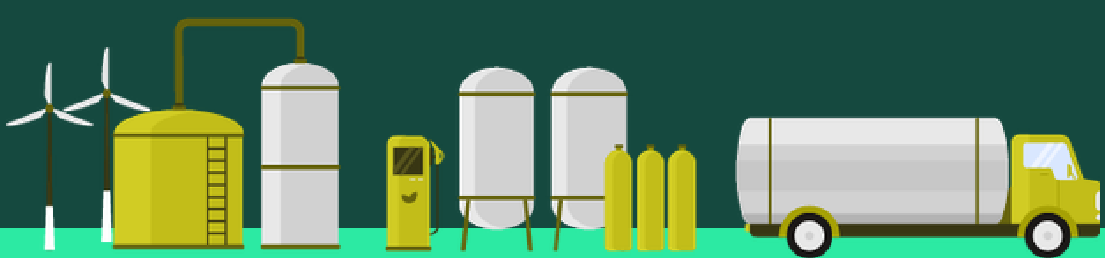
Research

Fuel Blending and Opportunities for Newfoundland and Labrador



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Glossary

B100	100% Biodiesel Content (Pure)
B##	##% Biodiesel Content
CFR	Clean Fuel Regulations
$C_{12}H_{23}$	Average chemical formula for diesel
C_8H_{18}	Average chemical formula for gasoline
C_9-C_{16}	Jet Fuel Hydrocarbons
$CH_3CH_2CH_2CH_2OH$	Butanol
CH_3CH_2OH	Ethanol
CH_4	Methane
CI	Carbon Intensity
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COP21	UN Climate Change Conference
E85	85% Ethanol Content
E##	##% Ethanol Content
EISA	Energy Independence and Security Act
EPA	Environmental Protection Agency
EU	European Union
EV	Electric Vehicle
FTIR	Fourier Transform Infrared Spectroscopy
gCO_2e/MJ	Grams of CO_2 Equivalent per Megajoule
GGRF	Greenhouse Gas Reduction Fund
GHG	Greenhouse Gas
GTF	Green Transition Fund
GTTC	Green Technology Tax Credit

GW	Gigawatt
H_2	Hydrogen
H_2O	Water
HAEC	Hydrogen-Assisted Environmental Cracking
HAP	Hazardous Air Pollutants
kt	Kilotonne , 1 Thousand Tonnes
LNG	Liquid Natural Gas
MC	Measurement Canada
MGO	Marine Gas Oil
Mt	Megatonne, 1 Million Tonnes
MW	Megawatt
NH_3	Ammonia
NL	Newfoundland and Labrador
NLERF	Newfoundland and Labrador Emissions Reduction Fund
N_2O	Nitrous Oxide
NO_x	Nitrogen Oxides
PM	Particulate Matter
PUB	Board of Commissioners of Public Utilities
RED III	EU Renewable Energy Directive
SAF	Sustainable Aviation Fuel
SO_2	Sulphur Dioxide
US	United States

Executive Summary

Newfoundland and Labrador (NL) will need to implement ambitious decarbonization measures to meet approaching federal and provincial net zero targets. Clean fuel blending is a practical near-term strategy, enabling lower lifecycle emissions by integrating cleaner fuels into existing systems without major infrastructure modifications. Fuel blending offers a gradual and scalable pathway to reduce emissions across NL's hard-to-abate sectors which are reliant on conventional fuels and difficult to electrify using existing low-carbon technologies. This discussion paper outlines fuel blending applications, policies and incentives driving the shift, and proposes tailored next steps to support NL's economic and environmental priorities.

Clean fuels considered in this paper are categorized as biofuels, renewable fuels, or other clean fuels (including green hydrogen and its derivatives, and synthetic fuels). Blending conventional fuels with clean fuels is a proven strategy to reduce greenhouse gases (GHGs), nitrogen oxides (NO_x), and particulate matter emissions, making it an implementable approach for decarbonization in the near term.

Government standards, incentives, and net zero targets are key drivers of clean fuel adoption and blending mandates globally. Federally, the Canadian Clean Fuel Regulations (CFR) require a 15% reduction in the carbon intensity of conventional gasoline and diesel by 2030 (from 2016 levels) and is managed through a compliance credit system. Several provincial and territorial governments have implemented specific blending mandates exceeding the requirements of the CFR. Internationally, policies such as the ReFuelEU Aviation Regulation, FuelEU Maritime Regulations, and the International Maritime Organization's (IMO's) proposed net-zero framework are accelerating global fuel blending adoption.

Fuels can be blended in liquid, gaseous, or solid forms, with liquid blending being the most common, involving batch or in-line methods that differ in accuracy, homogeneity, and logistical flexibility. Effective liquid blending 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. Solid fuel blending typically occurs in coal-coal or coal-biomass applications. Blending takes place in fuel yards using bulldozers, or alternatively at off-site fuel management facilities, as part of the fuel handling process, or directly in the boiler or furnace the fuel is to be used in, although size/shape limitations present challenges.

Fuel blending is projected to be a transitional solution for emissions reduction during the shift towards cleaner fuel use in sectors such as marine transport and port operations, heavy duty and public transport, and heavy industry. However, there are other sectors that can benefit from fuel blending in the long term such as in remote communities and as back-up capacity for the electricity grid, as well as in the aviation sector. As such, there is significant opportunity for the local development of fuel blending in NL due to available biomass feedstocks, emerging clean fuel production, proposed green hydrogen and ammonia projects, and identified demand across hard-to-abate sectors. However, geographic dispersion and logistical constraints pose challenges to its implementation.

Evidently, the development of fuel blending in NL will require further research into local production viability, including biomass availability assessments, techno-economic analysis of biofuel pathways, and progress toward final investment decisions for renewable energy and green fuel projects. Additional next steps include developing supportive policies and incentives, planning distribution and storage systems, preparing sector-specific implementation strategies, fostering collaboration across stakeholders, and piloting projects to demonstrate performance and emissions reductions in NL's cold climate conditions.

1.0 Introduction

With provincial and federal **net zero** targets set for **2030**, **2040**, and **2050**, Newfoundland and Labrador (NL) will need to adopt ambitious decarbonization measures to meet them. Provincial targets aim for a 30% reduction below 2005 levels in greenhouse gas (GHG) emissions by 2030, 60% by 2040, and net zero by 2050.[1] Federal targets aim for an overall reduction of 40% below 2005 levels by 2030, and net zero by 2050.[2] Net zero targets will be achieved through global shifts away from the use of conventional fossil fuels and the decarbonization of GHG emitting sectors under **The Paris Agreement**. The Paris Agreement is an international treaty enacted in 2016 and designed to limit global warming to mitigate dangerous climate change impacts.[3]

Clean fuel blending represents one of the most practical near-term strategies to support progress toward these targets. Clean fuels have significantly **lower lifecycle GHG emissions** than conventional fossil fuels,[4] and can often be blended at low levels into existing systems without requiring major equipment changes. This approach provides a **phased decarbonization pathway** that maintains reliability while avoiding immediate large capital replacements. For this discussion paper, hydrocarbons (molecules containing only carbon and hydrogen atoms) in the form of gasoline (general formula C_8H_{18}), diesel (general formula $C_{12}H_{23}$), and conventional jet fuel (C_9-C_{16} hydrocarbons) are considered as conventional fossil fuels.

A variety of clean energy technologies must be adopted to meet approaching net zero targets. This is especially true given the unique nature of GHG emitting sectors across Canada, such as energy generation, transportation, industrial, residential, and waste management sectors. Influential factors such as geology, topography, infrastructure, fuel availability, and climate all govern the suitability of clean technologies for a given location. It is important that **localized opportunities** are prioritized and harnessed whenever possible. However, other decarbonization strategies, such as the adoption of clean fuels, can be **deployed across entire sectors** for more efficient, broader reaching benefits.

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[1] 2025-2030 Climate Change Action Plans - https://www.gov.nl.ca/ecc/occ/action-plans/
[2] Net-zero Emissions by 2050 - https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/net-zero-emissions-2050.html
[3] The Paris Agreement - https://unfccc.int/process-and-meetings/the-paris-agreement
[4] Clean Fuels – Fueling the Future - https://natural-resources.canada.ca/energy-sources/clean-fuels/clean-fuels-fueling-future

Among the largest emitting sectors in NL are transportation (on-road and marine), industrial, electricity, and waste;[5] all of which can benefit from the use of clean fuels. Across these sectors, existing equipment often has the capacity to operate on low-proportion fuel blends of clean and conventional fuels, presenting a **significant opportunity for gradual decarbonization**. This strategy is necessary because of the current lack of widespread availability of technologies that run entirely on clean fuels. When feedstocks, such as biomass (waste) and landfill gases, are used as sources for clean fuel production, gradual adoption of these clean fuels will further abate **lifecycle emissions**. As such, clean fuels have the potential to decarbonize sectors with high conventional fuel use, as well as the waste sector.

The purpose of this discussion paper is to provide an **overview of fuel blending** and its applications, as well as the **opportunities** it presents for NL. Considerations for clean fuel strategies undertaken in other **global jurisdictions** are examined, as well as **standards and incentives** to enable the adoption of fuel blending on international and domestic scales. Potential **next steps** for the adoption of fuel blending in NL will be discussed and tailored to support the **economic and environmental priorities** of the province.

[5] Provincial and Territorial Energy Profiles – Newfoundland and Labrador- https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-newfoundland-labrador.html?=undefined&wbdisable=true

2.0 Fuel Blending and its Role in Decarbonization

Fuel blending is an emerging approach to reducing the carbon intensity of fuel and involves the mixing of two or more distinct types of fuels to produce a **composite blend**.

Carbon intensities are used to quantify the **lifecycle GHG emissions** produced by fuel **per unit of useful energy**.[6] Through blending, fuel properties such as octane rating, GHG intensity, and cost effectiveness are enhanced, allowing manufacturers to create fuels tailored to specific applications and regulatory requirements.

Fuel blending with clean fuels, such as biofuels, renewable fuels, green hydrogen and its derivatives (including ammonia and methane), as well as synthetic fuels is widely considered an effective method for reducing nitrogen oxides (NO_x), GHGs, and particulate matter (PM) emissions created through the combustion of conventional petroleum-based fuels. This is especially important for the decarbonization of **hard-to-abate sectors** such as heavy transportation, marine transportation (shipping), aviation, and heavy industry that rely on fossil fuels.[7]

Hard-to-abate sectors refer to sectors that are challenging to decarbonize due to high temperature and/or energy demands, process emissions where carbon is produced as a byproduct of specific chemical reactions, or limited ability for electrification using existing low-carbon technologies. As such, fuel blending provides an opportunity for emissions reduction within hard-to-abate sectors **without requiring major modifications** to existing infrastructure/processes.

There are three distinct forms of fuel blending: solid, liquid, and gas. Liquid fuel blending is the most common application, with the greatest number of possible alternative fuels available for blending applications. **Liquid fuel blending** is the mixing of two or more liquid fuels, for the purpose of achieving specific fuel properties not possessed by a single fuel on its own. Liquid fuel blending is one of the most advantageous methods of decarbonizing hard-to-abate sectors that currently rely on liquid fossil fuels.

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[6] Carbon Intensities - https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/renewable-low-carbon-fuels/carbon-intensities

[7] Decarbonizing Hard-to-Abate Sectors with Renewables - https://www.irena.org//media/Files/IRENA/Agency/Publication/2024/Apr/IRENA_G7_Decarbonising_hard_to_abate_sectors_2024.pdf

Gas fuel blending is the mixing of two or more gaseous substances to achieve favorable properties for specific applications, such as emission reductions in combustion processes. Common applications of gaseous fuel blending for emission reductions are hydrogen with natural gas. Offsetting the use of natural gas with blends of hydrogen has significant emission reduction opportunities, as well as enhanced energy efficiency benefits, without requiring modification of existing systems up to amounts of 15-20% hydrogen.[8]

Gaseous fuel blending is also utilized to create **propane-air** (LPG-air or Synthetic Natural Gas) as a drop-in replacement for natural gas, employed for back-up and peak shaving applications.[9] A mixture of approximately 60% atmospheric air (78.1% nitrogen, 20.9% oxygen, and 1% inert) and 40% propane achieves similar properties to that of natural gas, making it suitable as a drop-in replacement.[10]

Solid fuel blending is the mixing of two or more solid fuels, typically to be co-fired in a boiler.[11] This is commonly done with coal, either from the same coal rank or from different ranks (for example blending sub-bituminous coal with bituminous coal). Blending coal with biomasses such as wood and wood wastes, herbaceous crops and wastes, manure, and industrial wastes from the processing of biomass, began emerging in the 1990s to support a decreasing global reliance on the burning of coal.[11]

Solid fuel blending offers economic and environmental benefits. Costs are reduced through blending with lower-grade or more affordable fuels. Reduction of SO_2, NO_x, PM, CO_2, and Hazardous Air Pollutant (HAP) emissions is achieved through blending with biomass and other fuels with more favorable emission properties.[11]

[8] Blending Hydrogen with Natural Gas Could Help Fuel Energy Transition - https://www.ualberta.ca/en/folio/2023/02/blending-hydrogen-with-natural-gas-could-help-fuel-energy-transition.html
[9] Propane-Air Basics - https://algas-sdi.com/what-is-propane-air/
[10] What is a Propane Air Mixer? Overview - https://i-maximum.com/sng-lpg-blog/what-is-a-propane-air-mixer/615764058
[11] Chapter 2 - Principles of Solid Fuel Blending - https://www.sciencedirect.com/science/article/abs/pii/B9780123809322000027

3.0 Clean Fuel Standards

The adoption of clean fuels is largely driven by the **standards and incentives** put in place by governments, as well as the influence of international clean fuel policies on global industries. As global net zero deadlines approach, clean fuel blending mandates are becoming widespread across conventional fuel-reliant industries. The following section details relevant standards on a **domestic, provincial, and international** level. Please note that regulations and incentives discussed in this section were active at the time of writing and are subject to change.

3.1 Domestic

The federal **Renewable Fuels Regulations** were enacted in 2010, requiring fuel producers and importers to supplement at least 5% of the volume of the gasoline they produce or import into Canada with renewable fuel, and at least 2% of the volume of diesel and heating distillate oil.[12] If not achieved through their own fuel blending, compliance with this regulation was achieved by obtaining enough compliance units, which were available through a trading system where compliance units could be bought from other companies.[13] Compliance units were created through: fuel blending; importing already blended fuel into Canada; the use of biocrude as a feedstock to produce liquid petroleum fuel; or the sale/use of biodiesel or renewable fuel in a combustion device other than a diesel engine or domestic-type burner.[14]

Conventional gasoline, diesel, or heating distillate oil delivered or sold for use in NL, Nunavut, Northwest Territories, Yukon, and areas of Quebec at a latitude greater than 60°N were excluded under the Renewable Fuels Regulations.[14] NL was excluded from these regulations because of the lack of locally produced clean fuels. Further, the low feedstock availability, large distances between biomass producers (farms, fish plants, sawmills, etc.), and compatibility of these sources for processing methods presents challenges for the development of clean biofuels locally. Compliance with the regulation would require the province to import clean fuels across long distances by truck and ferry, impacting both

[12] Renewable Fuels Regulations - https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/renewable.html
[13] Federal Renewable Fuels Regulations: Overview - https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/renewable/overview.html
[14] Renewable Fuels Regulations - https://laws-lois.justice.gc.ca/eng/regulations/SOR-2010-189/20131025/P1TT3xt3.html

affordability and emissions in the lifecycle of the fuel.[15] At the time, NL had the highest price of gasoline out of all Canadian provinces, which would be driven higher to account for the cost of clean fuel transportation.[15]

Enacted in 2022, with carbon intensity reductions coming into effect on July 1, 2023, the **Clean Fuel Regulations** (CFR) replaced the Renewable Fuels Regulations (officially repealed in 2023).[16] Under the new CFR, importers and producers of gasoline and diesel are required to achieve a 15% reduction in 2016 carbon intensity levels by 2030, displacing at least 5% of gasoline and 2% of diesel with cleaner alternatives.[17,18] Table 1 below shows **carbon intensity limits** for both gasoline and diesel under the CFR from 2023 onwards. Each limit is given in gCO_2e/MJ, which represents the grams of carbon dioxide equivalent produced per megajoule of energy.

Table 1: Carbon Intensity Limits Under the CFR (gCO_2e/MJ)[18]

Fossil Fuel	2023	2024	2025	2026	2027	2028	2029	2030 onwards
Gasoline	91.5	90.0	88.5	87.0	85.5	84.0	82.5	81.0
Diesel	89.5	88.0	86.5	85.0	83.5	82.0	80.5	79.0

Similar to that of the Renewable Fuels Regulations, a compliance credit system is used under the CFR for importers and producers to either create their own credits, purchase credits from other creators, or contribute to a registered Emission Reduction Funding Program.[17] Compliance credits under the CFR fall into three categories, projects that: reduce the lifecycle carbon intensity of liquid fossil fuels; supply low carbon intensity fuels; or supply fuel or energy to advanced vehicle technology.[17] Emission Reduction Funding Programs under the CFR allow importers and producers to satisfy up to 10% of their annual carbon intensity reduction through investment in projects that support the development of processes or technologies that reduce CO_2 emissions.[17] Investments in Emission Reduction Funding Programs generate compliance credits, at a price of $350 (in 2022, CPI adjusted) per credit.[17]

There are four Emission Reduction Funding Programs authorized under the CFR, including: Emissions Reduction Advancement Program (ERAP), Newfoundland and

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[15] Province Exempt from Renewable Fuel Laws - https://www.saltwire.com/newfoundland-labrador/province-exempt-from-renewable-fuel-laws-125918]
[16] Clean Fuel Standard: Proposed Regulatory Approach - https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-regulations/regulatory-approach.html
[17] What are the Clean Fuel Regulations? - https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-regulations/about.html
[18] Clean Fuel Regulations - https://laws-lois.justice.gc.ca/eng/regulations/SOR-2022-140/page-2.html#docCont

Labrador Emissions Reduction Fund (NLERF), Emissions Reduction Alberta Clean Fuel Regulations Compliance Fund (ERA), and NorthX Emissions Reduction Fund.[17] The NLERF, created by econext, is the first fund created by a non-federal government entity authorized as a compliance mechanism. It is composed of two programs: greenhouse gas reduction projects, through which contributions are authorized compliance mechanisms under the CFR, and net zero research and development, through which contributions are eligible for a tax receipt.[19]

Gasoline and diesel produced or imported into NL and sold for use within the province may be removed from the volume used to calculate the renewable fuel displacement requirement under the CFR.[18] Suppliers therefore still comply with the regulation nationally, but the required displacement is calculated using gasoline sold for use in the rest of Canada. This exception was granted due to significant concerns raised by the provincial government, particularly surrounding the geography of NL and associated logistical challenges, energy security constraints, and limited transportation options, which would increase the cost of fuels in the province significantly under the CFR.[20]

NL's Board of Commissioners of Public Utilities (PUB), which regulates fuel prices in the province, separately includes a carbon price adjustment in regulated fuel prices to recover supplier compliance costs associated with the CFR.[21]

To support the adoption of clean technologies in Canada, the federal government has also implemented several tax credits potentially relevant to fuel blending initiatives and technologies.

- The **Clean Technology Investment Tax Credit** is a refundable tax credit of up to 30% of capital costs for the adoption and operation of new clean technology property.[22]
- The **Carbon Capture, Utilization, and Storage (CCUS) Investment Tax Credit** (Not available in NL) is a refundable tax credit of up to 60% on eligible expenditures for a qualified CCUS project, including those capturing CO_2 emissions from fuel combustion, industrial processes or directly from the air, as well as those transporting, storing, or utilizing captured carbon.[22]

[19] Investing in a Net Zero Future - https://nlerf.ca/
[20] Provincial Government Disagrees with Federal Clean Fuel Regulations - https://www.gov.nl.ca/releases/2023/iet/0628n05/
[21] Home – Petroleum Products – Carbon Price Adjustment - http://www.pub.nl.ca/HowPricesAreSet/CarbonPriceAdjustment.php
[22] The Potential for Biomass Energy in NL - https://econext.ca/wp-content/uploads/2025/06/Biomass-Energy-Potential-NL-Version-1.0-2025-06-11.pdf

- The **Clean Hydrogen Investment Tax Credit** is a refundable tax credit of up to 40% of eligible expenses incurred for property that produces hydrogen, and 15% for property used to convert clean hydrogen to clean ammonia.[22]
- The **Clean Technology Manufacturing Investment Tax Credit** is a refundable tax credit of up to 30% of capital costs incurred for clean technology manufacturing and processing or critical mineral extraction and processing.[22]
- The proposed **Clean Electricity Tax Credit** will be a refundable tax credit of up to 15% of investments in refurbishments or new equipment that generate clean electricity, store electricity without the use of fossil fuels, or transmit electricity between Canadian jurisdictions.[22]

3.2 Provincial

3.2.1 Newfoundland and Labrador

Provincially, the government of NL has not established specific fuel blending mandates and has been granted federal exemptions from blending mandates due to logistical and cost constraints.[20] However, the provincial government has committed to **incentivizing** the transition to clean technologies and renewable energy through **tax credits and supporting funds**.

The **Green Technology Tax Credit (GTTC)** grants a tax credit of up to 20% of capital costs for equipment that generates or conserves renewable energy, efficiently uses fossil fuels, or uses fuel from waste.[23] This tax credit can be used to reduce the amount of provincial tax payable, or can be refunded on the corporation's income tax return up to 40% of the total GTTC amount,[23] making the adoption of green technologies in the province cheaper. Similarly, the **Manufacturing and Processing Investment Tax Credit** grants a refundable tax credit of up to 10% of capital costs for property located in NL utilized for business operations (excluding qualified resource properties).[24] This tax credit incentivizes the development of business in the province, creating local opportunity. As such, these tax incentives can assist with the adoption of clean technologies in NL, and promote the development of local infrastructure, strengthening the local economy.

The **Green Transition Fund (GTF)** provides commercial and non-commercial funding for businesses, industry associations, and post-secondary institutions advancing the green

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[23] Green Technology Tax Credit (GTTC) - https://www.gov.nl.ca/fin/tax-programs-incentives/business/green-tech-tax-credit-gttc/

[24] Manufacturing and Processing Investment Tax Credit - https://www.gov.nl.ca/fin/tax-programs-incentives/business/manufacturing-and-processing-investment-tax-credit/

economy through the greening of existing operations or the development of new green/clean opportunities.[25] Minimum funding through the GFT is $75,000 with a maximum of $3 million, equating to 50% of eligible project costs for non-commercial projects, and 40% for commercial projects.[25] The purpose of this fund is to de-risk activities that facilitate collaboration, promote investment, and grow the provincial green industry. To date, there have been 40 projects awarded under the GTF, among which are clean fuel initiatives focused on strengthening the clean fuel industry in NL, subsequently presenting an opportunity for fuel blending initiatives in the province.[26]

The NL **Greenhouse Gas Reduction Fund (GGRF)** provides funding to support projects resulting in verifiable industrial GHG reductions across the provincial electricity generation, mining and quarrying, oil and gas, and manufacturing industries.[27] This fund was established under the Management of Greenhouse Gas Act (sections 6-9) as an industry funded program, whereby industrial operators make contributions to the GGRF to purchase credits to offset emissions.[28] Valued at over $431,000, funding is available through the GGRF at a maximum cost-sharing ratio of 50% of eligible project costs.[27, 29] The purpose of this fund is to incentivize investment in GHG reduction initiatives across NL's industrial sectors.

3.2.2 Other Jurisdictions in Canada

The federal CFR require suppliers to reduce the carbon intensity of conventional gasoline and diesel by at least 15% below 2016 levels by 2030, displacing at least 5% of gasoline and 2% of diesel with cleaner alternatives. Several provinces have set more **aggressive targets** and mandated further reductions. In addition to a focus on the overall reduction in carbon intensity, provincial governments have also made specific mention of the **significance of blending** clean fuels into conventional gasoline and diesel.

In Alberta, the provincial **Renewable Fuels Standard** (2010) requires a minimum of 5% of renewable alcohol content by volume in conventional gasoline, and a minimum of 2% bio-based diesel content by volume in conventional diesel fuel, which is aligned with the

[25] Green Transition Fund Program - https://www.gov.nl.ca/iet/funding/green-transition-fund-program/
[26] Green Transition Fund Supports Six New Projects - https://www.gov.nl.ca/releases/2025/iet-en/0912n01/
[27] NL Greenhouse Gas Reduction Fund Program Guidelines - https://www.gov.nl.ca/eccc/files/Newfoundland-and-Labrador-Greenhouse-Gas-Reduction-Fund-2024-Guidelines-and-Application.pdf
[28] NL Greenhouse Gas Reduction Fund Advisory Council - https://www.exec-abc.gov.nl.ca/public/agency/detail/?id=808&
[29] Applications Now Open for the Greenhouse Gas Reduction Fund - https://www.gov.nl.ca/releases/2024/ecc-en/0606n01/

federal CFR.[30] To qualify as a renewable fuel under the Alberta Renewable Fuels Standard, renewable fuels must have a GHG emissions intensity of at least 25% less than conventional gasoline and diesel fuels.[30]

In 2022, Manitoba implemented the **Ethanol Mandate**, which requires suppliers to replace at least 10% of conventional gasoline with ethanol.[31] Similarly, the provincial **Biodiesel Mandate** (2022) requires suppliers to blend an annual average of at least 5% renewable content in both on and off-road conventional diesel fuel.[31]

Ontario implemented the **Cleaner Transportation Fuels Regulation** in 2020, which required suppliers to blend at least 10% of renewable content in conventional gasoline from 2020-2024.[32] Under this provincial regulation, the blend amount gradually increases to 11%, 13%, and finally 15% in 2025, 2028, and 2030, respectively.[32] To qualify as renewable content under this regulation, the fuel must have 45% lower emissions than conventional gasoline on a lifecycle basis.[32] From 2030 onward, the renewable content must have 50% lower emissions to qualify.[32] Additionally, this regulation requires suppliers to blend at least 4% renewable content into conventional diesel.[32] To qualify as renewable content, the fuel must have 70% lower emissions than conventional diesel on a lifecycle basis.[32]

In Saskatchewan, the **Renewable Diesel Act** (2012) requires distributors to blend conventional diesel with at least 2% renewable diesel. Additionally, the provincial **Ethanol Fuel (General) Regulations** (2005) under the **Ethanol Fuel Act** (2002) required distributors to blend at least 1% ethanol in conventional gasoline from 2005-2007, which increased to at least 7.5% ethanol by the end of 2007, and remains at 7.5% ethanol since 2008.[33] These regulations were amended in 2022 under the **Ethanol Fuel (General) Amendment Regulations**, whereby distributors have until 2030 (instead of the previous deadline of 2023) to purchase 30% of the ethanol used for blending with automotive gasoline from producers in Saskatchewan who have a design capacity of 25 million liters or less per year.[33] This amendment was introduced to support local small-scale ethanol producers, strengthening the provincial clean fuel industry.

British Columbia implemented the **Greenhouse Gas Reduction (Renewable and Low Carbon Fuel Requirements) Act** in 2010, which mandated suppliers to blend a minimum

[30] Renewable Fuels Standard Regulation - https://kings-printer.alberta.ca/1266.cfm?page=2010_029.cfm&leg_type=Regs&isbncln=9780779813650
[31] Biofuels - https://www.gov.mb.ca/sd/environment_and_biodiversity/energy/biofuels/index.html
[32] Cleaner Transportation Fuels - https://www.ontario.ca/page/cleaner-transportation-fuels
[33] OC 533/2022 - The Ethanol Fuel (General) Amendment Regulations, 2022 (Minister of Energy and Resources) - https://publications.saskatchewan.ca/#/products/119833

of 5% renewable content in conventional gasoline and 3% renewable content in conventional diesel, with the blending rate for diesel increasing to 4% starting in 2011.[34] This act has since been replaced by the **Low Carbon Fuels Act** (2024) which outlines both renewable fuel and low carbon fuel targets. Under the renewable fuel targets, suppliers of gasoline must include at least 5% renewable content by volume from 2024 onward; diesel suppliers were required to have renewable content of at least 4% by volume in 2024, which increased to 8% from 2025 onward; and jet fuel suppliers will be required to include at least 1%, 2%, and 3% renewable content in 2028, 2029, and 2030 onward, respectively.[34] Under the low carbon fuel targets, suppliers of gasoline, diesel, and jet fuel are required to meet annual carbon intensity reduction targets, which increase incrementally from 2024-2030.[34] By 2030, gasoline and diesel suppliers will be required to have a 30% reduction in carbon intensity, and aviation fuel suppliers will be required to have a 10% reduction.[34]

In Quebec, fuel blending requirements for conventional gasoline and diesel are included under the Petroleum Products Act, under the **Regulation Respecting the Integration of Low-Carbon Intensity Fuel Content into Gasoline and Diesel Fuel** (2021).[35] 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.[35] 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.[35] 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.[35]

Table 2 below summarizes additional clean fuel requirements implemented in other Canadian jurisdictions compared to the federal CFR. As seen in the table, Ontario and Quebec have the highest mandated blending rates for gasoline (by volume), and Quebec and British Columbia have the highest mandated blending rates for diesel (by volume). Additionally, British Columbia is presently the only Canadian jurisdiction to set clear blending and carbon intensity (CI) reduction requirements for aviation fuel, requiring 3% (by volume) renewable fuel content and an overall 10% reduction in CI by 2030.[34]

[34] Low Carbon Fuel Standard requirements - https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/renewable-low-carbon-fuels/requirements
[35] Regulation Respecting the Integration of Low-Carbon-Intensity Fuel Content into Gasoline and Diesel Fuel - https://www.legisquebec.gouv.qc.ca/en/document/cr/P-30.01,%20r.%200.1

Table 2: Summary of Clean Fuel Requirements in Other Canadian Jurisdictions[36]

Province	Clean Fuel Composition: Gasoline	Clean Fuel Composition: Diesel	Clean Fuel Composition: Aviation Fuel
Alberta	5 %vol	2 %vol	
Manitoba	10 %vol	5 %vol	
Ontario	15 %vol	4 %vol	
Saskatchewan	7.5 %vol	2 %vol	
British Columbia	5 %vol (30% CI Reduction)	8 %vol (30% CI Reduction)	3 %vol (10% CI Reduction)
Quebec	15 %vol	10 %vol	
Federal Standard	15% CI Reduction (5 %vol)	15% CI Reduction (2 %vol)	

3.3 International

Decarbonization initiatives have been increasing in prominence across various industries for several years, and the 2015 Paris Agreement (enacted in 2016) has been a major driver for the adoption of clean technologies globally over the past decade. Adopted by 195 parties at the **UN Climate Change Conference (COP21)** in Paris, France, the Paris Agreement is a legally binding treaty on climate change with the overarching goal of holding the global average temperature increase to below 2°C above pre-industrial levels, and pursuing efforts to keep the increase below the critical threshold of 1.5°C.[3]

As such, a variety of decarbonization strategies have been adopted globally, including fuel blending. Differences in fuel availability, major industry, transportation, and energy resources result in different priorities for fuel blending from jurisdiction to jurisdiction. In the European Union (EU), for instance, the **ReFuelEU Aviation Regulation** requires significant blends of synthetic aviation fuels (SAF) and the **FuelEU Maritime Regulations** set expectations for overall GHG reductions in the marine sector for EU member states.[37]

[36] Canadian Transportation Fuels Dashboard - https://advancedbiofuels.ca/resources/canadian-transportation-fuels-dashboard/

[37] European Green Deal: Commission Proposes Transformation of EU Economy and Society to Meet Climate Ambitions - https://ec.europa.eu/commission/presscorner/detail/en/ip_21_3541

Another notable driver for fuel blending, particularly in the marine sector, is the International Maritime Organization's (IMO) proposed Net-Zero Framework. Although discussions are set to be reconvened in fall 2026, the IMO Net-Zero Framework is a set of international regulations designed to set a global fuel standard for the gradual reduction of carbon intensity of marine fuels, as well as a pricing mechanism for marine GHG emissions.[38] As such, if implemented, these regulations will be a major driver for the adoption of fuel blending in the marine sector and shipping globally.

The following examples provide an overview of **progressive approaches** to fuel blending around the world; however, it should be noted that policies and regulations are fluxional in response to changes in government.

3.3.1 United States

Authorized under the 2005 **Energy Policy Act** and expanded under the 2007 **Energy Independence and Security Act (EISA)**, the **Renewable Fuel Standard** aimed to reduce reliance on imported oil, expand the renewable fuels sector, and reduce GHG emissions.[39] Under this standard, fuel suppliers were required to substitute incremental volumes of conventional fossil fuels in transportation, home heating, and jet fuels with biofuels such as biomass-based diesel or cellulosic biofuel, advanced biofuel, or total renewable fuel from 2007 to 2022, escalating to 36 billion gallons per year.[40]

Advanced biofuels considered under this standard included ethanol derived from sugarcane, jet fuel derived from soybean oil, cellulosic ethanol derived from crop residue, and renewable natural gas collected from landfills.[40] To qualify as renewable fuels under this standard, conventional biofuels were required to meet a 20% reduction in lifecycle emissions compared to conventional fuels, while advanced biofuels and biomass-based diesel were required to meet a 50% reduction, and cellulosic biofuels a 60% reduction.[40] After 2022, although specific volumes are not defined under the Renewable Fuel Standard, the US **Environmental Protection Agency (EPA)** has been mandated to set subsequent clean fuel volume targets each year.[41]

[38] The IMO Net-Zero Framework – FAQs - https://www.imo.org/en/mediacentre/hottopics/pages/faqs-the-imo-net-zero-framework.aspx

[39] Renewable Fuel Standard - https://www.epa.gov/renewable-fuel-standard

[40] Overview of the Renewable Fuel Standard Program - https://www.epa.gov/renewable-fuel-standard/overview-renewable-fuel-standard-program

[41] Renewable Fuel Annual Standards - https://www.epa.gov/renewable-fuel-standard/renewable-fuel-annual-standards

On top of these federal blending mandates, state governments in the US have also established various laws and incentives to aid in the adoption of clean fuels, the extent of which can be seen in Figure 1, indicating the number of laws and incentives related to biodiesel, ethanol, hydrogen, and renewable diesel. Darker shading indicates a higher number of laws and/or incentives in that state. The bar below each map indicates the scale. The state of **California** is the most progressive with the highest rate of initiatives for biodiesel, ethanol, and hydrogen.

Laws and Incentives by State

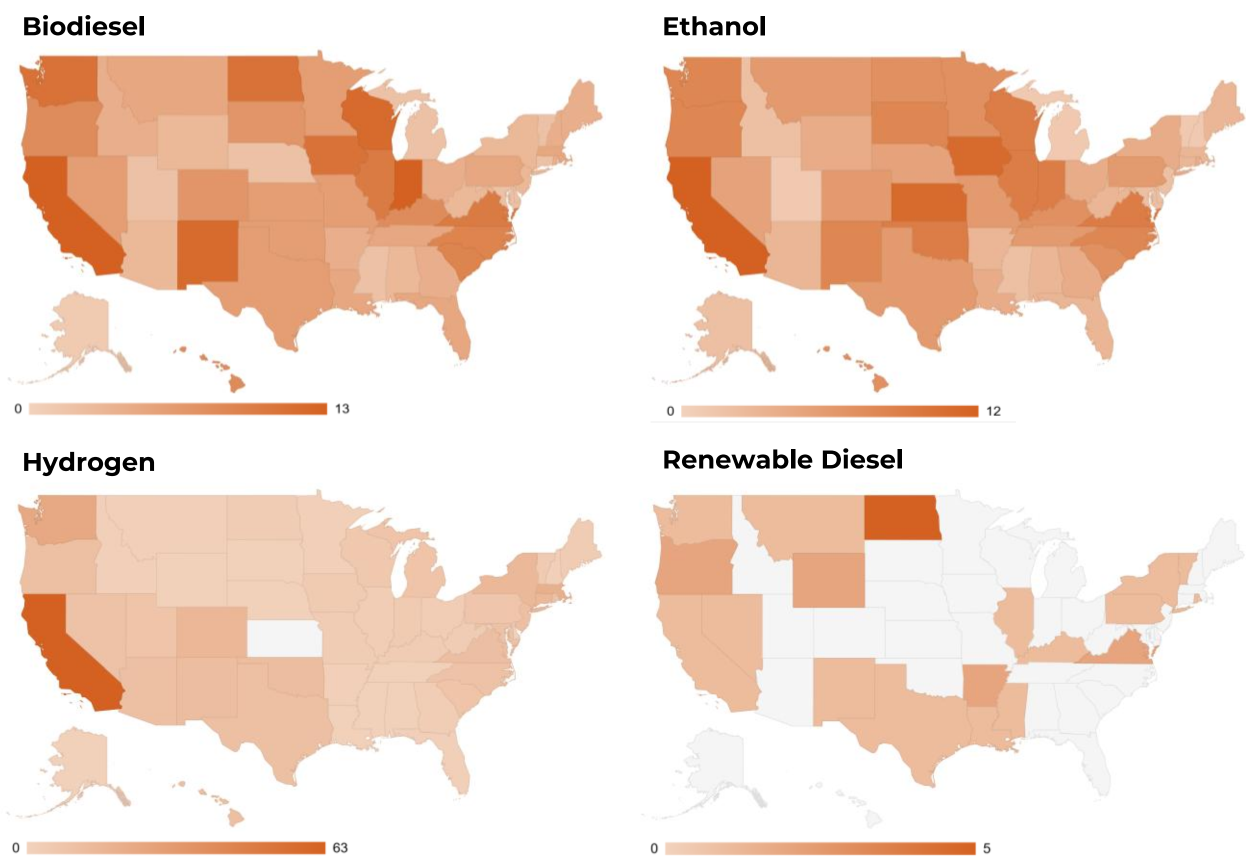

Figure 1: Biodiesel, Ethanol, Hydrogen, and Renewable Diesel Laws and Incentives by State[42]

[42] Maps and Data - https://afdc.energy.gov/data/categories/laws-incentives--3

Similarly, Figure 2 and Figure 3 below show the annual production, consumption, and export/trade of biodiesel and ethanol in the US up to 2023 and 2024, respectively. Steady **growth** is observed for both clean fuels, indicating the growth of the clean fuels sector as well as domestic use.

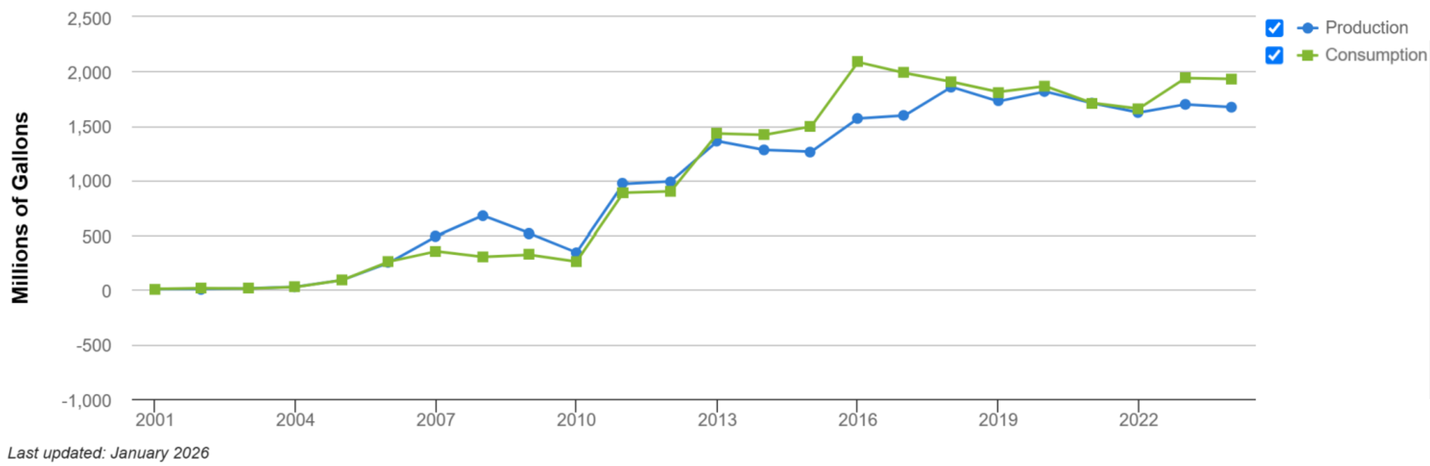

Figure 2: U.S. Biodiesel Production, Exports, and Consumption (2001-2023)[43]

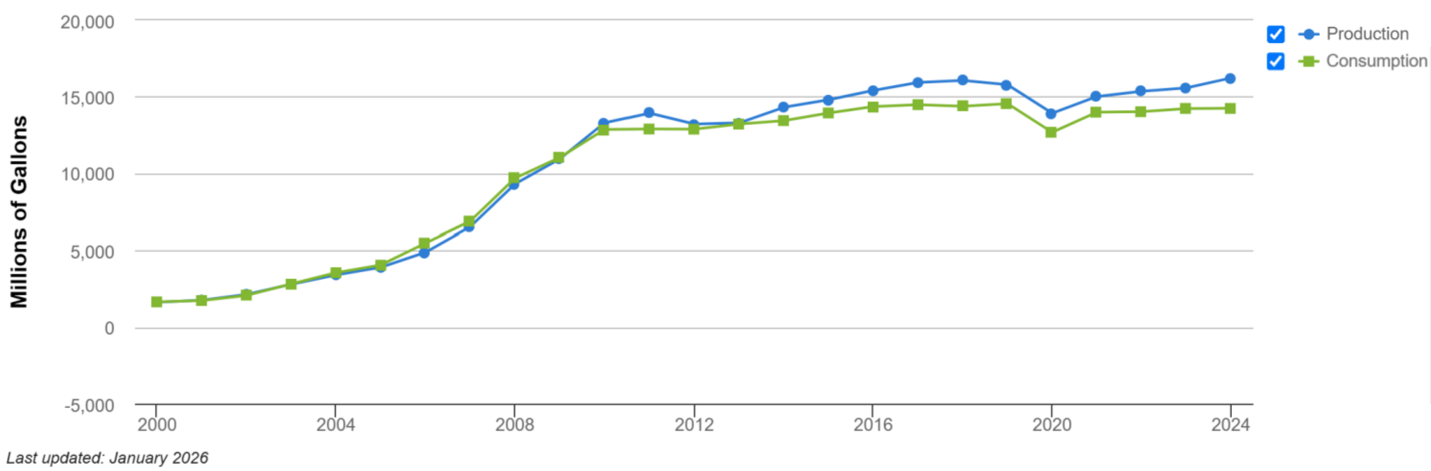

Figure 3: U.S. Ethanol Production, Consumption, and Trade (2003-2024)[43]

[43] Maps and Data - https://afdc.energy.gov/data/search?q=blend

Figure 4 shows the estimated consumption of SAF in the US up to 2024, which also displays steady growth, indicating an uptake in SAF use domestically. This trend is aligned with increasing quotas for advanced biofuels as issued by the EPA.

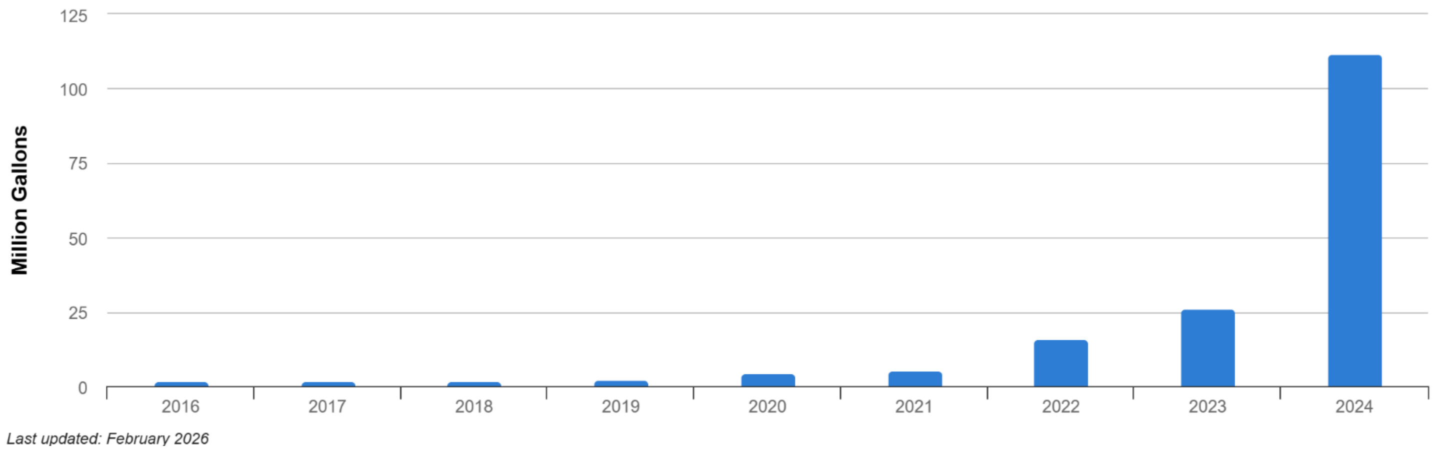

Figure 4: US SAF Consumption (2016-2024)[43]

3.3.2 Brazil

Brazil is the **second largest** producer of ethanol, and **third largest** producer of biodiesel, accounting for more than 26% and 10% of global production, respectively.[44] The majority of Brazilian ethanol is derived from sugarcane, known as **cellulosic ethanol**, however, a small portion is derived from corn food crops, known as **grain ethanol**.[45] As much as 70% of Brazil's domestically produced biodiesel is derived from **soybeans**, with the remainder derived from other **fatty oils** such as tallow, used cooking oil, or palm oil.[46]

As of August 2025, the ethanol blending rate in conventional gasoline was increased from 27% (E27) to 30% (E30) and the biodiesel blending rate in conventional diesel was increased from 14% (B14) to 15% (B15) in Brazil.[45] This expanded mandate increases the displacement of conventional fossil fuels, and Brazil is **gasoline self-sufficient** as a result.[45] Historical ethanol and biodiesel blending mandates in Brazil can be seen in Table 3.

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[44] Global Ethanol Production by Country or Region - https://afdc.energy.gov/data/10331#:~:text=The%20United%20States%20is%20the,while%20Brazil%20primarily%20uses%20sugarcane.

[45] Brazil Raises Biofuel Levels, Sees Gasoline Self-Sufficiency - https://www.reuters.com/business/energy/brazil-raises-biofuel-levels-sees-gasoline-self-sufficiency-2025-06-25/

[46] Biofuels Annual - https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Biofuels%20Annual_Brasilia_Brazil_BR2024-0022.pdf

Table 3: Ethanol and Biodiesel Blending Rates in Brazil [46]

Ethanol Use Mandate		
Year	Month	Mandate
2006	Jan–Feb	E25
2006	Mar–Oct	E20
2006	Nov–Dec	E23
2007	Jan–May	E23
2007	Jun–Dec	E25
2008	Jan–Dec	E25
2009	Jan–Dec	E25
2010	Jan	E25
2010	Feb–Apr	E20
2010	May–Dec	E25
2011	Jan–Sep	E25
2011	Oct–Dec	E20
2012	Jan–Dec	E20
2013	Jan–Apr	E20
2013	May–Dec	E25
2014	Jan–Dec	E25
2015	Jan–Mar 15	E25
2015	Mar 16–Dec	E27
2016	Jan–Jul 2025	E27
2025	Aug-Present	E30

Biodiesel Use Mandate		
Year	Month	Mandate
2008	Jan	B2
2008	Jul	B3
2009	Jul	B4
2010	Jan	B5
2014	Aug	B6
2014	Nov	B7
2017	Mar	B8
2018	Mar	B10
2019	Sep	B11
2020	Mar	B12
2020	Sep	B10
2020	Nov	B11
2021	Jan	B12
2021	Mar	B13
2021	May	B10
2021	Sep	B12
2021	Nov	B10
2022	Jan	B10
2023	Apr	B12
2024	Mar	B14
2025	Aug-Present	B15

3.3.3 Germany

In June 2025, a bill was drafted to expand the **German Greenhouse Gas Reduction Quota** to implement the **EU Renewable Energy Directive (RED III)** and **ReFuelEU**.[47] Under this bill, the GHG reduction quota was increased to 53% by 2040, and GHG obligations were extended to the aviation and shipping sectors.[48] Currently only gasoline and diesel suppliers must comply with existing GHG quotas, but the drafted bill extends these compliance requirements to shipping and aviation fuels.[48] Additionally, minimum quotas

[47] Germany Sets 2040 Mandate for Green Hydrogen in Transport Fuels Under New RED III Law - https://fuelcellsworks.com/2025/06/23/energy-policy/germany-sets-2040-mandate-for-green-hydrogen-in-transport-fuels-under-new-red-iii-law

[48] Implementing the RED III Directive – German Government Drafts Second Greenhouse Gas Reduction Quota Bill - https://www.gleisslutz.com/en/news-events/know-how/implementing-red-iii-directive-german-government-drafts-second-greenhouse-gas-reduction-quota-bill

for advanced biofuels (derived from wastes and residues) have also been increased in Germany, accounting for quotas of 2%, 2.5%, and 3% for 2026, 2028, and 2030, respectively.[48]

Blending mandates for SAF and GHG reduction targets to 2030 are given in Table 4 below (expressed in % cal, or percent energy content), and Table 5 displays multiple counting factors for various compliance categories. **Multiple counting** reduces the physical volume of clean fuels required to meet specific mandates, because they are counted twice or three times against mandates, making them more desirable than single counted clean fuels.[49] Note that in the drafted bill under the German Greenhouse Gas Reduction Quota multiple counting for advanced biofuels is removed, as there is now sufficient market availability to meet quotas without multiple counting. In Germany, and all other RED III compliant countries, there are also **caps** placed on certain categories of clean fuels (crop-based, fatty oils, etc.) to prioritize the adoption of advanced biofuels and limit negative impacts to agricultural industries.[48,49]

Table 4: Biofuel Mandates Germany[49]

<table>
<tr><th>Year</th><th>GHG Emission Reduction (%)</th><th>Advanced Biofuels (% cal)</th><th>Cap on crop-based biofuel (% cal)</th><th>Cap on used cooking oil and animal fat-based biofuels (% cal)</th><th>Sustainable Aviation Fuel (% cal)</th></tr>
<tr><td>2022</td><td>7</td><td>0.2</td><td rowspan="9">4.4</td><td rowspan="9">1.9</td><td rowspan="4">N/A</td></tr>
<tr><td>2023</td><td>8</td><td>0.3</td></tr>
<tr><td>2024</td><td>9.25</td><td>0.4</td></tr>
<tr><td>2025</td><td>10.5</td><td>0.7</td></tr>
<tr><td>2026</td><td>12</td><td>1</td><td>0.5</td></tr>
<tr><td>2027</td><td>14.5</td><td>1</td><td>0.5</td></tr>
<tr><td>2028</td><td>17.5</td><td>1.7</td><td>1</td></tr>
<tr><td>2029</td><td>21</td><td>1.7</td><td>1</td></tr>
<tr><td>2030</td><td>25</td><td>2.6</td><td>2</td></tr>
</table>

Table 5: Multiple Counting for Biofuels in Germany[49]

Compliance Option	Conditions	Factor
Advanced biofuels	Volumes that exceed the mandate	2
Hydrogen and Power-to-X Fuels	If not derived from biomass	2
Electricity	For road e-vehicles	3

[49] Biofuel Mandates in the EU by Member State – 2025 - https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Biofuel%20Mandates%20in%20the%20EU%20by%20Member%20State%20-%202025_Berlin_European%20Union_E42025-0004

4.0 Types of Fuel Blends and Their Applications

The focus of this discussion paper is the blending of clean fuels for the purpose of reducing the carbon intensity of conventional fuels. Clean fuel classifications are not universally standardized, and as such, there is some variation amongst industry. However, for the purpose of this paper, clean fuels are classified as biofuels, renewable fuels, and other clean fuels (including hydrogen, ammonia, and synthetic fuels).

Fuel blending rates depend on the application for which they are intended, the compositions and properties of the fuel being blended, as well as social and cultural acceptance in the jurisdiction they are being used in. In this section, clean fuels commonly used for blending applications are described, including typical blending rates and industries which may be applicable.

4.1 Biofuels

Biofuels are commonly defined as fuels that are derived from **living matter**, or **biomass**, to create a product similar to that of conventional fuels.[50] Biofuels can be further categorized as first, second, or third generation, where: **first generation biofuels** are produced from sugars, starches, and oils in food crops; **second generation biofuels** are produced from grasses and woody materials or the nonfood portions of food crops; and **third generation biofuels** are produced from algae and cyanobacteria.[50]

Although biofuels have similar properties to conventional fuels, their chemical composition is different and therefore **cannot** typically be used as **drop-in** (or direct) replacements. Existing equipment that utilizes conventional fuels may become damaged if biofuels are used as a complete substitution due to the differences in chemical make-up. As such, fuel blending with biofuels is a common practice to offset the use of conventional fuels, reducing the overall carbon intensity of the fuel, while maintaining the integrity of existing equipment. Biofuels that are being used globally in fuel blending applications include ethanol (cellulosic and grain), biodiesel, bio-butanol, bio-methanol, sustainable aviation fuel derived from biomass, and bio-crude.

[50] Bioenergy - https://www.sciencedirect.com/book/9780128154977/bioenergy

4.1.1 Ethanol

The blending of ethanol in conventional gasoline is one of the most common applications of clean fuel blending globally. All existing gasoline engine vehicles are able to use gasoline with an ethanol content of up to 10% (E10) without modifications, however, only **flex-fuel** or light duty vehicles made after 2001 are able to use E15 (15% ethanol).[51] Flex fuel vehicles, which are designed to run on fuel with higher ethanol content, can be used with up to E85 (85% ethanol).[52] Figure 5 below shows the blending rates for ethanol in different regions around the globe, highlighting **Brazil**, **India**, and **Norway** as having the most progressive ethanol blending mandates, with Canada falling into a moderate range on a global scale.

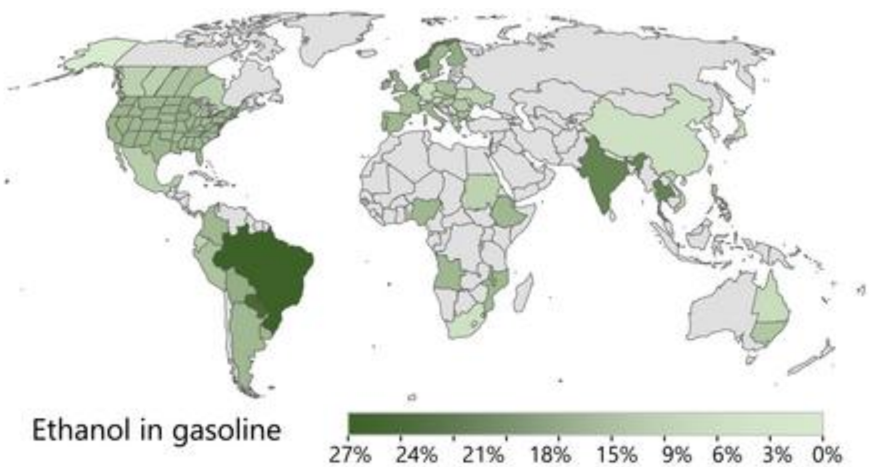

Figure 5: Global Ethanol Blending Mandates[53]

4.1.1.1 Cellulosic Ethanol

Cellulosic ethanol is a secondary biofuel, produced from **plant fibers** and **agricultural waste**, such as corn stalks, rice stalks, poplar and willow trees, grasses, and biomass from solid municipal waste (paper, cardboard, food waste, yard waste, and leather products). Cellulosic ethanol is advantageous over grain ethanol, because it is derived from materials that are typically discarded as waste, and does not exacerbate the grain markets that are relied upon for livestock feed.[54] Additionally, trees and grasses can be grown on lands not

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[51] How Much Ethanol is in Gasoline, and How Does it Affect Fuel Economy? - https://www.eia.gov/tools/faqs/faq.php?id=27&t=10
[52] Flex-fuel Vehicles - https://www.fueleconomy.gov/feg/flextech.shtml
[53] Biofuel Technologies: Lessons Learned and Pathways to Decarbonization - https://onlinelibrary.wiley.com/doi/10.1111/gcbb.13091
[54] Grain and Cellulosic Ethanol: History, Economics, and Energy Policy - https://www.sciencedirect.com/science/article/abs/pii/S0961953407000396

suitable for food crops, and typically require less fuel, fertilizers, and water than grain crops do, reducing overall **lifecycle emissions**.

4.1.1.2 Grain Ethanol

Grain ethanol is a primary biofuel, derived from **food crops** such as corn, sorghum, and barley. Grain ethanol remains more common in North America than cellulosic ethanol due to economic limitations. The chemical structure (CH_3CH_2OH) and properties of ethanol remain the same no matter what feedstock it is derived from and can be used in any ethanol blending applications as such.[55]

4.1.2 Biodiesel

The blending of biodiesel in conventional diesel is another commonly used application of clean fuel blending; the blending mandates from regions across the globe can be seen in Figure 6 below. Biodiesel differs from renewable diesel, as will be discussed in Section 4.2.2, as it cannot be used as a drop-in replacement due to its differing chemical composition from conventional diesel, although it does have similar properties. It is common practice for biodiesel to be blended with conventional diesel to reduce the overall carbon intensity of the fuel.

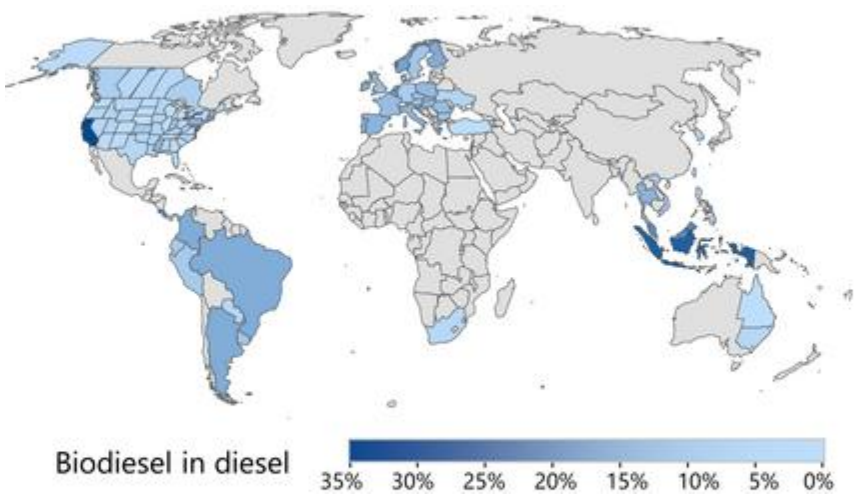

Figure 6: Global Biodiesel Blending Mandates[53]

Similar to that of ethanol in conventional gasoline, a biodiesel content of 5% (B5) in conventional diesel can typically be used in any diesel engine without modification.[56] Higher biofuel blends up to B20 may be approved for use in existing engines without

[55] Ethanol Fuel Basics - https://afdc.energy.gov/fuels/ethanol-fuel-basics
[56] Diesel Vehicles Using Biodiesel - https://afdc.energy.gov/vehicles/diesel

modification, but it is advisable to check with the original equipment manufacturer before doing so. In addition to providing a reduction in carbon intensity, biodiesel also offers **improved lubricity** even at low blend levels, reducing engine friction and **improving efficiency**.[56] Pure biodiesel is referred to as B100, and is derived from **vegetable oils** or **animal fats**.[57] The key difference between biodiesel and renewable diesel are the production methods, which is discussed further in Section 4.2.2.

4.1.3 Bio-butanol

Bio-butanol is derived from the same feedstocks as ethanol, however, butanol benefits from immiscibility with water (further context for this benefit in Section 5.1.3.1) and a **higher energy density**.[58] Although there are benefits, the processing of grain yields less bio-butanol ($CH_3CH_2CH_2CH_2OH$) for the same amount of feedstock than if it were processed into ethanol due to the longer carbon chain in butanol.[58]

Generally, ASTM D7862 permits butanol blending of up to 12.5% with gasoline.[58] In the US, the EPA has granted a waiver to Butamax Advanced Biofuels, LLC legalizing a 16% bio-butanol blend as an equivalent to E10.[59] Demonstration-scale bio-butanol plants have been successfully retrofitted from existing corn ethanol plants in the US, whereby solvents, plastics, and fibers are valuable byproducts, presenting opportunities for **additional revenue streams** to reduce the cost of the bio-butanol.[58]

4.1.4 Bio-methanol

Bio-methanol is derived from **woody biomass** or **biogas (renewable natural gas)**, through steam reforming or torrefaction.[60] Bio-methanol is a suitable drop-in replacement for conventional marine fuels and has common applications in dual-fuel engines.[61]

Methanol (CH_3OH) also has historical applications for blending with gasoline, at rates of up to 5% by volume, although modern vehicle technology has been known to be compatible with blends of up to 15% by volume.[61] Although it is compatible, methanol is less common

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[57] Biodiesel Science and Technology - https://www.sciencedirect.com/book/9781845695910/biodiesel-science-and-technology
[58] Biobutanol - https://afdc.energy.gov/fuels/emerging-biobutanol
[59] Registration of Isobutanol as a Gasoline Additive: Opportunity for Public Comment - https://www.federalregister.gov/documents/2018/03/29/2018-06119/registration-of-isobutanol-as-a-gasoline-additive-opportunity-for-public-comment
[60] How Green Methanol is Made - https://perpetualnext.com/en/news/how-green-methanol-is-made/
[61] The Methanol Institute - https://methanol.org/embed/

than ethanol for gasoline blending applications today, due to its **lower energy content**, as well as **handling concerns** because of its severe **toxicity**.[62]

4.1.5 Sustainable Aviation Fuel (SAF) from Biomass

SAF is derived from **fatty oils**, **forest and agriculture wastes**, and **industrial waste gases**, and must be produced using ASTM International (formally known as the American Society for Testing and Materials) approved methods to qualify as a drop-in fuel for conventional jet fuels.[63] Although SAF is suitable as drop-in replacement, it is commonly used in blending applications of 10-50% by volume.[63] SAF can reduce lifecycle emissions by more than 80% compared to conventional jet fuels, offering significant GHG emission reductions even in blending applications. As discussed in previous sections, many countries have adopted gradual blending mandates for SAF, likely due to the current global lack of availability. Figure 7 shows a map of global SAF policies, with Europe having established mandates, North America having direct incentives, and South America, Asia, and Australia in the process of establishing legislation.

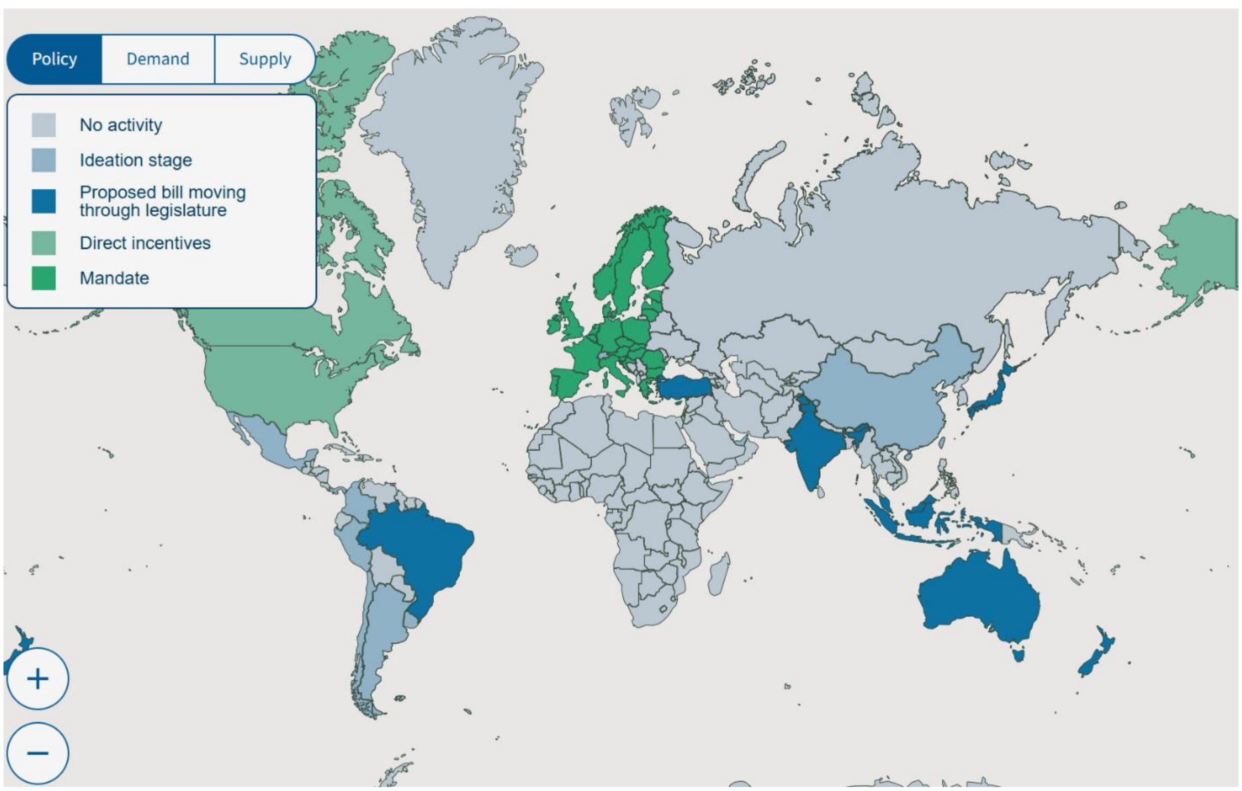

Figure 7: Global Policies for SAF[64]

[62] Fuel Properties Comparison - https://afdc.energy.gov/fuels/properties
[63] Sustainable Aviation Fuel - https://afdc.energy.gov/fuels/sustainable-aviation-fuel
[64] Sustainable Aviation Fuel Market Outlook - https://saf.rmi.org/

4.1.6 Bio-crude

Bio-crude is derived from **forest and agricultural waste**, **manure**, **sewage sludge**, or **algae**, and is a substitute for conventional crude oil.[65] Bio-crude can be refined in existing equipment when pre-treated and blended with conventional crude oil at low blend rates, for the production of renewable gasoline and diesel.[65] Bio-crude volumes of 5-20% by weight can be **co-processed** effectively in conventional crude oil facilities without major modification, reducing overall lifecycle emissions.[66]

4.2 Renewable Fuels

4.2.1 Renewable Natural Gas (Biogas)

Renewable natural gas, or biogas, is produced through the decomposition of **organic matter** at landfills, wastewater treatment facilities, or agricultural and forestry operations. At these facilities, renewable natural gas (methane, CH_4) is emitted naturally because of **anaerobic digestion**, or can be produced deliberately through thermochemical conversion, for capture and conditioning to be used as a drop-in replacement for conventional natural gas.[67]

4.2.2 Renewable Diesel

Renewable diesel is chemically and physically the same as conventional diesel fuel but is derived from **fats and oils** instead of fossil fuel. Unlike biodiesel, renewable diesel **can** be used as a **drop-in** replacement for conventional diesel. Biodiesel and renewable diesel can be derived from some of the same feedstocks, but there are significant differences in the **chemical reactions** and **processing methods** used to produce each fuel (Figure 8). Renewable diesel is produced using hydrotreating, gasification, or pyrolysis, while biodiesel is produced using transesterification.[68]

Hydrotreating is the reaction of a lipid (fats, oils, waxes, etc.) feedstock with hydrogen in the presence of a catalyst under high temperatures and pressures.[68] **Gasification** is the thermal conversion of biomass to syngas for catalytic conversion into hydrocarbon fuels

[65] Biocrude & Renewable Fuel Oil - https://advancedbiofuels.ca/fuels-and-tech/biocrude-and-renewable-fuel-oil/
[66] Bio-Oil Co-Processing Can Substantially Contribute to Renewable Fuel Production Potential and Meet Air Quality Standards - https://research-hub.nrel.gov/en/publications/bio-oil-co-processing-can-substantially-contribute-to-renewable-f-4
[67] Renewable Natural Gas - https://advancedbiofuels.ca/fuels-and-tech/renewable-natural-gas/
[68] Renewable Diesel - https://afdc.energy.gov/fuels/renewable-diesel

(i.e. renewable diesel).[68] **Pyrolysis** is the decomposition of organic material at high temperatures without the presence of oxygen, producing liquid pyrolysis oil that can be upgraded or co-fed for the production of hydrocarbon fuels such as renewable diesel.[68] **Transesterification** is the conversion of fatty acids into biodiesel through a reaction with an alcohol and a strong base catalyst.[69]

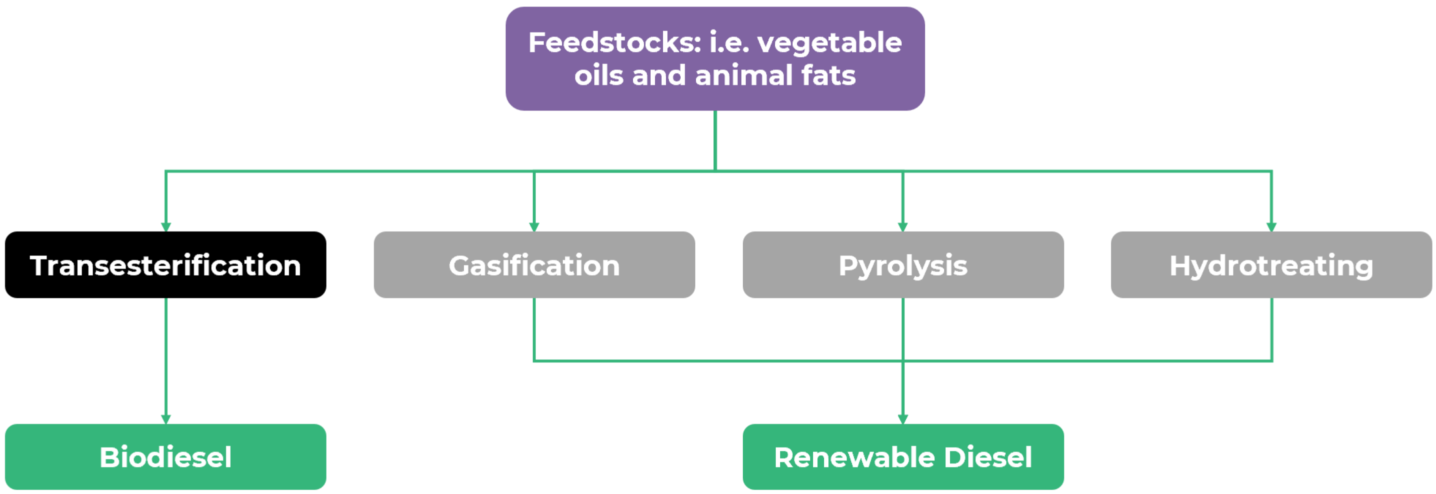

Figure 8: Biodiesel vs. Renewable Diesel Production Processes

The cloud point (discussed in Section 5.1.3.2) of renewable diesel is **not** affected by feedstock properties as much as biodiesel, however, the yield of renewable diesel is typically **15% less** than that of biodiesel using the same feedstock.[70] As such, biodiesel may be more suitable for blending applications, while renewable diesel may be best suited for complete substitutions. Although, renewable diesel also offers reductions in carbon intensity when blended with conventional diesel if **sufficient quantities** are not available for full substitution.

The Canadian Coast Guard (CCG), for example, is using a novel blend of 10% biodiesel, 40% renewable diesel, and 50% conventional diesel for emissions reductions in the CCGS *Sir Wilfrid Laurier*.[71] This demonstrates not only the viability of biodiesel and renewable diesel for marine applications, but also the viability of blending a combination of fuels to achieve desirable emissions properties. Furthermore, as more testing in real world applications

[69] The Reaction of Biodiesel: Transesterification - https://courses.ems.psu.edu/egee439/node/684
[70] Readiness of Producing and Deploying Liquid Drop-In Fuels in Canada - https://natural-resources.canada.ca/energy-efficiency/transportation-energy-efficiency/readiness-producing-deploying-liquid-drop-fuels-canada
[71] Greening Initiatives - https://www.ccg-gcc.gc.ca/corporation-information-organisation/greening-initiatives-ecologisation-eng.html

occur, a greater understanding about blending formulations for particular conditions will emerge.

4.3 Other Clean Fuels

4.3.1 Green Hydrogen

Hydrogen is an **energy carrier** with high potential for green and sustainable applications, as it is carbon-emission free, energy-dense, can supply many energy sectors, and can be produced from renewable energy sources. Hydrogen can be produced in a variety of different ways, with varying levels of carbon intensity. To categorize hydrogen based on its production method and how carbon intense that production method is, a color naming convention is commonly used. (Note: all hydrogen is colourless, no matter the feedstock or production method.) The most common "colors" of hydrogen are as follows:

- **Grey hydrogen:** Produced from fossil fuels, grey hydrogen is generated by steam methane reforming. CO_2 is released into the atmosphere in this process.
- **Blue hydrogen:** Blue hydrogen generation uses the same method as grey hydrogen, however, the CO_2 produced is captured and stored (sequestered) and is prevented from being released into the atmosphere.
- **Green hydrogen:** Green hydrogen is produced from water using the electrolysis process, with the electricity generated from a renewable source. This process is depicted in Figure 9.
- **Turquoise hydrogen:** Methane pyrolysis (heating methane to high temperatures in the absence of oxygen) splits the methane molecule (CH_4) into hydrogen gas and solid carbon. This turquoise hydrogen avoids direct CO_2 emissions because the process yields carbon in the form of carbon black or graphite. The carbon intensity of this hydrogen depends on the energy source used for pyrolysis.
- **Pink hydrogen:** Electrolysis powered by electricity from a nuclear power plant yields pink hydrogen. This is considered zero-emission at the point of production because no greenhouse gases are emitted by the nuclear power plant during operation.
- **Orange hydrogen:** Orange hydrogen gets its name from the oxidized iron byproducts that result from this hydrogen production process. Carbon-enriched solutions (typically CO_2-saturated water) are injected into underground iron-rich rock formations. Geochemical reactions are triggered by geothermal heat and pressure. CO_2 becomes sequestered in the form of iron, magnesium, and calcium carbonates. The side product, hydrogen gas, is collected.

- **White hydrogen:** White hydrogen is the term used to describe hydrogen produced from naturally occurring geochemical reactions. It is considered a zero-carbon source since it does not require energy input from human-made sources to produce it. Some emissions may arise from its extraction.

Some experts argue against color labelling and want hydrogen labelling based on measurement of the CO_2 footprint of the hydrogen molecule. The transition from a "color" classification for hydrogen to a robust, emissions-based labelling system is considered crucial for enabling a truly clean hydrogen economy. This involves comprehensive certification processes that measure the GHG emissions across the entire hydrogen production lifecycle, from feedstock extraction to the point of use (often referred to as "well-to-gate" or "well-to-wheel" emissions, with "well-to-wheel" encompassing end-use emissions). Rather than broad categorizations like "green" or "blue," which can be misleading due to varying grid mixes, methane leakage, or carbon capture rates, an emissions-based label provides a quantifiable carbon intensity (e.g., kg CO_2e per kg H_2).

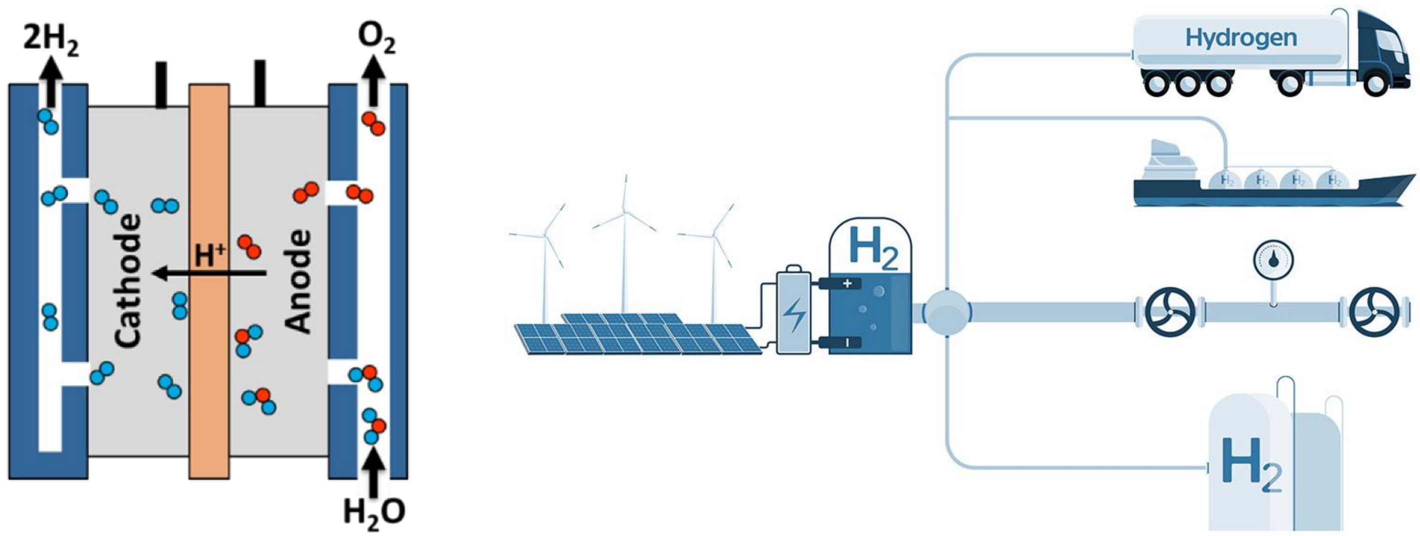

Figure 9: Hydrogen Electrolysis and Production, Transportation, and Storage[72,73]

Due to storage limitations, direct use of hydrogen for blending is mainly limited to **gaseous applications**. As such, there is opportunity for hydrogen blending with natural gas, and volumes of up to 20% have been proven to reduce emissions without major infrastructure modifications. Higher blend volumes may pose a risk of **hydrogen embrittlement** to

[72] Hydrogen Production: Electrolysis - https://www.energy.gov/eere/fuelcells/hydrogen-production-electrolysis
[73] The Many Colors and Applications of Hydrogen - https://www.elsevier.com/connect/the-many-colors-and-applications-of-hydrogen

existing steel pipelines as a result of hydrogen reacting with the steel. Polyethylene plastic pipelines like those found in Nova Scotia and New Brunswick are better suited for higher hydrogen concentrations.

Hydrogen is a gas at room temperature and takes up a lot of space. Very large tanks would be required to transport it at this temperature, and this is not currently economically viable. If hydrogen is cooled to a liquid or compressed and stored at high pressure, a greater amount can be stored in a smaller volume. Maintaining these conditions for storage and shipment is challenging, particularly if it needs to be stored for a long time.

An alternative form to transport this chemical energy is to convert it once more from hydrogen to a **liquid hydrogen carrier**. A substance that is a liquid at around ambient temperature conditions is easier and safer to handle, store, and transport. These derivative fuels can also be low-carbon or 'clean' depending on the 'color' or CO_2 footprint of the hydrogen. This includes fuels such as green ammonia and electro-fuels, as discussed further in sections 4.3.2 and 4.3.3 below.

4.3.2 Green Ammonia

Green ammonia (NH_3), which is a liquid at -33°C, is a well-known hydrogen carrier, popular due to its high **hydrogen content** (17.8% by weight; compared against other hydrogen carriers in Figure 10).

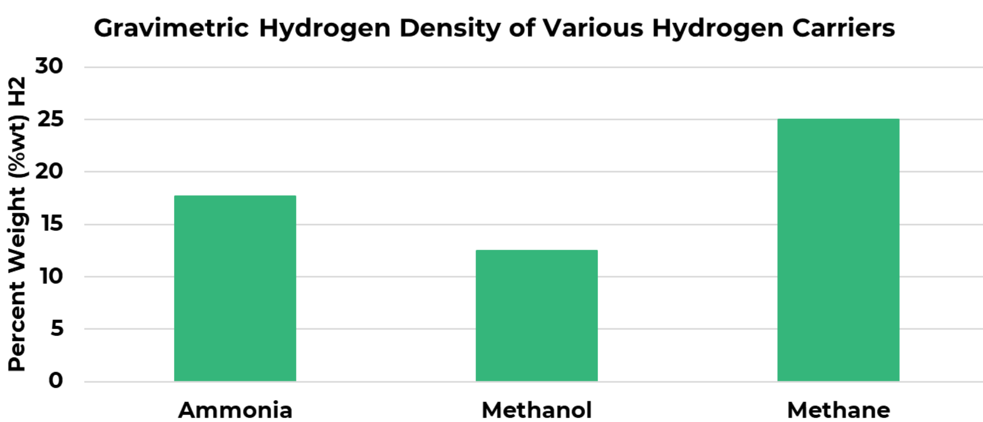

Figure 10: Gravimetric Hydrogen Density (%wt) for Various Hydrogen Carriers

It can be easily liquefied under moderate conditions, making it suitable for storage and transport. Transport of ammonia is well established, and large quantities are transported globally per year. The ammonia may be used as it is by the customer, or it may be converted back to hydrogen depending on the need. Its relatively high **volumetric energy density** (682 kg/m^3) compared to other fuels (Figure 10), is another benefit of ammonia.[74]

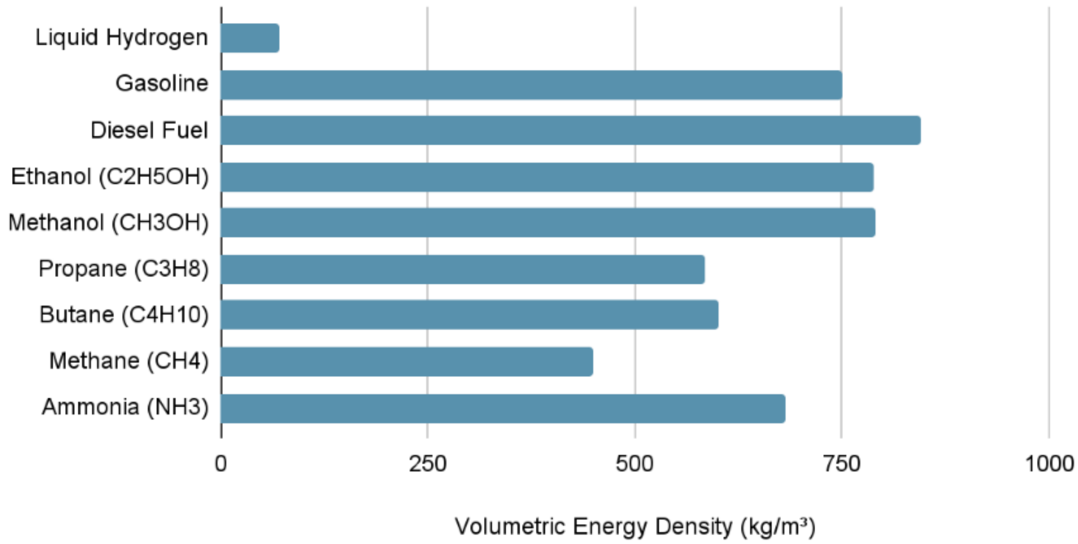

Figure 11: Volumetric Energy Density (kg/m^3) of Various Liquid Fuels[74]

Green ammonia is a promising clean fuel for the marine sector in particular, with several major engine manufacturers in the process of developing ammonia-fueled engines.[75] As illustrated in Figure 11, ammonia has a comparable volumetric energy density to conventional diesel fuel, making it a viable clean alternative for hard-to-abate industries such as shipping.

Although ammonia is a proven energy carrier and considered to be carbon-free, ammonia emits nitrogen oxides (NO_x) and nitrous oxide (N_2O) when burned, which is a more potent GHG than CO_2. As such, significant consideration must be made for limiting NO_x and N_2O emissions when using ammonia as a clean fuel. One strategy proven effective to do so is through blending applications with diesel and hydrogen.[76] At a lab scale, blending 70% ammonia by volume with conventional diesel resulted in an overall GHG emissions reduction of 50-60%.[76]

[74] Hydrogen Energy Density: Practical Solutions For Efficient Storage And Transport - https://h2iq.org/hydrogen-energy-density-practical-solutions-for-efficient-storage-and-transport/
[75] Net Zero Roadmap, A Global Pathway to Keep the 1.5 ˚C Goal in Reach - https://iea.blob.core.windows.net/assets/8ad619b9-17aa-473d-8a2f-4b90846f5c19/NetZeroRoadmap_AGlobalPathwaytoKeepthe1.5CGoalinReach-2023Update.pdf
[76] A Review on Ammonia Blends Combustion for Industrial Applications - https://www.sciencedirect.com/science/article/abs/pii/S001623612202974X

4.3.3 Synthetic Fuels

Synthetic fuels encompass a variety of fuels derived from the conversion of **syngas** (a gaseous mixture containing the elements hydrogen and carbon) to liquid hydrocarbons.[77] Syngas can be sourced from natural gas, biomass feedstocks (i.e. renewable natural gas), or a mixture of CO/CO_2 and gaseous hydrogen.[77]

Electro-fuels (e-fuels) are clean synthetic fuels produced using renewable electricity with a captured source of CO_2 and green hydrogen, making them a carbon-neutral alternative to conventional fuels.[77] Common types of e-fuels include e-methanol, e-diesel, and synthetic SAF, and they can be used for the same applications as their biofuel equivalents.

[77] Synthetic Fuels - https://advancedbiofuels.ca/fuels-and-tech/synthetic-fuels/

5.0 Fuel Blending Approaches and Standards

Fuels may be blended using a variety of methods, differing based on the physical state of fuels: liquid, gaseous, or solid. Given that liquid blending is the most common and has the greatest number of variations, most of the focus will be on the specifics of liquid fuel blending, including methods, equipment, potential issues, and testing requirements, followed by a brief discussion of gaseous and solid fuel blending.

5.1 Liquid Fuel Blending

5.1.1 Blending Methods

The general process of creating liquid fuel blends involves measuring the fuel components, mixing, and sampling. There are many blending methods available, and they can be categorized as batch blending or in-line blending.

In-line blending methods meter constituent fuels into a single pipe, allowing mixing within the pipe prior to injection into a container. These methods can be further categorized based on the point at which the components are combined. Configurations include side stream, ratio, sequential, and hybrid blending.

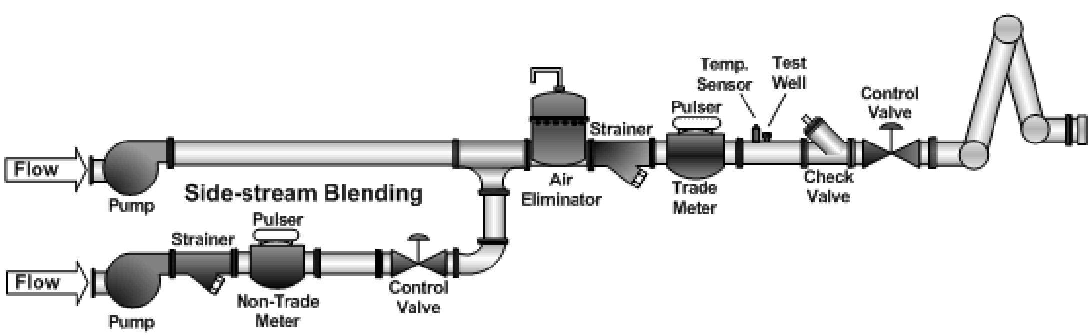

Figure 12: Diagram of Side Stream Blending[78]

Side stream, also known as wild stream blending, strains and meters a secondary fuel component into a primary stream, after which the mixture is strained and re-metered. This can be seen in Figure 12. The metering of the secondary fuel into the primary stream can

[78] Blend Systems - https://ised-isde.canada.ca/site/measurement-canada/en/laws-and-requirements/v-28-blend-systems

be either proportional or non-proportional. Proportional metering refers to a constant input of the secondary fuel into the primary stream at the desired ratio, whereas non-proportional metering achieves the desired output ratio by intermittently opening and closing the secondary stream control valve. The frequency at which the control valve is opened and closed is chosen so that the desired ratio is achieved over a specified period.

Ratio blending simultaneously and individually meters the fuel components and combines the streams at the end of the process. Two separate streams undergo straining and metering, after which they are combined into one stream. As in side stream blending, the desired ratio can be achieved through proportional or non-proportional metering. The ratio blending configuration can be seen in Figure 13.

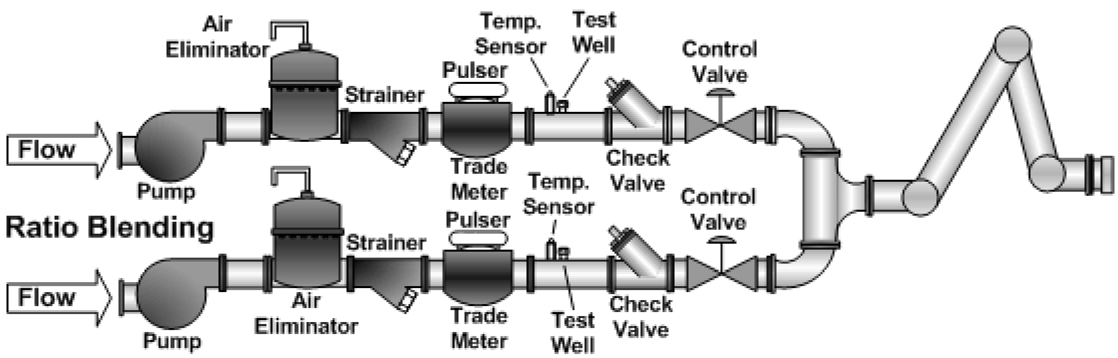

Figure 13: Diagram of Ratio Blending[78]

Sequential blending uses the same straining and metering equipment for each fuel component, which must be alternately passed through the pipe. The first fuel component is passed through a control valve into the common pipe, where it is strained and metered, after which its control valve is shut, and the other fuel component is allowed to pass through the common pipe (Figure 14). In sequential blending, little mixing occurs between components in the pipe; mixing primarily occurs in its storage or transportation vessel.

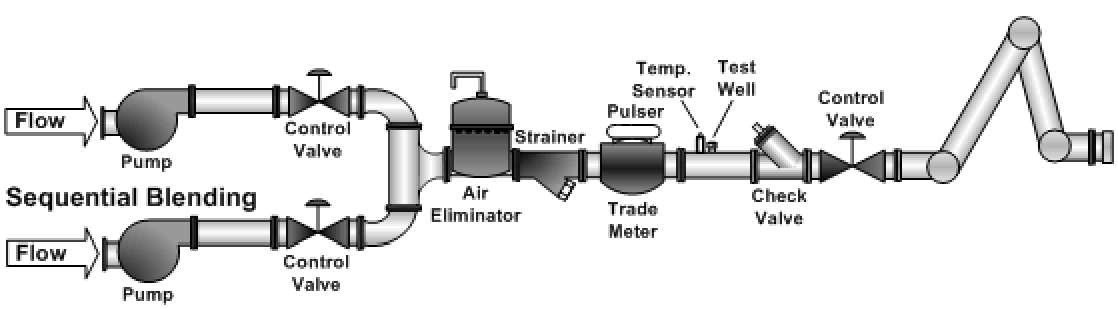

Figure 14: Diagram of Sequential Blending[78]

There are additional, more complicated configurations of in-line blending that combine side stream, ratio, and sequential blending, allowing for more complicated fuel mixtures. For example, there exists a hybrid blending configuration that combines sequential and ratio blending, designed to ratio blend B100 (pure biodiesel) into existing diesel oil sequential blenders.[79] In-line blending can be done at a refinery, at a specific blending terminal, or at the fuel pump.

As an alternative to in-line blending, **batch blending** may be used, whereby mixing occurs solely within the storage or transportation vessel. Two primary versions are in-tank and splash blending. **In-tank blending**, or pre-blending, is a simple blending method where the component fuels are separately pumped into a container and are mixed using either the incoming turbulence or additional static mixing. This blending method is typically done at the refinery. **Splash blending** is a form of in-tank blending that is specifically used during transportation of the fuel mixture. The constituent fuels are separately pumped into the transportation vessel and mixing is achieved through the "splashing" of the fuels during transportation.

While blending fuels at the fuel pump is not common, it is possible and is referred to as **rack blending**.[80] This allows users to directly add constituent fuels at the pump and can allow for more customizable blend ratios.

The method of fuel blending used has a significant impact on the homogeneity of the product. In-line blending generally produces blends with better homogeneity when compared to batch blending methods such as in-tank and splash blending. Batch blending methods suffer issues with **stratification**, particularly when fuel components have different densities, which can result in varying component concentrations throughout the blend.[79] For splash blending, the resulting blend is often not adequately mixed on arrival, requiring additional mixing,[79] and is frequently not acceptable due to its lack of precision and control.[81] It is generally recommended that if splash blending is used, the heavier fuel should be loaded on top of lighter fuels to avoid issues with settling.[80]

In-line methods typically produce blends of higher accuracy due to their use of high accuracy flow meters for component measurement. In addition to considerations regarding blend quality, there are several logistical advantages to in-line blending. When using in-line blending methods, fuels can be blended as needed, while being pumped into

[79] Industrial process technology for biodiesel production - https://www.sciencedirect.com/science/article/pii/B9781845695910500115
[80] Biodiesel Blending - https://www.targray.com/biofuels/biodiesel/blending
[81] Fuel Blending - https://www.advancedlubes.com/glossary/fuel-blending

storage or transportation vessels, allowing for quick and flexible blending. When using in-tank blending, large amounts of fuel are blended at one time, and require significant space for mixing and storage equipment. These blends are also time-consuming, requiring time for pumping in each component, mixing, and pumping to transportation vessels.

5.1.2 Blending Equipment

To create accurate liquid fuel blends, highly accurate flow meters are required to measure the constituent fuels. A **Coriolis meter** is a type of mass flow meter commonly used in the oil and gas industry, which measures mass flow using inertial forces with a high degree of accuracy, but is quite expensive.[82] Another common type of flow meter used for fuel measurement is the **positive displacement meter**, which is also very accurate, but less expensive than the Coriolis meter, and measures flow based on the displacement of internal mechanical components.[83] Temperature has a quantifiable effect on this type of measurement and must be accounted for by additional temperature sensors and feedback.[82]

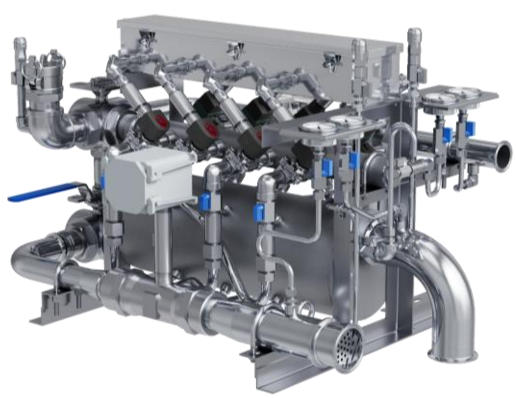

Figure 15: Example of a Commercially Available Fuel Blending System[84]

There are a variety of commercially available fuel blending systems, an example of which can be seen in Figure 15. Specially designed fuel blending systems typically include all the necessary pumps, valves, flow meters, and temperature sensors, and incorporate programmable logic control to ensure accurate blend ratios in real time. One system can often be configured to use various blending methods, including batch and in-line

[82] Gas Measurement: 4 Types of Flow Meters - https://kimray.com/training/gas-measurement-4-types-flow-meters
[83] All About Flow Meters - https://www.dwyeromega.com/en-ca/resources/flow-meter-types?srsltid=AfmBOopXB5Xifrnv6fabivsP5GDrxvgbVX3yatqAh056x-7ETv4Q1UkL
[84] Biofuel Blending System - https://www.veeder.com/us/biofuel-blending-system

blending, and can be designed for underground or above ground use. There are additional features that can be added to commercial blending systems, including heaters to mitigate gelling effects of biodiesels. Gelling is described further in Section 5.1.3.2.

For any flow measurement that will be used for trade purposes in Canada, a calibrated flow meter (trade meter) is required to ensure accurate measurement. These meters must be calibrated by Measurement Canada (MC) prior to use and be subject to periodic testing and recalibration.[85]

5.1.3 Difficulties with Liquid Fuel Blending

There are some difficulties with liquid fuel blending that must be taken into consideration relating to the quality of blends, cold weather issues, and equipment issues.

5.1.3.1 Blend Quality

Blend quality is incredibly important with respect to both regulatory requirements and fuel efficacy. Factors impacting blend quality include homogeneity, impurities, and blend ratios. As discussed in section 5.1.1, the method used for blending can significantly impact the homogeneity of the resulting blend, and in-line blending methods typically result in better homogeneity. Additionally, components of a blend may separate due to unwanted water content in the mixture, particularly when using ethanol. Ethanol and water are naturally attracted to each other, so water introduced to a blend containing ethanol will pull ethanol molecules out of the blend and settle at the bottom of the container.[86]

A common impurity in fuel blends is sulfur particles, which can become trapped in particulate filters and NO_x traps of engines, causing blockages and requiring special desulfurization cycles.[87] Other impurities in a fuel blend, including dirt, sand, metal particulates, or unwanted fuels, can significantly impact performance and create safety hazards. Fuel contamination can clog various engine components, especially fuel filters and injectors, which can reduce fuel efficiency, overall engine performance, or even result in engine failure. In some cases, contaminants in fuels can ignite or burst, creating serious safety hazards and potentially introduce dangerous contaminants into the environment.[88]

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[85] Interim policy on the examination of volumetric devices used to measure low-carbon fuels - https://ised-isde.canada.ca/site/measurement-canada/en/v-30-interim-policy-examination-volumetric-devices-used-measure-low-carbon-fuels
[86] Protecting Your Stored Fuel Quality - https://www.bellperformance.com/protecting-your-stored-fuel-quality
[87] Controlling Fuel Impurities and Additives - https://oica.net/controlling-impurities-and-additives/
[88] Problems Associated with Fuel Contamination - https://network-environmental.co.uk/problems-associated-with-fuel-contamination/

Due to the additional steps of the blending process that increase the risk of impurities, as well as the numerous issues that may result from impurities in fuel, proper filtration is crucial. **Filtration** can drastically reduce the amount of particulate impurities in a blend, and there are additional, specially designed filters that are able to detect phase separation.[89] All filters should be regularly checked and replaced to ensure proper operation.

One of the factors impacting blend quality that is most difficult to control is the blend ratio. If at any point in the blending process there is an inaccuracy in measurement or flow control, then the resulting blend ratio will likely be inaccurate. This is mitigated in commercially available blending equipment by using real-time measuring and feedback to compensate for any inaccuracies in up-stream flow control.

5.1.3.2 Cold Weather Considerations

Cold weather can cause complications for fuel blending, particularly for **biodiesel gelling**. Biodiesel begins to solidify in low temperatures, which can cause issues with separation, filtration, and pumping. The cold-weather behavior of various biodiesels can be characterized by their cloud point and pour point. The point at which solid crystals begin to form in the fuel is called the **cloud point**, whereas the **pour point** is defined as the lowest temperature at which the fuel can be poured out of its container. Table 6 displays the cold-weather behavior of biodiesel of various feedstocks; biodiesels can begin to experience gelling at temperatures as high as 17°C.

Table 6: Cloud Point and Pour Point of Various Biodiesel Feedstocks[90]

Biodiesel Feedstock	Cloud Point (°C)	Pour Point (°C)
Soybean oil	1	0
Canola oil	0	-9
Palm oil	17	15
Jatropha oil	8	6
Tallow	12-17	6

[89] Understanding the Dangers of Phase Separation in Ethanol Blends - https://petroclear.com/resources/dont-be-phased.php

[90] Biodiesel Cloud Point and Cold Weather Issues - https://farm-energy.extension.org/biodiesel-cloud-point-and-cold-weather-issues/

When blending with biodiesel, it is generally recommended to keep the biodiesel at least 10°C above its cloud point; the chance of achieving an adequate blend is otherwise greatly reduced.[79]

5.1.3.3 Risks to Blending Equipment

Two of the primary risks to blending equipment when using biofuels are corrosion and clogging. Corrosion of equipment can be an issue when using alcohol-based fuels such as ethanol or methanol,[91] or when fuels undergo chemical breakdown when exposed to water.[92] Clogging can arise in filters or narrow pipes, particularly when using biodiesels. This requires regular equipment maintenance. It is recommended not to use the same equipment for different fuel types and to empty and clean fuel lines and storage tanks every 2-5 years.

5.1.4 Sampling

Sampling is an important step in liquid fuel blending to ensure adequate blend quality. Small samples should be taken from the blended fuel to undergo testing of various parameters. Recommended parameters to test include density, flash point, total contamination, oxidative stability, acid value, and free and total glycerol.[79] Additional parameters that can be tested include concentration/blend ratio, water content, and specific contamination of copper, sulfur, sulfates, and chlorides.[93]

One of the most common testing methods is **Fourier Transform Infrared Spectroscopy (FTIR)**, which analyzes a sample based on its absorption and transmission of infrared radiation and determines its molecular composition.[94] This method can effectively verify the blend ratio, check for impurities, and check the homogeneity when multiple samples are taken at different points. Other testing methods include gas chromatography and fluorescence spectroscopy.

[91] Fuel Blending : Types, Process, Benefits, Challenges, Equipment - https://www.isoilmeter.it/en/fuel-blending-types-process-benefits-challenges-equipment
[92] Quality Assurance of Fuel - https://log.logcluster.org/en/quality-assurance-fuel
[93] Ethanol Fuel Testing - https://www.intertek.com/biofuels/fuel-grade-ethanol-quality/
[94] Introduction to Fourier Transform Infrared Spectrometry - https://www.chem.uci.edu/~dmitryf/manuals/Fundamentals/FTIR%20principles.pdf

Analysis by **gas chromatography** works by first vaporizing a sample and then allowing the vapor to interact with a second "carrier" gas, after which the various components of the sample are identified based on their interactions with the carrier gas.[95]

Fluorescence spectroscopy analyzes a sample by exciting the sample molecules with radiation, and measuring the amount of energy emitted.[96] There are several variations of fluorescence spectroscopy, one of the most common for fuel analysis being X-ray fluorescence spectroscopy, for which X-rays make up the incoming radiation.[97]

There are many testing devices available on the market that use FTIR, gas chromatography, and fluorescence spectroscopy, and many companies who offer services in fuel testing using various methods. Regardless of the method used, the tests should abide by the ASTM International standards for fuel testing, as required for regulatory testing in Canada.

5.2 Gaseous Fuel Blending

The most common application of gaseous fuel blending is the blending of hydrogen and natural gas, which is achieved by injecting hydrogen gas directly into natural gas pipelines. This is a similar method to in-line blending methods for liquid fuel but is designed to be added to existing pipelines and can be implemented at any point in the pipeline network.[98]

The blend ratios are determined by the limits of the pipeline materials and infrastructure equipment, as the addition of hydrogen can cause extra wear and corrosion of the pipelines.[99] The small size of hydrogen molecules allows it to diffuse into pipeline materials, which can reduce ductility and fracture toughness, and increase the rate of intergranular failure and crack growth within the pipeline walls. Under dynamic or static stress, these conditions can result in hydrogen-assisted environmental cracking (HAEC), causing significant safety concerns.[100] Additionally, the presence of hydrogen in natural gas

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[95] Gas Chromatography: Principle, Parts, Steps, Procedure, Uses - https://microbenotes.com/gas-chromatography/
[96] What is Fluorescence Spectroscopy? - https://www.horiba.com/int/scientific/technologies/fluorescence-spectroscopy/what-is-fluorescence-spectroscopy/
[97] Energy dispersive X-ray fluorescence (EDXRF) - https://www.malvernpanalytical.com/en/products/technology/xray-analysis/x-ray-fluorescence/energy-dispersive-x-ray-fluorescence
[98] Hydrogen Blending in Natural Gas - https://www.emerson.com/en-ca/expertise/automation/roadmap-to-industrial-sustainability/hydrogen-value-chain/blending
[99] HyBlend: Opportunities for Hydrogen Blending in Natural Gas Pipelines - https://www.energy.gov/eere/fuelcells/hyblend-opportunities-hydrogen-blending-natural-gas-pipelines
[100] Hydrogen blending in natural gas pipelines - https://www.sciencedirect.com/science/article/pii/S036031992404597X

pipelines may increase the energy requirement for pumping. Hydrogen has a lower volumetric energy density than natural gas, therefore, the blend must be pumped at higher flow rates to maintain the same output energy.[101]

There are strategies for mitigating safety concerns of adding hydrogen to natural gas pipelines, such as implementing automated corrosion monitoring systems and anti-corrosion valves. Similar to liquid fuel blending, sampling is important to ensure accurate blend ratios free of impurities, and in-line gas chromatographs can be used for analysis.[98]

It is important to note that liquified natural gas (LNG) is only in its liquified form during storage or while being transported by truck, rail, or ship.[102] Pipelines transport natural gas in its gaseous form.

5.3 Solid Fuel Blending

The process of solid fuel blending typically occurs in the fuel yard of a power plant but can occur at an off-site fuel management facility, as part of the fuel handling process, or in the boiler or furnace.[103]

When mixed in the fuel yard, fuels are commonly mixed together using bulldozers before being sent to the feed system, as seen in the image on the left in Figure 16.[104] Similarly, the constituent fuels may be loaded into the feed system separately to mix as they are transported to the boiler or furnace. These methods can only be used for coal-coal blends and cofiring coal with woody biomass, as the size and shape of other agricultural products make them difficult to blend with coal.

[101] Hydrogen Blending into Natural Gas Pipeline Infrastructure: Review of the State of Technology - https://docs.nrel.gov/docs/fy23osti/81704.pdf
[102] How Does Regasification of LNG Work? - https://www.econnectenergy.com/articles/how-does-regasification-of-lng-work
[103] Solid Fuel Blending: Principles, Practices, and Problems - https://books.google.ca/books?id=sw0rvcD_is0C&pg=PA31&source=gbs_toc_r&cad=2#v=onepage&q&f=false
[104] Lessons Learned from Existing Biomass Power Plants - https://docs.nrel.gov/docs/fy00osti/26946.pdf

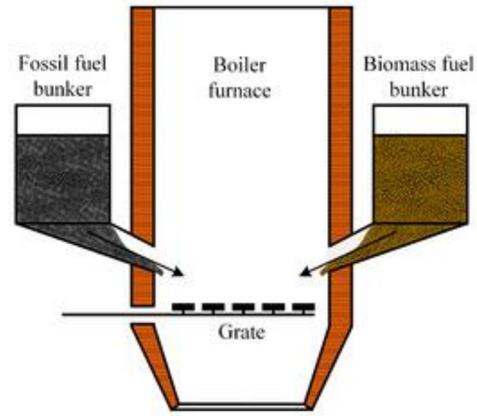

Figure 16: Blending Before Being Sent to Feed System (Left) and Blending Within Boiler (Right) [105,106]

When blending with agricultural products, it is more effective for blending to take place within the furnace or boiler, as seen in the image on the right in Figure 16. In this method, the constituent fuels are prepared and introduced to the system separately but burn together. In power plants that do not always use blended fuels, this method is preferable as the coal delivery system is not affected, and the operation can return to burning only coal very easily. The type of furnace or boiler limits the use of this method for some systems. For example, introducing oversized biomass particles to a pulverized coal boiler may negatively impact the system.[103]

[105]Conquering Co-Combustion - https://biomassmagazine.com/articles/conquering-co-combustion-5752
[106] Co-Combustion of Coal and Biomass: Heating Surface Slagging and Flue Gases - https://www.mdpi.com/2571-6255/8/3/106

6.0 Fuel Blending Opportunities in Newfoundland and Labrador

NL is in a position to implement and benefit from various forms of fuel blending due to current and planned developments, current and projected fuel usage, and availability of domestic feedstock for biofuel production, but may face challenges due to geographic spread, low population, logistical challenges, and proximity to market. This section will review the available resources, relevant operational and proposed energy developments, and potential applications of fuel blending for various sectors within NL.

6.1 Available Resources

The feasibility of domestic fuel blending with biofuels is largely dependent upon the availability of feedstocks for production. An *econext* discussion paper provides a detailed review of potential biomass use in NL, and lists the following as potential local sources:[22]

- Landfills
- Agriculture
- Forestry
- Household/commercial organics
- Fishery
- Aquaculture
- Clearing and trimming
- Construction and demolition lumber
- Wastewater sludge
- Landfill gas

This wide range of biomass sources provides the feedstock to produce the following fuels:

- Ethanol
- Transportation fuel (including biodiesel and renewable diesel)
- Hydrogen
- Biogas and syngas (which can produce renewable natural gas)
- Heating oil
- Solid fuel

While this is a promising spread of biomass feedstocks, there is currently little clean fuel production in NL. The single refinery in operation in NL that produces alternative/clean fuels is the **Braya Renewables Refinery** in Come By Chance. It began operation in 2024 and has a current production capacity of up to 18,000 barrels of renewable diesel per day.[107] The plant has plans to begin production of SAF,[108] which would greatly expand the availability of domestic clean fuels.

Additionally, there has been significant interest in the domestic **production of green hydrogen and ammonia**. Multiple companies in NL have secured crown land for this purpose and are currently navigating the regulatory process and preliminary front-end engineering design prior to final investment decisions being made. Many of the proposed projects plan to use wind energy (some supplementing with solar) to power the synthesis of hydrogen by electrolysis and conversion to green ammonia. According to announced plans, production is anticipated to begin between 2028 and 2030.

The **Robin Hood Bay landfill gas** capture system collects approximately 60% of the methane emissions from the landfill located in Logy Bay, NL.[109] It does so through landfill capping with an impermeable liner. An extraction system routes the collected gases to be flared, reducing the GHG intensity of the emitted gases versus directly emitting into the atmosphere. Methane is considered a more harmful GHG than the CO_2 produced from flaring. Instead of flaring the captured methane, there is opportunity to use it as renewable natural gas for blending with green hydrogen. Similarly, renewable natural gas could be used for conventional natural gas applications. Considering the current lack of use of natural gas in NL, there is not a local application for the methane captured from the landfill.

Other fuels that have the potential to be produced locally in NL (particularly those from biomass) all require specific production methods, making implementation complex and potentially cost prohibitive. An additional consideration is the geographic spread of available feedstocks; transporting widespread feedstocks to production facilities may incur greater costs. Further research should be done into the viability of producing these clean fuels in NL, taking into consideration the issues regarding transportation and production methods.

In the context of fuel blending, smaller volumes of constituent fuels are required, particularly when blending with a low percentage of biofuel. This could be considered both an advantage and disadvantage to fuel blending, as less production capacity is needed for

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[107] Braya Renewable Fuels - https://brayafuels.com/
[108] Braya Renewable Fuels Commences Commercial Operations - https://brayafuels.com/wp-content/uploads/2024/02/Braya-Renewable-Fuels-Commercial-Operations-Release-FINAL-2-22-2024.pdf
[109] Resilient St. John's Community Climate Plan: Energy Transition - https://www.stjohns.ca/en/living-in-st-johns/resources/Documents/Resilient_St_Johns_Climate_Plan-EnergyTransition.pdf

the constituent fuels, but may cause issues with using fuels from a variety of sources simultaneously, causing logistical challenges.

6.2 Offshore Natural Gas

All natural gas that is currently produced offshore NL is either being used to power offshore production facilities, flared to atmosphere, reinjected for enhanced oil recovery, or sequestered in a gas storage reservoir. None of the gas produced is sold on the market due to NL's lack of gas export infrastructure, namely gas pipelines.[110] It is possible that these reserves may be commercialized in the future, and there are initiatives currently underway to pursue these opportunities.

It is possible that the commercialization of offshore natural gas reservoirs could utilize fuel blending with hydrogen or renewable natural gas. If natural gas were to be blended with hydrogen, it would be less feasible to convert to its liquid form, therefore making transportation and export more difficult. This gaseous fuel blend would result in reduced emissions during combustion as compared to pure natural gas. If the extracted natural gas was to be blended with renewable natural gas, the resulting blend could be transported and handled exactly as pure natural gas, while also resulting in lower emissions.

6.3 Hard-to-Abate Sectors

In an *econext* discussion paper on domestic clean fuels use, eight hard-to-abate sectors in NL were identified as requiring the adoption of clean fuels to meet GHG emission reduction targets. In the paper, the current and projected clean fuel use in these sectors was assessed.[111] These sectors are:

- marine transportation
- port operations
- remote communities
- electricity grid integration
- heavy-duty transportation
- public transportation
- heavy industry

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[110] Provincial and Territorial Energy Profiles – Newfoundland and Labrador - https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-newfoundland-labrador.html

[111] Opportunities for Domestic Clean Fuels Use in Newfoundland and Labrador - https://econext.ca/wp-content/uploads/2025/04/econext-Domestic-Clean-Fuels-Opportunities-Analysis-2025.04.07.pdf

- aviation

These sectors all have the potential to benefit from fuel blending, and in some cases will require it. Renewable diesel is projected to be a key factor in reducing the emissions of hard-to-abate sectors, both being used as a temporary fuel replacement during the transition to other clean fuels and as a total replacement for conventional diesel, marine gas oil (MGO), and no. 6 fuel. With the exception of aviation, each hard-to-abate sector is projected to partially or fully transition to renewable diesel by 2050. For either of these cases, there are potential barriers to a full transition to renewable diesel based on availability and cost. During the process of increasing access to renewable diesel, biodiesel blends can be an effective interim solution.

Throughout this section, projected clean fuel adoption rates will be discussed within the context of fuel blending, to provide an idea of the potential scale of adoption. These projections are theoretical and the original paper should be referenced for details regarding the methodology used. Further work is required to make more accurate assessments.

Based on these projections in the paper on domestic clean fuel use, a rough estimate of the maximum annual renewable diesel consumption of these sectors can be calculated. The current use of diesel, MGO, and no. 6 fuel, as well as projected peak values of renewable diesel consumption are presented Table 7.

Table 7: Projected Peak Renewable Diesel Use of Each Hard-to-Abate Sector in NL[111]

Sector	Current diesel, MGO, and no.6 fuel use (million L)	Projected peak renewable diesel use (million L)	Year of peak
Marine transportation	357.3	71	2050
Port operations	0.4	0.1	2040
Remote communities	15.8	16	2050
Electricity grid integration	201.2	19	2050
Heavy-Duty Transportation	161	47	2042
Public Transportation	5.5	1.7	2042
Heavy Industry	529.1	127	2042
Total	1,270.3	281.8	-

As seen in Table 7, the total of each sector's peak renewable diesel use is 281.8 million liters. It is important to note that these projected peaks do not necessarily coincide, so the actual peak renewable diesel use should be less than this value in the years leading up to 2050.

The remainder of this section assumes there will be sufficient renewable diesel supply into the future, with only potential interruptions to supply due to unplanned plant outages.

6.3.1 Fuel Blending During Transition Period

There are several hard-to-abate sectors in NL that are projected to use renewable diesel as a temporary tool for emissions reduction during the transition to other, cleaner fuels. These sectors include marine transport and port operations, heavy duty and public transport, and heavy industry.

6.3.1.1 Marine Transport and Port Operations

In NL, marine transport accounts for 14.8% of the provincial annual emissions and is currently reliant on diesel.[111] It is important to note that in the referenced data, the fuel is listed as marine gas oil (MGO), which is identical to diesel for land vehicles.[112] By 2050, this sector is projected to use a combination of renewable diesel, hydrogen, ammonia, methanol, and some remaining MGO. A notable barrier to a full conversion to alternative fuels is the high cost of retrofitting, which disproportionally affects small vessels. Biodiesel and renewable diesel can be blended into MGO, which has the potential to reduce emissions during the process of converting marine vessels to hydrogen or methanol. This is generally seen as an important step in the short term, if it is followed by the eventual complete transition to other clean fuels.[113] Alternatively, ammonia may be blended with conventional diesel if a supply of ammonia is available during this transition period.

Many of the proposed green hydrogen projects in the province plan to convert green hydrogen to green ammonia for export, so there is local opportunity for the use of these domestically produced fuels in the NL marine transport industry. As such, the synergies between the two industries present an attractive value proposition for the development of local green ammonia production.

The process of converting marine vessels to alternative fuels has already begun, with the newest Marine Atlantic vessel using dual fuel technology.[114] The vessel can use marine diesel and LNG, with marine diesel being the primary current fuel, and LNG to be used in greater quantities as it becomes more readily available. While distinct from fuel blending in that dual fuel technology switches between fuels rather than burning them together,[115]

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[112] Biodiesel as alternative fuel for marine diesel engine applications: A review - https://www.sciencedirect.com/science/article/pii/S1364032118303770
[113] From Diesel to Data: Decarbonizing Canada's Ships - https://nrc.canada.ca/en/stories/diesel-data-decarbonizing-canadas-ships
[114] Ala'suinu - https://www.marineatlantic.ca/onboard-experience/our-fleet/alasuinu
[115] Dual Fuel Engine - https://www.yanmar.com/global/marinecommercial/products/dual_fuel_engine/

both fuels may instead use fuel blends to reduce emissions. Marine diesel may be blended with renewable diesel, biodiesel, or ammonia, and LNG may be blended with renewable natural gas, reducing emissions of either operating mode.

6.3.1.2 Heavy Duty and Public Transport

Heavy duty transport currently consumes 161 million liters of diesel annually, while public transportation consumes 5.52 million liters annually, contributing a combined 6.3% of provincial emissions.[111] This sector is forecasted to transition to a combination of Electric Vehicles (EV) and hydrogen fuel cells by 2050, which requires substantial investment in hydrogen refueling infrastructure throughout the province. Combined with logistical issues of transporting and storing hydrogen, this is a significant barrier to transition and may become a lengthy process. To reduce emissions during this process, blending biodiesel, renewable diesel, and/or ammonia into the current diesel supply has the potential to reduce emissions ahead of the current trajectory.

6.3.1.3 Heavy Industry

The combined mining, manufacturing, and construction industries, together considered heavy industry, contribute 19.85% of the province's total emissions.[111] This is due to on-site electricity generation, process/space heating, equipment fueling, and vehicle transport, which consume 529 million liters of diesel annually. Just as in the transport sectors, diesel used in this sector is forecasted to be replaced with electricity, renewable diesel, and hydrogen by 2050, and can benefit from fuel blending to reduce emissions during its transition.

6.3.2 Fuel Blending as a Long-Term Solution

While the hard-to-abate sectors discussed in previous sections have a greater use for fuel blending in the short term, there are others that can benefit from fuel blending in the long term. Remote communities and the electrical grid which continue to use generators and combustion turbines can benefit from long-term blending of diesel with biodiesel/renewable diesel if alternative clean energy options are not feasible. Blending of aviation fuel will be an important application to address emissions in that sector.

6.3.2.1 Remote Communities

Remote communities in NL are primarily reliant on diesel generators and are often located where local renewable electricity generation or connection to the electricity grid is hard to implement, making a transition away from diesel generators difficult. Currently 15.8 million liters of diesel are consumed annually,[111] and it is forecasted that this sector will transition to using renewable diesel in order to continue using the same infrastructure.

One difficulty in fueling remote communities is the cost of delivering fuel. Due to the isolated nature of remote communities, diesel must be delivered by either boat, plane, or truck.[116] While there could be sufficient supply of renewable diesel for local needs from the Braya Renewables facility as discussed previously, there is the potential for supply to be interrupted due to unexpected facility downtime, or supply chain or delivery issues. Diesel should remain available as a backup and can be blended with available renewable diesel to reduce emissions in the case that it must be used.

Additionally, in the case of supply issues of renewable diesel, biodiesel may also be blended into conventional and/or renewable diesel. This may only be feasible during the summer months due to issues with biodiesel gelling that were discussed in Section 5.1.3.2.

6.3.2.2 Electrical Grid

While NL's electrical grid is already supplied >90% by renewable energy, there are diesel generators in place as backups for periods of high demand or emergencies. There are currently four plants that consume a combined 9.6 million liters of diesel, with three of the plants planned to be shut down. There is one additional plant that consumes 191.6 million liters of heavy fuel oil. These backup generators are forecasted to transition to renewable diesel by 2025, based on overall sector fuel projections. [111]

NL Hydro has already begun planning for alternative fuels and fuels blends in combustion turbines. The planned upgrade to the Holyrood generating station includes a requirement that the new combustion turbine be able to operate, or be converted to operate, on alternative fuels such as biodiesel, natural gas, or blends of natural gas and hydrogen.[117] Additionally, NL Hydro stated that they would only consider implementing a combustion turbine if it met Canada's clean electricity regulations, requiring significant GHG emission reductions.[118] For the Holyrood generation station reform, a long-term fuel supply study was completed, which considered the use of biofuel, bioethanol, hydrogen and natural gas, but only bioethanol was found to be feasible, and only to be used if diesel supply becomes an issue.[119]

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[116] The Clean Energy Transition in Remote Communities - https://www.pembina.org/blog/clean-energy-transition-remote-communities

[117] 150 MW (Nominal) Avalon Combustion Turbine Project : Environmental Assessment Registration - https://nlhydro.com/wp-content/uploads/2025/05/env_assessment_y2025_2350-Registration-DOC.pdf

[118] What Was Said Report - https://nlhydro.com/wp-content/uploads/2024/07/Final_2024-RAP_App-D_Engagement.pdf

[119] Reliability and Resource Adequacy Study Review - https://nlhydro.com/wp-content/uploads/2024/07/2024-07-09_NLH_RRA-Study_2024-RAP.pdf

Based on overall sector projections and the specific Holyrood station fuel study, renewable diesel is likely to be a primary fuel for NL electricity backup. Similar to the case of remote communities, there would be adequate renewable diesel supply produced at the Braya Renewables refinery, but there should be conventional diesel and biodiesel backups available if there are any supply chain issues. If conventional diesel or biodiesel is needed, they may be blended with any available renewable diesel.

6.3.2.3 Aviation

As more biofuel SAF and synthetic SAF are used and conventional jet fuel use is reduced, fuel blending will play a crucial role in aviation. In NL, an estimated 98 million liters of jet fuel are consumed annually, contributing 3.3% of provincial emissions.[111] The use of biofuel SAF is projected to grow to 10% internationally by 2030, and by 2050 aviation fuel is projected to be made up of roughly equal parts biofuel SAF, synthetic SAF, and conventional jet fuel. The projections are laid out in Table 8.

Table 8: Projected International Aviation Fuel Adoption to 2050[111]

Clean Fuel Type	2022	2030	2040	2050
Biofuel SAF	0%	10%	22%	33%
Synthetic SAF	0%	1%	4%	37%
Conventional jet fuel	100%	89%	74%	30%

Given that current restrictions typically set a 50% maximum usage of synthetic SAF, fuel blending is required to allow for its use. With the overall share of aviation fuels being a mix of three different fuels well into the future, fuel blending will continue to be a crucial aspect of this industry based on current projections.

6.4 Gasoline Blending

As per the federal CFR, gasoline suppliers typically blend ethanol into their fuel at terminal stations where they are intended for use.[120] In NL, there are six terminal facilities, represented by the yellow triangles in Figure 17 on the following page. As discussed previously, however, fuel supplied to NL decreases a supplier's total pool of conventional fossil fuels under the CFR, reducing the overall volume of ethanol that must be obtained. This is done as a means of reducing gasoline prices in NL because of expensive transportation costs and logistical challenges. However, there is opportunity for the

[120] ARCHIVED – Where does Canada's gasoline come from? - https://www.cer-rec.gc.ca/en/data-analysis/energy-commodities/crude-oil-petroleum-products/report/archive/2019-gasoline/index.html?=undefined&wbdisable=true

development of a local ethanol value chain to supply terminals with the required volumes of ethanol for gasoline blending, reducing transportation costs while also strengthening the local economy.

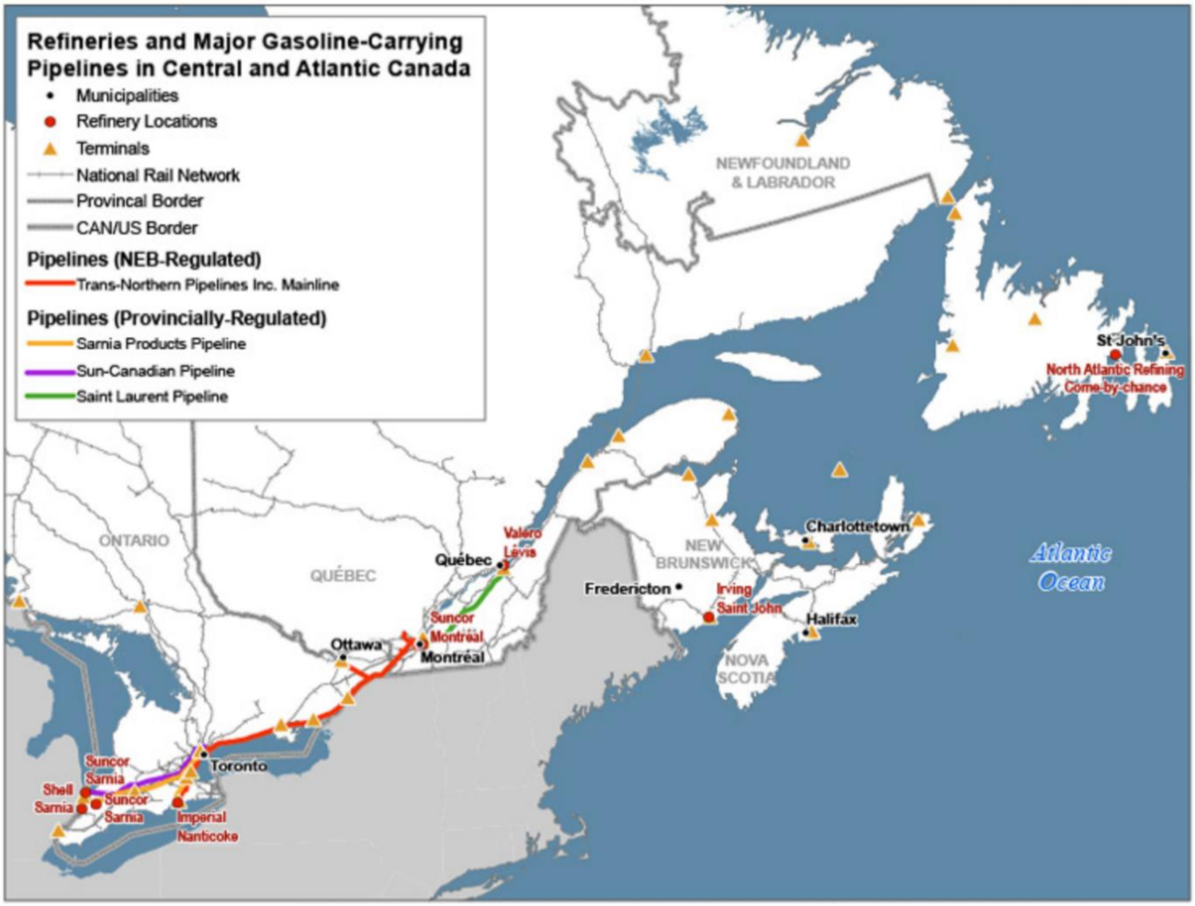
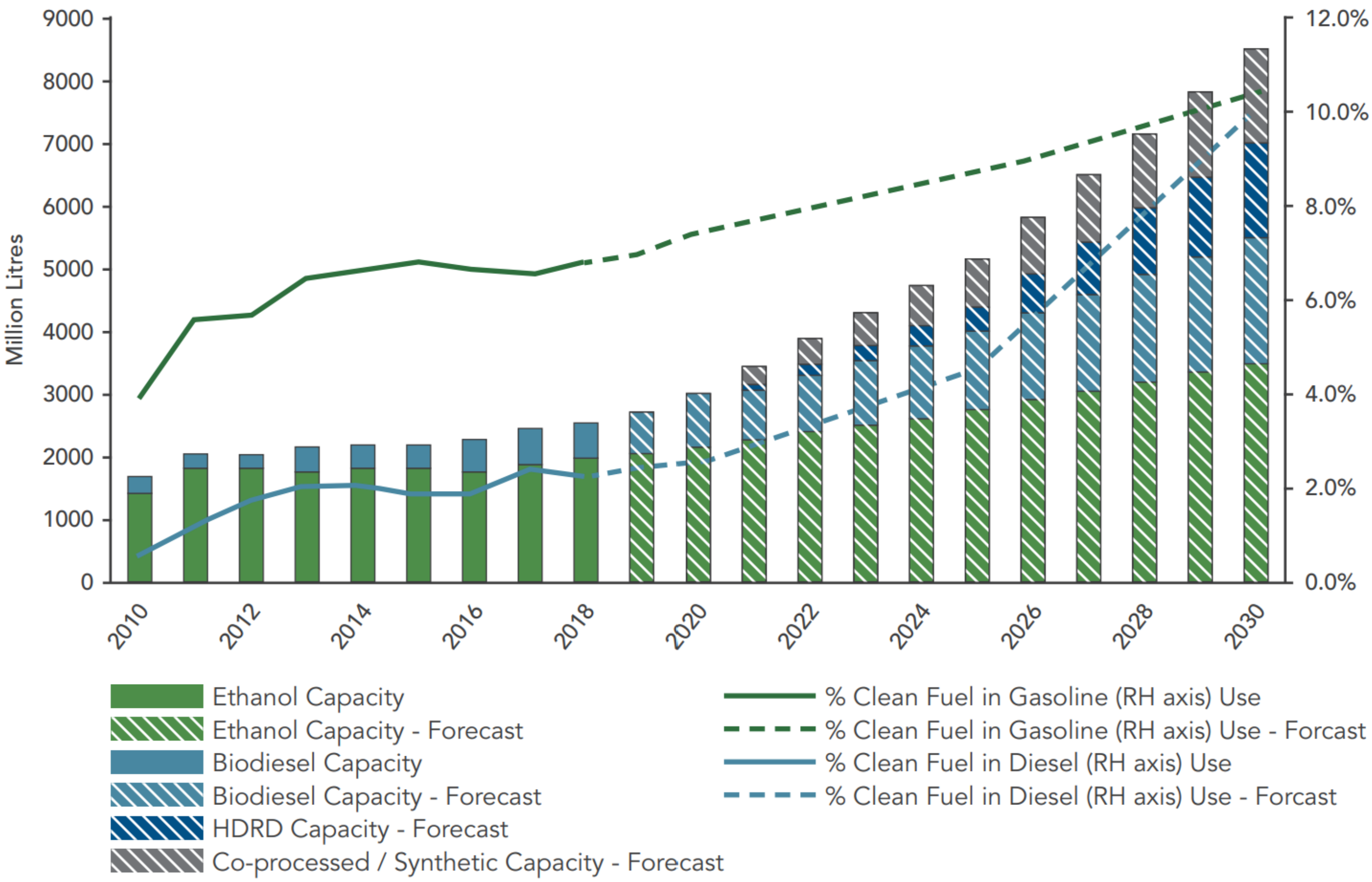


Figure 17: Central and Atlantic Canadian Gasoline Infrastructure[120]

7.0 Next Steps

There is significant opportunity for blending with clean fuels in NL, to support both provincial and federal net zero targets set for 2030, 2040, and 2050. Growth projections for the production of ethanol, biodiesel, renewable diesel, and synthetic fuels, as well as clean fuel blending rates for gasoline and diesel in Canada can be seen in Figure 18 below. Many fuel blends can be implemented without major modification to existing infrastructure, positioning fuel blending as a viable initiative for emissions reductions in the short term.



Source: Advanced Biofuels Canada

Figure 18: Projections for Liquid Clean Fuels in Canada (Note: HDRD = Hydrogenation-Derived Renewable Diesel)[121]

[121] Clean Fuels Investment in Canada - https://advancedbiofuels.ca/wp-content/uploads/Clean-Fuels-Investment-in-Canada-Roadmap-to-2030-ABFC-Nov21-2019.pdf

To harness this opportunity and satisfy provincial/federal net zero targets, recommended next steps for the development of fuel blending in NL include:

- Evaluate the viability of producing clean fuels in NL, taking into consideration the issues regarding transportation and production methods.
- Conduct detailed biomass resource assessments to quantify feedstock availability for domestic clean fuels production.
- Conduct techno-economic analysis to determine most promising biofuel production pathways including considerations for feedstock, geography, and logistics as well as cost benefits associated with diversion of organic waste from landfills.
- Progress local renewable energy and renewable fuel development projects to FID and construction phases.
- Foster collaboration among clean fuel producers, industry, post-secondary institutions, local and Indigenous communities, and government agencies.
- Align priorities between clean fuel producers in the province with potential local end-users.
- As clean fuel supply increases, initiate planning for fuel distribution and storage across key regions and sectors.
- Prepare sector-specific implementation plans for NL's hard-to-abate industries.
- Develop provincial policies and regulations to mandate the blending of fuel, as well as additional incentives to support local production.
- Monitor and evaluate emissions reduction impacts through mandatory GHG emissions reporting, comparing pre-blending emissions to those following the adoption of fuel blending.
- Develop case studies and pilot projects to demonstrate renewable diesel performance in cold climates such as those in NL remote communities, as well as fostering social and cultural acceptance for the shift to clean fuels.