is worthwhile as these are near term demands which can be more easily incorporated into existing equipment infrastructure.

Biofuels and renewable biofuels are expected to play a particularly important role in decarbonizing transport by providing a low-carbon solution for existing technologies, such as light-duty vehicles in the near term and heavy-duty trucks, ships and aircraft with few alternative and cost-effective solutions in the long term[76].

The International Energy Agency (IEA) reports that biofuel (including renewable biofuel) demand in 2022 reached a record high of 4.3 EJ (170 000 million litres). However, a significant increase in biofuel production is needed to get on track with the IEA's net zero scenario modeling and deliver the associated emission reductions[77]. Biofuel production reaches over 10 EJ by 2030 in the net zero by 2050 scenario, requiring an average growth of around 11% per year from 2023-2030.

Multiple recent factors are further driving global demand.

For example, the European Union Emissions Trading System (ETS) was extended in 2024 to cover marine transportation and CO2 emissions from all large ships entering EU ports. The system covers 50% of emissions from voyages starting or ending outside of the EU and 100% of emissions that occur between two EU ports and when ships are within EU ports. There is an overall ETS emissions cap and restrictions on emissions individual companies can produce. Shipping GHGs are being phased into inclusion, but quickly – from 40% of reported emission in 2024 to 100% in 2027 and subsequent years[78]. In the future there is potential for more international adoption of similar rules through the International Maritime Organization (IMO)[79]. Emissions reductions within the marine transportation sector will drive greater adoption of biofuels and renewable biofuels which can be blended with conventional fuels (i.e., diesel, natural gas).

[76] https://www.iea.org/energy-system/low-emissions-fuels/biofuels
[77] https://www.iea.org/energy-system/low-emissions-fuels/biofuels
[78] https://climate.ec.europa.eu/eu-action/transport-decarbonisation/reducing-emissions-shipping-sector_en
[79] https://www.imo.org/en/mediacentre/pressbriefings/pages/imo-progresses-work-on-ship-emissions-pollution-and-ocean-protection.aspx

Geopolitical events are also shifting energy demands. The conflict in Iran has resulted in fuel shortages worldwide, increasing the cost of conventional fuels like gasoline and diesel – inflating prices of goods and services economy-wide. Increasingly the domestic production of fuels – including low-carbon fuels – is being viewed through the lens of energy security.

According to T&E, a 'current scramble' for biofuels is expected to lead to a surge in consumption, with demand set to rise by 30% this year, and could increase by as much as 70% by 2030[80]. This is being driven, in part, by increased blending mandates that nations are implementing to protect against fuel supply shortages and price shocks. For example, the more locally produced ethanol that is blended with gasoline, the less gasoline is required to be imported.

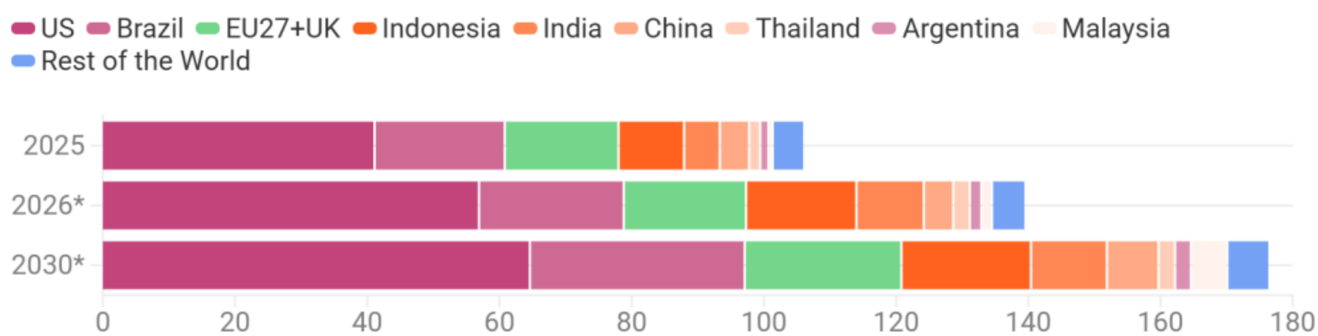


Figure 14: Changing global fuel blending mandates and increased biofuels demand (Mtoe)

One of the unintended consequences of such sharp demand increases is scaling biofuel supplies without affecting food supplies. is 'hard to achieve' – for example, if biofuels were used to supply 20% of global road transport fuel demand, an additional 130 million hectares of land would be needed – equal to the entire land mass of South Africa[81].

This means that it will become increasingly important for jurisdictions like NL to make the most of its biomass resources (which are otherwise disposed of) to help meet global demand even if that is vis-à-vis supplying for local consumption.

7. Biomass Energy Technologies

Just as there are different sources of organic waste (or inputs for biomass energy), there are different methods by which these materials can be transformed into fuels like those described above.

[80] https://www.transportenvironment.org/articles/global-biofuel-demand-set-to-grow-by-nearly-70-as-food-prices-rise
[81] https://www.transportenvironment.org/articles/global-biofuel-demand-set-to-grow-by-nearly-70-as-food-prices-rise

Biomass can be converted to energy – i.e., heat, electricity, and/or fuels – through a number of different processes including direct combustion, thermochemical and chemical conversion, and biological conversion. This discussion paper focuses on processes which result in low-carbon fuels production.

The following sources were used in the development of the next two sections of this discussion paper:

- Net Zero Clean Fuels: A Profile of Advanced Biofuels in Canada[82]
- International Energy Agency: Bioenergy Technology Collaboration Programme[83]
- U.S. Energy Information Administration[84]
- U.S. Department of Energy[85]

Each technology or process has different ideal biomass inputs and produces a collection of different outputs. Key abbreviations to refer to in this section include:

- CO – carbon monoxide
- CO_2 – carbon dioxide
- CH_4 - methane
- H_2 – hydrogen
- H_20 - water

Direct Combustion

Direct combustion is, most simply, the burning of biomass which produces heat. Generally, direct combustion is carried out inside a furnace, steam turbine, or boiler at a temperature range of 800–1000°C. Electricity is generated from combustion of biomass which is used to generate high pressure steam used in a turbine. Waste heat generated in the process can be recovered in a combined process which is referred to as CHP (combined heat and power). All types of biomass (except for shellfish waste) are suitable for use in direct combustion, but higher moisture content biomass (e.g. fish offal, food processing waste) are less efficient. At a minimum, the feed water content should be <20wt%. Direct combustion is the most straightforward approach to biomass energy, however as with the combustion of fossil fuels, gaseous by-products (CO_2, CO, CH_4, polycyclic aromatic hydrocarbons [PAH], nitrogen oxides) are also produced. Biomass does have negligible sulfur content and therefore there are negligible sulfur dioxide emissions (unlike petroleum-based heating oils). This would be the 'easiest' pathway for biomass energy use

[82] Net Zero Clean Fuels: A Profile of Advanced Biofuels in Canada - https://netzerocleanfuels.ca/
[83] International Energy Agency: Bioenergy Technology Collaboration Programme - https://www.ieabioenergy.com/
[84] U.S. Energy Information Administration - https://www.eia.gov/energyexplained/biomass/
[85] U.S. Department of Energy - https://www.energy.gov/sites/prod/files/2014/04/f14/pyrolysis_report_summary.pdf

in NL. However, as direct combustion of biomass is GHG-intense it is therefore not considered further in this discussion paper.

Thermochemical Conversion

Thermochemical processes are those where biomass materials are heated in closed, pressurized vessels called gasifiers at high temperatures. The goal of thermochemical processing of biomass to fuels is to convert material of diverse composition that is challenging to use directly as a fuel (due to water content, contaminants etc.) into a more homogenous biofuel product.

The most common processes are pyrolysis (where the end product is solid and/or liquid fuel), gasification (where the end product is gas), and hydrothermal (where the end product is solid and/or liquid products). Pyrolysis and gasification are both thermal decomposition processes, with the difference between the two being in the temperatures employed and end products produced. Hydrothermal processing is thermochemical/hydrolysis decomposition process, better suited for high water content biomass (e.g. aquaculture and dairy industries).

More information on each of these processes is below.

Pyrolysis

Pyrolysis involves heating to between 400° C and 600° C in the near complete absence of oxygen. Pyrolysis can be performed on (i) waste solid biomass (municipal solid wastes, forestry residues, fish offal etc). or (ii) oil-based wastes (e.g. waste cooking oil, algae lipids, canola oil, fish oil etc) or bio-oil from (i).

(i) In solid biomass pyrolysis, three products are produced: liquid (bio-oil), solid (biochar) and gas. The proportion of these products depends on several factors including the type of biomass and temperatures used and time it is used for. Pyrolysis can be loosely defined into torrefaction (temperatures of approximately 300°C and several hours reaction time), slow pyrolysis (400-500°C and hours reaction time), and fast pyrolysis (450-600°C and reaction times in range of several minutes). Torrefaction and slow pyrolysis favour a solid fuel (biochar – see 'biomass outputs and uses' below) while fast pyrolysis produces a bio-oil as a primary product and a by-product biochar. Gases are also produced (CO, CO_2, H_2, light hydrocarbons), some of which can be combusted to provide the heat for the process.

Depending on the feedstock used, the bio-oil and biochar can be used as low-grade fuels. The bio-oil heating value (~16-20 MJ/kg) and other fuel properties (viscosity etc.) are a function of the feedstock and operating conditions. If the intent is to produce drop-in fuels (see 'distinguishing between fuels' below), the oil must be upgraded (e.g. oxygen removal)[86]. The biochar can be used in solid fuel applications, as a soil amendment, or adsorbent. Adding a catalyst can decrease the required reactor temperature and enhance bio-oil quality. A 2020 survey conducted by the International Energy Association (Bioenergy group) identified nine commercial scale pyrolysis plants producing bio-oil and char, where feedstock varied from forestry and agriculture residues[87]. There are two operating fast pyrolysis plants in Canada.

(ii) In waste oil/bio-oil pyrolysis, the product is a liquid hydrocarbon that, depending on feedstock, can be used directly in transportation (from renewable diesel to bioaviation fuels[88]). Reactor temperatures vary from 300-600°C, with or without catalyst, higher temperatures are usually associated with noncatalytic processes. As noted, the bio-oil produced in (i) can be used in this process and upgraded to a drop-in fuel.

Gasification

Gasification operates at temperatures from 700 up to over 1000°C where the biomass is mixed with a gasifying agent (such as air, oxygen, steam or air-steam combination). The generated gasses can be used directly in gas turbines ('producer gas') or in conversion for biodiesel / bioaviation fuel (syn-gas). The temperature of the process depends on the type of oxidant (steam, O_2, air) and the use of catalysts. Processes can be operated at lower temperatures when a catalyst is used. Where air is the gasifying agent, the main product is a producer gas type and when steam is used the composition resembles a syn-gas and is more H_2 heavy:

Gas	Producer Gas	Syn-gas
CO (vol%)	18-22	35-40
H_2 (vol%)	13-19	20-40
CH_4 (vol%)	1-5	0-15

[86] Upgrading of biomass sourced pyrolysis oil review: Focus on co-pyrolysis and vapour upgrading during pyrolysis Biomass Conversion and Biorefinery - https://inis.iaea.org/records/w5eqe-tgv71
[87] Commercial status of direct thermochemical liquefaction technologies, IEA Bioenergy - https://www.ieabioenergy.com/blog/publications/new-publication-commercial-status-of-direct-thermochemical-liquefaction-technologies/
[88] Bio-hydrocarbons through catalytic pyrolysis of used cooking oils and fatty acids for sustainable jet and road fuel production - https://ui.adsabs.harvard.edu/abs/2015EnPro..82..343C/abstract

CO_2(vol%)	9-12	25-35
Tar (vol%)	0.2-0.4	-
N_2(vol%)	45-55	2-5
Moisture	<4	Variable depending on steam:biomass ratio
Heating Value (MJ/m^3)	4.5-6	5.3-12.6

Figure 15: Table from Jude A. Onwudili et al., Sustainable Energy Fuels, 2023, 7, 3505.

Hydrothermal Processes

Pyrolysis or gasification require drying the biomass which can be expensive depending on the amount of water. Hydrothermal processing is ideal for a "wet" biomass where, due to nature of processing or storage conditions, the biomass has a significant water content. Hydrothermal processing uses the water in the biomass as a reactant and solvent to produce fuels. The temperatures of the process vary from 180-600°C, the water is kept in a liquid state via pressure and is referred to as "subcritical water". Hydrothermal treatment falls into similar categories as pyrolysis and gasification; hydrothermal carbonization (HTC), hydrothermal liquefaction (HTL), and hydrothermal gasification (HTG). In HTC the primary product is a solid "hydrochar", the temperature is typically between 180-280°C and pressures from 2-10 MPa . However, it should be noted this applies to woody, agricultural, and algae biomass, whereas shellfish processing by-product have slightly higher operating HTC temperature range due to the differences in structure. The hydrochar can be pelletized and used as a solid fuel depending on the heating value and ash content. HHV and ash will vary depending on feedstock, for forestry and agricultural by-products. In HTL the produces a liquid (bio-oil) with byproducts of solid hydrochar, and gases containing CO, CO_2, H_2, CH_4. The bio-oil can be used in fuel applications.

Chemical Conversion

Chemical conversion involves the use of chemical agents to convert biomass into liquid fuels. 'Transesterification' is the most common process for converting waste vegetable oils, animal fats, and greases to biodiesel. Unlike catalytic pyrolysis (which produces a hydrocarbon-based biodiesel), in transesterification the product is a fatty acid methyl esters (FAME) based biodiesel. The FAME acts the same as diesel in engines (cold flow properties, etc.) but is compositionally different. This allows for the end product to be a 'drop in' fuel (see 'distinguishing between fuels' below). Transesterification uses common chemicals (e.g. sodium hydroxide and methanol) in the process. FAMEs based biodiesels can also be produced via enzymatic transesterification (outlined below).

Biological Conversion

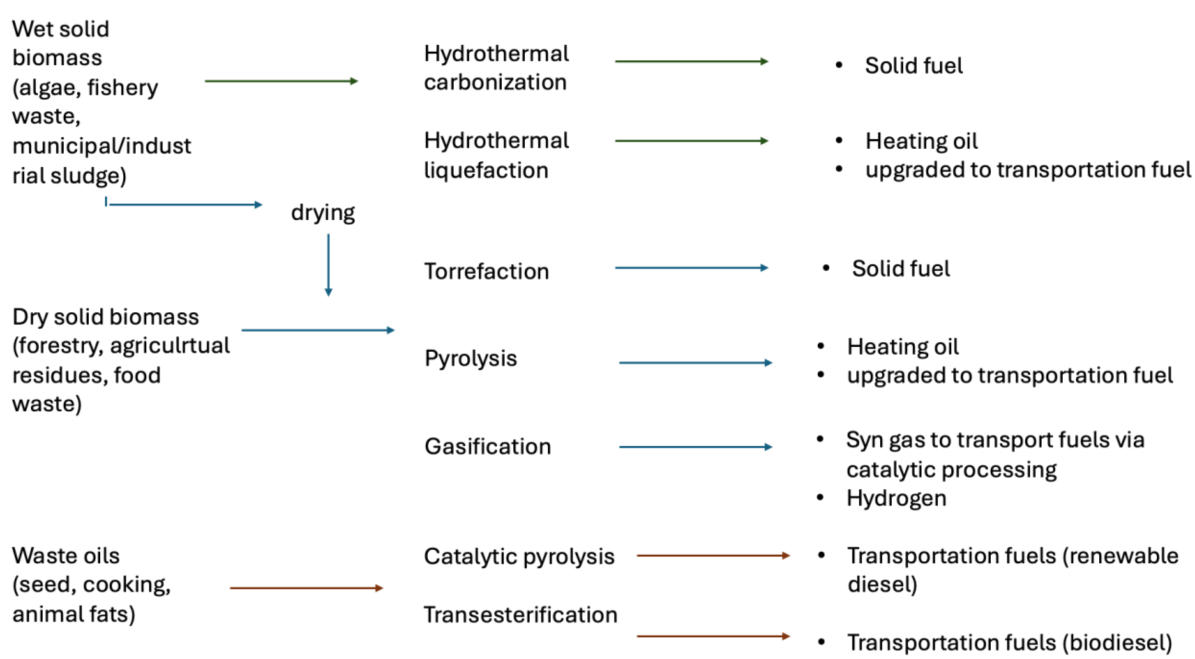
Biological conversion of biomass includes fermentation to make ethanol and anaerobic digestion to produce biogas.

Anaerobic Digestion

Anaerobic digestion is a process through which bacteria break down organic matter—such as animal manure, wastewater biosolids, and food wastes—in the absence of oxygen. Inputs can include all types of biomass (even some types of mining tailings), although wood wastes can adversely affect outputs. The process produces a biogas, consisting of CH_4, CO_2, and traces of other 'contaminant' gases. The byproduct of anerobic digestion is 'digestate', which is a substance that can be used as a fertilizer in agriculture or compost material.

Fermentation

Fermentation is a series of chemical processes that breaks down sugars within organic materials to produce alcohol or acid. Inputs can include all types of biomass. Yeast or bacteria are added to the biomass to produce ethanol and CO_2. The ethanol is distilled and dehydrated to obtain a higher concentration of alcohol to achieve the required purity for the use as fuel. The solid residue from the fermentation process can be used as livestock feed.



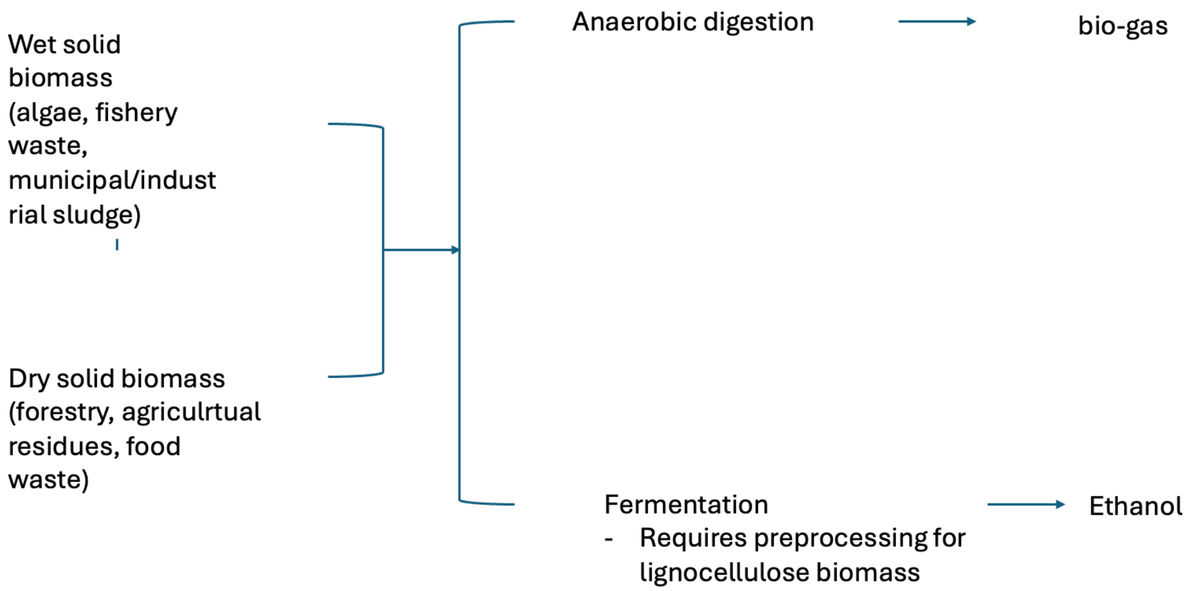


Figure 16: Examples of biomass energy pathways

8. Considerations of Biomass Use for Low-Carbon Fuels Production in Newfoundland and Labrador

In exploring the production of low-carbon fuels in NL', there are factors – beyond strictly technical feasibility – and Canadian/NL conditions that should be considered.

Economics and Geography

Fuel users are price-conscious, particularly if they use significant quantities as increased fuel costs can easily disrupt business models. Given this sensitivity, the costs associated with low-carbon fuels production and distribution are a concern; biofuels, renewable biofuels, and e-fuels are all generally much more expensive than the conventional fuel alternative.

Economies of scale matter for biomass energy. The volume of any single source of organic waste in NL is relatively small. This remains true when all organic waste is considered collectively. Moreover, NL's population and industrial activities are not just small - but they are dispersed across a vast geography. The aggregation of relatively small amounts of organic waste will result in significant transportation costs. Low volumes of inputs into biomass energy processes with transportation requirements for aggregation will negatively impact the cost of the outputs.

This may limit the potential end uses for the final product(s). However, co-processing of different types of biomass would enhance overall economies. Further, unlike fossil fuels, biofuels can be produced at much smaller scales meaning fuels could be produced in the region for the region.

All tools available to producers, distributors, and adopters will need to be leveraged in order to advance low-carbon fuel use. Some of these supports are explored in further detail below.

Revenues

Of course, the sale of low-carbon fuels will generate revenues. In addition, there may be secondary revenue streams if markets exist for various byproducts of low-carbon fuel production such as biochar (or 'black carbon' as it is becoming commonly known).

Displacement of Waste Management Costs

Organic waste – an important feedstock for various low-carbon fuels – is currently sent directly to landfill in NL. Organic waste makes up approximately 30% of waste that enters into landfills, with much more estimated to be disposed of elsewhere. Landfilling is not free, and therefore there are financial benefits associated with the diversion of this volume of material.

Robin Hood Bay Waste Management Facility in St. John's, NL (Tract Consulting Inc.)

Each region within the province sets a 'tipping fee', or the cost per tonne of waste disposed of at their site(s). Tipping fees can vary depending on the material being disposed and who is disposing of it but, generally speaking, fee ranges from $90.75 per tonne in Eastern Newfoundland[89] to $145 per tonne in Central Newfoundland[90] to $164 in Corner Brook and area[91] (amongst a variety of areas across the province).

Approximately 155,000 MT of organics waste is generated annually in NL with only a small fraction (2.5%) diverted[92]. If all organic waste was diverted at an average tipping fee of $100 per tonne, $15,500,000 in annual savings would be realized. In municipalities, it is often the case that tipping fees are paid by the municipality itself with costs blended into tax rates for residents; in these cases, direct savings are possible for municipalities.

Tipping fees are not a perfect indicator of organic waste management costs as they are often reflective of landfill operational costs and may not cover the true cost of landfill waste (capital expenses, closure/post closure expenses etc.). If organic waste makes up 30% of all waste, landfill operators may face difficulties operating with 30% less revenue from lost tipping fees. 100% diversion of organic waste is also, of course, highly unlikely. However, this serves as a starting point for stakeholders to consider expenses that could be used instead as investments in solutions that are more economically impactful and environmentally sustainable – such as the production and use of low-carbon fuels,

Investment Tax Credits

A number of tax credits have been released at the federal and provincial levels in recent years which can help offset some of the capital costs associated with low-carbon fuels production and infrastructure. Federally, the passage of Bills C-59 and C-69 on June 20, 2024[93], activated four tax credits at the federal level with relevance to biomass energy:

- **Clean Technology Investment Tax Credit**[94] – The CT ITC is a refundable tax credit of up to 30% for capital invested in the adoption and operation of new clean technology (CT) property. This includes various electricity generation, energy storage, refueling, etc. equipment – much of which could apply to portions of biomass energy projects.

[89] Eastern Regional Service Board - https://easternregionalserviceboard.com/residents/fees-and-payment/
[90] Central Newfoundland Waste Management - https://www.cnwmc.com/services/fee-schedule/
[91] Western Regional Waste Management - https://wrwm.ca/corner-brook-area/
[92] Report on Review of Provincial Waste Management Strategy - https://www.gov.nl.ca/releases/2020/mae/0129n08/
[93] Government of Canada Launches the First Clean Economy Investment Tax Credits - https://www.canada.ca/en/natural-resources-canada/news/2024/06/government-of-canada-launches-the-first-clean-economy-investment-tax-credits.html
[94] Clean Technology Investment Tax Credit - https://www.canada.ca/en/revenue-agency/services/tax/businesses/topics/corporations/business-tax-credits/clean-economy-itc/clean-technology-itc.html

- **Clean Hydrogen Investment Tax Credit**[95] – The CH ITC is a refundable tax credit of up to 40% that applies to eligible expenses incurred for property that produces hydrogen. These are expenditures that may be applicable to portions of low-carbon fuel production projects if they do involve hydrogen. Property used to convert clean hydrogen to clean ammonia is also eligible at a 15% ITC rate, but unfortunately the ITC is not applicable to property that is used to convert hydrogen to other fuels like methanol.
- **Clean Technology Manufacturing Investment Tax Credit**[96] – The CTM ITC is a refundable tax credit that applies to investment of capital for clean technology manufacturing and processing and critical mineral extraction and processing. This tax credit may not have applicability within the context of low-carbon fuel production, however it should be explored.
- **Clean Electricity Tax Credit**[97] – The CE ITC is a refundable tax credit of up to 15% of investments in projects that generate clean electricity, store electricity without the use of fossil fuels, or transmit electricity between provinces and territories. These are expenditures that may be applicable to portions of low-carbon fuel production projects.
- **Carbon Capture, Utilization, and Storage Investment Tax Credit**[98] – The CCUS ITC is a refundable tax credit of up to 60% that applies to eligible expenditures incurred for a qualified CCUS project. Note that NL, at this time, is not one of the eligible jurisdictions for the CCUS ITC as the credit requires a jurisdiction to have 'sufficient environmental laws and enforcement governing the permanent storage of captured CO^2. This ITC is related to the acquisition of property used to capture CO_2 emissions from fuel combustion, industrial process or directly from the air, to transport the captured carbon and to store it or use it in industry. This is relevant for any low-carbon fuels project which includes CCUS components.

NL's provincial government introduced two investment tax credits in 2022 which are potentially relevant to new biomass energy projects:

- **Green Technology Tax Credit**[99] – The GTTC is a refundable tax credit of up to 20% of capital investments in equipment that generates or conserves renewable-source energy, uses fuels from waste, or makes efficient use of fossil fuels.

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[95] Clean Hydrogen Investment Tax Credit - https://www.canada.ca/en/revenue-agency/services/tax/businesses/topics/corporations/business-tax-credits/clean-economy-itc/clean-hydrogen-itc.html
[96] Clean Technology Manufacturing Tax Credit - https://www.canada.ca/en/revenue-agency/services/tax/businesses/topics/corporations/business-tax-credits/clean-economy-itc/clean-technology-manufacturing-itc.html
[97] Budget 2024, Chapter 4 - https://www.budget.canada.ca/2024/report-rapport/chap4-en.html
[98] Carbon Capture, Utilization, and Storage Tax Credit - https://www.canada.ca/en/revenue-agency/services/tax/businesses/topics/corporations/business-tax-credits/clean-economy-itc/carbon-capture-itc.html
[99] Green Technology Tax Credit - https://www.gov.nl.ca/fin/tax-programs-incentives/business/green-tech-tax-credit-gttc/

- **Manufacturing and Processing Investment Tax Credit**[100] – The MPITC is a refundable tax credit of up to 10% if capital investments in qualified activities that may include aspects of biomass energy projects.

In addition to the above, there is a specific investment tax credit available throughout Atlantic Canada:

- **Atlantic Investment Tax Credit**[101] – The ATC is based on specified percentages available for certain investments in new buildings, and new machinery and equipment used in the Atlantic Canada and Atlantic Region including expenditures relating to biomass energy projects: prescribed new energy generation and conservation property; the production or processing of electrical energy or steam in certain areas; and manufacturing and processing.

The above tax credits should be considered and included where appropriate for any future economic analysis of low-carbon fuels production and adoption projects in NL.

Clean Fuel Regulations

Canada's Clean Fuel Regulations (CFRs) came into effect in 2023 and create incentives for the development and adoption of clean fuels, technologies and processes[102].

The stated goal of the CFRs is to significantly reduce pollution by making the fuels Canadians use every day cleaner over time. The CFRs require liquid fossil fuel (gasoline and diesel) suppliers to gradually reduce the carbon intensity – or the amount of pollution – from the fuels they produce and sell for use in Canada over time, leading to a decrease of approximately 15% (below 2016 levels) in the carbon intensity of gasoline and diesel used in Canada by 2030.

There are a number of methods for regulated industry to be compliant with the CFR.

[100] Manufacturing and Processing Investment Tax Credit - https://www.gov.nl.ca/fin/tax-programs-incentives/business/manufacturing-and-processing-investment-tax-credit/
[101] Atlantic Investment Tax Credit - https://www.canada.ca/en/revenue-agency/services/tax/individuals/topics/about-your-tax-return/tax-return/completing-a-tax-return/deductions-credits-expenses/line-41200-investment-tax-credit/atlantic-investment-tax-credit.html
[102] Government of Canada: What are the Clean Fuels Regulations? - https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-regulations/about.html

econext's emissions reduction fund is a mode of compliance under the CFR (www.nlerf.ca)

The first approach is the creation of compliance credits. There are three compliance categories, with the first two being relevant in the context of low-carbon fuels:

Compliance Category 1: Undertaking projects that reduce the lifecycle carbon intensity of liquid fossil fuels (e.g., carbon capture and storage, on-site renewable electricity, co-processing). This includes the blending of fuels with lower carbon GHG intensity with conventional fuels.

Compliance Category 2: Supplying low carbon intensity fuels (e.g., biodiesel, hydrogen, e-methanol, etc.)[103].

There is, therefore, an incentive structure that exists for the production and supply of low-carbon fuels to customers like those found within the electricity sector – including when those fuels are blended.

The second approach to compliance is for regulated industry to contribute to an Emissions Reduction Fund (ERF) authorized by the Minister of Environment and Climate Change Canada (ECCC). econext's Newfoundland and Labrador Emissions Reduction Fund is one of a select few organizations in Canada with a registered ERF approved as a compliance mechanism under the CFR. ERF funded projects could also conceivably involve partnerships between low-caron fuel producers, distributors, and users.

[103] https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-regulations/compliance.html

Output-Based Pricing System (OBPS)

NL implemented a carbon pricing system in 2019 to reduce GHGs. The system includes performance standards for large industrial facilities through the *Management of Greenhouse Gas Act* (MGGA) and its regulations. Under this legislation, industrial facilities that emit 15,000 tonnes or more of GHG emissions per year are required to report their emissions on an annual basis.

MGGA also provides for the establishment of a GHG reduction target for industrial facilities that have either emitted 25,000 tonnes or more of GHG emissions per year or emitted 15,000 tonnes or more and opted to be regulated by the Act[104].

Credits can be generated by regulated facilities by exceeding their GHG reduction targets in any given year. These credits can be sold to other MGGA-regulated facilities who have not met their GHG reduction targets and need to achieve compliance.

The Holyrood Gas Turbine is regulated under the MGGA with GHG emissions that have, at times, exceeded the 25,000 tonnes of GHGs annual threshold[105], but operation of the unit has changed substantially with the completion of Muskrat Falls in the LIL resulting in far fewer GHGs in recent years. It is unknown if the future Avalon Combustion Turbine will be considered as being the same 'facility' as the existing gas turbine or if these assets will be treated differently under the regulations.

While there are many credits active within the OBPS market[106], credits may become more scarce in the medium to longer term. The adoption of low-carbon fuels may help utilities generate credits within the OBPS which can be sold to others regulated under the OBPS to potentially generate revenues.

Carbon Offsets

The production and use of low-carbon fuels can be net negative in terms of GHGs, making production and adoption projects potentially eligible to achieve carbon offsets.

The federal government has created a Greenhouse Gas Offset Credit System, which will allow for the purchase and trading of eligible carbon offsets as a means of compliance for

[104] https://www.gov.nl.ca/eccc/occ/greenhouse-gas-data/
[105] https://www.gov.nl.ca/eccc/files/Facility-GHG-Data-for-Website-by-Gas-2016-24-Jan-2026.pdf
[106] https://www.gov.nl.ca/eccc/files/GHG-Annual-Outcomes-Report-2019-2024-1.pdf

federally regulated activities[107]. Eligible offsets must meet the stringent requirements of 'protocols' which are developed for each specific type of negative emissions activity.

The system was introduced in 2022, but only a few protocols have been developed thus far including: (1) Landfill Methane Recovery and Destruction; (2) Reducing Greenhouse Gas Emissions from Refrigeration Systems; and (3) and Improved Forest Management on Private Land; and (4) Reducing Enteric Methane Emissions from Beef Cattle. ECCC is currently developing more protocols including Direct Air Carbon Dioxide Capture and Geological Storage, Reducing Manure Methane Emissions, Enhanced Soil Organic Carbon, Improved Forest Management on Public Land, and Bioenergy with Carbon Dioxide Capture and Geological Storage[108].

These offsets can currently be traded under federal output-based pricing system (OBPS)[109]. Note that NL has its own federally authorized carbon pricing system for large emitters within the province (see above), and this system is independent of the federal OBPS. Emitters in NL cannot achieve compliance through the purchase of federal offsets. It is expected that federal carbon offsets will be tradeable under the forthcoming Clean Electricity Regulations (CER).

It is possible that some of the protocols under the federal system will present opportunities for generation of credits from low-carbon fuels production and adoption initiatives – creating a revenue stream to improve project economics.

Policy Drivers

Canada's CFR were not the first national policy intervention to decrease the carbon intensity of fuels in the country.

The Renewable Fuels Regulations came into force in 2010. These standards required fuel producers and importers across Canada to have an average renewable fuel content of at least 5% based on the volume of gasoline that they produce or import and of at least 2% based on the volume of diesel fuel and heating distillate oil that they produce or import into Canada[110]. Newfoundland and Labrador has a permanent exemption from these

[107] https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/output-based-pricing-system/federal-greenhouse-gas-offset-system.html
[108] https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/output-based-pricing-system/federal-greenhouse-gas-offset-system/protocols.html
[109] https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/output-based-pricing-system.html
[110] https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/renewable.html

regulations for diesel fuel and heating distillate oil to account for logistical challenges in blending in the region[111].

Beyond these regulations, individual provinces have taken additional steps that require fuel blending.

British Columbia established its 'low carbon fuel standard' in 2008 which adds an additional requirement on fuel suppliers to progressively decrease the average carbon intensity of their fuels to achieve a 10% reduction in 2020 relative to 2010[112].

Saskatchewan enacted regulations in 2007 establishing an ethanol fuel mandate. The standard requires fuel suppliers to blend their fuel to contain at least 7.5% ethanol for gasoline and 2% ethanol for diesel[113].

Manitoba enacted a regulation in 2007 that established a renewable fuel standard. The standard requires fuel suppliers in the province to blend their fuel to contain at least 8.5% ethanol for gasoline and 2.0% ethanol for diesel[114].

Ontario's Cleaner Transportation Fuels regulation requires that fuel suppliers blend 10% of renewable content in gasoline from 2020 to 2024. The renewable content requirement increases to 11% in 2025, 13% in 2028, and 15% in 2030 and onward. This renewable content must emit 45% fewer greenhouse gas emissions than fossil gasoline on a lifecycle basis before 2030, and 50% fewer from 2030 onward[115].

In **Quebec**, fuel blending requirements for conventional gasoline and diesel are included under the **Regulation Respecting the Integration of Low-Carbon Intensity Fuel Content into Gasoline and Diesel Fuel** (2021). Under this regulation, distributors must include an increasing percentage of low-carbon intensity fuel into gasoline, requiring 10%, 12%, 14%, and 15% by volume in 2023, 2025, 2028, and 2030, respectively. Similarly for distributors of conventional diesel, there is a low-carbon intensity fuel requirement of 3%, 5%, and 10% by volume for 2023, 2025, and 2030, respectively.[116] Under this regulation, qualifying low-carbon intensity fuels are those that are manufactured from organic material, waste materials, or carbon monoxide (CO) and CO_2.

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111 https://stikeman.com/en-CA/kh/canadian-energy-law/2017/08/23/21/19/canada-requires-2-percent-biofuel-content-in-diesel-fuel-and-heating-oil-as-of-july-1
112 https://www.c2es.org/document/canadian-provincial-renewable-fuel-standard/
113 https://www.c2es.org/document/canadian-provincial-renewable-fuel-standard/
114 https://www.c2es.org/document/canadian-provincial-renewable-fuel-standard/
115 https://www.ontario.ca/page/cleaner-transportation-fuels
116 https://www.legisquebec.gouv.qc.ca/en/document/cr/P-30.01,%20r.%200.1

While not strictly related to fuels, in 2022 **Nova Scotia** ordered its utility to use biomass to generate 135,000 MW/h of electricity each year until 2025[117]. In 2025, the province ordered its utility to use biomass to generate 160,000 MW/h of electricity each year until 2027[118].

While the motivations for these policy interventions may differ from GHG reductions to supporting the success of adjacent industries (i.e., agriculture, forestry), it does demonstrate that there is a precedent across Canada for making fuel blending a requirement.

Partnerships

The considerations and supports above are relevant to different potential future actors in the adoption of low-carbon fuels within the electricity sector – from those with feedstock(s), to regional service boards, to project developers and fuel producers, to fuel suppliers and distributors, to municipal, provincial, and federal governments. All are likely to be involved in the low-carbon fuels adoption; there may be opportunities for strategic partnerships between these stakeholders to maximize the opportunity for low-carbon fuels adoption within the electricity sector and to help the province realize the associated environmental, economic, and security benefits.

Financing

Beyond traditional means of financing and newly introduced tax credits (see above), new options are emerging that can help with biomass energy and/or organic waste management projects.

In June of 2024 the federal government introduced new measures to regulate methane emissions from Canadian landfills[119]. Funding will be attached to these regulations to help landfills achieve compliance:

> *"To help assist with compliance costs that some landfills may incur, the Canada Community-Building Fund provides $2.4 billion in funding every year to provinces and territories who, in turn, distribute this funding to communities for strategic investments in essential infrastructure, including solid waste management*

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[117] https://www.cbc.ca/news/canada/nova-scotia/biomass-forestry-electricity-nova-scotia-power-tory-rushton-1.6691389
[118] https://www.cbc.ca/news/canada/nova-scotia/biomass-renewable-energy-electricity-1.7483028
[119] The Government of Canada introduces new measures to regulate methane emissions from Canadian landfills - https://www.canada.ca/en/environment-climate-change/news/2024/06/the-government-of-canada-introduces-new-measures-to-regulate-methane-emissions-from-canadian-landfills.html

infrastructure. This funding could support communities who develop landfill gas management infrastructure projects to comply with the proposed Regulations."

The Canada Infrastructure Bank (CIB) is a federal crown corporation tasked with financially supporting revenue-generating infrastructure projects that are "in the public interest" by catalyzing private investment through methods such as direct investment and public-private partnerships. The CIB has five priority sectors, two of which are relevant to biomass energy projects. The CIB has allocated $10B for clean power, renewables, district energy, storage, interties, and/or transmission projects. The CIB has also allocated $10B for green infrastructure projects including energy efficient building retrofits, water, wastewater, carbon capture, utilization and storage, clean fuels, hydrogen, zero emission vehicle charging projects.

Opportunities for the advancement of biomass energy projects have also emerged from time to time from Natural Resources Canada[120].

As waste management is a service provided by municipal governments (or other public entities like the regional service boards) and, given the opportunities that diversion of organic waste presents for economic and environmental benefit, public-private partnership business models may be appropriate for biomass energy projects in NL.

Where Indigenous groups have a financial interest in biomass projects, various additional funding and financing models are made available.

Safety

The production, handling, transportation, storage, and use of different fuels presents different safety considerations. For example, hydrogen has high ignition energy and flame speed[121]. Ammonia has a low flame speed and has higher toxicity[122]. RNG would also present different considerations as natural gas is not used in NL and users would not be used to its characteristics. Each of these fuels (or their chemically identical conventional alternative) have been widely and globally used at scale safely for many years. Processes, procedures, and measures exist that allow for their safe use. However, as these fuels would be 'new' to NL, a degree of training and skills development would be required in advance of their domestic use. This is the subject of a future econext discussion paper.

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[120] Natural Resources Canada: Funding, grants, and incentives - https://natural-resources.canada.ca/funding-partnerships/grants-incentives
[121] https://www.siemens-energy.com/global/en/home/products-services/solutions-usecase/sustainable-fuels.html#Hydrogen-tab-0
[122] https://www.siemens-energy.com/global/en/home/products-services/solutions-usecase/sustainable-fuels.html#Ammonia-tab-1

Culture

Culture plays a role in the acceptance of different products and process. Those engaged in the adoption of low-carbon fuels have reported resistance to change from front line personnel. It is econext's experience that there is a very low level of understanding in NL on the important benefits that low-carbon fuels can yield. As the province has had an exemption from the Renewable Fuel Regulations, the concept of blended fuels is not commonly known. Continued education, testing, and demonstrations are needed to demystify low-carbon fuels and the benefits that they can present to NL.

Fuel Blending and Testing Capabilities

As evident throughout this discussion paper, blending will play an important role in the adoption of low-carbon fuels. This is a specialized activity with specific equipment and skills required.

Fuels can be blended in liquid, gaseous, or solid forms, with liquid blending being the most common.

Effective liquid blending often requires precise flow measurement, calibrated equipment, filtration, and sampling to manage risks such as phase separation, contamination, incorrect blend ratios, cold-weather gelling (particularly for biodiesel), corrosion, and clogging. Gaseous blending most commonly involves injecting hydrogen into natural gas pipelines, with blend limits determined by infrastructure constraints and safety considerations such as hydrogen embrittlement and energy density differences[123].

There are many different possible fuel blends with optimizations unique to their specific use cases and application. As industry is averse to affecting the integrity of their equipment, the safety of their employees, and the experience of its customers – risks to low-carbon fuels adoption must be mitigated to greatest extent possible. This is true for most industries.

To achieve this risk mitigation and enable the adoption of low-carbon fuels, adequate research and deployment capabilities in terms of equipment and personnel is required. The availability of accessible blending and testing equipment appears to be scarce. econext is undertaking work to delineate capabilities in Canada that can be leveraged and gaps that may need to be filled within NL to advance the adoption of low-carbon fuels.

[123] Forthcoming discussion paper from econext on Fuel Blending

9. Recommendations

Analysis of bio-based low-carbon fuels production reveals a number of next steps which should be taken in order for environmental, economic, and energy security benefits to be realized.

9.1 Define best use cases for available biomass in NL and techno-economic feasibility of low-carbon fuels production

There are multiple fuel production pathways using locally available biomass that are relevant in the electricity generation context. Moreover, there are multiple different sources of biomass that each has their own characteristics influencing how they would be best used in fuel production. Lastly, there are other fuel demands that are expected to arise over time – particularly in support of marine transportation decarbonization. A techno-economic analysis is required to determine the best end uses at a provincial level for each of these organic waste materials (in addition to landfill gas) and the feasibility of low-carbon fuel production and adoption business cases. Special attention should be placed on technologies that can incorporate various feedstocks to improve economies of scale and simplify logistics, and the use of 'mobile' units should be considered to overcome geographic and transportation challenges. This study should include research identifying the best available commercial technologies that align with best use cases and the NL context, as well as consideration for the various supports and frameworks (i.e., ITCs, CRF, CER, waste diversion, etc.) that can impact economics.

9.2 Align provincial climate and energy strategy with domestic production capabilities

The fact that renewable diesel is already in production in NL should drive low-carbon fuels adoption decision-making in the near term as it is directly compatible with all of the existing generation assets and equipment. Meanwhile, if and when final investment decisions are made on hydrogen production projects in NL and development commences, this development should drive low-carbon fuels adoption decision-making in the medium and long term. Hydrogen is present – in one shape or form – in a variety of low-carbon fuels adoption pathways. Only when locally produced low-carbon fuels are used are the full benefits relating to environment, economy, and energy security realized. Climate and energy planning should consider and incorporate findings from the biomass low-carbon fuel techno-economic feasibility study.

9.3 Establish workable business models for low-carbon fuels adoption in NL

Establishing local demand for biomass-based low-carbon fuels within NL will create the certainty that investors will need to advance production projects. Business models need to be developed in collaboration with governments and end-users to maximize the use of tools that can be leveraged to make domestic fuel production and adoption economically feasible.

9.4 Invest in fuel blending/testing research and infrastructure

To overcome industry risk aversion with the adoption of new technologies, adequate research and development capabilities in terms of equipment and personnel is required. These capabilities must be relevant to the NL context and accessible. Blending and testing capabilities are understood to be few and difficult to access in Canada, presenting an opportunity for the province to create facilities that would be in-demand and attract interest and investment. The testing of biodiesel and renewable diesel blends in real-world NL scenarios should be an immediate priority, followed by hydrogen and relevant derivates.

10. Conclusion

Organic waste diversion through low-carbon fuels production could simultaneously (a) reduce GHG gas emissions in NL and other environmental impacts, (b) reduce overall waste management costs for taxpayers, governments, and industries, (c) create products that can be used in NL to further reduce the province's GHGs, (d) increase the province’s energy security, and (e) create new green jobs and revenues in the process.

The findings of this discussion paper suggest that there may be significant value to organic waste streams in NL related to biomass-based low-carbon fuels production and that further investigation is warranted.