CEAP | CLEAN ENERGY ACCOUNTING PROJECT

CLEAN FUELS IN THE GROUND TRANSPORTATION SECTOR

Background Report | August 2024

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Key Takeaways

- Making up roughly one third of global greenhouse gas (GHG) emissions, the transportation sector is still largely reliant on fossil fuels, but recent policy and technological developments have increased sector-wide decarbonization capacity.
- There is a diversity of clean fuel options for the transportation sector, including renewable hydrogen, biomethane (RNG), biodiesel, renewable diesel, and ethanol.
- Many of the clean fuels applicable to this sector have drop-in capacity, meaning they can be used in existing vehicles and infrastructure without requiring modifications.
- Adoption of clean fuels in ground transportation may be hindered by challenges in distribution infrastructure.
- There is a global emergence of market mechanisms for accounting for clean fuels in the transportation sector.

1. Introduction

In 2021, transportation was the largest emitting sector in the U.S., accounting for 28% of total U.S. GHG emissions.[1] In recent years, the transportation sector has begun to see a global transition from an almost exclusive reliance on fossil fuels, to alternative methods of powering vehicles including electricity and clean fuels.

The primary GHG emitting activities in the transportation sector can be attributed to use of light duty vehicles, medium and heavy vehicles, off-road vehicles and equipment, rail, shipping, and aviation.[2] While there has been significant progress in decarbonizing the transportation sector, especially with the increasing adoption of electric light duty vehicles, other activities such as trucking and railroad transportation still heavily rely on fossil fuels. Currently, clean fuels are primarily being tracked and accounted for through the use of certificate-based systems. This background report explores how clean ground transportation fuels are produced and transacted, and considers opportunities for market-based accounting.

This document includes a summary of the ground transportation sector's key fuel consuming scale and scope, production and distribution characteristics of the clean fuel types available, and examples of relevant regulations and initiatives.

2. Ground Transportation Sector Overview

The ground transportation sector's primary fuel consuming activities are personal and public transportation, heavy-duty truck and railroad transportation of goods, and off-road vehicles and equipment.

Personal Transportation

Electric and hybrid cars have been growing in popularity and accounted for 16% of light-duty vehicle sales in 2023 in the United States.[3] While many of the low emissions vehicles available today are electric vehicles, light duty vehicles that can be powered by low carbon fuels are becoming more accessible. Some personal vehicles operate exclusively on alternative fuels, such as hydrogen fuel-cell vehicles, but many can run on a mix of conventional petroleum-based fuels and clean fuels. For example, most conventional diesel vehicles can operate on a biodiesel blend, B20, which ranges from 6% to 20% biodiesel blended with petroleum diesel.[4] The most prominent low carbon

[1] EPA. Fast facts on transportation greenhouse gas emissions. https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions
[2] EPA. Why we need to decarbonize transportation | U.S. EPA. https://www.epa.gov/greenvehicles/why-we-need-decarbonize-transportation
[3] Electric vehicles and hybrids make up 16% of U.S. light-duty vehicle sales - U.S. Energy Information Administration (EIA). (n.d.). https://www.eia.gov/todayinenergy/detail.php?id=60321
[4] U.S. DOE. Diesel vehicles using biodiesel. Alternative Fuels Data Center: Diesel Vehicles Using Biodiesel. https://afdc.energy.gov/vehicles/diesel.html

fuels used for personal vehicles are hydrogen, methanol, biodiesel, renewable diesel, and ethanol.[5]

Public Transportation

Public transportation mainly consists of buses, trolleys, and passenger trains. Vehicles in the public transportation sector generally operate on a fixed route within confined areas. There are a variety of low carbon fuels used internationally for public transportation, most commonly with buses. Some of the most used low carbon fuels in the public transportation sector are biomethane (RNG) and biodiesel.[6]

Trucking and Rail

Unlike the public transportation sector, the trucking and rail sector requires vehicles to run for longer distances with fewer stops. This, and the greater weights that cargo trucks and trains carry, make decarbonization through electrification using batteries that are currently available challenging.[7] The use of low carbon fuels in the trucking and rail sectors is essential for near-term decarbonization. Biodiesel and renewable diesel are currently the most widely used low carbon fuels here.[8]

Off-Road Vehicles and Equipment

Off-road vehicles and equipment primarily consist of heavy-duty vehicles and machinery used in industrial, construction, and agricultural settings. This includes tractors, cranes, bulldozers, and similar equipment. Off-road vehicles and equipment are generally fueled by conventional diesel, though renewable diesel is a viable alternative fuel option and growing in use. While there is limited information available for clean fuels used for off-road vehicles and equipment, electrification of off-road vehicles is gaining traction. For example, the California-based company *Monarch Tractor* has been manufacturing electric powered tractors for agricultural applications since 2018.[9]

3. Clean Fuels in this Sector

The adoption of clean fuels in the ground transportation sector presents an opportunity to significantly reduce global carbon emissions. There are many types of clean fuels that are already accessible and used in vehicles on an international scale due to their ability to be dropped into existing infrastructure and technology. Some

[5] U.S. DOE. Alternative fuels and advanced vehicles. Alternative Fuels Data Center: Alternative Fuels and Advanced Vehicles. https://afdc.energy.gov/fuels/
[6] U.S. DOE. Alternative fuels in public transit: A match made on the road. https://afdc.energy.gov/files/pdfs/public_transit.pdf
[7] IEA. Trucks & Buses. https://www.iea.org/energy-system/transport/trucks-and-buses
[8] UP. How are locomotives getting more fuel efficient for the railroad industry? https://www.up.com/customers/track-record/tr040522-locomotive-fuel-efficiency-improvements.htm
[9] Smithsonian Magazine. "Could electric tractors revolutionize farming?". Smithsonian.com. https://www.smithsonianmag.com/innovation/could-electric-tractors-revolutionize-farming-180982012/

drop-in fuels in the transportation sector are blended with conventional fuels like gasoline and diesel, while others can be used in their pure form and do not require blending.[10]

3.1. Renewable Hydrogen

Production Process and Feedstocks

The two most common methods for producing hydrogen are natural gas reforming (also known as steam methane reforming or SMR) and electrolysis.[11] Natural gas reforming is currently used to produce approximately 95% of the hydrogen in the world.[12] For hydrogen to be considered "renewable", the production process must be powered by renewable resources.[13]

Recent policy such as the United States Inflation Reduction Act (IRA) Section 45v and the European Union Hydrogen Directive have proposed a three-pronged approach for determining the "cleanness" of hydrogen production. These three pillars are incrementality/additionality (is the clean energy used for hydrogen production new or would it have gone online without this incentive?), temporal matching (matching the hour of generation of the renewable source to the hour of hydrogen production), and deliverability/geographical correlation (how close the renewable source is to the hydrogen facility).

Distribution Networks

Distribution networks for hydrogen are still largely undeveloped. In the United States, most hydrogen is currently distributed through high-pressure tube trailers and liquefied hydrogen tankers.[14] As a result, the fuel is generally used close to the production sites.[15] Hydrogen can be transported in existing natural gas pipelines at low volumes, though the logistics of this delivery option are still being researched. In cases where hydrogen could be delivered in natural gas pipelines, the molecules would not be disaggregated at the site of consumption; rather, hydrogen and natural gas would be used as a blend.[16] Hydrogen delivery through natural gas pipelines could present an opportunity for market-based accounting in the ground transportation sector.

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[10] IEA Bioenergy. (n.d.-c). 'Drop-in' biofuels. https://www.ieabioenergy.com/wp-content/uploads/2019/09/Task-39-Drop-in-Biofuels-Full-Report-January-2019.pdf
[11] U.S. DOE. (n.d.). Hydrogen Basics. Alternative Fuels Data Center: Hydrogen Basics. https://afdc.energy.gov/fuels/hydrogen_basics.html
[12] ScienceDirect Topics. (n.d.). Methane steam reforming. Methane Steam Reforming - an overview. https://www.sciencedirect.com/topics/engineering/methane-steam-reforming
[13] Electrolysis using renewable electricity demonstrated through the retirement of renewable energy certificates (RECs) is the primary method for producing renewable hydrogen.
[14] U.S. DOE. (n.d.). Hydrogen production and distribution. Alternative Fuels Data Center: Hydrogen Production and Distribution. https://afdc.energy.gov/fuels/hydrogen_production.html
[15] U.S. DOE. Hydrogen production and distribution. Alternative Fuels Data Center: Hydrogen Production and Distribution. https://afdc.energy.gov/fuels/hydrogen_production.html
[16] U.S. DOE. Hyblend: Opportunities for hydrogen blending in natural gas pipelines. https://www.energy.gov/eere/fuelcells/hyblend-opportunities-hydrogen-blending-natural-gas-pipelines

Hydrogen distribution networks in European countries like Germany and France are also being constructed. Hydrogen is commonly distributed in Europe through dedicated hydrogen pipelines. Europe plans to develop cross-border hydrogen distribution networks, like the proposed hydrogen pipeline through Spain, France, and Germany.[17] The market for transacting green hydrogen in Europe is still being developed and is largely dependent on funding for the infrastructure programs.[18]

3.2. Biomethane (RNG)

Production Process and Feedstocks

Biomethane, or renewable natural gas, is primarily produced through anaerobic digestion or gasification. To produce fuel grade biomethane, biogas must go through a purification process called upgrading.[19] Biomethane can be used as a clean fuel for vehicles in the form of compressed natural gas (CNG) and liquefied natural gas (LNG), both of which are widely used in the ground transportation sector for medium and heavy-duty vehicles.

The most common feedstocks used in biomethane production are animal manure, organic municipal solid waste, and wastewater sludge.[19]

Distribution Networks

Biomethane is generally distributed via existing natural gas pipelines.[20] As a transportation fuel, biomethane is primarily used in the United States and in Europe.[19] In California under the LCFS, pipeline-injected biomethane can be tracked by the environmental attributes of the gas through book and claim accounting.[21]

Some European countries have also developed systems to track and trade biomethane conveyed through pipelines via book and claim certificates known as Guarantees of Origin (GOs)[22] or Renewable Gas Guarantees of Origin (RGGOs). The European Renewable Gas Registry (ERGaR) is an example of a cross-border GO registry that tracks the trading and consumption of biomethane across fourteen European countries using the GO certificate system.[22]

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[17] Offshore. Hydrogen pipelines start to materialize in France, Germany and Spain. Offshore. https://www.offshore-mag.com/regional-reports/north-sea-europe/article/14292219/rystad-energy-hydrogen-pipelines-start-to-materialize-in-france-germany-and-spain

[18] The value of green hydrogen trade for Europe. RMI. https://rmi.org/insight/the-value-of-green-hydrogen-trade-for-europe/

[19] IEA. An introduction to biogas and biomethane – outlook for biogas and biomethane: Prospects for organic growth – analysis. IEA. https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth/an-introduction-to-biogas-and-biomethane

[20] Storage and transportation of biogas and biomethane. (n.d.-d). https://suscon.org/pdfs/cowpower/biomethaneSourcebook/Chapter_4.pdf

[21] LCFS guidance - California Air Resources Board. (n.d.). https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/guidance/lcfsguidance_19-01_Revised_Oct2023_ADA.pdf

[22] In Europe, certificates used to trace electricity—including renewable electricity—are also referred to as Guarantees of Origin, or GOs

3.3. Biodiesel

Production Process and Feedstocks

Biodiesel, also referred to as B100 in its pure form, is produced from vegetable oils, animal fats, and recycled restaurant grease.[23] Biodiesel is produced through transesterification where fats and oils are converted into biodiesel and the coproduct, glycerin.[24] Once biodiesel is produced, it is usually blended with conventional diesel fuels at different ratios, most commonly 5% biodiesel to 95% fossil diesel to produce B5.[24]

Distribution Networks

In the United States and Europe, the maximum percentages of biodiesel that are allowed to be blended with conventional diesel at commercial fueling stations are 5% and 7%, respectively.[25] Biodiesel can generally be used at higher blend ratios with conventional diesel, or in its pure form (B100) in fleet operations like taxis and city buses. Being a drop-in fuel, biodiesel can be used without any modifications to conventional diesel-powered vehicles. Biodiesel, either in the pure form or blended, is distributed to the end user similarly to petroleum diesel through pipelines, trucks, trains, or barges.[25]

In the U.S., Biodiesel transactions often involve RINs (Renewable Identification Numbers) which are used to comply with the U.S. Renewable Fuel Standard.[26]

3.4. Renewable Diesel

Production Process and Feedstocks

Renewable diesel, like biodiesel, is commonly produced from feedstocks like oils, fats, and greases, though the production process differs.[27] The most common production method for renewable diesel is hydrotreating, though other methods include gasification, pyrolysis, hydrothermal processing, catalytic conversion of sugars, and biological sugar upgrading.[27] In hydrotreating, the feedstocks react with hydrogen at a high temperature and high pressure to produce renewable diesel in its pure form.

Distribution Networks

Like biodiesel, renewable diesel is commonly blended with conventional diesel at different ratios before being distributed for consumption. Renewable diesel is also a

[23] U.S. DOE. *Biodiesel Fuel Basics*. Alternative Fuels Data Center: Biodiesel Fuel Basics. https://afdc.energy.gov/fuels/biodiesel_basics.html
[24] U.S. DOE. (n.d.). *Biodiesel production and distribution*. Alternative Fuels Data Center: Biodiesel Production and Distribution. https://afdc.energy.gov/fuels/biodiesel_production.html
[25] AMF. (n.d.). https://www.iea-amf.org/content/fuel_information/fatty_acid_esters/compatibility
[26] Jiao, H. Overview of the RIN compliance system and pricing of Rins for the U.S. renewable fuel standard. farmdoc daily. https://farmdocdaily.illinois.edu/2023/05/overview-of-the-rin-compliance-system-and-pricing-of-rins-for-the-us-renewable-fuel-standard.html
[27] U.S. DOE. Renewable diesel. Alternative Fuels Data Center: Renewable Diesel. https://afdc.energy.gov/fuels/renewable_diesel.html

drop-in fuel and can be used in diesel engines in its pure form.[28]

3.5. Ethanol

Production Process and Feedstocks

The most common feedstock in ethanol production is corn, though there are certain cellulosic feedstocks that can be used in ethanol production including grass, crop residues, and wood.[29] Ethanol is a widely used low carbon fuel in the transportation sector globally. The production process for ethanol is dependent on the feedstock. For starch-based feedstocks, like corn, the primary production method is dry-milling. In the dry-milling process, corn is ground into a flour and fermented to produce ethanol. Distillers grains and carbon dioxide are co-products of the dry-milling process. Dry-milling plants produce nearly 90% of the starch-based feedstock ethanol in the United States.[29] Wet-milling is another option for producing ethanol with starch-based crops and follows a similar process but produces different co-products.

Ethanol can also be produced using cellulosic feedstocks in cellulosic production, though this method is more chemically involved and not as frequently used.

Distribution Networks

Ethanol is generally distributed as a transportation fuel at blended ratios with conventional petroleum gasoline. Ethanol is primarily transported with trucks and trains, as dedicated ethanol pipelines are still largely undeveloped.[29]

4. Regulations and Initiatives

The use of clean fuels in the ground transportation sector has been increasingly supported by jurisdictions on an international scale through regulations and initiatives. These typically require the commercial fuel pool in the region to contain a minimum percentage of clean fuels. Generally, requirements are met by blending clean fuels with conventional petroleum-based gasoline, though in some regions, like in California, there are fueling stations distributing non-blended clean fuels, such as hydrogen. Some of the most prominent regulations in the ground transportation sector include:

4.1. Renewable Fuel Standard (US)

The Renewable Fuel Standard is administered by the U.S. Environmental Protection Agency (EPA) and originated with the Energy Policy Act of 2005.[30] The program

[28] ScienceDirect Topics. (n.d.-d). Renewable Diesel - an overview. https://www.sciencedirect.com/topics/engineering/renewable-diesel
[29] U.S. DOE. (n.d.). Ethanol production and distribution. Alternative Fuels Data Center: Ethanol Production. https://afdc.energy.gov/fuels/ethanol_production.html
[30] U.S. DOE. Alternative Fuels Data Center: Renewable Fuel Standard. https://afdc.energy.gov/laws/RFS

promotes the use of alternative fuels in the United States by requiring the transportation fuel supply to contain a minimum volume of low carbon fuels.[330] The program establishes minimum thresholds for alternative fuels based on the following categories: conventional biofuel, advanced biofuel, biomass-based diesel, and cellulosic biofuel.[31] The EPA has established the Renewable Identification Number (RIN) system where each gallon of renewable fuel in the system is assigned a distinct RIN. For RINs to be used as tradable credits, the associated batch of renewable fuel must first be blended with a conventional fuel (i.e. gasoline or diesel).[31] Once the renewable fuel has been blended, RINs can be traded and retired by parties to meet compliance of the RFS's minimum renewable fuels volume requirements. Failure to comply with minimum requirements results in fines administered by the EPA.30

The RFS has created a market for buying and selling RINs in the United States. RINs represent environmental attributes and are generated by fuel producers or importers. RINs can be transacted in their bundled form along with the renewable fuel (Assigned RINs) or separate from the fuel (Separated RINs) and in both forms RINs are retired by an obligated party to meet their Renewable Volume Obligation (RVO)[32] for the current compliance year or the following compliance year after the RINs generation.[33] The EPA-moderated transaction system (EMTS) keeps track of renewable fuels entering the United States' transportation fuel supply and ensures renewable volume obligations are being met.[33] It is important to note that there have been several cases of fraud in the RIN market since the inception of the RFS. Fraud has generally occurred by parties that generate and sell fraudulent RINs, and the EPA has responded to this activity by developing a more thorough and secure process for tracking and auditing transactions of RINs by participants in the program.[34]

4.2. Low Carbon Fuel Standard (US)

California's Low Carbon Fuel Standard was officially implemented by the California Air Resources Board (CARB) in 2011.[35] The Low Carbon Fuel Standard incentivizes the production and use of alternative fuels in the California transportation sector based on the Carbon Intensity (CI) scores of fuels. CI scores are measured in grams of carbon dioxide equivalent per megajoule of energy and are calculated using an equation that accounts for the associated GHG emissions of a fuel's lifecycle.[36] The scores are then compared to a benchmark defined in the LCFS to determine the fuel's associated carbon intensity related to conventional fossil fuels. Fuels with lower carbon intensity scores, and therefore lower levels of associated GHG emissions, are

[31] RIN. McKinsey Energy Insights. (n.d.). https://www.mckinseyenergyinsights.com/resources/refinery-reference-desk/rin/
[32] Environmental Protection Agency. EPA. https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rin-trades-and-price-information
[33] Environmental Protection Agency. EPA. https://www.epa.gov/renewable-fuel-standard-program/renewable-identification-numbers-rins-under-renewable-fuel-standard
[34] Practical steps to mitigate RIN market fraud risk in light of EPA's Inspector General RFS Audit Report. JD Supra. https://www.jdsupra.com/legalnews/practical-steps-to-mitigate-rin-market-6266255/
[35] California Air Resources Board. Low Carbon Fuel Standard | California Air Resources Board. https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/about
[36] LCFS basics with Notes - California Air Resources Board. (n.d.-a). https://ww2.arb.ca.gov/sites/default/files/2020-09/basics-notes.pdf

supported through the LCFS. Low carbon fuels highlighted in the LCFS are hydrogen, biodiesel, ethanol, and biomethane.[37]

The LCFS has created a market in California that had a value of over $2 billion in credit transactions in 2018. Credits are generated through the LCFS based on the CI score of fuels used in the program. Fuels with lower CI scores generate more credits and fuels with higher CI scores generate deficits. For credits to be generated, suppliers of fuels used in California's transportation fuel supply must have a certified CI score and report their transactions each quarter.[36] Credits can be traded and retired by parties to balance out their deficits. There is no timeframe in which LCFS generated credits expire. The credit system is used to ensure that renewable requirements are being met in California's transportation fuel supply.

Through this program, California has set carbon intensity benchmarks for the state's fuel pool with a goal of reducing the carbon intensity of the transportation fuel supply by 20% by the year 2030.[38] CARB is working with several other jurisdictions including Oregon, Washington, Canada, and Brazil to implement similar clean fuel programs.[39]

4.3. Fuel of the Future (Brazil)

The Fuel of the Future program, or "Combustível do Futuro", is a pending bill in Brazil supporting the reduction of carbon emissions associated with fuels in the nation's transportation sector. The program covers all activities in the transportation sector including aviation and shipping. Ethanol, an already prominent clean fuel used in Brazil's ground transportation sector, is highlighted in this program as the government proposes to increase the range of ethanol-gasoline blending distributed at commercial fueling stations from 18%-27.5% ethanol to 22%-35%.[40] This program also supports the development of other low carbon fuels such as biodiesel, biomethane, and sustainable aviation fuel (SAF).[40]

The program would require that 10% of the gasoline sold in Brazil must be composed of biomethane by 2034 and 20% of diesel sold in Brazil must composed of biodiesel by 2030.[40] The Fuel of the Future bill was approved by Brazil's Congress in March 2024 and is currently awaiting approval from the Senate.

4.4. In-Use Off-Road Diesel-Fueled Fleets Regulation (US)

The California Air Resources Board (CARB) approved the In-Use Off-Road Diesel-Fueled Fleets Regulation (also referred to as the *Off-Road Diesel Regulation*) in 2007 and has since approved several amendments to the regulation. The Off-Road Diesel

[37] Mills, R. Understanding California's low carbon fuel standards regulation. RMI. https://rmi.org/understanding-californias-low-carbon-fuel-standards-regulation/
[38] California Climate Policy Fact Sheet Low Carbon Fuel Standard. (n.d.-a). https://www.law.berkeley.edu/wp-content/uploads/2019/12/Fact-Sheet-LCFS.pdf
[39] *California Air Resources Board*. Low Carbon Fuel Standard | California Air Resources Board. (n.d.). https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/about
[40] Zancaner, A. *How Will the Fuel of the Future Bill Impact Brazil's Energy Industry*? CZ. https://www.czapp.com/analyst-insights/how-will-the-fuel-of-the-future-bill-impact-brazils-energy-industry/

Regulation is specific to existing off-road diesel-fueled vehicle fleets in California and aims to reduce emissions while promoting the use of renewable diesel in heavy-duty vehicles. The regulation requires that older vehicles with higher emissions contributions be completely phased out of fleets and all eligible existing vehicles must be fueled by renewable diesel (R99 or R100).

Off-road fleet owners in California are required to register their vehicles with CARB and each vehicle is assigned an equipment identification numbers (EIN). Owners must report to CARB on a yearly basis and provide records detailing their procurement and use of renewable diesel.[41] The regulation does not currently utilize a certificate-based system to account for fuels, therefore fleet owners are not able to procure renewable diesel through a book and claim system.

4.5. Clean Fuel Regulations (Canada)

The Clean Fuel Regulations (CFR) in Canada aim to reduce the carbon intensity of gasoline and diesel by 15% from 2016 levels by 2030.[42] The Clean Fuel Regulations supports the development of low carbon fuels in Canada. The CFR implemented a credit trading system similar to that of the LCFS. Credits in the CFR are generated based on a CI score and its relation to the benchmark defined by the CFR.[43] Credits can be sold and retired by parties to meet the requirements of the CFR. Credits in the program are issued to "Registered Creators", meaning parties who meet the CFR eligibility requirements.[44] To qualify as a Registered Creator, a party must either own a project that reduces emissions from the fuel production process, produce or import low-CI fuels, or supply low-CI fuels directly to vehicles.[44] The CFR requires that the earnings from credits sales must be used to fund decarbonization efforts.[45]

Many local jurisdictions within the country have set their own goals that go beyond the requirements in the CFR. For example, the Canadian province of Ontario has introduced a regulation called Cleaner Transportation Fuels. The Cleaner Transportation Fuels program requires transportation fuel in Ontario to contain 10% renewable content from 2020-2024 increasing to a minimum of 15% renewable content by 2030.[45] The regulation also requires that the renewable content must emit at least 45% fewer greenhouse gas emissions than conventional gasoline through 2030, and from 2030 onward the minimum requirement increases from 45% to 50%.[45]

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[41] *California Air Resources Board*. In-Use Off-Road Diesel-Fueled Fleets Regulation | California Air Resources Board. (n.d.). https://ww2.arb.ca.gov/our-work/programs/use-road-diesel-fueled-fleets-regulation
[42] Government of Canada. https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-regulations/about.html
[43] Canada's Clean Fuel Regulations (CFR). Canadian Fuels Association. (2023, June 29). https://www.canadianfuels.ca/our-industry/clean-fuel-regulations/
[44] Meyer, D. (2023, March 27). *Maximizing your earnings: Navigating the Canadian Clean Fuel Regulation as a credit creator*. 3Degrees. https://3degreesinc.com/resources/navigating-the-canadian-clean-fuel-regulation-as-a-credit-creator/
[45] ibid

5. Summary

The incorporation of clean fuels such as biomethane, renewable hydrogen, and ethanol in the ground transportation sector have been largely supported through federal and international regulations. Some programs have implemented certificate market-based accounting systems that allow for tracking and trading of clean fuels without the need to physically transact the product. Transactions of certificates, or credits, associated with clean fuels has led to an expanding market both in the United States and internationally. Decarbonizing the ground transportation sector is an essential piece of climate change mitigation as the sector is one of the largest contributors to greenhouse gas emissions.