IEA Bioenergy

Technology Collaboration Programme

Implementation Agendas:

Compare-and-Contrast Transport Biofuels Policies

(2021-2023 Update)

IEA Bioenergy: Task 39

Task 39 IEA Bioenergy

The BC-SMART Low Carbon Fuels Consortium

BC Bioenergy Network PARTNERING FOR A GREENER FUTURE

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Background

IEA Bioenergy Task 39 has published six issues of the implementation agenda report in 2007, 2009, 2014, 2017, 2019 and 2021. This current issue (2023) updates the progress in biofuel production and use in member countries and the policies that have been used by Task 39 nations to promote low-carbon intensity (CI) biofuels.

An important “take-home” message from the report is that effective biofuel policies are needed to stimulate the growth of biofuel markets. For example, mandates continue to be an important policy tool that have been successfully used to encourage the production and use of biofuels, by establishing markets and facilitating market entry. However, to date, most biofuel policies have focused on promoting “first-generation/conventional” biofuels such as ethanol and biodiesel. While these types of biofuels currently dominate the market, the production and use of “drop-in” biofuels such as renewable diesel (RD, also termed HVO) and Sustainable Aviation Fuels (SAF)/biojet has been increasing.

As covered in more detail, “market-pull” policies have played a significant role in supporting mature technologies, such as production and use of ethanol and biodiesel. Although these policies have also helped develop drop-in biofuels such as renewable diesel, additional polices such as low carbon fuel standards (LCFS) have increasingly emphasised the CI of biofuels (rather than volumetric targets such as 10% ethanol, 2% biodiesel). The CI of a biofuel is a key component of the updated report as, one of the main reasons for using biofuels, is to reduce the greenhouse gas (GHG) emissions associated with transportation. In particular, the “hard to electrify” long distance transport sector such as aviation, marine, trucking and much of the world’s rail, is predisposed to using drop-in biofuels. By using low-CI, drop in biofuels, this sector can make use of much of the current infrastructure/supply chain while decreasing the carbon emissions associated with long-distance transport.

As described in the report, policies such as California’s LCFS (CA-LCFS) require various entities, (typically fuel and energy providers), to progressively reduce the GHG emissions of the fuels they sell. The CA-LCFS assesses emissions resulting from the production, transportation and consumption of the fuel with providers “marketing” low-CI fuels (such as “green” hydrogen, “green” methane, etc.), with a credit trading system used to enhance flexibility. It should be noted that LCFS-types of policies have also been shown to enhanced the production and use of “conventional” biofuels such as ethanol while promoting the growth of drop-in biofuels such as RD/SAF. As detailed in the full report, regions such as California, Oregon and Washington States, the Province of British Columbia (BC), and in countries such as Canada (Clean Fuel Regulations), Brazil (RenovaBio) and the EU (Fit-for-55), have either implemented or are considering implementing similar measures.

As described below, policies such as the US Inflation Reduction Act (IRA) have had a significant impact as they have helped promote the production and use of low-CI fuels such as SAF, "green" hydrogen and renewable natural gas (RNG). It should also be noted that, in many cases, these Federal policies can be “stacked” with various State based bioenergy and biofuel tax credits.

In summary, the “right/enabling” policies continue to be crucial for the continued growth of biofuels. As discussed below, the increasing focus on the CI of the biofuel requires the use of Life Cycle Analysis (LCA) models. However, the variability resulting from the use of different LCA models (i.e., GREET, GHGenius, VSR, etc.), and the various assumptions, boundaries, default values, etc., within these models, is one of the ongoing “discussions/projects” carried out within IEA Bioenergy Task 39.

Acknowledgements

The Task 39 country representatives who contributed to this report are listed below, including their country and institutional affiliations. We thank the country representatives of IEA Bioenergy Task 39 for their participation in completing the questionnaires and engaging in insightful discussions.

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List of Abbreviations

AFCD: Agriculture, Fisheries and Conservation Department
BC: British Columbia
Bcm: Billion Cubic Meters
BL: Billion liters
BG: Billion Gallons
BTC: Blender's Tax Credit
CA: California
CBIO: Decarbonization Credit
CCS: Carbon Capture and Storage
CFR: Canadian Fuels Regulations
CFS: Clean Fuel Standard
CI: Carbon Intensity
CO2: Carbon Dioxide
CO2eq: Carbon Dioxide Equivalent
COP: Conference of the Parties
ECCC: Environment and Climate Change Canada
EEDI: Energy Efficiency Design Index
EEXI: Existing Ship Index
EJ: Exajoules
ENS: Emissions Trading System
EPA: Environmental Protection Agency
EU: European Union
EUR: Euro
GHG: Greenhouse Gas
GHGenius: GHG Emission Model for Canada
Gt: Gigatonnes
HDRD: Hydrogenation-derived renewable diesel
HEFA: Hydroprocessed Esters and Fatty Acids
HVO: Hydrogenated Vegetable Oil
ICAO: International Civil Aviation Organization
IEA: International Energy Agency
ILUC: Indirect Land Use Change
IMO: International Maritime Organization
IRS: Internal Revenue Service
LCA: Life Cycle Assessment
LCFS: Low Carbon Fuel Standard
LNG: Liquefied Natural Gas
M^3: Cubic meters
MG: Million Gallons
MJ: Megajoules
ML: Million liters
MMT: Metric Million Ton
MtCO2eq: Million tonnes CO2 equivalent
Mtoe : Million Tonnes of Oil Equivalent
PJ: Petajoules
PTC: Production Tax Credits
RED: Renewable Energy Directive
REN21: Renewable Energy Policy Network for the 21st Century
RES: Renewable Energy Sources
RFA: Renewable Fuels Association
RFS: Renewable Fuel Standard
RNG: Renewable Natural Gas
SAF: Sustainable Aviation Fuel
SEEMP: Ship Energy Efficiency Management Plan
SPK: Synthetic Paraffinic Kerosene
TJ: Terajoules
TWh: Terawatt hour
UCO: Used Cooking Oil
USA: United States of America
VIB: Vehicle Inspection Bureau
VSB: Virtual Sugarcane Biorefinery
wt.%: Weight Percent
Yr: Year

Executive Summary

In 2021, the transport sector consumed 113.4 exajoules (EJ) of energy which is about one-third of the world's total energy demand. Fossil fuels, mainly oil (90%) and natural gas (5%) were the dominant sources of transportation fuels. Road transportation consumed the majority of transport-related-energy (nearly 78%), followed by marine (11%), aviation (8%) and rail (3%). However, renewables made up only 4.1% of transport related energy consumption, with biofuels accounting for 3.6% and renewable electricity 0.4%. Despite the small contribution of renewables, biofuels are a significant part of most countries decarbonization strategies, especially for road transportation. The transport sector emitted 7.7 giga tonnes (Gt) of CO2 in 2021, which is about 20% of the total world emissions. In 2021, road transport accounted for over three-quarters of the worlds transport related emissions (76.6%, 5.9 Gt CO2), with marine transport contributing 11% and aviation 9.2% (REN21, 2023).

As discussed in more detail throughout the report, many countries, particularly those involved with IEA Bioenergy Task 39, have made commitments to achieve carbon neutrality by 2050. Despite the growth in low-CI fuels such as ethanol and bio/renewable diesel, the growth in electric vehicles and the use of "green" electricity is expected to play an increasing role in decarbonising road transport. However, long-distance and heavy-duty transportation will be difficult to (green) electrify, with low-CI, drop-in biofuels playing a major role in decarbonising aviation, shipping, rail and trucking.

Consequently, there has been an increasing focus on the hard-to-electrify, long distance transport sector with biojet/SAF increasing used by the aviation sector and bio/renewable diesel used by the shipping sector. Both airline and shipping companies are actively exploring ways to meet the carbon reduction goals that have been defined by "umbrella" organisations such as the International Civil Aviation Organization (ICAO) and International Maritime Organization (IMO) (IEA, 2022a).

1.1. The increasing use of Carbon Intensity (CI) reduction policies rather than volumetric/energy mandates, when biofuels are made and used

As detailed in previous issues of the Implementation Agenda report, mandates have been widely used to help drive the growth of biofuels and they have proven to be a key policy. However, while mandates have generally helped to reduce GHG emissions, they have tended to be volumetric or energy based, rather than focusing on reducing the CI of the fuel. Although volumetric or energy targets can sometimes be difficult to determine, defining and measuring the CI of a biofuel has proven to be considerably more challenging.

1.2. Key features of the biofuel policies used by the Task 39 countries

As described in more detail in the main body of the report, the Task 39 countries have successfully promoted the production and use of transport biofuels by using a combination of market demand and research and development policies. Market-pull policies, such as LCFS have encouraged investment in mature technologies, such as renewable diesel production/use, while technology-push (R,D&D) policies have supported research, development and demonstration efforts.

However, policies such as the US's IRA and Europe's Fit-for-55 package, will-and-have played a significant role in promoting the production and use of low-CI fuels. These policies have also helped narrow the price difference between fossil fuels and alternative, low-CI fuels. The US's IRA has also introduced new tax credits to support biojet/SAF, clean fuel production and clean hydrogen. In parallel, the European Union (EU) has set targets to increase the share of renewable energies in transport while implementing regulations to encourage the use of biofuels and renewable gases. Similarly, Brazil's RenovaBio program has encouraged biofuel producers to reduce their GHG emissions, while California's LCFS offers tax credits for producers who have lowered the CI of the fuels they provide. In Canada, federal and provincial programs have supported biofuels production by implementing blending mandates while policies such as the federal low-carbon fuels regulation (CFR) and British Columbia's Low Carbon Fuels Standard (LCFS) have played significant roles in reducing transport-related emissions.

1.3. Challenges posed by different CI results in life cycle assessment (LCA) models

Existing and evolving policies such as the US's IRA/ Renewable Fuel Standards (RFS)/CA-LCFS, the EU's RED II, REPowerEU, Fit-for-55, Brazil's RenovaBio, Canada's CFR, etc., all require the determination of the CI of transportation fuels. However, assessing the CI of a biofuel is complex as it is influenced by various factors such as default values, direct/indirect land use change (ILUC), allocation methodology, etc. Differences in the data used for cultivating and processing feedstock, (such as variations in fertilizer types, amounts, timing, and allocation methods) can also result in different LCA models producing varying results. Although regional differences in feedstock production and processing have been shown to contribute to these discrepancies, previous Task 39 work has shown that, when these differences are "rationalised", similar LCA values are obtained (IEA, 2019). This past Task 39 work also showed the impact that various assumptions, such as land-use changes, the use of fossil/green electricity, etc., all, significantly, affected the CI values that were determined.

1.4. Biofuels Market development

1.4.1. Biofuel production

Although, over the last 20 years there has been a global increase in amount of biofuel produced and used, this declined somewhat in 2020 due to the COVID-19 pandemic (AFCD, 2023; RFA, 2023). The global biofuel produced in 2022 was estimated to be 144 BL (114 BL of ethanol, 45 BL of biodiesel and 12 BL of renewable diesel) (IEA, 2022). The United States (41%), Brazil and Indonesia were the three main producers of biofuels (Statista, 2021b). The US (15 billion gallons (BG)) and Brazil (7 BG) are the world's leading ethanol producers, together account for 82% of global production. The EU was third. The US and Brazil were the largest global biodiesel producers (followed by Indonesia), totaling 6.9 and 6.2 BL, respectively, in 2021 (Statista, 2021).

In 2022, the US produced 15 BG of ethanol, 1.6 BG of biodiesel, 1.6 BG of renewable diesel, and 60 million gallons (MG) of SAF (AFCD, 2023; RFA, 2023). However, it is worth noting that a significant amount of new investment was directed towards establishing "stand-alone" refineries that primarily produced renewable diesel.

Brazil has 359 facilities that produce anhydrous and hydrated ethanol, with an anhydrous ethanol production of about 132 million liters (ML) per day and hydrated ethanol production of about 246 ML per day. The country also has 53 licensed biodiesel plants with a total annual production capacity of 12.3 billion liters (BL). Although, Brazil does not currently produce much renewable diesel, it will in the future.

The EU uses roughly 7% of the global biofuel market, worth EUR 100 billion in 2020, which is mostly first generation biodiesel. In 2020, the EU-27 produced about 5.5% of the total transport fuel consumption in the EU. In 2020, the overall EU production of biofuels was 20 BL, of which 15 BL biodiesel and 5 billion liters bioethanol. The largest EU biofuels producers are Germany, France, Spain and Italy.

China is currently one of the world's largest producers of fuel ethanol, with 3.8 BL produced in 2022. (In comparison, production of syngas ethanol is anticipated to soon reach 2.5 BL). Biodiesel production is projected to grow by 2.4 BL, a growth of over 32% from 2021, primarily due to robust exports. China has also increased its yearly production of biodiesel to 2.6 BL while hydrogenation-derived renewable diesel (HDRD) is anticipated to increase to 2.3 BL.

In contrast, Canada has experienced moderate biofuels growth, primarily due to an increase in biodiesel production. Canada has five operational biodiesel facilities with a combined capacity of about 590 ML per year. Ethanol production has remained relatively stable at around 1.7 BL per year and it is produced in 14 facilities. Additionally, the Tidewater and Parkland oil refineries have been co-processing lipid feedstocks at increasing volumes, with the Parkland refinery processing over 111 ML of lipids in 2022. However, it is worth noting that a considerable amount of Canada's biofuels is imported from the US.

Japan imported ethanol 9.6 ML of biodiesel were manufactured by 38 Japanese companies while New Zealand produced 5 ML of ethanol and 0.5 ML of biodiesel. As covered in more detail in each of the "country chapters", although the remaining Task 39 countries are not major biofuel producers, they are significant users.

Feedstocks

Approximately 60% of the world's ethanol comes from corn with about 25% derived from sugarcane. The remainder is usually derived from molasses, wheat, other grains, cassava and sugar beet. About 75% of the world's biodiesel is derived from vegetable oils (20% rapeseed oil, 25% soybean oil, and 30% palm oil), or "lipid wastes" such as used cooking oil (UCO) (20%).

In the US, corn is the primary feedstock used for bioethanol production, while bio/renewable diesel is primarily produced from soybean oil, UCO, animal fats and inedible corn oil. Brazil primarily produces ethanol from sugar cane, but increasingly corn, while soybean oil is primarily used for biodiesel production. As China is limited by feedstock availability and food-vs-fuels concerns, the country primarily relies on wastes or imported feedstocks (AFCD, 2023; RFA, 2023) with their biodiesel industry heavily reliant on using UCO. In the EU, renewable diesel, primarily sourced from UCO and other waste-based lipids, accounted for 23.2% of the EU's bio-derived diesel.

1.4.2. Biofuel consumption

Biofuel consumption is expected to increase significantly over the next decade, primarily driven by policies. In 2021, ethanol demand increased by 6% compared to the previous year but remained 7% below 2019 levels. Renewable diesel use has grown by approximately 70% since 2019, while biodiesel demand saw a slight increase of 0.2%. "Advanced" biofuels, derived from waste and residues, accounted for about 8% of the EU's biofuels (IEA, 2022b). Biofuels accounted for 19.2% of the US's overall renewable energy use in 2021.

1.5. Biofuel Policies

As emphasised in the main report, policy has-and-will play a critical role in decarbonizing transportation in all of the Task 39 countries. Policies such as targets, incentives, mandates, etc., have increased biofuel production and use with key policies used at different stages of the biofuel supply chain. For example, technology-push policies have driven early-stage development while market-pull policies have created demand for more developed biofuels such as ethanol and biodiesel. Blending mandates have also been used to promote the production and use of biofuels, help establish markets while facilitating market entry. Mandates have been shown to help deal with variable, and particularly low, oil prices, while promoting renewable transportation fuels.

Volumetric blending mandates, ranging from 5% (E5), 10% (E10) and higher ethanol blends have been successfully used in countries such as the Brazil, Canada and the US. Other countries, such as Austria, have set substitution targets based on the energy content (at least 3.4% ethanol and 6.3% biodiesel). Although the Netherlands removed mandatory blending targets it introduced an annual energy obligation for fuel suppliers to include a minimum level of renewable energy in transportation fuels. Brazil has increased its biofuel blending mandates to 27% anhydrous ethanol in gasoline (E27) and 12% for biodiesel (B12). Canada has a federal blending mandate that requires a certain percentage of gasoline and diesel to be replaced by low-CI fuels. Provincial-level mandates range from 5% to 15% ethanol in gasoline and 2% to 5% in diesel. China is currently promoting the use of 10% ethanol-blended gasoline in addition to conducting trial programs for 2% and 5% biodiesel blends. For Japan, ethanol is primarily used to make ETBE while biodiesel is blended at a 5% level (B5) for use in cars, buses, and trucks.

1.5.1. Low carbon fuel standard (LCFS)

As mentioned earlier, LCFS-type policies are focussed on decreasing the CI of the transportation fuel rather than imposing specific blending or volumetric requirements. These policies have been successful in promoting the production and use of low-CI, drop-in biofuels, particularly in sectors such as aviation and marine. Although the US, Canada and Brazil are developing national policies to promote the adoption of low carbon fuels, in many countries, the CI aspect of biofuels has yet to be incorporated into their "enabling" policies. However, as discussed below, determining the CI of a biofuel is not straightforward.

1.5.2. Life-cycle assessments (LCA)

LCA is typically used to assess the sustainability and environmental performance of a biofuel throughout the entire lifecycle of its production. An effective LCA ensures compliance with regulations, from feedstock production through to biofuel use. Biofuels derived from wastes (such as UCO) or residues (such as municipal solid waste (MSW)) often achieve significant GHG emission reductions or even negative emissions. ICAO has established the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) to develop a global sustainability framework for fuels and their certification. However, as shown in related Task 39 work (IEA, 2019), comparing LCA results between models is challenging, primarily due to varying assumptions, pathways, feedstocks, default values, regional conditions, etc., that are incorporated into the model. Despite these challenges, LCA models such as the US's GREET (US RFS, CA-LCFS) and Canada's GHGenius (BC-LCFS) continue to be used to evaluate the CI of various biofuels.

1.5.3. Co-processing biogenic feeds in existing oil refineries

Co-processed fuels, which combine low-CI, biogenic feedstocks (such as UCO) with fossil fuels, are currently being produced at a commercial scale in several Task 39 member countries. Policies such as the CA-LCFS, BC-LCFS and Canadian CFRs have promoted co-processing as an economically viable compliance option for oil refineries. The US Environmental Protection Agency (EPA) is currently reviewing the approval of co-processing so that they can generate Renewable Identification Numbers (RINs) as part of the RFS program.

1.5.4. Tax incentives and credits

Tax incentives have been used to foster the development and utilization of biofuels as part of various country's efforts to transition towards a more sustainable and low-carbon transport sector. The extent and nature of these incentives vary from country to country. For example, some countries such as US, Brazil, Canada and Japan have implemented significant tax incentives and funding to support biofuel initiatives. In Brazil, the RENOVABIO program encourages biofuel production and social inclusion through tax exemptions and incentives for biodiesel while, in Canada, preferential tax treatment is given to low-carbon fuels that are used in various energy generation applications. In Japan, gasoline tax exemptions and duty-free status are applied to bioethanol while, in China, bioethanol and biodiesel are taxed at 90% of normal taxation levels. Although Germany does not provide tax cuts for the use of biofuels in road transport, a tax on CO2 emissions has been established within the Fuel Emissions Trading Act. Austria offers a tax exemption for the percentage of biofuel used in a fuel and the Netherlands have a credit trading system based on the RED obligation. In New Zealand, the bioethanol component of a transportation fuel is tax exempt. However, these exemptions do not apply to other biofuels such as biodiesel.

1.5.5. Fundings and grant incentives

In the US, initiatives such as the IRA and SAF Grand Challenge, have allocated funding for research, innovation and infrastructure development to incentivize the production and uptake of clean energy technologies. Some states, such as California, Oregon, Washington and Illinois, offer credits for SAF production and use, based on the CI of the fuel. Canada has provided financial support through low-interest loans, grants for feasibility studies and funding for infrastructure development. This is administrated through the Net-Zero Accelerator Initiative which has a goal of promoting the clean fuel market and low-carbon alternatives. Brazil has specific financing programs for bioenergy and sustainability, such as Fundo Clima and RenovaBio Line while Germany offers funding which is primarily focused on advanced biofuels and e-fuel development. In Austria, funding is available for research, development and plant construction related to sustainable fuels from non-food feedstock.

1.5.6. Sustainability

Sustainability typically involves environmental, economic and social considerations and it is a key component of many biofuels policies. For example, the US excludes palm-based feedstocks to try to minimize land-use impacts. As the EU's RED program worries about biodiversity and maintaining carbon stocks, many vegetable-based lipids cannot be used to make biofuels. Brazil's RenovaBio program certifies biofuels based on various sustainability criteria while many countries, such as Japan and China, worry about food-vs-fuels concerns and plan to develop biofuel policies that achieve *a balanced and sustainable future*.

1.6. Brief summary of country reports

1.6.1. China

The National Energy Administration of China (NEA) issued the Guiding Opinions on Energy Work in 2022 which promoted the use of E10. The country also hopes to expand ethanol production and is promoting its use as transportation fuel. In 2021, the State Council released an "Action Plan for Carbon Dioxide Peaking Before 2030", which advocates the use of advanced biofuels, SAF and other alternatives to fossil fuels. The Civil Aviation Administration of China's Specialized Green-development Plan for Civil Aviation also promoted SAF's commercial application, with a target of consuming over 20,000 tons of SAF by 2025 and 50,000 tons during the entire 14^{th} Five-Year Plan period (2021-2025).

1.6.2. Japan

Japan has set a target of 46% reduction in GHG emissions by 2030 and carbon neutrality by 2050. In 2020, Japan formulated the "*Green Growth Strategy associated with carbon neutrality in 2050*" to transform its energy and industrial structure. This includes the increased use of biofuels by the transport sector. The *6th Basic Energy Plan* emphasizes the importance of introducing biofuels, particularly advanced biofuels and SAF. Japan developed a roadmap in 2021 that has a goal of replacing 10% of Japanese aviation fuel with SAF by 2030. Guidelines for handling shipping of biofuels were also developed in 2023.

1.6.3. EU

The EU has promoted the production and use of sustainable and low-carbon fuels though programs such as *Fit-for-55* which have a target of a 55% reduction in CO2 emissions by 2030. This program includes specific goals which are described within RED III, ReFuel Aviation, FuelEU Maritime, Fuel Quality Directive (FQD), the Emissions Trading System (ETS) and the Energy Taxation Directive (ETD). The REPowerEU initiative is primarily focused on energy savings, supply diversification and aims to increase renewable energy production from 40% to 45% by 2030. Its main objective is to substitute fossil fuels, reduce dependence on Russian fossil fuels and expedite the transition to clean energy in EU. It hopes to do this by expanding renewable energy deployment and increasing the mandatory share of SAF used in EU flights to 2% by 2025 and 63% by 2050. RED III aims to increase the share of renewable energy in the EU's overall energy consumption to 42.5% (by 2030), specifically for the transport sector. The member states have a choice of meeting a binding target of a 14.5% reduction in GHG intensity by using renewables or, having 29% of renewables within the final transportation related energy sector by 2030. The agreement also includes a binding combined sub-target of 5.5% for advanced biofuels (derived from non-food-based feedstocks) used by the transport sector (Council of the EU, 2023).

1.6.4. Austria

Within Austria's *National Energy and Climate Plan 2019*, targets include a 36% reduction in GHG emissions (non-ETS) compared to 2005 and a reduction of 7.2 Mt CO2-eq for the transport sector. The country hopes to increase the share of renewable energy in its gross final energy consumption by 46-50% and achieve 100% renewable electricity production. The transport sector has a target of achieving at least 14% renewable energy by using biofuels and green electricity by 2030. This will be achieved by implementing biofuel obligations (a minimum of 3.4% ethanol and 6.3% biodiesel) in the overall energy content, with advanced biofuels targeted to provide 3.5% of these amounts by 2030. There are no specific policies promoting aviation or marine biofuels.

1.6.5. Germany

To meet the country's domestic transport decarbonisation targets the emissions cap will be reduced from 164 Mt CO2-eq in 2019 to 85 Mt CO2-eq by 2030. It is worth noting that GHG savings are the primary driver for establishing German biofuel policies. For this reason, the national implementation of the European Renewable Energy Directive (RED II) 2018/2001, defined as the *'Directive on the Promotion of the Use of Energy from Renewable Sources*,' will be realized through a GHG reduction quota (including sub-quotas for advanced biofuels and e-fuels). This quota is the most important element within the CO2 tax-related Fuel Emissions Trading Act (BEHG, Bundesemissionshandelsgesetz). Currently, the biofuel market is predominantly reliant on "conventional" biofuels, which are expected to remain dominant in the coming years (if the German GHG quota is not adjusted to phase out conventional biofuels). Regarding advanced biofuels, there are only a few production plants for biomethane available, as well as some biodiesel and ethanol plants that also use feedstocks compliant with the current RED II Annex IX A. Although biomethane is produced in significant capacities it serves different markets, with only about 4% used in transport applications.

1.6.6. The Netherlands

The Dutch *Energy for Transport legislation and regulations* were updated in 2022 to align with RED II. The Dutch Climate Agreement mandates a company to deliver an increased share of renewable energy in their fuel supply, from 17.9% in 2022 to 28% in 2030. The Dutch regulations also include a sub-target for advanced biofuels, starting at 2.4% in 2023 (includes double counting), increasing to 7% by 2030. The intended post-2022 policy on renewable fuels in the Netherlands includes a biofuel blending mandate of 60 petajoules (PJ) in road transport by 2030. Currently, there are no market-based mechanisms such as a carbon tax or emissions trading aimed at reducing transport related CO2 emissions. The country's Climate Agreement aims to further reduce transport related emissions, compared to the 2030 projection of the National Energy Exploration 2017. It also limits the use of first-generation biofuels from food and feed crops to the 2020 levels and seeks to maximize the share of biofuels in road transport.

1.6.7. Belgium

In Belgium, two important laws have been enacted to promote the incorporation of biofuels in fossil fuels. The first law requires fossil fuel companies to include at least 8.5% bioethanol and 6% biodiesel. The second law, called the "blending mandate 2020," aims to achieve an 8.5% energy-based blending of biofuels in petrol. These laws are significant as they align with the European Union's target for all member states to achieve a minimum of 10% biofuels in transport petrol and diesel consumption. In 2020, Belgium had enough biogasoline and biodiesel available to cover 8% and 10% of the energy needs for motor gasoline and gas/diesel in the road-transport sector, respectively. Overall, both biofuels covered 9.3% of the total gasoline and diesel energy requirements, indicating that the country was making progress towards the EU target with relatively little effort remaining. However, in 2022, Belgium joined Denmark, France, and the Netherlands in banning biofuels derived from palm oil or soy. This decision was motivated by concerns related to deforestation, loss of biodiversity, and human rights violations associated with these biofuel sources. While the ban on palm oil-derived biofuels seems reasonable, the restriction on soybean-derived biofuels could pose challenges as it may hinder biodiesel availability in the country and potentially affect the fulfillment of the EU's biofuel targets.

1.6.8. Brazil

Brazil plans to achieve a 37% GHG emissions reduction by 2025 and a 43% reduction by 2030, compared to 2005 emission levels. Brazil also plans to increase its share of sustainable bioenergy in its energy mix to approximately 18% by 2030. This will involve expanding the production and consumption of biofuels. The country aims to have renewables account for 45% of its total energy matrix by 2030, with hydropower providing at least 66% of the county's electricity. The RenovaBio policy recognizes the importance of biofuels in the Brazil's energy mix for energy security and GHG emissions reduction. This policy has incentivized the biofuel industry by issuing GHG emissions reduction certificates (CBIO). Close to 36 million CBIOs were marketed in 2022, increasing to 95.7 million by 2031. The Rota 2030 program includes measures to promote the use of ethanol and biodiesel to meet increasingly stringent vehicle emissions regulations. Brazil has increased its ethanol blending mandates to E27 while 100% ethanol is available at nearly all gas stations. The biodiesel blending mandate has risen from B10 to B12 and will be further increased to B15 in 2026.

1.6.9. New Zealand

New Zealand has committed to reducing its GHG emissions by 30%, below 2005 levels by 2030. However, New Zealand currently lacks any mandates or volumetric obligations for biofuel use. There are no specific policies aimed at promoting advanced biofuels. While there is market demand for aviation and marine biofuels, the country's trading scheme does not include carbon emissions from international aviation and marine fuel use. Consequently, there are no incentives to encourage biofuel substitution in these sectors.

1.6.10. Canada

Canada's biofuels related policies include the federal Clean Fuels Regulation (CFR) and various Provincial policies such as the BC-LCFS. The Canadian Net-Zero Emissions Accountability Act of 2021 set binding emissions reduction targets while the CFR established CI reduction requirements. The government claims that this should result in 26 Mt CO2-eq of GHG emission reduction by 2030 while a parallel credit market will incentivize innovation and compliance. Aviation and non-diesel marine fuels are currently not covered by the CFR. At a Provincial level, policies such as the BC-LCFS have played a significant role in reducing transport-related carbon emissions. The BC-LCFS has been a key contributor to achieving the CleanBC goals and is projected to achieve a reduction of 5 Mt of GHG emissions by 2030. Both the BC-LCFS and the federal CFR currently encourage oil refineries to co-process biogenic feedstocks as a cost-effective way of achieving compliance.

1.6.11. US

As mentioned earlier, the US has become an attractive destination for biofuel investors and feed-stock exporters, primarily due to its policy environment. Federal policies such as the Renewable Fuel Standard (RFS) and 2022 Inflation Reduction Act (IRA), and a growing number of state policies such as the California Low-Carbon Fuel Standard (LCFS), have resulted in significant investment in the R,D&D aspects of biofuel production. The US IRA has introduced multiple and phased fuel credits for biofuels, especially for SAF. The act defines eligible SAF mixtures in alignment with international standards (such as those describe by ICAO in CORSIA), requiring a minimum 50% reduction in lifecycle GHG emissions. As summarised in this Task 39 report, the US's RFS, IRA and the CA-LCFS have proven to be some of the most successful biofuel policies as they are technology-agnostic and are primarily focused on reducing the CI of biofuels while promoting biofuel production.

1.7. Concluding remarks

Policies have-and-will-play a key role in decarbonizing the transportation sector and growing each country's biofuel markets. As described here, market-pull and technology-push policies have been successfully used in all of the Task 39 countries. However, increasing attention is being given to the carbon emissions resulting from the worlds transportation sector. Thus "enabling" policies that target this component of biofuels production and use is of increasing attention. Although various IEA Bioenergy Task 39 countries have deployed, or are developing, these types of policies, the US IRA, RFS, RINs and CA-LCFS have highlighted the importance of reducing the CI of any biofuels that are used. One consequence is that the US has become an attractive destination for biofuel investors and feed-stock exporters. Although market-pull and technology-push policies will continue to be important, if the ultimate goal is to decarbonise transport, those biofuel policies that are technology-agnostic and focused on reducing the CI of the biofuel, rather than defining volumetric/or energy targets, will continue to develop. As well as policies such as the US's RFS and IRA, the EU's REDs and Fit-for-55 programs, Canada's CFR and more "regional" LCFS's (such as California, Oregon, Washington and British Columbia's) are likely to continue to grow.

The hard to (green) electrify long distance transport sector (e.g., aviation, marine, long-distance trucking and much of the world's rail) will be highly dependant on low-CI drop in biofuels if this sector is to meet its decarbonation targets. Although many countries have developed various policies to encourage the adoption of EVs (e.g., tax credits, purchase rebates, grants, discounts, free parking, etc.) organisations such as aviation's ICAO/IATA and marine's IMO recognise that the long distance transport sectors will not be easy to electrify. Although the production and use of drop-in biofuels is expected to increase significantly (e.g., renewable diesel/biojet/SAF), determining the CI of a biofuel is not easy, with many factors, such as the default values used, the impact of land use changes, source of electricity, etc., all influencing the values that are reported. Related Task 39 work has also shown how the assumptions within the LCA models that are used (e.g., GREET, GHGenius, etc.) will also influence the CI value for various biofuels. The international cooperation that is provided by IEA Bioenergy Task 39 allows a *compare-and-contrast* of successful, enabling policies and highlights the need for ongoing cooperation, as the world tries to decarbonise its transportation sector.

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Country Chapters

This section provides the update on biofuels policy and market development for each member country based on the collected data and information from the completed questionnaires.

1. China

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1.1. Summary

- Bioethanol and biodiesel are taxed at only 90% of regular fuel taxation.
- Ethanol blending: the National Energy Administration (NEA) issued the "Guideline on Energy Development for 2022" to promote the use of China VI b gasoline (ethanol content of 10%).
- Biodiesel blending: A small trial program using 2% and 5% biodiesel blends has been carried out in some regions of China (e.g., Hainan and Shanghai).
- China's ethanol import volume has fluctuated significantly in the past six years, with more imports in 2018 and 2021. In 2022, the imports were only 0.16 ML, mainly from France and the United States.
- Under the influence of raw material cost and market demand, China's 2022 ethanol exports were depressed. Denatured ethanol exports totaled 2.6 ML, predominantly to India.
- The import of diesel in 2022 was 387.89 ML which was an increase of 89% from last year. More than 90% of the imports were palm oil (biodiesel) from Indonesia and Malaysia.
- In 2022, the biodiesel exports surged to 2.08 billion liters (BL), and over 92% were exported to EU, of which about 73% were to Holland.
- There is an excise tax exemption for waste oil-based biodiesel production and export. However, no tax exemption for ethanol production and use. There are import tariffs on US-origin ethanol.
- China has formulated many national key research and development plans related to biofuels. These have been used to promote the development of bioenergy.
- Biofuels policy support in China distinguishes between conventional, 1.5 generation and second-generation feedstocks. However, the policies used to enhance biofuel development should not compete with arable land designated for food crops. Thus, China promotes ethanol production based on the use of cassava, sweet sorghum and other non-food feedstocks.
- Although China began producing commercial-scale cellulosic ethanol in 2013, it also encountered the same technological challenges that have limited expansion of cellulosic ethanol production elsewhere in the world.

1.2. Introduction

As the world's largest energy user, China has surpassed Japan and became the largest liquefied natural gas import country in 2021. It is the first time that China has become the world's largest LNG importer since the early 1970s (Luo, 2021). China's gasoline market is now the second largest in the world. It exceeded the EU's demand a few years ago and now is only exceeded by the US. However, unlike the US market, which has slowing gasoline consumption, China's gasoline market continues to expand rapidly with year-to-year growth surpassing all other markets. Although China's transport diesel market is the third largest in the world, China's annual diesel use is growing at a rate comparable to the US and the EU, the two much larger markets.

At present, the industrialization process in China has not yet ended, its carbon emissions and energy consumption are both on the rise. In 2000, China's national fleet totaled less than 20 million passenger vehicles. However, from 2005 to 2015, China's passenger car fleet increased by a factor of ten. In 2018, China surpassed the US as the largest car market in the world and now totals more than 322 million vehicles (GAIN, 2018). The proportion of energy consumed by the transportation sector also reached its maximum in 2018, as shown in Figure 1.1. The GHG emissions in China continues to grow, and the contribution of transportation is also increasing (Figure 1.2). Biofuels offer a means to stretch the economic efficiency and environment value of energy utilization. In China, biodiesel is used primarily to fuel electrical power generation, fishing vessels, and farm equipment. On-road transport accounted for about one-third of total demand (GAIN, 2018). One major reason for this type of preferred usage was the low quality of the produced biodiesel (van Dyk et al., 2016). Very little information is available on production of biofuels other than ethanol or biodiesel. For example, there is no updated statistics on biobutanol, renewable diesel ((Hydrotreated Vegetable Oil (HVO)), Hydroprocessed Esters and Fatty Acids (HEFA) or other drop-in biofuels. However, the Chinese government has been encouraging the production and sale of natural gas vehicles, with the 12th Five-Year Plan targeting that 8% of transportation energy demand should to be met from natural gas by 2015 (Clean Energy Compression, 2014; van Dyk et al., 2016). Prospects for China's transportation fuel demand depend on macroeconomic factors, the adoption rate of New Energy Vehicles (NEVs) such as electric cars and advanced fuel vehicles, and implementation of China's ambitious new drive to reach a national E10 fuel ethanol target.

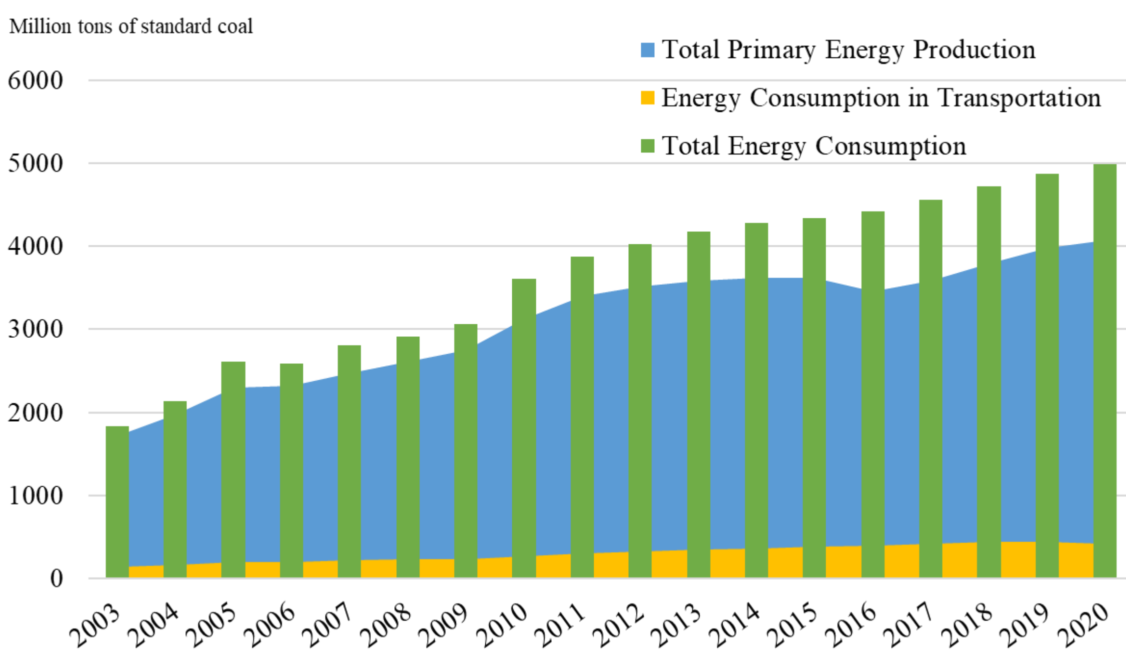

Figure 1.1. Energy production and transportation consumption in China, 2003 to 2020.

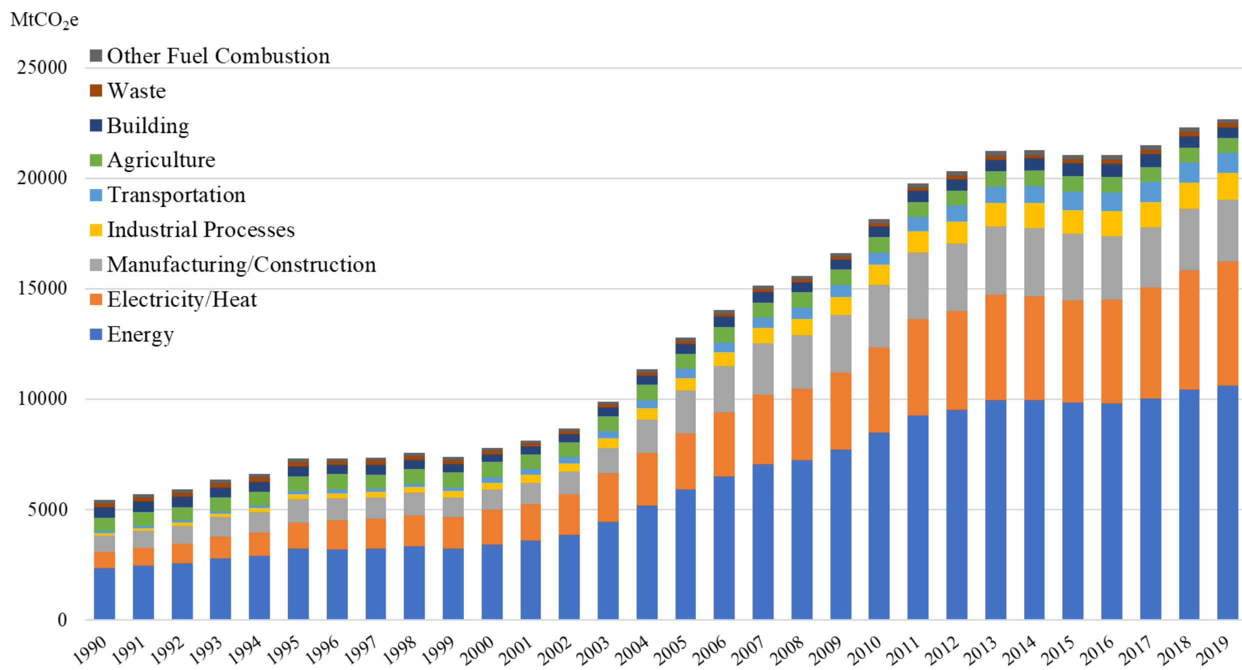

Figure 1.2. GHG emissions of various industries in China, 1990 to 2019

1.3. Main drivers for biofuels policy

Biofuels are part of China's long-term strategy to conserve resources, improve air quality, and solve the issues relating to agriculture, rural areas, and rural people. The increasing demand for fossil fuels has contributed to the country's increasing energy security concerns. As a result, China has taken steps to secure energy supply through various strategies such as intensive domestic exploration, investment in overseas oil companies, securing long-term contracts with suppliers of fossil fuels, such as natural gas from Russia and investing heavily in renewable forms of energy.

As China's economy has rapidly grown, it has also become the world's largest CO_2 emitter and faces growing concerns over air pollution. Thus, climate change mitigation and pollution abatement, particularly in its large cities, have also become important policy drivers for the country. To undertake international responsibility for tackling climate change, China has updated its Nationally Determined Contributions and put forward pragmatic emission reduction targets, striving to carbon dioxide peaking before 2030 and carbon neutrality before 2060. This is also indicated by China's 14th Five-Year Plan that was released in March 2021 which described a large number of binding commitments to aid in environmental reform. Figure 1.3 demonstrates the road map of China's carbon reduction, and Figure 1.4 summarizes China's carbon emission policies.

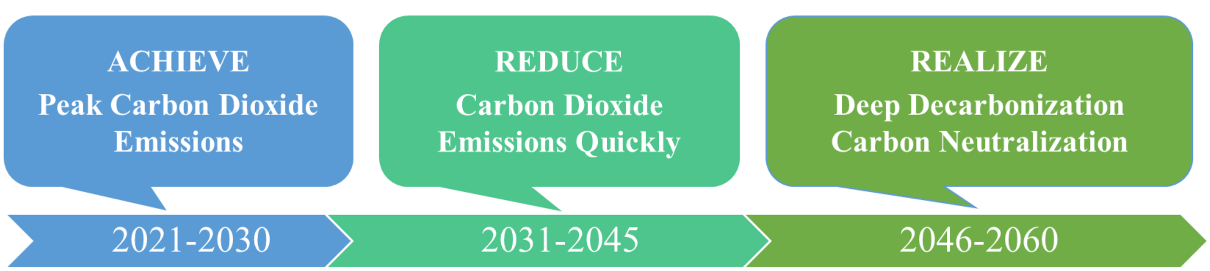

Figure 1.3. China's Carbon Reduction Road Map

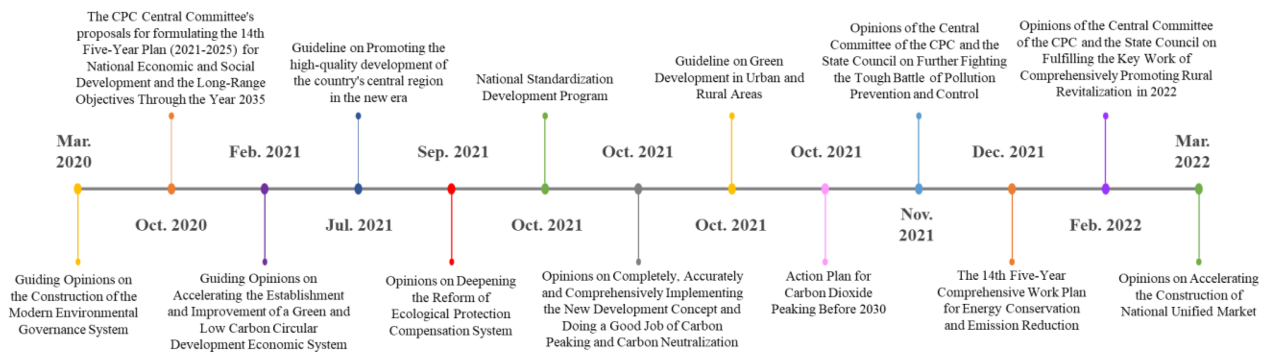

Figure 1.4. China's Carbon Emission Policy

China has a large rural population, and huge quantities of biomass resources without reasonable use. The vigorous development of bioenergy can not only solve the serious resources wasting problem, but also improve the rural ecological environment. More importantly, it can promote modern agriculture construction, cultivate new farmers, bring more employment opportunities, and increase farmers' income, which are conducive to solving the issues relating to agriculture, rural areas, and rural people. Promoting the development of biofuel is an important channel to develop rural circular economy and realize rural economic and environmental benefits.

1.4. Biofuel Policy

In order to promote the application of biofuels, the Chinese government has introduced many policies, as shown in Table 1.1. Article 4 of the Energy Law of the People's Republic of China (Draft for Comments) declares that "The state adjusts and optimizes the energy industry structure and consumption structure, gives priority to the development of renewable energy, safely and efficiently develops nuclear power, increases the proportion of non-fossil energy, and promotes the clean and efficient use of fossil energy and low-carbon development". Article 32 also states that "The state encourages the development and utilization of efficient and clean energy resources, and supports the priority development of renewable energy".

China is one of the world largest fuel ethanol producers after the US, Brazil, and the EU, but its fuel ethanol market has remained insular throughout its 20-year history with the exception of a few recent years. The law of People's Republic of China (PRC) restricts fuel ethanol processing to licensed facilities that produce and supply fuel ethanol to national refiners and fuel marketing companies. In February 2022, the State Council released its annual policy guidelines on agriculture and rural development known as the “No. 1 Central Document” which stipulated those officials “strictly control the corn-based fuel ethanol processing industry.” In June 2022, the National Development and Reform Commission (NDRC) led nine ministries to publish the “14th Five-Year Plan for Renewable Energy.” The Plan calls for the development of non-grain biofuel ethanol such as cellulosic biofuel. (GAIN, 2022; Industrial prospect, 2022). The guidance documents on fuel ethanol development in China are summarized in Table 1.1.

The PRC’s commitment to peak carbon emissions is driving and creating new prospects for expanded biodiesel use and production. In January 2015, NEA issued the Biodiesel Industry Development Policy, which proposed to “build a sustainable raw material supply system that is suitable for the characteristics of China’s resources, based on waste oil, and supplemented by wood (grass) based non edible oil plants”. In December 2020, the White Paper on “Energy in China’s New Era” issued by the State Council Information Office clearly stated that “(China shall) on improving the quality of biodiesel products and promoting the industrialization of non-grain biofuel technology”.

As a liquid fuel for commercial aviation, SAF has attracted much attention and been taken as an important strategic reserve for industry decarbonization. In 2021, the State Council proposed in the Action Plan for Carbon Dioxide Peaking Before 2030 to vigorously promote the use of advanced biological liquid fuels, SAF and other alternatives to traditional fuels to improve the energy efficiency of terminal fuel products. In 2022, the Specialized Green-development Plan for Civil Aviation Green Development in the 14th Five-Year Plan issued by the Civil Aviation Administration of China also put forward a proposal to promote the breakthrough in commercial application of SAF, and strive to achieve more than 20,000 tons of SAF consumption in 2025, as well as 50,000 tons of SAF consumption during the 14th Five-Year Plan period. Meanwhile, goals for oil saving and emission reduction were set that the fuel consumption per ton kilometer of the transport aviation fleet decreased to 0.293 kg, and the CO_2 emissions per ton kilometer of transport aviation dropped to 0.886 kg. In 2022, the NDRC proposed in the 14th Five-Year Plan for Bio-economic Development to carry out biodiesel promotion pilot in areas where conditions permit, and promote the demonstration and application of bio aviation fuel; as well as in the 14th Five-Year Plan for Renewable Energy to vigorously develop non grain biomass liquid fuel, and support the research, development and promotion of advanced technology and equipment in fields such as biodiesel and bio aviation kerosene.

Table 1.1. Guidance documents on fuel ethanol and biodiesel development in China (Hao et al., 2018)

Year	Policy document	Highlight contents
2002	Dedicated plan on the development of fuel ethanol and ethanol gasoline during the 10th Five-Year Plan period	• The scale of fuel ethanol use is planned to reach 1.02 million tons (1.29 BL) during the 10th Five-Year Plan period.
2002	Planning on the pilot demonstration of ethanol gasoline use	• The pilot cities are Zhengzhou, Luoyang, Nanyang in Henan province, and Harbin, Zhaodong in Heilongjiang province. • The fuel ethanol for the demonstration in Henan province is provided by Tianguan Group LLC; the fuel ethanol for the demonstration in Heilongjiang province is provided by Jinyu Group LLC. • The retail price of ethanol gasoline is the same with pure gasoline with the same grade.
2004	Planning on expanding the demonstration of ethanol gasoline use	• The pilot regions were expanded to cover five provinces (Heilongjiang, Jilin, Liaoning, Henan, Anhui) and 27 cities in other four provinces (Jiangsu, Shandong, Hubei, and Hebei). • Jilin fuel ethanol LLC, with the 300,000 tons (368 ML) of fuel ethanol capacity co-established by China National Petroleum Corporation (CNPC), will be responsible for providing fuel ethanol to Jilin and Liaoning; Huarun ethanol LLC, with the 100,000 tons (126 ML) of fuel ethanol capacity, will be responsible for providing fuel ethanol to Heilongjiang; Tianguan group LLC, with the 300,000 tons (368 ML) of fuel ethanol capacity co-established by Sinopec, will be responsible for providing fuel ethanol to Henan, Hubei and Hebei; Fengyuan LLC, with the 320,000 tons (403 ML) of fuel ethanol capacity co-established by Sinopec, will be responsible for providing fuel ethanol to Anhui, Shandong, Hebei and Jiangsu.

Year	Policy document	Highlight contents
		• The trade price between fuel ethanol producers and petroleum companies is specified to be the price of 90# gasoline multiplied by a coefficient of 0.9111. • The retail price of ethanol gasoline is the same with pure gasoline with the same grade (same with previous document).
2006	Urgent notification on strengthening the management of corn processing projects	• No new corn-based fuel ethanol projects will be approved. • All existing corn-based fuel ethanol projects should be thoroughly examined regarding their land use, environmental impacts and financial conditions.
2006	Notification on strengthening the management of fuel ethanol projects, and promoting the healthy development of fuel ethanol industry	• Non-food crops are prioritized as the feedstock for fuel ethanol, with tuber crops, sugar sorghum, and cellulosic crops as focuses. • The establishment and expansion of fuel ethanol capacities are strictly controlled.
2007	Notification on promoting the healthy development of corn deep processing industry	• The amount of corn used for deep processing should be controlled below 26% of total corn consumption.
2007	Mid-long term planning on the development of renewable energy	• By 2010, non-food crop-based fuel ethanol consumption will reach 2 million tons (2.52 BL); biodiesel consumption will reach 0.2 million tons (252 ML). • By 2020, fuel ethanol consumption will reach 10 million tons (12.6 BL); biodiesel consumption will reach 2 million tons (2.52 BL).
2011	Notification on Adjusting the Settlement Price of Denatured Fuel Ethanol	• The settlement price between denatured fuel ethanol production enterprises and petroleum and petrochemical enterprises is set as 91.11% of the ex-factory price of 93 # gasoline.
2015	The 13th Five-Year Plan for Biomass Energy	• By 2020, China's annual utilization of biofuel ethanol will reach 4 million tons.
2017	Implementation Plan on Expanding the Production of Biofuel Ethanol and Popularizing the Use of Automotive Ethanol Gasoline	• By 2020, the use of ethanol gasoline for vehicles will be promoted nationwide in China, and will basically cover the whole country.
2018	The State Council executive meeting	• In general, the biofuel ethanol industry has been developed. Beijing and other places have begun to discuss the timetable for promoting the use of ethanol gasoline. Tianjin has become the first municipality directly under the Central Government to promote the use of ethanol gasoline in China.
2022	No. 1 Central Document	• The corn-based fuel ethanol processing industry will be strictly controlled.

1.4.1. State and Provincial Clean Fuel Regulations and Standards

In 2007, the Chinese government established biofuels production targets for the first time under the Medium and Long Term Development Plan for Renewable Energy (NDRC, 2007; van Dyk et al., 2016). One goal was to produce 2 million tons of ethanol (≈ 2.53 BL) and 0.2 million tons (≈ 0.23 BL) of biodiesel by 2010. The 2007 Medium and Long Term Development Plan for Renewable Energy also established the important policy, applicable to both ethanol and biodiesel, that domestic production of feedstocks for biofuels should not compete with land needed for food or feed production and must not inflict harm to the environment ((NDRC, 2007; van Dyk et al., 2016). The 12th Five Year Plan covering the period of 2011-2015 targeted production of 4 million tons (≈ 5.1 BL) of ethanol by 2015. However, this target was not achieved (China, 2011; van Dyk et al., 2016). The 12th Five-Year Plan(2011-2015) targeted production of 4 million tons (≈ 5.1 BL) of ethanol by 2015. However, this target was not achieved (China, 2011; van Dyk et al., 2016). In 2016, China's State Council announced its 13th Five-Year Plan goal to produce 5.1 BL of ethanol and 2.3 BL of biodiesel by 2020. While the goal requires ethanol production to rise four-fold from 2016 levels, underlying economic fundamentals and the lack of national or provincial government support undermined large-scale efforts to expand production. China's 2022 fuel ethanol production is forecast to increase to 3.8 BL, up 383 ML from the previous year. Synthetic ethanol production will remain unchanged in 2022 (GAIN 2022).

A key motivation for the ethanol gasoline for motor vehicles (E10) mandate is to reduce China's large corn stockpiles, which peaked in 2015/2016 at over four billion bushels (Li, et al., 2017). China's E10 target is planned to follow an incremental expansion by pilot provinces and cities until the program is implemented nationwide. As of 2017, 11 provinces and cities were selected as fuel ethanol pilot zones for mandatory E10 blending. In 2018, the executive meeting of the State Council determined the overall layout of the biofuel ethanol industry and decided to orderly expand the promotion and application of ethanol gasoline for vehicles. In addition to 11 pilot provinces such as Heilongjiang, Jilin and Liaoning, it will be further promoted in 15 provinces such as Beijing, Tianjin and Hebei. But the goal was unofficially suspended in late 2020 and ethanol blend rates in pilot areas have since declined. High corn prices pushed up the cost of fuel ethanol production while ethanol price gains were held in check using a formula tied to gasoline prices, forcing the provinces and cities which had announced E10 expansion plans in 2019 to scale back implementation. The PRC has reportedly delegated E10 blending goals and decision-making authority to provincial governments while requiring existing E10 pilot areas to continue to blend at E10 (GAIN 2022). In 2022, NEA issued the "Guideline on Energy Development for 2022" to promote the use of China VI b gasoline (ethanol content is 10%) on January 1, 2023.

The government continues to emphasize that demand for feedstocks directed towards fuel ethanol production should not compete with inventories for food stocks, and promotes ethanol production using cassava, sweet sorghum and other non-food grain feedstocks. Central government production subsidies for grain-based ethanol were eliminated in 2016. Meanwhile, from October 2016 to June 2017, several provincial governments in North East China offered subsidies to state-owned ethanol processors who purchased and processed old-crop corn inventories from the State Administration of Grain to produce corn starch, amino acids, industrial alcohol, and fuel ethanol (GAIN, 2018). The "No. 1 Central Document" for 2022 and the "Guideline on Energy Development for 2021" proposed the combination of technology and prevention, strengthening the dynamic supervision of grain inventory, and strictly controlling the processing of fuel ethanol with corn as the raw material.

The implementation plan concerning the expansion of ethanol production and promotion for transportation fuel also calls for China to shift renewable fuel production to commercial scale cellulosic ethanol by 2025. The 2018 advanced biofuels production is forecast at 395 ML, up from 2017 on expanded production capacity. The government has unofficially set a target to produce 3.8 BL of cellulosic and non-grain based ethanol by 2020.

Regarding the biodiesel, Shanghai is the only local authority implementing a biodiesel program. In October 2017, Sinopec Shanghai began offering B5 diesel at a $0.05 per liter (0.3 yuan) discount to regular diesel as part of a pilot program. With full market maturity, Shanghai will consume as much as 682 ML (600,000 tons) of B5 (or 34 ML of pure B100 biodiesel) each year (GAIN, 2018). Besides that, a small trial program using 2% and 5% biodiesel blends was carried out in Hainan province. The state-owned oil companies, CNPC and Sinopec, control over 90% of the gas stations in China and the sale of biodiesel has not been encouraged. Thus, producers either have to sell to brokers who mix the fuel or sell it directly to end-users at small, private gas stations (van Dyk, et al., 2016). China does not apply sustainability criteria to imports or domestic use of biofuels.

1.4.2. The use of LCA to assess the CI of a fuel

As an international environmental management tool, the life cycle assessment (LCA) has increasingly become an important means to help governments and enterprises develop green economy and low-carbon technologies. With the policies of bioenergy promotion and carbon reduction, especially the proposal of the goal of "carbon peaking and carbon neutrality", the LCA in China has attracted the wide attention and application. In December 2021, the State Council issued the "14th Five-Year Plan" for the Development of Digital Economy to accelerate the construction of information network infrastructure, deepen comprehensive digital transformation in key industries, as well as promote the aptitude upgrades of energy production, transportation, consumption and other links. In April 2022, the Implementation Plan to Accelerate the Construction of a Unified and Standardized Statistical Accounting System for Carbon Emissions was issued to promote the improvement of the carbon emission statistical accounting system for enterprises in key industries, establish and improve the carbon emission accounting methods for raw materials, semi-finished products and finished products in key industries.

However, China has not yet established an open and complete LCA database. The LCA mainly relies on foreign databases. To address this issue, Sichuan University has created the Chinese Life Cycle Database (CLCD) which is an industry average database based on the core model of the life cycle of China's basic industrial system. The China City GHG Working Group (CCG) has coordinated the construction of the GHG emission coefficient set (2022) for the whole life cycle of Chinese products, which has been fully publicized. The state-established ecological environment big data platform has also accumulated the ecological environment data base for LCA. While, the national GHG emission factor database and the basic product life cycle database around LCA and carbon footprint assessment are under construction.

1.4.3. Carbon Pricing

Carbon pricing curbs GHG emissions by placing a fee on emitting and/or offering an incentive for emitting less. As an approach to spur climate action, carbon pricing is advancing rapidly. The instruments can take on multiple forms, while there are two main types of carbon pricing: carbon taxes and emissions trading systems (ETS) which is also the main form of carbon pricing in China. On July 16, 2021, China's national carbon market started online trading, which is a significant step to help the country reduce its carbon footprint and meet emission targets. As of December 31, 2022, the carbon emission quota (CEA) of the national carbon market had a total turnover of 230 million tons (about 10.475 billion yuan). Since August 2002, China's carbon emission trading market has gone through three stages. The first stage is from the official approval of the Kyoto Protocol in August 2002 to the end of 2012, during which China's carbon emissions trading market is in the clean development mechanism (CDM) project stage. Then, the second stage is in the pilot stage, from 2013 to 2020. China carried out carbon-trading pilot programs in eight regions, Beijing, Shanghai, Tianjin, Chongqing, Hubei, Guangdong, Shenzhen and Fujian, which has achieved significant progress in controlling the total carbon emissions and carbon intensity. In the third stage, China has established a national carbon trading market since 2021, stepping into the construction stage.

1.4.4. Fiscal incentives and Investment subsidies

The subsidy scheme for fuel ethanol production experienced frequent changes. Figure 1.5 shows the trend of subsidies for ethanol from conventional, 1.5 generation and second-generation feedstocks. Although subsidies for conventional grain ethanol were as high as RMB 2000 (about $300) per ton in 2009, these subsidies have been gradually phased out and no longer existed since 2016. Subsidies for 1.5 generation ethanol (from cassava or sweet sorghum) were introduced in 2013 at RMB 750 per ton (about $114), while cellulosic ethanol started receiving a subsidy in 2014 at RMB 800 per ton (about $120). Production subsidies for non-food grain feedstocks was expected to phase out by 2018, as shown in Figure 1.5. The advanced cellulosic ethanol production subsidy was $0.07 per liter (600 RMB per ton) (GAIN, 2018).

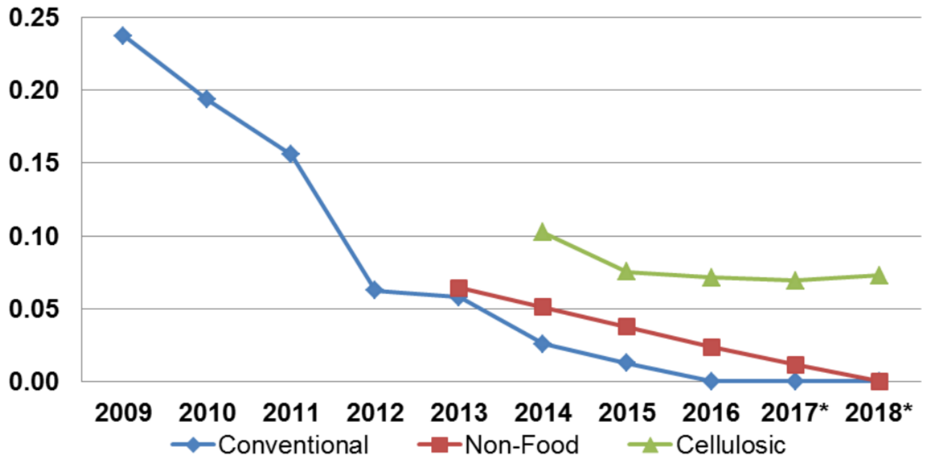

Figure 1.5. Fuel ethanol subsidies in $/liter, 2017 and 2018 exchange rates are forecasts (Innovation Center for Energy and Transportation; and Pacific Exchange Rate, GAIN, 2017)

In terms of the taxation policy, the early published government documents specified that the excise tax for fuel ethanol production is exempted, and the Value Added Tax (VAT) for fuel ethanol production is reimbursed. However, with the change of the government's attitude towards fuel ethanol development, the tax incentive for food crop-based fuel ethanol production gradually phased out. Specifically, the VAT for food crop-based fuel ethanol production was reimbursed by 80% in 2011, 60% in 2012, 40% in 2013, 20% in 2014 and no reimbursement from 2015 on. The excise tax for food crop-based fuel ethanol production was 1% in 2011; 2% in 2012; 3% in 2013; 4% in 2014; and 5% from 2015 on. Despite this, the tax incentive for non-food crop-based fuel ethanol was retained.

China's Ministry of Finance announced March 2018 that effective independent crude oil refiners, also known as "teapot" refiners, are required to pay consumption taxes of $38 per barrel of gasoline and $29 of diesel produced. Higher taxes will lower production margins, and spur refiners to seek lower-cost substitutes, like ethanol and biodiesel (GAIN, 2018).

Regarding biodiesel, the excise tax for waste oil-based biodiesel production is exempted. In addition, the Biodiesel Industry Development Policy released in 2014 specified that China should launch dedicated price, taxation, finance and investment incentives to promote biodiesel development (Hao, et al., 2018). Table 1.2 summarizes the taxation policy for ethanol and biodiesel since 2002. In 2017, China's General Department of Taxation lowered the effective VAT applied to exported ethanol products from 13% to 11%. Biodiesel exports made from used animal and vegetable oils also enjoy a 70% VAT rebate. Qualified producers also benefit from a 90% discount on taxable income from relevant products. To support biodiesel development, tax authorities have issued policies to waive consumption taxes on B100 biodiesel produced using UCO (0.8 RMB/L tax). With the exception of minor tax incentives for the consumption tax and export rebates, biodiesel does not receive any subsidies nor mandate support that fuel ethanol enjoys, and must compete with other markets for used cooking oil (UCO) feedstock. This being the case, the market for biodiesel remains very limited and the national average blend has never moved off of 0.2 to 0.3% (GAIN, 2018).

Table 1.2. Taxation and subsidy policy for biofuels production in China (Hao et al., 2018)

Year	Policy document	Major contents
2002	Panning on the pilot demonstration of ethanol gasoline use	• The excise tax for fuel ethanol production is exempted. • The VAT for fuel ethanol production is reimbursed. • The aged crops used for fuel ethanol production are qualified for subsidies. • Additional subsidies are granted to fuel ethanol producers to guarantee reasonable profit.
2004	Panning on expanding the demonstration of ethanol gasoline use	• The excise tax for fuel ethanol production is exempted (same with previous document). • The VAT for fuel ethanol production is reimbursed (same with previous document). • The aged crops used for fuel ethanol production are qualified for subsidies (same with previous document). • The subsidy for fuel ethanol producers is determined with fixed quotas, rather than with reasonable profit criteria
2005	Notification on the subsidy policy for fuel ethanol	• The subsidy intensity for fuel ethanol production is specified to be ¥1883/ton (t), ¥1628/t, ¥1373/t and ¥1373/t from 2005 to 2008.
2005	Notification on the taxation policy for fuel ethanol producers	• The excise tax for fuel ethanol production is exempted (same with previous document) • The VAT for fuel ethanol production is reimbursed (same with previous document)
2006	Notification on the financial incentives for bio-energy and biochemical industries	• The elastic loss subsidy mechanism was established to determine the subsidy for fuel ethanol producers. Namely, when fuel ethanol production is profitable, no subsidy is available; at the same time, the fuel ethanol producers should establish risk funds with the profit; when fuel ethanol production is facing losses, the risk funds will be firstly used to cover the losses; If production losses last for a long time, subsidy from the government will be available. • Taxation incentive will be established to promote the development of bio-energy and biochemical industries.
2007	Finance management regulations on the elastic subsidy for fuel ethanol	• Detailing of the subsidy mechanism established by the previous guidance document. • Based on the subsidy mechanism, the subsidy intensity for fuel ethanol production was ¥2055/t, ¥1659/t, and ¥1276/t from 2009 to 2011.
2011	Notification on adjusting the taxation policy for fuel ethanol producers	• The VAT for food crop-based fuel ethanol production will be reimbursed by 80% in 2011; 60% in 2012; 40% in 2013; 20% in 2014. The VAT reimbursement policy for food crop-based fuel ethanol production will be cancelled from 2015. • The excise tax for food crop-based fuel ethanol production will be 1% in 2011; 2% in 2012; 3% in 2013; 4% in 2014 and 5% from 2015 on.
2012	Notification on adjusting the subsidy policy for fuel ethanol production	• The subsidy intensity for food crop-based fuel ethanol production is ¥500/t . • The subsidy intensity for non-food crop-based fuel ethanol production is ¥750/t.
2014	Notification on further adjusting the subsidy policy for fuel ethanol production	• The subsidy intensity for food crop-based fuel ethanol production is specified to be ¥300/t, ¥200/t, and ¥100/t from 2013 to 2015. • The subsidy for food crop-based fuel ethanol production will be cancelled from 2016.
2014	Notification on the subsidy quotas for fuel ethanol producers	• The subsidy intensity for cellulosic ethanol production is ¥800/t.
2014	Notification on the taxation policy for non-food crop-based fuel ethanol production	• The excise tax for non-food crop-based fuel ethanol production is exempted. • The VAT for non-food crop-based fuel ethanol production is reimbursed.

1.4.5. Other measures stimulating the implementation of biofuels

From the "13th Five-Year Plan" to the "14th Five-Year Plan", China has set up national key R&D plans related to biofuels almost every year. The Chinese Academy of Sciences has taken the lead in carrying out biomass energy research in China, from rural energy development technology to modern bioenergy technology. It has integrated institutes like Qingdao Institute of Bioenergy and Bioprocess Technology (QIBEBT), Guangzhou Institute of Energy Conversion (GIEC), Dalian Institute of Chemical Physics (DICP), and Institute of Process Engineering (IPE), and formed a systematic and institutionalized research system integrating multiple disciplines. For example, the Chinese Academy of Sciences' Key Laboratory of Biofuels, basing on the QIBEBT, devotes to the renewable resources and transformation technologies such as bioethanol from industry flux gas and biomass, catalytic conversion of oil and fat to biodiesel, aa well as biomass to high quality jet fuels (China Science Daily, 2017). With the support of relevant national funds, especially the strategic leading science and technology project of the Chinese Academy of Sciences, a group of products with independent intellectual property rights has been built, such as million ton/yr liquid molecular catalytic production of second-generation biodiesel, 300,000 tons of straw ethanol and supporting cogeneration, 1000 tons of biological aviation oil cogeneration chemicals, 1000 tons/yr trans aconitic acid ester, 1000 tons of straw sugar to ethylene glycol/furan, etc. Besides that, four Chinese national biofuel research centers have been established (Table 1.3) with each of these national biofuel research centers having a different focus. The National Energy R&D Center for Non-food Biomass, which is led by the China Agricultural University, has the major responsibility for biomass breeding, cultivation and logistics research; while the National Energy Research Center of Liquid Biofuels, which is led by COFCO (a major Chinese Energy Enterprises), is mainly focused on technology implementation. The other two national research centers put their major efforts into technology development and integration (van Dyk et al., 2019).

Table 1.3. China main biofuel research centers (van Dyk et al., 2016; China Science Daily, 2017)

China main biofuel research centers	Leading institute
National Energy R&D Center for Biorefinery	Beijing University of Chemical Technology
National Energy Research Center of Liquid Biofuels	COFCO
National Energy R&D Center for Non-food Biomass	China Agricultural University
National Energy R&D Center for Biofuels	GIEC
Chinese Academy of Sciences Key Laboratory of Biofuels	QIBEBT

1.5. Promotion of advanced biofuels

Ethanol from non-food grain feedstocks is considered an advanced biofuel in China. After the initial development of ethanol production facilities based on stale grain reserves in 2007, the government limited further ethanol development based on grains and phasing-out national production supports with China's 11th Five-Year Plan for 2006-2011 (China, 2006; van Dyk et al., 2016). This Plan described a new policy which prohibited the construction of any new ethanol production facilities based on grains (i.e., maize/corn, wheat) due to concerns over food security. According to the policy, any new ethanol facilities in China could only use so-called 1.5 generation feedstocks (non-grain sugar or starch crops), such as cassava, sweet sorghum, sweet potato and sugarcane, or lignocellulosic feedstocks such as forestry or agricultural wastes. In February 2022, the State Council released its annual policy guidelines on agriculture and rural development known as the "Number 1 Document" which stipulated that officials "strictly control the corn-based fuel ethanol processing industry." Although so-called 1.5 generation feedstocks are used as food in many cases, the main emphasis in this category was the move away from using grains for biofuel production (GAIN,2022; Li, et al., 2018; van Dyk et al., 2016).

In June 2022, the NDRC led nine ministries to publish the "14th Five-Year for Renewable Energy Development". The Plan calls for the development of non-grain biofuel ethanol such as cellulosic biofuel (GAIN, 2022). Cassava- and sweet sorghum-based ethanol production remain in research and exploratory phases of commercialization. High operating costs have limited expansion of production capacity using these feedstocks. China depends on imported cassava for most of its non-food grain ethanol production. High-costs and logistics hampered full-scale operations. Lastly, ethanol production subsidies for non-food grain, non-cellulosic feedstock use were discontinued after 2017 (GAIN, 2018) (Figure 1.5) and an E10 mandate which shifted in 2020 to the "strict control of the expansion of fuel ethanol processing capacity." This shift from 2017 to 2020 and reinforced in 2022 illustrates the gradual transition away from the original first-ever push for E10 nationwide (GAIN, 2022).

According to the 12th Five-Year Plan (2011-2015) for strategic emerging industries, China aimed to develop biomass energy sources to develop second generation biofuels including production of 5,068 ML (4 million tons) of cellulosic fuel ethanol, and 1.1 BL of algae-based biodiesel. In May 2017, China's Central Government announced its 13th Five-Year Plan for Biological Innovation. The plan focused on promoting innovation in biological-based technologies, including new energy sources using bio-based feedstocks like cellulosic ethanol. Cellulosic ethanol is prominently featured in the joint announcement by China's NDRC and other ministries in September 2017, "Implementation Plan for the Expansion of Ethanol Production and Promotion for Transportation Fuel". Major domestic cellulose ethanol manufacturers in China are shown in Table 1.4.

Table 1.4. Production Capacity of China's Fuel Ethanol Licensed producers (2022 estimates) (GAIN, 2022)

No.	Producers	Production Capacity	Feedstock
1	SDIC Jilin Alcohol	887 ML	Corn
2	Henan Tianguan	887 ML	Wheat, Corn, Cassava
3	COFCO Biochemical (Anhui)	798 ML	Corn, Cassava
4	COFCO Bioenergy (Zhaodong)	507 ML	Corn, Cellulosic
5	SDIC (Zhanjiang)	190 ML	Cassava
6	Shandong Longlive	65 ML	Cellulosic
7	COFCO Bioenergy (Guangxi)	253 ML	Cassava
8	Zonergy (Inner Mongolia)	38 ML	Sweet Sorghum
9	SDIC (Tieling)	380 ML	Corn
10	Liaoyuan Jufeng Biochemical	380 ML	Corn
11	Jilin Boda Biochemistry	507 ML	Corn
12	Jiangsu Lianhai Biotechnology	152 ML	Corn
13	Shandong Fu'en Biochemical	152 ML	Cassava
14	Jiangxi Yufan	127 ML	Cassava
15	Shougang Lanza Tech	58 ML	Coal, Waste Residues, Industrial Flue Gases
16	SDIC (Hailun)	380 ML	Corn
17	Wanli Runda (Baoqing)	380 ML	Corn
18	Hongzhan (Nehe)	380 ML	Corn
19	Hongzhan (Huanan)	380 ML	Corn
20	Ningxia Shougang Lanza Jiyuan	57 ML	Coal, Waste Residues, Industrial Flue Gases
21	Hongzhan (Bayan)	380 ML	Corn
22	SDIC (Jidong)	380 ML	Corn
	TOTAL	**7,720 ML**	

Source: Post Industry Sources

China began producing commercial-scale cellulosic ethanol in 2013, but also faced the same technological challenges which have limited the expansion of cellulosic ethanol production elsewhere in the world. As a result, China has not been able to sustain annual cellulosic ethanol production levels above 40 ML. According to Asiachem's 2018 Fuel Ethanol Annual Report, China's cellulosic fuel ethanol production capacity, projects operating and under construction, is forecast to reach about 4 BL in 2018 (GAIN, 2018). Cellulosic ethanol production is forecast at 20 ML in 2018 as China's major cellulosic projects have been idled, or remain under development. Expanded cellulosic ethanol production will depend on lowering the costs of production relative to crude oil prices, which includes more efficient feedstock handling. Although global benchmark crude oil prices have risen in recent months, current crude oil prices remain less than $100 per barrel, or less than the economic breakeven point for China's cellulosic ethanol producers. Although nascent, China's projects that convert coal and industrial waste-gas to ethanol (synthetic fuels and non-bio-based) appear to be expanding incrementally (GAIN, 2018).

China's efforts to reduce air particulate matter and other fossil fuel toxins include projects to convert coal and industrial waste gas into synthetic ethanol. The world's first bio fermentation fuel ethanol production project using steel industry tail gas as raw material is located in Caofeidian, Tangshan City, Hebei Province. It was put into operation in May 2018, with an annual design output of 45 000 tons of fuel ethanol. At the same year, Xinjiang Tianye signed a contract with DICP, Chinese Academy of Sciences for a 1.2 million tons/yr syngas ethanol project. Other institutes, such as QIBEBT, and SINOPEC Research Institute of Petroleum and Petrochemicals, are also working on the syngas fermentation. The PRC press and industry contacts report that China's Syngas ethanol production capacity is expected to reach 2.5 BL by the end of 2022 (GAIN, 2022).

The first, partially fueled, biojet flight in China took place in October 2010. This was a result of a collaboration between the CNPC, Air China, Boeing, Honeywell, the China National Aviation Fuel Group and Pratt & Whitney. The Sinopec Corporation, another Chinese national oil company, built a biofuel facility in Southeast China's Hangzhou in 2011 with a supposed production capacity of 6,000 tons of aviation bio-fuel each year from UCO. Sinopec also built a blending facility within its Zhenhai Refinery to produce aviation bio-fuel products. Biojet developed by Sinopec was used in a demonstration flight in 2013 and in February 2014, the Civil Aviation Administration of China (CAAC) granted China's first biological jet fuel airworthiness certificate to Sinopec Corporation (van Dyk, et al., 2016). Sinopec has a cooperative biojet initiative with China Eastern Airlines, while China's top oil and gas producer, CNPC, has a joint biojet initiative with Air China. The first, commercial passenger flight using biojet took place in March 2015 (Biofuels International, 2015; van Dyk et al., 2016). This was a collaboration between Hainan Airlines, Boeing and Sinopec. Boeing has been very involved in biojet fuel development in China and the company has collaborated with a range of stakeholders including the Commercial Aircraft Corporation of China, Ltd. (COMAC) and several research institutions, such as the Chinese Academy of Science's Qingdao Institute of Bioenergy and Bioprocess Technology (QIBEBT). Boeing and COMAC opened a demonstration facility in 2014 that will produce biojet fuel from UCO at about 650 liters per day. The project's goal was to assess the technical feasibility and cost of producing higher volumes of biofuel (Schroeder, 2014; van Dyk et al., 2016). However, the current status of this project is unclear. Ongoing research on the potential of biojet fuel production is currently carried out at several Chinese institutions.

At present, there are few enterprises with actual production capacity of SAF in China. In 2017, Zhenhai Refining & Chemical Company built a new SAF industrial unit, which used waste cooking oil as raw materials and can process 100,000 tons of raw materials per year. ECO Environmental Investments Limited also disclosed information that it "expects to produce SAF soon", but did not specify the specific time and scale of production. On June 2022, the company announced that it has produced biological aviation coal which is the first time in China (Xinhuanet, 2022). Scientific research institutions such as GIEC and QIBEBT, parts of Chinese Academy of Sciences, are also actively studying the process route for preparing SAF from agricultural and forestry wastes.

In 2009, PetroChina and UOP cooperated and signed a memorandum of understanding on cooperation to verify the existing biofuel technology and jointly design a new equipment to make use of China's biological raw materials to produce the second-generation biodiesel and renewable aviation fuel. In the same year, SINOPEC Research Institute of Petroleum Processing (RIPP) has developed the sub-critical alcoholysis process (SRCA process), which has been successfully applied to the 60,000 t/a biodiesel plant of CNOOC Hainan Dongfang Bioenergy Company. On July 30, 2020, the QIBEBT and Shijiazhuang Changyou Bioenergy Company jointly developed the ZKBH process for the production of second-generation biodiesel by continuous hydrogenation, and realized the continuous production of biodiesel on the 200,000 t/a scale industrial plant. All 30,000 tons of products obtained during the trial operation were exported to the EU (China Science Daily, 2020).

Green methanol nowadays is the only marketable low-carbon fuel in the shipping industry. Through the development of advanced gasification technology and high-performance catalysts, QIBEBT has developed green fuel and chemical preparation technologies represented by methanol, dimethyl ether, gasoline, high-quality aviation oil, 2nd generation biodiesel, etc. basing on the biomass gasification synthesis technology. China International Marine Container Group Company (CIMC)'s Shijiazhuang Enric Gas Equipment Co., Ltd. (ENRIC) signed a cooperation agreement with Maersk, a global shipping giant, to develop biomass methanol projects for Maersk in China. It is estimated that in 2024, the Phase I project will have the capacity to produce 50,000 tons of biomass green methanol annually. The annual output of green methanol in Phase II project is expected to increase to 200,000 tons. Sichuan Zhongming New Energy Technology Co., Ltd. also plans to use this process to build a 50,000 t/a first generation biodiesel production demonstration plant which is expected to be officially put into operation within two years. In 2023, the world's biggest and the first 100 000 ton green low-carbon methanol plant, which is jointly established by Zhejiang Geely Holding Group and Henan Shuncheng Group Co. Ltd., is officially put into operation in Henan Province. The project comprehensively utilizes the by-product hydrogen in the coke oven gas of Shuncheng Group and the carbon dioxide captured from the industrial tail gas to synthesize green low-carbon methanol, and can produce 110,000 tons of methanol annually which directly reduces carbon dioxide by 160,000 tons.

Furthermore, China has great potential for the development of bioenergy resources. The standing amount of bioenergy resources is 6.74×10^8 t standard coal, while the standing amount of waste biomass resources in agriculture, forestry and animal husbandry counts 6.42×10^8 t standard coal. Among them, the resources provided by energy plants suitable for planting in barren mountains, barren slopes and other marginal lands have also reached 0.32×10^8 t standard coal (Zhang, 2009). After the limits in 2007 on the use of grains as the feedstock for new biofuels facilities, Jatropha and other oilseed-bearing trees were highlighted as potential biodiesel feedstocks. All of these potential crops had to be cultivated on marginal land so as not to compete with food production. The Chinese definition of marginal land refers to land with poor natural conditions for crop cultivation, which nevertheless has potential to be developed for growing adaptable energy crops/trees (Yan et al., 2008, van Dyk et al., 2016), including shrub land, sparse forest land, moderate dense grassland and sparse grassland (Jiang et al, 2014; van Dyk et al., 2016). The plan to use jatropha oil as a biodiesel feedstock never materialized. Trees covering hillsides in Southwest China were abandoned years ago because they failed to pollinate and lacked sufficient water.

At present, the cultivation of new varieties of energy plants is relatively lagging behind that the application of advanced molecular design breeding technology in the innovation of energy plant germplasm is facing difficulties. The complex genome, self-incompatibility, difficulty in genetic manipulation and other characteristics of energy plants are the main reasons that hinder the application of new technologies. However, QIBEBT has still achieved leading technologies and achievements in molecular breeding of energy plants that they have established a genetic transformation and gene editing system for various energy plants, and realized molecular design and new germplasm creation in some energy plants. However, it is still necessary to conduct large-scale planting and comprehensive utilization demonstration for such marginal lands as saline alkali land, barren mountains and barren slopes in the future, so as to assess their ecological, economic and social benefits.

1.6. Market development and policy effectiveness

China is the world's fourth largest fuel ethanol producer and consumer after the US, Brazil, and the EU. Since 2016, China's corn processors, including fuel ethanol and industrial chemical producers, have enjoyed the benefit of corn processing subsidies based on throughput volumes. Additionally, China is expected to expand gasoline-ethanol blending on a nationwide basis, expanding national demand, as well as investment to expand production capacity (GAIN, 2018). The fuel ethanol market in China is highly regulated and production facilities can only be built with direct government approval. As only official facilities are entitled to subsidies and incentives, all of the current biofuels facilities are owned and operated by state-owned enterprises. In contrast, the biodiesel industry is mostly unregulated and dominated by a large number of small, private producers (van Dyk et al., 2016).

1.6.1. Biofuels consumption in China

In 2022, fuel ethanol consumption is estimated at 3.8 BL, down 164 ML from 2021 resulting in a 2022 national average fuel ethanol blend rate estimated at 1.8% (Table 1.5). While only slightly lower than the 2021 blend rate, it is significantly lower than the 2.8% peak blend rate achieved eleven years ago. This is in part attributed to continued COVID-19 lockdowns in various locations which completely halted fuel ethanol production and transportation in Northeast provinces for several months during the first half of 2022 (GAIN, 2022). Fuel ethanol demand is expected to increase in the 2023 as the promotion of National VIB standard motor gasoline throughout the country.

Table 1.5. Ethanol Production, Supply, and Distribution in China (GAIN 2022)

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022f
Ethanol Used as Fuel and Other Industrial Chemicals (ML)										
Beginning Stocks	0	0	0	0	0	0	0	0	0	0
Fuel Begin Stocks	0	0	0	0	0	0	0	0	0	0
Production	5,795	6,921	7,868	8,071	9,211	9,770	10,740	10,830	10,580	11,850
Fuel Production	2,934	2,951	2,914	2,534	3,041	2,914	4,339	3,801	3,421	3,804
>of which fossil-based synthetic	0	0	0	0	0	0	0	30	30	40
>of which biobased	2,934	2,951	2,914	2,534	3,041	2,914	4,339	3,771	3,391	3,764
>of which biobased cellulosic	25	25	38	40	30	20	0	0	0	0
Imports	0	27	687	890	24	1,035	104	69	824	10
Fuel Imports	0	26	477	871	8	759	0	63	550	5
Exports	40	33	25	34	135	79	21	367	13	10
Fuel Exports	2	2	0	1	3	35	7	21	0	2
Consumption	5,755	6,915	8,530	8,927	9,100	10,726	10,823	10,532	11,391	11,850
Fuel Consumption	2,932	2,975	3,391	3,404	3,046	3,638	4,332	3,843	3,971	3,807
Ending Stocks										
Fuel Ending Stocks										
Refineries Producing First Generation, Bio-based Fuel Ethanol (ML)										
Number of Refineries	6	7	7	10	11	12	14	20	22	22
Nameplate Capacity	3,000	3,200	3,200	3,600	4,200	5,000	5,257	6,578	7,720	7,720
Capacity Use (%)	97%	91%	90%	69%	72%	58%	83%	57%	44%	49%
Refineries Producing Cellulosic Fuel Ethanol (ML)										
Number of Refineries	1	3	3	1	1	1	1	1	1	1
Nameplate Capacity	50	129	129	65	65	65	65	65	65	65
Capacity Use (%)	50%	19%	29%	62%	46%	31%	0%	0%	0%	0%
Co-product Production (1,000 million tons)										
DDGs	1,652	1,661	1,640	1,427	1,598	1,536	2,796	2,436	2,279	2,471
Feedstock Use for Fuel Ethanol (1,000 million tons)										
Corn Kernals	5,277	5,308	5,241	4,558	5,105	4,542	6,763	5,426	4,229	4,694
Rice Kernals						364	2,170	2,357	3,052	3,199
Cassava (dried chips)	2,203	2,215	2,188	1,902	2,283	2,188	1,303	1,132	1,018	1,469
Wheat	N/A	N/A	N/A	N/A	387	371	552	480	173	96
Cellulosic Biomass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fossil Fuels/Waste Gas	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Market Penetration (ML)										
Fuel Ethanol Use	2,932	2,975	3,391	3,404	3,046	3,638	4,332	3,843	3,971	3,807
Gasoline Pool 3/	130,017	135,837	157,490	164,502	170,477	182,197	193,853	191,631	211,207	209,357
Blend Rate (%)	2.3%	2.2%	2.2%	2.1%	1.8%	2.0%	2.2%	2.0%	1.9%	1.8%

Notes: f = forecast
Corn kernels: 1 million ton = 402 (before 2014) to 417 liters (after 2014)
Rice: 1 million ton = 400 liters
Wheat kernels: 1 million ton = 393 liters
Sorghum (Sweet) 1 million ton = 430 (used in 2014 Baseline)
Cassava (fresh root): 1 million ton = 143 to 150 liters (25 to 35% starch content)
Cassava (dried chips): 1 million ton = 333 to 400 liters (15 to 65% starch content)
Sources: Post estimates and industry sources

Although there is approximately equal demand for gasoline and diesel in China's transportation supply chain, biodiesel market penetration and production targets have been very low compared to ethanol (Table 1.6). China's 2022 biodiesel consumption is estimated at 600 ML, slightly higher than 2021, but 50% below 2019 levels and 40% below 2018. This is attributed to China's demand drop off from October through December 2019 when the price of biodiesel was competitive with fossil diesel and is essentially absent in 2020 and 2021. In contrast to most other countries, biodiesel in China is mainly used for electric power generation, fishing vessels, and farm equipment. Post contacts report that on-road transport accounts for over one-third of total biodiesel demand (GAIN, 2022).

Table 1.6. Biodiesel Production, Supply, and Distribution in China (GAIN, 2022)

Calendar Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022f
Beginning Stocks (ML)		0	0	0	0	0	0	0	0	0
Production (ML)	1,079	1,133	787	909	1,043	834	939	1,455	1,835	2,430
Imports (ML)	895	1,028	33	8	18	853	953	102	204	295
Exports (ML)		43	27	76	194	357	752	1,035	1,475	2,125
Consumption (ML)	1,974	2,118	793	841	867	1,330	1,140	522	564	600
Ending Stocks (ML)										
Production Capacity (ML)										
Number of Biorefineries	53	53	53	48	46	44	40	42	44	46
Nameplate Capacity	4,000	4,000	4,000	2,680	2,680	2,680	2,680	2,726	2,800	4,700
Capacity Use (%)	27.0%	28.3%	19.7%	33.9%	38.9%	31.1%	35.0%	53.4%	65.5%	51.7%
Feedstock Use (1,000 million tons)										
UCO	1,055	1,108	771	891	1,022	816	918	1,426	1,798	2,381
Market Penetration (ML)										
Biodiesel, on-road use	324	340	236	273	313	410	430	250	260	276
Diesel Pool, on-road use	133,383	133,365	134,375	130,564	130,538	126,898	135,370	136,149	141,000	139,828
Blend Rate (%)	0.2%	0.3%	0.2%	0.2%	0.2%	0.3%	0.3%	0.2%	0.2%	0.2%
Diesel Pool, total										

Notes: Fuel pools are defined as fossil fuels plus all "bio-components" (biofuels) blended with fossil diesel.
F= forecast; All PSD data are B100 or B100-equivalent (see statistical info section of Reporting Instructions).
UCO:1 million ton = 1,043 liters of UCOME (UCO methyl ester)
Source: Post and Industry sources

1.6.2. Biofuel production in China

At this time, Chinese law restricts fuel ethanol processing to licensed facilities that produce and supply fuel ethanol to national refiners and fuel marketing companies. Provincial Development and Reform Commissions (DRCs) are responsible for the distribution of franchise licenses for fuel production, refining, and marketing. Industry sources report no new facilities began production in 2022. The total production capacity is forecast to remain at 7.7 BL, and the fuel ethanol production is forecast to increase to 3.8 BL, up 383 ML from the previous year. It is also reported that China's fuel ethanol production was over 80%

grain-based (i.e., corn, wheat, and rice) in 2022 and 10% cassava or sugarcane-based. Due to limited supplies of sugarcane and record high molasses prices, sugar and molasses- ethanol producers continue to struggle with low margins. Cassava ethanol (for fuel and other industrial use) production capacity is forecast at 2.82 MMT in 2022, mainly in Shandong, Anhui, and Jiangsu, as a result of relatively low cassava prices compared to corn (Gain, 2022).

Fuel ethanol in China is produced predominately from corn through conventional fermentation. However, the biofuels industry is investing resources to transition to advanced biofuels such as cellulosic bioethanol as well as coal and industrial flue gas-based synthetic ethanol. In late 2021, Hebei Yigao Biofuel Company reportedly successfully operating the first trial of their 240,000 tons per year biomass comprehensive use project. The project produced qualified ethanol on November 14 after successful enzyme decomposition and fermentation. The project is designed to produce 25,000 tons of biofuel, 27,000 tons of other by-products. Table 1.7 summarizes suspended or planned cellulosic ethanol production capacity in China. As for the synthetic ethanol, Currently, one 58 ML/yr fuel ethanol facility in Hebei is operational and another 57 ML/yr production line, the Ningxia Shougang Lanza Jiyuan started production in May 2021. In September 2020, the first syngas-based fuel ethanol plant project in Guizhou held a signing ceremony. Once operational, the plant will produce 76 ML (60,000 tons) of fuel ethanol per year.

China's 2022 biodiesel production is forecast at 2.4 BL, up by over 32% from 2021 due to strong exports. Beginning in 2020, China's production yearly capacity of fatty acid methyl esters (FAME) grew to 2.6 BL. These facilities are located mainly in Shandong, Guangdong, Shaanxi, and Jiangsu (Table 1.8). Hydrogenation-derived Renewable Diesel (HDRD) plants have a combined annual capacity of 2.3 BL with an additional 3.4 BL capacity planned. Nearly all plants are export-oriented to take advantage of EU tax policies. Zhuoyue New Energy is the leading FAME biodiesel producer, with a new 114 ML/yr production line that will start production in October 2022. The company plans to expand capacity to 852 ML (including more than 114 ML of HDRD capacity) from the current 454 ML in 3-5 years. Zhejiang Jia'ao also plans to expand capacity to 398 ML from current capacity of 171 ML. China's only publicly traded company, Beiqing Huanneng which focuses on UCO business, also plans to build 795 ML (including 454 ML of HDRD and 341 ML of FAME) of biodiesel production capacity, on top of their existing UCO business. Availability of UCO may limit biodiesel production as China's UCO export rebate polices incentive UCO exports (GAIN, 2022).

There has also been some information published in the Chinese media about biojet fuels in recent years. Sinopec Zhenhai Refinery established China's first SAF commercial production facilities in 2020. The company's HEFA products passed Roundtable on Sustainable Biomaterials (RSB)'s certification in 2022. On June 28, 2022, Sinopec Zhenhai Refinery produced the first test batch of SAF products (GAIN, 2022). And in the same year, December 15th, the bio-aviation jet fuel has been first used in international freight transport.

Table 1.7. Suspended or Planned Cellulosic Ethanol Production Capacity in China (2022 estimates) (GAIN, 2022)

Producers	Production Capacity	Status
COFCO Biochemical (Zhaodong)	6.3 ML	Announced in 2006
Jinan Shengquan	25 ML	Announced in 2012
Shendong Zesheng	25 ML	Announced in 2012
Xin Tianlong (Jilin's Siping)	N/A	Announced in 2015
Meijie Guozhen (Anhui's Fuyang)	230 ML	Announced in 2017
Shandong Longlive	65 ML	Production suspended
SDIC Jilin Alcohol	101 ML	Planned
COFCO Biochemical (Anhui's Bengfu)	127 ML	Planned
SDIC Hailun	38 ML	Planned
Hebei Yigao	304 ML	In Trial

Source: Post Industry Sources

Table 1.8. Major Renewable Diesel Producers in China (GAIN, 2022)

	Producer	Production Capacity
Biodiesel	Zhuoyue New Energy	454 ML
	Hebei Jingu Group	284 ML
	Bimei New Energy	114 ML
	Tangshan Jinhai Biodiesel	68 ML
	Hebei Longhai Biofuel	68 ML
	Shandong Fenghui	68 ML
	Zhejiang Jia'ao Environment Protection	171 ML
	Zhejiang Dongjiang Energy Technology	57 ML
	Jingzhou Dadi Biotechnology	57 ML
	Shanghai Zhongqi Environment Protection	41 ML
HDRD	Beijing Sanju Environmental Protection	613 ML
	Jiangsu's Yangzhou Jianyuan Biotechnology	159 ML
	Shijiangzhuang Changyou Bioenergy	227 ML
	Zhangjiagang Eco Biochemical Technology	284 ML

Source: Post Industry Contacts

1.6.3. Biofuel Imports to China

Affected by the internal and external arbitrage activities and domestic supply and demand, China's ethanol import volume has fluctuated significantly in the past six years, with more imports in 2018 and 2021. According the statistics from the General Administration of Customs of the People's Republic of China, China's 2022 fuel ethanol imports that mainly from France and the United States were only 0.16 ML, down drastically from 2021 (Figure 1.6). In 2023, the domestic ethanol supply is sufficient, hence the import volume is expected to remain low. As for biodiesel, the imports in 2022 are 387.89 ML, increased 89% from the last year (Figure 1.7). As in the past, more than 90% of imports are palm oil biodiesel from Indonesia and Malaysia.

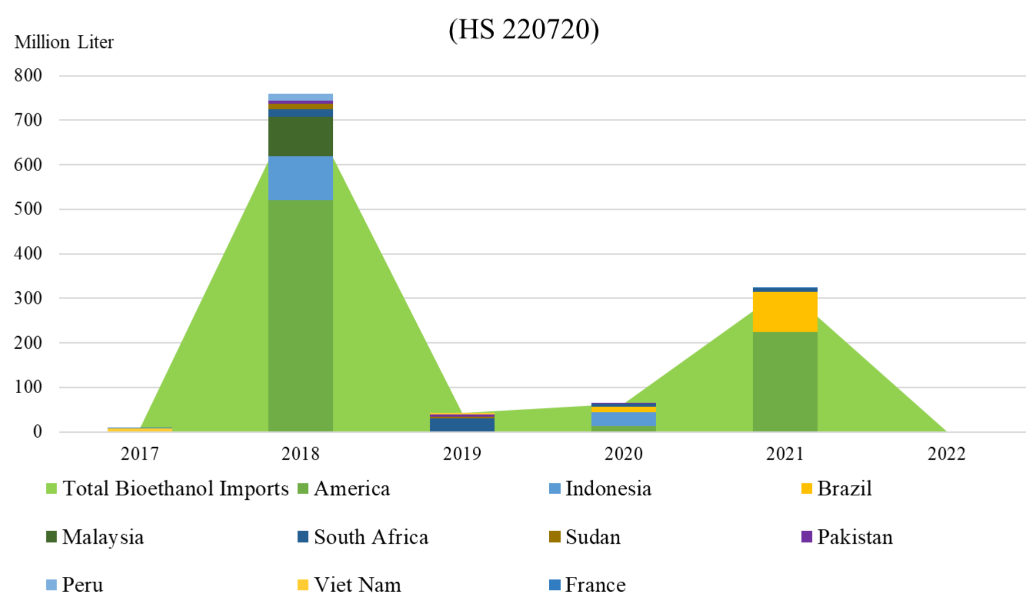

Figure 1.6. Bio-ethanol Import Statistics of China

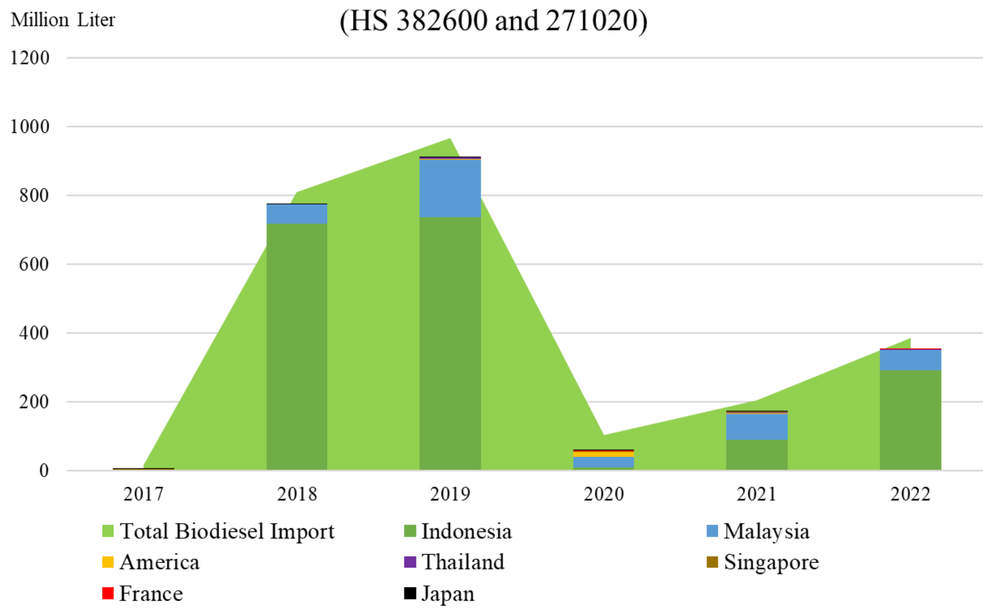

Figure 1.7. Biodiesel Import Statistics of China

1.6.4. Biofuel exports from China

Under the influence of raw material cost and market demand, China's 2022 ethanol exports keep depressed. In 2022, the denatured ethanol exports totaled 2.6 ML, predominantly to India, which covered 61.5%. But the export volume was still less than the previous two years. Conversely, the exports of biodiesel in China were on the rise. In 2022, the exports surged to 2.08 BL, up 41% than last year. Due to the double-counting provisions for UCO-based biofuels of the EU's Renewable Energy Directive (REDII) and supported by a 70% VAT rebate (GAIN, 2022), over 92% exported to EU, of which about 73% were Holland (Figure 1.8 and Figure 1.9).

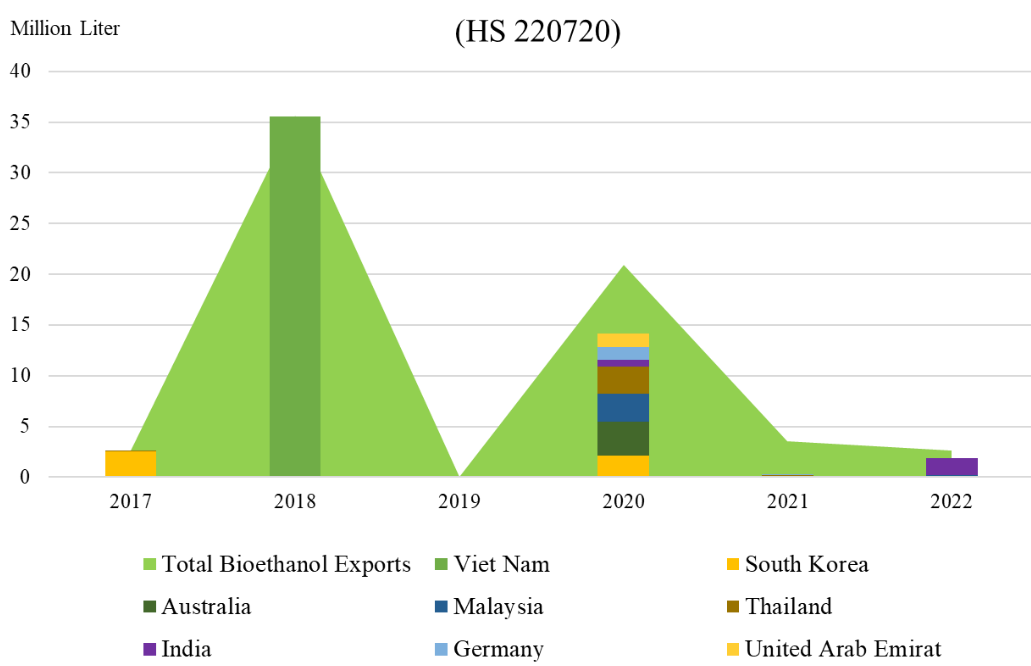

Figure 1.8. Bio-ethanol Export Statistics of China

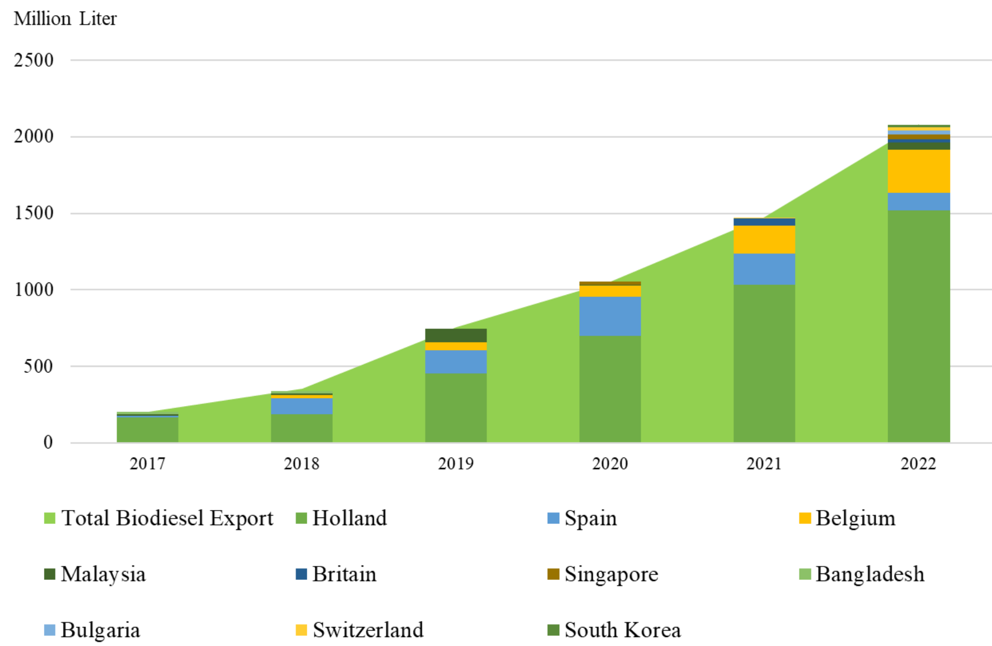

Figure 1.9. Biodiesel Export Statistics of China

1.6.5. Feedstocks

In China, there are many raw materials can be utilized for renewable fuel production. As shown in Figure 1.10, according to different raw materials, biofuels are roughly divided into three generations. China's biofuel policy defines second generation biofuel as those made from cellulosic biomass. While cellulosic ethanol has been mentioned in various government planning documents and policies as early as 2011, including a goal to a build yearly capacity of more than 760 ML (600,000 tons) by 2020, little has materialized. Cellulose ethanol uses 30~50 times more enzymes than starch ethanol, which leads to the high cost of cellulosic bioethanol. Institutions and enterprises such as QIBEBT, Beijing University of Chemical Technology, Shandong University, and COFCO have made important contributions to the cellulosic bioethanol production processes, like the pretreatment, cellulase preparation, enzymatic hydrolysis process, ethanol fermentation, as well as ethanol distillation. The metabolomics group of QIBEBT has established an integrated technology system with cost advantages of full strain biological saccharification and efficient fermentation, which can provide important technical support for the resource, energy and material utilization of straw, help to realize the high value utilization of low value straw, and achieve the industrial application of cellulose fuel ethanol/butanol and straw biomass refining (QIBEBT, 2021).

The coal and industrial flue gas mixture composed of CO, CO_2, and H_2, also termed as syngas, is considered as the third generation of biofuel feedstock. China has attached great importance to the development of syngas related technologies that in December 2016, NDRC and NEA issued the "Energy Supply and Consumption Revolution Strategy (2016-2030)", and in February 2017, NEA issued the "13th Five-Year Plan for Demonstration of Deep Processing of Coal", which mentioned the innovation of clean and efficient coal utilization technology, breaking through the production of high carbon primary alcohol from synthetic gas, and exploring the one-step production of olefins, ethanol and other technologies from synthetic gas. Developing the technology of preparing high-value chemicals from synthetic gas is of great significance for saving the coal consumption in China and ensuring the national energy security.

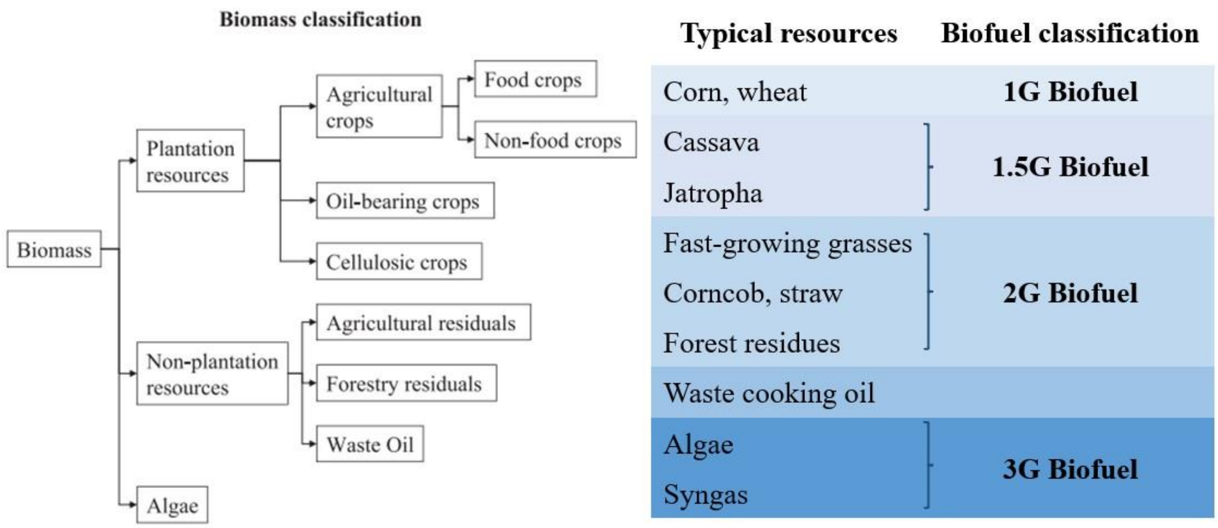

Figure 1.10. Biomass and biofuel classifications in China (Hao et al., 2018)

A major challenge limiting the expansion of biodiesel is the availability of feedstock. China is a net importer of vegetable oils (e.g., soy oil, palm oil) which are the main constituent feedstocks used to make biodiesel. As a result, China's small-scale, private owned biodiesel producers have primarily relied on UCO ("gutter oil") or oil rendered from animal fats as main feedstock. China's biodiesel industry continues to wholly rely on UCO for feedstock. Some smaller food-grade oil brokers blend waste cooking oil, commonly known as "gutter oil," with food grade oil to resell for restaurant use. From its inception, China's biodiesel production plan has aimed to divert UCO away from food use and allay concerns about food safety. In 2013, researchers at Tsinghua University estimated that China is the world's leading producer of waste oil and fats, producing 13.74 million tons in 2010 (GAIN, 2018).

One of the Chinese government's attempts to make better use of the underutilised biodiesel refinery capacity was to encourage the production of 1.5 generation feedstocks such as oilseed bearing trees. This was incorporated into the 11th Five-Year Plan in 2006, where planting targets of 400,000 ha of jatropha, plus another 433,000 ha of other oilseed bearing trees such as yellowhorn (Xanthoceras sorbifolia), Chinese pistachio (Pistacia chinensis), varnish tree (Koelreuteria paniculata), Chinese tallow tree (Sapium sebiferum), Swida wilsoniana, idesia (Idesia polycarpa), sumac (Rhus chinensis), aveloz (Euphorbia tirucalli), and tung tree (Vernicia fordii) (Chang et al., 2012; Li et al, 2014; van Dyk et al., 2016). It was estimated that the potential production volumes of biodiesel based on oilseed-bearing trees grown on marginal land alone could be between 20.5 and 123.1 BL (Chang et al., 2012). However, as of early 2014, the extensive development of these feedstocks has failed to materialise. Jatropha production, which was originally promoted as the most promising of all non-traditional feedstock sources used to make biodiesel, has stagnated. This has been attributed to underdeveloped policies for biodiesel consumption and lack of financial support for farmers (Li et al., 2014; van Dyk et al., 2016).

As the third-generation resources, microalgae bioenergy technology has become an international science and technology hotspot in the past two decades. It is considered as a potential future biofuel production route, which can convert carbon dioxide and solar energy into liquid biofuels in a one-stop manner. In the past ten years, the Chinese government has deployed national key scientific research programs such as "scientific basis for large-scale preparation of microalgae energy", "carbon dioxide flue gas microalgae emission reduction technology", "rational design and system optimization of microalgae chassis", and devoted to promoting the development and industrial application of microalgae energy technology from different aspects such as basic science, technology development, and engineering application. SINOPEC, ENN, SDIC, CR and other enterprises also conducted 100-ton scale energy microalgae industry technology demonstration through cooperation with Chinese Academy of Sciences, Zhejiang University and other scientific research institutions. However, in terms of the current technology, the recovery and treatment of carbon dioxide from flue gas and other sources by cultivating microalgae is of certain significance in the context of the current construction of "carbon peaking - carbon neutralization", but it is not economically feasible to provide energy products. Therefore, there is no practical application progress of microalgae energy technology in China or even in the world.

1.7. Co-processing at oil refineries

In 2021, China's refining capacity continued to grow at a faster pace, with a net increase of 25.2 million tons /yr, the total capacity to 910 million tons /yr, and slightly higher than the average annual increase of 23.5 million tons /yr during the 13th Five-Year Plan period. At present, China has built 34 ten million-ton refining bases and put into operation, with the total capacity accounting for about 53.6% of China's total refining capacity (Fei, 2021).

Under the constraints of excess refining capacity, slowing growth of refined oil demand, and the goal of carbon peaking and carbon neutralization, China's refining industry accelerated its capacity optimization and adjustment. Sinopec Zhenhai Refinery established China's first SAF commercial production facilities in 2020. The company's HEFA products passed Roundtable on Sustainable Biomaterials (RSB)'s certification in 2022. On June 28, 2022, Sinopec Zhenhai Refinery produced the first test batch of SAF products (GAIN, 2022).

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2. Japan

Drafted and submitted by Yuta Shibahara (New Energy and Industrial Technology Development Organization (NEDO));

2.1. Summary

- The Japanese Cabinet has decided to reduce its 2030 GHG emissions by 46% from 2013 levels and strives to meet energy security and climate mitigation goals.
- The Ministry of Economy, Trade and Industry (METI) formulated a "*Green Growth Strategy Through Achieving Carbon Neutrality*" in collaboration with related ministries and agencies in 2020. This strategy is an industrial policy to lead the challenging goal of achieving carbon neutrality by 2050
- There is a Bioethanol blending mandate of 824 ML (500 ML, crude oil equivalent) until at least FY2027. Currently, there is no blending mandate for Biodiesel in Japan.
- Although the government has mandated the utilization of Bioethanol, it left the decision of how to meet the requirement to industry. Consequently, industry has chosen to use bio-ETBE as it has no/minimum impact on the fuel distribution infrastructure. As the demand for Biodiesel in Japan is very limited, Biodiesel plays virtually no role in meeting the country's biofuel goals.
- The import of bio-ETBE is encouraged through a zero tariff which will be in place until March 2024.
- Consumption of ethanol is encouraged through a special tax incentive effective until March 2024. Diesel oil delivery tax is not charged for B100 (100% Biodiesel) and many local governments are investigating the use of B100 for fueling municipal vehicles such as garbage trucks.
- Biofuels continue to be supported in Japan, but with a focus on next generation technologies based on feedstocks that do not compete with food (e.g., the development of algal-based biofuels).
- METI plans to introduce 10 ML/yr (Ethanol equivalent) as the target for introducing next-generation Bioethanol from FY2028 to FY2032.
- The government maintains several incentive programs to promote the use of biofuels.
- Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has set a target of using SAF for 10% of aviation fuel in Japan by 2030.
- G7 Climate, Energy and Environment Ministers' Communique Extract (Sapporo, April 16, 2023)

Road sector: We reaffirm our commitment to a highly decarbonized road sector by 2030. We recognize the range of pathways that G7- and beyond-G7 members are adopting to approach this goal. We note the opportunity to collectively reduce by at least 50%, CO2 emissions from G7 vehicle stock by 2035 or earlier relative to the level in 2000.

International shipping: We reaffirm our commitment to strengthen global efforts to achieve GHG lifecycle zero emissions from international shipping by 2050 at the latest.

International aviation: We commit to accelerate global efforts to achieve the ICAO's Long-Term Global Aspirational Goal (LTAG) of net-zero emissions in international aviation by 2050 (building on the momentum of ICAO's CORSIA which is the only global market-based measure applying to CO2 emissions from aviation).

2.2. Introduction

Japan is the world's largest liquefied natural gas importer, second-largest coal importer, and third-largest net importer of crude oil and oil products. Japan has limited domestic energy resources that have met less than 12% of the country's total primary energy use since 2011, compared with about 20% before the removal of nuclear power following the Fukushima plant accident. Domestic production of renewable energy has therefore become important, including increased utilisation of wood wastes and increased import of wood pellets for bioenergy production (co-fired with coal). Bioenergy power production is promoted through a feed-in tariff system. Table 2.1 show Japan's total primary energy supply (TPES) and the contribution of the transport sector within the TPES. The transportation sector has been contributing about 15% to TPES.

Table 2.1. Japan's total primary energy supply (TPES) and the contribution of the transport sector within the TPES (in PJ)

(PJ)	FY2017	FY2018	FY2019	FY2020	FY2021
TPES	18,202	17,979	17,535	16,506	17,229
TFC *	11,802	11,514	11,375	10,657	10,845
Transport	3,062	3,028	2,969	2,639	2,657

Source: https://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline8
*TFC: Total Final Consumption for Energy Use

In terms of GHG emissions generation, the transportation sector has also contributed about 17% to the total GHG emissions inventory in Japan in recent years (see Table 2.2).

Table 2.2. Japan's GHG emissions inventory and the contribution of the transport sector to national GHG emissions (in Mt CO2eq)

(Mt CO2eq)	FY2017	FY2018	FY2019	FY2020	FY2021
Japan total	1,189	1,144	1,107	1,042	1,064
transport	204	202	197	176	178

Source: http://www-gio.nies.go.jp/aboutghg/nir/nir-e.html

Japan to announce the 6th Strategic Energy Plan in 2021, which is being reviewed every 3years and to show the direction of Japan's energy policy under the Basic Act on Energy Policy. Renewable energies form a key focus based on their potential to foster energy security, climate change mitigation and revitalisation of regional economies. After the Fukushima disaster, all nuclear reactors in Japan were shut down with the result that energy imports increased dramatically. However, some reactors are now restarting.

Japan's current renewable energy policy focuses on generating power from solar, wind, biomass, and geothermal sources, and biofuels are also part of this renewable energy policy. Against the backdrop of the challenge of becoming carbon neutral by FY2050, It was announced that Japan has significantly raised its GHG emission reduction target for FY2030, aiming for a 46% reduction compared to FY2013 by FY2030, and will continue to take on the challenge of achieving a further 50% reduction. For bio fuels (Bio-Ethanol), the government plans to maintain its 500 ML (crude oil equivalent) mandate until at least FY2027.

Biofuels continue to be supported, but with a focus on next generation technologies based on feedstocks that do not compete with food, and also on the development of algal-based biofuels. A major reason for focusing research efforts on expanding to cellulosic ethanol (Next Generation) is the fact that it does not compete with food, as debate continues about how much food prices are affected when food/feed feedstocks are also used for biofuel production.

From 2009 to 2013, Japan's New Energy and Industrial Technology Development Organization (NEDO) focused on "Development of an Innovative and Comprehensive Production System for Cellulosic Bio-Ethanol" that coupled cultivation of feedstock that does not compete with food resources to an ethanol production process. In 2014, NEDO started the "Demonstration and Development Project of Production System for Cellulosic Bio-Ethanol" in 2014 in order to prove out a comprehensive production process and establish scale-up technology. Consistent with the government's "Standards for Judgment for Oil Refiners regarding Implementation of Non-Fossil Energy Sources Use", demonstration and development of production system for cellulosic ethanol, which satisfy 50% reduction in CO_2 emissions and fossil energy use, were carried out to verify suitable combinations of key process technologies. Development of production technologies for SAF project is currently underway from 2017 to 2024. In addition, new technology developments in Japan and abroad will be researched and investigated. Concrete themes are as follows:

- Investigate and study superior technologies developed domestically or internationally
- Determine the best combinations of elemental process technologies and perform feasibility studies
- Develop technologies for integrated production of cellulosic ethanol from woody biomass that meets the Japanese standard for sustainability and conduct empirical researches i.e., SAF/ATJ.
- Develop and evaluate the use of steam explosion pre-treatment of pulp for ethanol production
- Develop the biomass to SAF production and research supply chain construction

2.3. Main drivers for biofuels policy

The first two main drivers are the goals of 46% reduction in GHG emissions by FY2030 and carbon neutrality by FY2050. At the end of 2020, the 'Green Growth Strategy associated with carbon neutrality in 2050' will be formulated to transform the energy and industrial structure, and biofuel is also mentioned for use in the transport sector and in the carbon recycling industry. In addition, in Japan's energy supply and demand outlook for FY2030, the share of natural gas, coal and oil is smaller than at present, and also from the perspective of energy security, it will become more important to reduce dependence on conventional (fossil) fuel through the use of biofuel.

2.4. Biofuels Policy

2.4.1. Biofuels targets

In October 2021, Japan published its Strategic Energy Plan, which is reviewed and revised every three years. For biofuels, it states that "concerning biofuels, which are mostly imported at the moment, Japan will introduce next-generation biofuels based on international trends and technological development progress" According to industry sources, this statement reflects the policy that biofuels should be sourced from non-food crops (e.g., cellulosic ethanol).

In 2023, Japan extended its preliminary biofuel policy to FY2027, and it plans to maintain the 500 ML of Bio-Ethanol mandate. Table 2.3 shows the Bio-Ethanol blending mandates in Japan since FY2011. Those GHG of Bio-Ethanol shall be less than 45% compared to gasoline derived from fossil fuels. The carbon intensity of volatile oil is currently set as 88.74 gCO_2eq per Megajoule (MJ).

Regarding 2nd-generation Bio-Ethanol, Japan set the target amount of 10 ML/yr from FY2023 to FY2027, under the "Sophisticated Methods of Energy Supply Structures Act". This number will be included in the total target for Bio-Ethanol 500 ML, and also 2nd Bio-Ethanol & SAF-usage double count rules apply.

Table 2.3. Biofuel obligations/mandates (target volumes)

Year	Ethanol *	Biodiesel
2011	346 ML (210 ML)	-
2012	346 ML (210 ML)	-
2013	428 ML (260 ML)	-
2014	527 ML (320 ML)	-
2015	626 ML (380 ML)	-
2016	725 ML (440 ML)	-
2017	824 ML (500 ML)	-
2018	824 ML (500 ML)	-
2019	824 ML (500 ML)	-
2020	824 ML (500 ML)	-
2021	824 ML (500 ML)	-
2022	824 ML (500 ML)	-

*The values in parenthesis shows the amount of displaced crude oil
Sources: http://www.meti.go.jp/committee/materials2/downloadfiles/g100913aj02.pdf
http://www.jari.or.jp/portals/0/jhfc/data/report/2005/pdf/result_ref_1.pdf

Bio-ETBE blended gasoline is far more prevalent than E3 gasoline and is widely distributed. In 2012, the Government began to permit sales of E10 and ETBE22 gasoline, and vehicles designed to use these biofuels. However, this change has had little effect on the market as the supply of E3 and E10 remains small compared to that of bio-ETBE gasoline, and the Japanese petroleum industry does not have plans to supply ETBE22 gasoline.

Most of the ethanol for fuel is used in ETBE. The distribution channel for ethanol blended gasoline (E3) is limited compared to that of ETBE blended gasoline. Presently, E3 gasoline is available at only few gas stations, while ETBE blended gasoline is available throughout the nation.

The acceptable blend level for Biodiesel is 5% (B5), and is applied to cars, busses, and trucks. Of Japan's 33.6 BL of diesel used in 2015, approximately 76% (25.7 BL) was for on-road use. Ministry of Economy, Trade and Industry (METI) provides special approvals for operators to use Biodiesel at a blend level higher than 5% for trucks and buses. Trade data shows that Japan's imports of Biodiesel in 2016 grew by 19.7% (or 210,000 liters) from the previous year. According to industry sources, this trend may not be for transportation fuel but be attributed to increased use by small-scale power plants and large-scale oil-fired power plants.

The food-vs-fuel debate is a significant issue in Japan. Japan has a low level of food self-sufficiency – imports comprise the majority of the food it consumes. As a result, Japanese people are highly sensitive to above. Table 2.4 summarizes the timeline of biofuel policies in Japan since 2008.

Table 2.4. Timeline of the development of biofuels policies in Japan

Year	Policies
2008	➢ Amendment of the Quality Control of Gasoline and Other Fuels Act (gasoline tax exemption) ➢ Amendment of the Customs Tariff Act (tariff exemption for Bio-ETBE)
2010	➢ Law Concerning the Promotion of Use of Non-fossil Energy Sources and Effective Use of Fossil Energy Raw Materials by Energy Suppliers
2014	➢ 4th Basic Energy Plan
2016	➢ Amendment of the Customs Tariff Act (tariff exemption for Bio-Ethanol)
2018	➢ Revision of Notice under the Law Concerning the Promotion of Use of Non-fossil Energy Sources and Effective Use of Fossil Energy Raw Materials by Energy Suppliers ➢ 5th Basic Energy Plan

Year	Policies
2019	➢ Roadmap for Carbon Recycling Technologies
2020	➢ Revision of Notice under the Law Concerning the Promotion of Use of Non-fossil Energy Sources and Effective Use of Fossil Energy Raw Materials by Energy Suppliers
2021	➢ 6th Basic Energy Plan
2023	➢ Revision of Notice under the Law Concerning the Promotion of Use of Non-fossil Energy Sources and Effective Use of Fossil Energy Raw Materials by Energy Suppliers

2.4.2. Excise duty reductions

Diesel oil delivery tax (¥32.1/liter) is not charged for B100 (100% Biodiesel). Therefore, in many local governments, the use of B100 as fuel is investigated for municipal vehicles such as garbage trucks. Consumption of ethanol is encouraged through a special tax incentive effective until March 2022. If gasoline contains 3% ethanol (volume basis), the gasoline tax is lowered by ￥1.6/L (= 1.5¢/L, under a currency exchange rate of US$1 = ￥ 110). The tax for unblended gasoline is ￥53.8/L. 3.1% import tariff on bio-ETBE and 10% import tariff on Bio-Ethanol are amended. Import of bio-ETBE is encouraged through a zero tariff in place until March 2021.

2.4.3. Incentives, subsidies and other measures to promote biofuels

Although a number of ministries collaborate on Japan’s biofuels policy, the two ministries that play major roles in developing and implementing Japanese biofuels policies are the Ministry of Economy, Trade and Industry (METI) and the Ministry of Environment (MOE). MOE is concerned with preventing global warming and meeting Japan’s commitment to reduce its GHG emissions. In May 2016, Japan committed to reduce its GHG emissions to 46% of its 2013 levels by fiscal year (FY) 2030 (April 2030 to March 2031), in October 2020, Japanese Prime Minister presented Carbon Neutrality by 2050 at the first Diet policy speech. METI’s interest in biofuels is as supplemental sources of fuels for Japan, and in analyzing the costs and benefits of shifting to renewable fuels, including impacts on automobiles and infrastructure. METI collaborates with the oil industry to determine how and when to introduce biofuels into the Japanese market.

The Ministry of Agriculture, Forestry and Fisheries (MAFF) previously played a leading role in developing and implementing biofuels policies in Japan. MAFF’s interest was focused on the potential to revitalize rural communities through the production of biofuels from domestic resources (e.g., rice for non-food purpose). However, its focus has shifted from biofuels to the production of renewable energies (i.e., heat and power) from wastes generated by the livestock and forestry sectors.

The government of Japan maintains the following programs and incentives to promote the use of biofuels:

- In 2008, the “Quality Control of Gasoline and Other Fuels Act” was amended to lower the gasoline tax (¥53.8/liter) by ¥1.6 per liter (about $0.02/liter) if the fuel contains 3% ethanol. This incentive is effective until March 2022.

- In 2008, the “Customs Tariff Act” and the “Temporary Measures Concerning Customs Act” were amended to eliminate the 3.1% import tariff on bio-ETBE. Moreover, in 2016, these acts were further amended to eliminate the 10% import tariff on Bio-Ethanol for the production of bio-ETBE. As with the gasoline tax, the Customs Tariff Act must be renewed annually and is currently approved through March 2021.

- In 2008, MAFF proposed and the Diet (Japanese Parliament) passed the “Law Concerning the Promotion of Biomass Resources as Raw Materials for Biofuels.” This law provides tax breaks and financial assistance to newly built biofuels production facilities that MAFF determines qualified for benefits. Although initially available only to ethanol producers, benefits now have been extended to producers of alternative forms of bio-energy (such as Biodiesel, wood pellets, methane gas, or hydrogen gas).

Under the scheme, newly built biofuel facilities that are approved for the program by 2018 will have their fixed property tax reduced by half for three years. The legislation authorizes MAFF to extend the repayment period of interest-free loans in two-year increments for a maximum of 12 years. MAFF records show that 21 projects have been qualified for the benefits since the program began in 2008, though some have since ceased operations.

Figure 2.1 shows the timeline of NEDO's biomass energy and fuel projects in the period of 2007-2020.

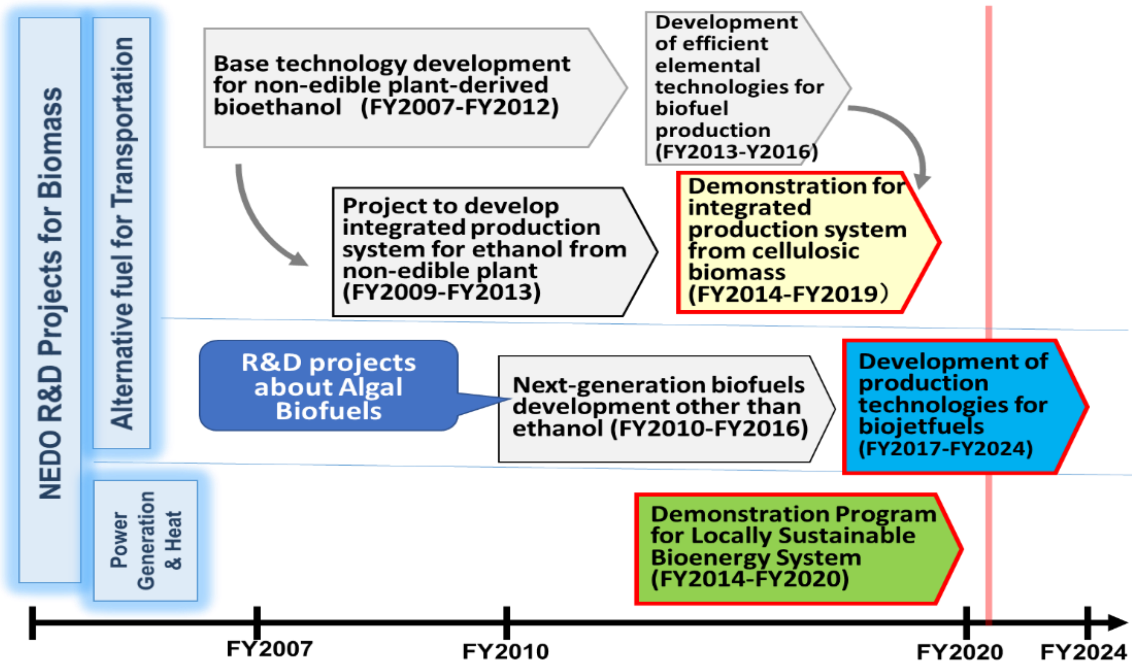


Figure 2.1. The timeline of NEDO's biomass energy and fuels project in the period of 2007-2020.

2.4.4. Other measures stimulating the implementation of biofuels

Under the "Basic Law for Promoting Biomass Utilization" enacted in 2009, MAFF had a target to establish biofuel manufacturing technology and provided tax breaks and financial assistance to biofuel producers and farmers producing feedstock.

2.5. Promotion of advanced biofuels

In order to promote advanced biofuels, Japan has decided that next-generation Bio-Ethanol and ethanol derived from waste materials will be doubled within the amount introduced under the "Sophisticated Methods of Energy Supply Structures Act". In other words, advanced Bio-Ethanol is counted twice for meeting the blending mandate. From 2023 to 2027, special mandate for advanced Bio-Ethanol (10 ML) will be introduced as mentioned in the next Act notification introduction The government has decided to introduce 10,000 kl from 2023 to 2027 as the target amount. Japanese private companies and Japan's scientific community, including universities and public and private research institutions, continue substantial basic and applied research related to biofuels. A major focus of research projects is on cellulosic and algal feedstocks and conversion technologies to produce biofuels at commercial scale in a sustainable way. Several joint research projects aim to produce commercial-scale SAF from algae, with the goal of commercializing these fuels by 2030. Table 2.5 lists some of the industry-led advanced biofuels projects active in Japan. To utilize domestic biomass feedstock at its maximum potential, not only cellulosic biomass but also food waste will be investigated as feedstocks not competing with food.

Table 2.5. Partial list of company-led advanced biofuel projects in Japan

Name of company	Status (planned; operational; closed)	Technology	Production capacity (ML/yr)
DINS Sakai	Operational (2007-)	saccharification with diluted sulphuric acid and fermentation using recombinant *E. Coli*, KO11	Unpublished
Oji/JXTG (NEDO)	Pilot plant (2015-2017)	simultaneous saccharification and co-fermentation	100 kL/yr
Biomaterial in Tokyo (NEDO)	Pilot plant (2015-2017)	simultaneous saccharification and co-fermentation	100 kL/yr
GEI	Operational	ATJ	Unpublished
Euglena (NEDO)	Pilot plant (2020-2021)	CHJ (catalytic hydro-thermolysis jet), HEFA	125 kL/yr
MHI/JERA/TEC (NEDO)	Pilot plant (2017-2021)	Gasification FT	2.4 kL
IHI (NEDO)	Pilot plant (2017-2021)	HC-HEFA SPK	0.1 kL
SEKISUI	Operational (2022-)	Waste to Ethanol -Gasification -Microorganism catalyst utilization technology	1 to 2 kL /day
ENEOS (SAF)	①Planned ②Project Operational: 2022-2028 (NEDO)	①HEFA, ②synthetic fuel production technology converting CO2 and hydrogen to liquid fuels using reverse shift, FT)	①Around 400 ML/yr in 2026 ②Pilot Scale in 2028
Idemistu	Project Operational ①2022-2028 (NEDO) ②2021-2025	①ATJ, ②synthetic fuel production technology	①Around 100 ML/yr in 2026 ②Unpublished
Cosmo	①Project Operational (NEDO) ②Planned	①HEFA, ②ATJ	①several ten of ML/yr in 2025 ②220 ML/yr in 2027

Source:
http://www.dinskansai.co.jp/business/baio_business/index.html
https://www.sekisuichemical.com/news/2022/1373480_38754.html
http://www.nedo.go.jp/content/100862614.pdf
https://gei.co.jp/en/newsrelease.html
https://www.meti.go.jp/shingikai/energy_environment/bio_nenryo/pdf/008_02_00.pdf

As shown in Table 2.6, it is projected that the gasoline demand will decrease in 2021 compared to 2006 because of EV shift and structural reasons such as population reduction. However, demand for fuels to supply larger vehicles and airplanes that rely on high energy density fuels is expected to remain steady. In the medium- and longer-term, the possible introduction of SAF and Biodiesel fuels is likely to be further investigated to better assess or estimate needed policy(ies), biomass resource supply and investment.

Table 2.6. Change in the fuels in Japan, 2006-2021 (ML)

Fuel	2006	2021 (estimated)	Decrease rate
Gasoline	60,550	47,050	-22%
Jet Fuel	5,390	5,340	-1%
Diesel	36,610	33,360	-9%

Source: Statistics of Agency for Natural Resource and Energy, Petroleum products demand and supply calculation 2017-2021

The Government wants to introduce SAF for commercial flights within 2021. In 2015, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and METI jointly established a "Committee for the Introduction of SAF for Olympic and Paralympic Games Tokyo 2020," (which have been postponed). The committee is conducting research into the SAF supply chain and investigating fuel production. For this national project, NEDO has completed R&D of the pilot plant for the production of new-generation SAF at the gasification FT synthesis technology (ASTM D7566 Annex 1) using wood cellulose as a raw material. A brand-new generation technology (ASTM D7566 Annex 7) that uses microalgae as a raw material, was evaluated and verified (FY2017-FY2021). In 2021, both fuels met ASTM standards after mixing with fossil fuels and completed SAF production. NEDO Project is working to expand the production volume by deploying the basic plan of "SAF Production Technology Development Project" during FY2017-FY2024. NEDO is promoting the basic plan of "SAF Production Technology Development Project" in FY2017-FY2024, and is working to expand those production volumes.

In addition, a venture company in Tokyo, which is also a member of the SAF Committee, constructed the demonstration plant in Yokohama in 2018 to produce and commercialize bio-fuel. The fuel is made from Euglena algae that grow on Ishigaki Island in Okinawa and waste cooking oil (UCO) around Yokohama. This plant is operational in the summer of 2019 with an annual bio-fuel production capacity target of 125,000 liters.

SAF can be used to meet the Bio-Ethanol mandate under the Law Concerning the Promotion of Use of Non-fossil Energy Sources and Effective Use of Fossil Energy Raw Materials by Energy Suppliers.

2.6. Market development and policy effectiveness

Japan's total fuel ethanol consumption in 2018 was 823 ML, including both the pure ethanol equivalent of ETBE consumed plus a small amount of ethanol consumed in direct blending in gasoline. This translates to an effective national average blend rate of 1.7%; Japan's estimated gasoline consumption in 2018 was 50.8 BL. The government mandated the utilization of biofuels, leaving the decision of how to meet the requirement to industry, which is using bio-ETBE (leaving Biodiesel out of the picture).

Japan's number of conventional ethanol plants and their combined production capacity, which was as high as 6 plants with 35 ML annual capacity, has diminished. Today, Japan has one plant that annually produces approximately 0.2 ML of ethanol for fuel use from domestic rice. This plant is located in Niigata Prefecture and is operated by JA Zen-noh, the federation of agricultural cooperatives. It uses high yield rice grown specifically for biofuel production. The ethanol is used as part of an E3 blend, and the E3 gasoline is sold at six affiliated gas stations around Niigata Prefecture.

In 2010, Japan Biofuels Supply LLP started to produce ETBE domestically. In 2019, the union produces 143 ML of ETBE, using 61 ML of ethanol. Previously, mostly imported ethanol with some domestically produced ethanol added were used to make ETBE, but following the closure of two ethanol plants in Hokkaido in 2014, the company became fully reliant on imported ethanol.

In 2019, Japan imported 823 ML of ethanol for transportation, consisting of 817 ML of ethanol imported as ETBE and 61 ML of ethanol to be used for domestic ETBE production. Due to sustainability requirements, all imported ethanol used in domestic ETBE production has come from Brazil, and all imported ETBE from the United States, made using Brazilian ethanol. The government of Japan is assessing alternative sources for fuel ethanol, and U.S. corn ethanol is designated as eligible under Japan's sustainability policy (see Policy and Programs section for more information on Japan's requirement to reduce GHG emission by at least 55%). Following the recent policy change in the sustainability criteria by the Japanese Government, the country received its first shipment of ethyl tert-butyl ether (ETBE) made from US corn-based ethanol in July 2019. Japan will allow US ethanol to meet up to 44% of a total estimated annual demand of 824 ML of ethanol used in the production of ETBE, which equates to around 363 ML of ethanol.

The use of ETBE is expected to increase further, as the Petroleum Association of Japan (PAJ) aims to start supplying 1.94 BL of ETBE annually by 2017. Accordingly, the PAJ continues to supply the same amount of ETBE from 2018 to 2022. All results up to 2019 have been successfully achieved. The PAJ expects to import most of its supply (annually 1.8 BL of the 1.94 BL of ETBE) from the United States. There are no import tariffs on ETBE derived from biomass or on ethanol used to make ETBE and this measure has been extended. Japan does not export either ETBE or ethanol.

Japan's Biodiesel market is extremely limited, meeting just 0.04% of national on-road transportation demand for diesel fuel, and there is no renewable diesel market. 13 ML of Biodiesel was produced in 2019 based on National Biodiesel Fuel Utilization Council (NBUC) data. Compared to Europe and the United States, Japan uses extremely little diesel fuel, thus the demand for Biodiesel fuel and technology development has not been sufficient so far. In the other hand, there is a strong desire to develop new technologies based on the premise of next-generation raw materials, and the development of technologies for microalgae biofuel production and SAF production is progressing. In addition, the pathway to carbon neutrality in 2050 is being built.

The most common feedstock for biodiesel production in Japan is UCO. It is reported that the annual supply of UCO is about 450,000 MT, from which about 410 ML of Biodiesel (or renewable diesel) could be produced. Some 18,000 MT of UCO is currently used to produce Biodiesel. In the past, there were 116 projects being administered by municipal governments and regional non-profit organizations across Japan that took part in small-scale Biodiesel projects through the "Rapeseed Project." The projects involved growing rapeseed to produce cooking oil, collecting the used oil, and recycling it as Biodiesel to fuel regional garbage and cargo trucks.

There is another project by the City of Kyoto to collect UCO from restaurants and individual households. The oil is processed into Biodiesel at the city's refinery, which produces approximately 5,000 liters per day or annually 1.3 ML of Biodiesel fuel that is used in the city's garbage trucks (B100) and municipal buses (B20). Furthermore, in Kyoto, there is also a private company (REVO International Kyoto) producing UCO-based Biodiesel. This firm started from a citizen's group whose activities included collecting UCO for the purpose of environmental protection. To date, the firm has established its own network to collect feedstock from individual households, restaurants, and any public or private organization nationwide. Its refinery in Kyoto can produce 11 ML of Biodiesel annually. According to the company, it is the largest capacity Biodiesel refinery in Japan. Since 2011, the company has been exporting Biodiesel fuel to the Netherlands.

Biodiesel has no role in meeting the government target to introduce 500 ML of biofuels (crude oil equivalent) in the market, even though there is considerable unrealized potential since Japan is the 4th largest diesel market following the EU, United States and Brazil. The Japanese oil industry selected bio-ETBE and ethanol to meet the renewable fuel target because this solution requires no significant oil industry investment in new delivery infrastructure. That said, renewable diesel (hydrogenated vegetable oil is one type which is produced on a commercial scale in Europe, Singapore and the United States) is fully substitutable with fossil diesel and thus requires no new investments in infrastructure. UCO is the only abundant feedstock locally available and few large-scale collection systems exist to exploit this resource in a cost-effective manner. In 2019, Japan exported 8.9 ML of Biodiesel primarily to the European Union and Switzerland, a 30% increase from 2018 (USDA GAIN, 2020).

According to an industry source, consumption of Biodiesel in the transportation sector is not expected to increase beyond small changes because distribution channels are not established and fuel standards limit blending due to concern that the fuel blended at higher rates may damage engines.

Since 2011, a private company in Kyoto has been exporting Biodiesel to the Netherlands (see Production section above). Exports have risen over the years but remain very limited, reaching 5.5 ML in 2016 and forecasted to total 6 ML in 2017 and 2018.

While Japan's imports of Biodiesel have increased in recent years, they remain limited. According to some industry sources, Biodiesel may be imported for generating power at oil-fired power plants. In 2016, Japan imported 1.27 ML of Biodiesel, 98% from Malaysia (see Table 2.7); there is no import tariff on Biodiesel from Malaysia under a bilateral economic partnership agreement.

Table 2.7. Key suppliers of Biodiesel to Japan (ML) (The World Trade Atlas)

Supplier	2012	2013	2014	2015	2016	2017	2018	2019
World	0.08	0.49	0.61	1.06	1.27	1.29	1.34	0.88
Malaysia	-	0.42	0.44	1.02	1.24	1.20	1.31	0.84
Philippines	-	-	-	-	0.2	0.03	0.03	0.03
United Kingdom	-	-	-	-	0.01			
Germany	0.03	0.03	0.04	0.04	0.01			

The Bio-Ethanol Division of a private company in Sakai City, Osaka Prefecture, operates recycling facilities to process waste products and materials, and began producing ethanol from wood and cellulosic lumber waste in 2007. Its annual ethanol production capacity is 1.4 ML. For the first several years, the company supplied its ethanol to a couple of oil distributors making E3 gasoline to sell at the distributors' affiliated gas stations. However, because E3 gasoline did not come into wide use, there is little demand for the company's fuel ethanol. The company is currently using most of the ethanol it produces to generate power for its facility, and it sells the rest to an industrial alcohol distributor. Biofuels production and consumption capacity, market share, import and export trends since 2006 are shown in Table 2.8 to Table 2.11.

Table 2.8. Transport biofuels actual production (ML/yr)

Year	Bio-Ethanol (conventional)	Biodiesel (FAME)
2017	0.191	13.527
2018	0.201	13.198
2019	0.182	14.246
2020	0.182	11.703
2021	0	9.653

Note: All fuels are assumed to be for transport, as statistical data is not available for transport fuels only.
Source: https://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline8

Table 2.9. Summary of transport fuel consumption (ML)

Year	Gasoline	Diesel fuels	Aviation fuel	Bio-Ethanol	Biodiesel*
2017	49996.1	25794.8	4191.7	815.6	14.9
2018	48942.5	25905.0	4243.9	826.9	14.1
2019	47586.4	25767.5	4231.2	780.8	15.7
2020	42815.7	23830.4	2116.7	838.2	12.6
2021	41186.8	25002.0	2748.6	852.2	10.2

*Based on survey replies; it could be 20-25 ML/yr.
Source: https://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline8

Table 2.10. Import volumes of Bio-Ethanol and Biodiesel in Japan in the period of 2017-2021 (ML)

Year	Bio-Ethanol	Biodiesel
2017	815.6	1.359
2018	826.9	0.945
2019	780.8	1.652
2020	838.2	0.938
2021	852.2	0.528

Note: All fuels are assumed to be for transport, as statistical data is not available for transport fuels only.
Source: https://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline8

Table 2.11. Import & Export volumes of Feedstocks (HS code 15 18 00*, tonnes/yr)

Year	Import	Export
2017	9,250	64,233
2018	8,523	75,676
2019	8,882	83,929
2020	7,905	90,465
2021	8,559	109,374

*Animal, vegetable or microbial fats and oils and their fractions, boiled, oxidized, dehydrated, sulphurated, blown, polymerized by heat in vacuum or in inert gas or otherwise chemically modified, excluding those of 1516; inedible mixtures or preparations of animal, vegetable or microbial fats or oils or of fractions of different fats or oils of this Chapter, not elsewhere specified or included.
Source: https://www.customs.go.jp/tariff/index.htm

2.7. Co-processing at oil refineries

As shown in Figure 2.2, there are 22 oil refineries in Japan with a total refining capacity of 3,518,800 barrels/day. No co-processing trials have been yet conducted in Japanese oil refineries.

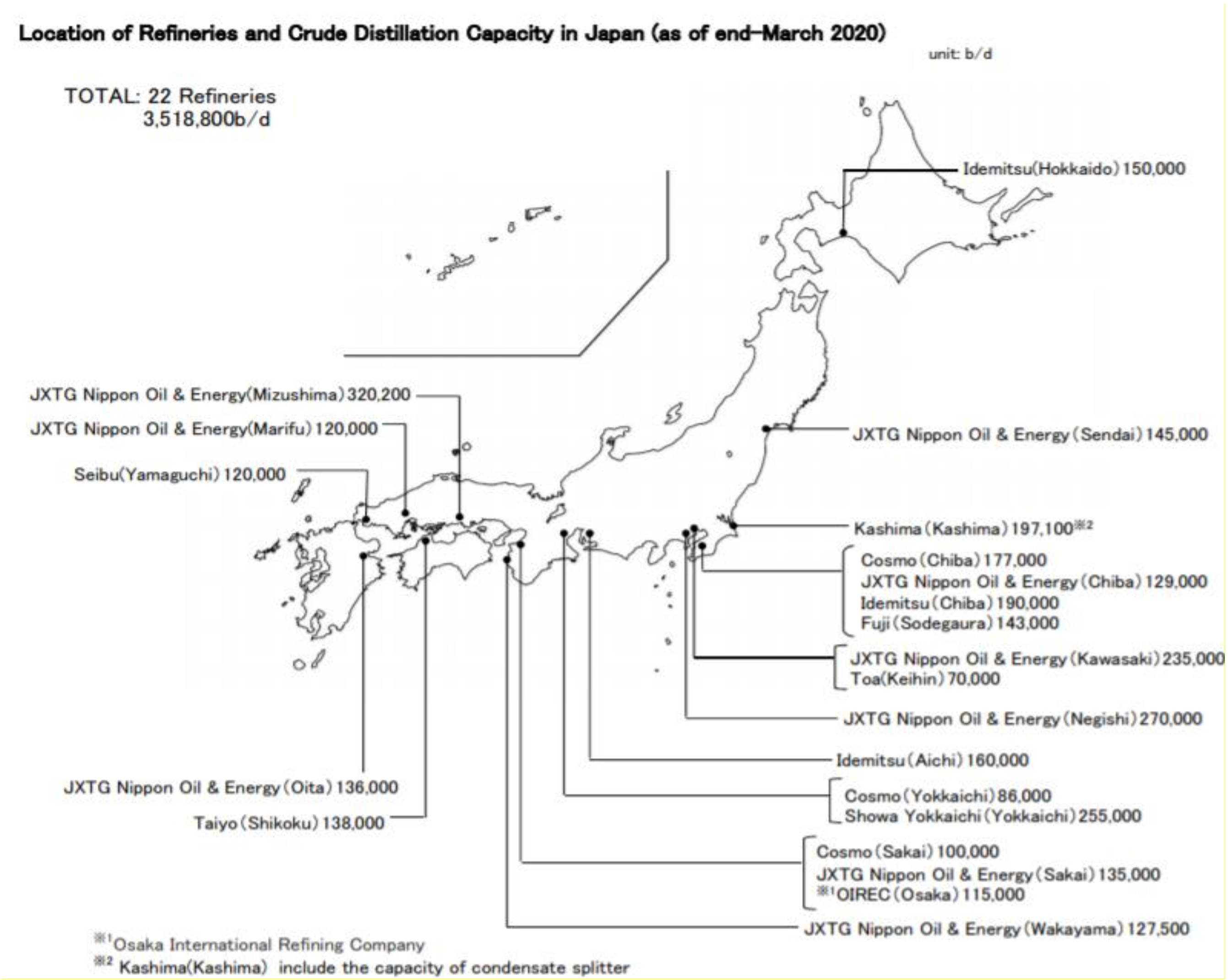


Figure 2.2. Oil refineries and the refining capacity in Japan (DWT)

Sources:
https://www.foc.co.jp/en/index.html
https://www.eneos.co.jp/company/about/branch/map/
https://www.cosmo-energy.co.jp/ja/about/company/group/cosmo-coc/office.html
https://www.idemitsu.com/jp/business/factory/
https://www.seibuoil.co.jp/business/seisan.html
https://www.taiyooil.net/corporate/business/shikoku/capacity/

2.8. Sources

The Strategic Energy Plan of Japan, METI (Ministry of Economy, Trade and Industry):
https://www.enecho.meti.go.jp/en/
https://www.meti.go.jp/english/press/2021/1022_002.html
https://www.enecho.meti.go.jp/en/category/others/basic_plan/

NEDO (New Energy and Industrial Technology Development Organization):
http://www.nedo.go.jp/activities/introduction8_01_03.html
https://www.nedo.go.jp/activities/ZZJP_100127.html
https://www.nedo.go.jp/content/100899767.pdf
https://www.youtube.com/watch?v=MdcK7tRNf-8&list=TLPQMjkwNjIwMjBcA-88XdUM6A&index=1
https://www.youtube.com/watch?v=MdcK7tRNf-8
USDA (2017) Japan Biofuels Annual. GAIN Report Number JA7100.

Japan's National Energy Strategy;(2006)
http://eneken.ieej.or.jp/en/data/pdf/350.pdf,
https://eneken.ieej.or.jp/en/
"Standards for Judgment for Oil Refiners regarding Implementation of Non-Fossil Energy Sources Use": http://www.nedo.go.jp/content/100862614.pdf

Ethanol (ETBE, E3, E10):
http://www.jbsl.jp/biogasoline/; http://www.env.go.jp/earth/ondanka/biofuel/okinawabio/bio_hokokusyo.pdf

Biodiesel (B5, B100)
http://www.svctokyo.co.jp/japanese/bio/1diesel.html

B100 (pure diesel) and ETBE for gasoline tax-exempted.
http://www.tax.metro.tokyo.jp/shitsumon/tozei/index_n.html
http://www.maff.go.jp/j/aid/zeisei/bio/pdf/250401_23.pdf
http://www.nedo.go.jp/content/100776053.pdf
http://v4.eir-parts.net/v4Contents/View.aspx?cat=tdnet&sid=1199361
https://www.nikkei.com/article/DGXLASDZ28HZ6_Y5A520C1TJC000/

Registered Biodiesel production facilities:
http://www2.jarus.or.jp/biomassdb/instinfolist03.html

JST/ALCA (Japan Science & Technology Agency/Advanced Low Carbon Technology Research and Development Program) under MEXT (Ministry of Education, Culture, Sports, Science and Technology)
http://www.jst.go.jp/alca/kadai/bnk_07.html

MAFF (Ministry of Agriculture, Forestry and Fisheries)
http://www.maff.go.jp/j/shokusan/bio/nenryoho/

MOE (Ministry of the Environment)
http://www.env.go.jp/earth/ondanka/biofuel/index.html

JST/ALCA (Japan Science & Technology Agency/Advanced Low Carbon Technology Research and Development Program) under MEXT (Ministry of Education, Culture, Sports, Science and Technology), Advanced Ethanol Production with Acetic Acid Fermentation from Lignocellulosics
http://www.jst.go.jp/alca/kadai/prj_07.html#h22_02

Oil refineries in Japan

Japan

https://www.paj.gr.jp/english/statis/data/08/paj-8%E7%B2%BE%E8%A3%BD%E8%83%BD%E5%8A%9B%E4%B8%80%E8%A6%A7E202006.pdf

Japan receives first shipment of ETBE from US corn-based ethanol
https://biofuels-news.com/news/japan-receives-first-shipment-of-etbe-from-us-corn-based-ethanol/

Comprehensive Energy Statistics
https://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline2

NEDO SAF PR video
https://www.youtube.com/watch?v=MdcK7tRNf-8 (Full version)
https://www.youtube.com/watch?v=j-uMdIEJSs4 (Trailer version - Reverse production)

3. European Commission

Drafted and submitted by Marco Buffi and Nicolae Scarlat (European Commission Joint Research Centre, Directorate C - Energy, Transport and Climate, Energy Efficiency and Renewables - Unit C.2. Ispra (Varese), Italy);

3.1. Summary

- The EU-27 production of biofuels in 2020 was around 18.5 million tonnes of oil equivalents (Mtoe), which accounted for 5.5% of the total transport fuel consumed in the EU.
- In 2020, the overall EU production of biofuels was 20 BL/yr, consisting of 15 BL biodiesel and 5 BL bioethanol. Most biofuels are conventional biofuels, but a growing amount is produced from feedstocks listed in Annex IX (Part A and B) of the Renewable Energy Directive 2018/2001 (RED II). This reached more than 4 Mtoe in 2020, representing around 25% of total biofuel consumption. Of this amount, 1.2 Mtoe were advanced biofuels, produced from feedstocks listed in Part A, with a limited planned production up to 1.85 Mt/yr.
- After the Covid-19 period, the production of liquid biofuels for road transport remained almost constant. However, a rapid market uptake is expected in coming years, particularly for advanced biofuels such as biomethane and SAF/Biojet.
- New policy mechanisms have been promoted to stimulate the production of biofuels. In particular, the Fit-for-55 package, which revisits RED II, by setting more ambitious targets for GHG emissions reduction by 2030. The package also introduced specific targets for non-biological fuels (power-to-x), as well as aviation and maritime biofuels.
- As part of the REPowerEU plan the EC proposed (in May 2022) to further increase the share of energy from renewable sources (in the gross final consumption of energy) to 45% by 2030. One aspect of REPowerEU is to encourage substitutes for fossil fuels, reduce dependence on Russian fossil fuels and accelerate Europe’s clean energy transition including further deployment of renewables.
- REPowerEU has also set a goal of promoting renewable gases such as hydrogen and biomethane. Particularly increasing biomethane production to 35 bcm (billion cubic meters) by 2030 (to replace natural gas).
- Advanced biofuels are expected to play an increasing role in transport. A sub-target for advanced biofuels supplied to the transport sector was set at 0.2% in 2022; 1% in 2025 and 4.4% in 2030 (allowing double counting for these types of fuels, according to the Council’s revision of Council’ position on the Fit-for-55).
- Several delegated acts are expected to be adopted by the European Commission, as requested by the RED II. For example, a delegated act setting the rules to determine the sustainability and eligibility of hydrogen and non-biological fuels (released in February 2022). A delegated act setting the methodology for bio-carbon in co-processing crude oil and bio-based feedstock. A delegated act updating the RED II Annex IX list for the feedstocks eligible for advanced biofuels production will also be released soon.

3.2. Biofuels in the EU scenario

3.2.1. EU biofuels production

European Union (EU) increased steadily biofuels production over the years, driven by EU policies aimed at reducing GHG emissions and increasing the share of renewable energy in the energy mix. The majority of biofuels produced in the EU are biodiesel, made from lipids, and bioethanol, made from sugar- and starch- based crops. The ethanol production in EU, after growing from 1.6 BL to 5.2 BL between 2006 and 2014, remained at around this level until 2020. On average, the production stays below 60% of nominal capacity (Figure 3.1).

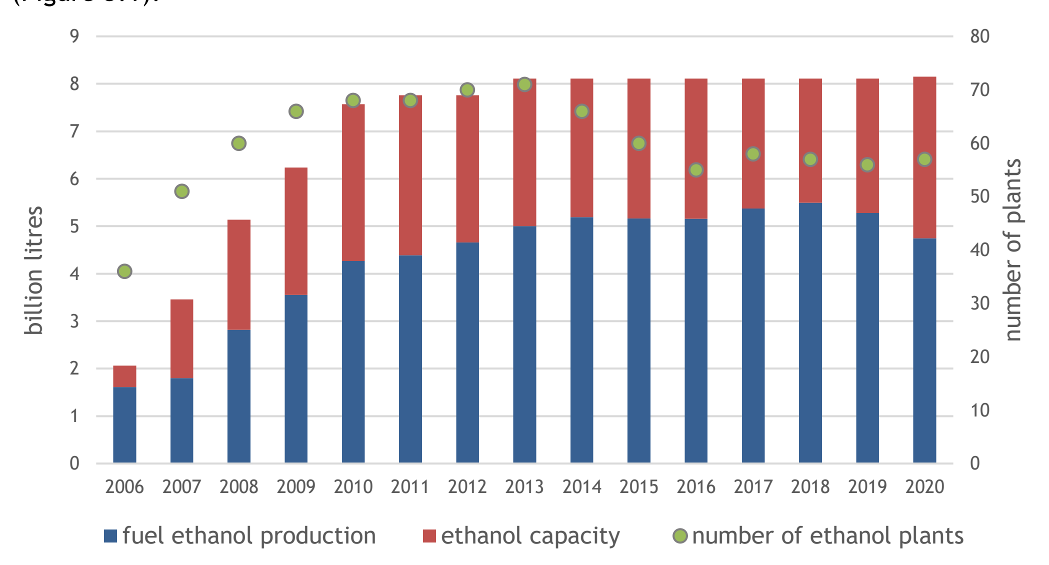


Figure 3.1. Evolution of ethanol production and capacity in the EU [2], [3]

The remarkable biodiesel production capacity increase in EU between 2006 and 2012, from 7 BL/yr to 25 BL/yr, while the actual production was around 50% of nominal capacity in 2013 and has raised to 78% in 2020 (Figure 3.2). This limited growth in biofuel production is related to the sustainability debate in the EU and the cap for biofuels made from food and feed crops introduced by the so-called ILUC Directive.

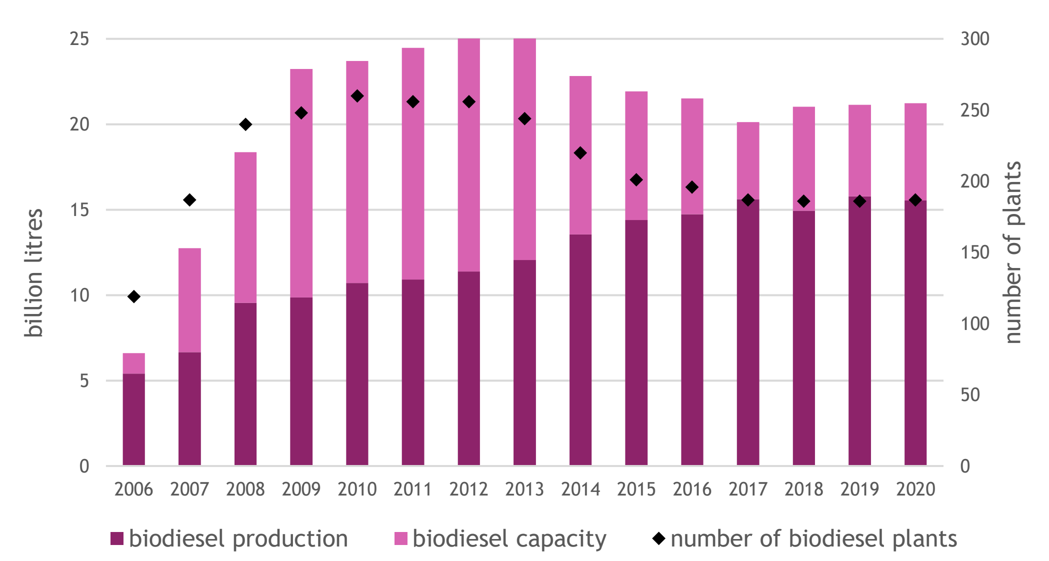


Figure 3.2. Evolution of biodiesel production and capacity in the EU [2], [3]

According to the European Biofuels Observatory, the production of biofuels in the EU-27 in 2020 was around 18.5 Mtoe, which accounted for 5.5% of the total transport fuel consumption in the EU. As shown in Figure 3.3, the largest biofuels producers in the EU are Germany, France, Spain, and Italy. The production of biofuels in these countries is supported by national policies and incentives, such as blending mandates and tax exemptions, as well as by the EU's regulatory framework for biofuels.

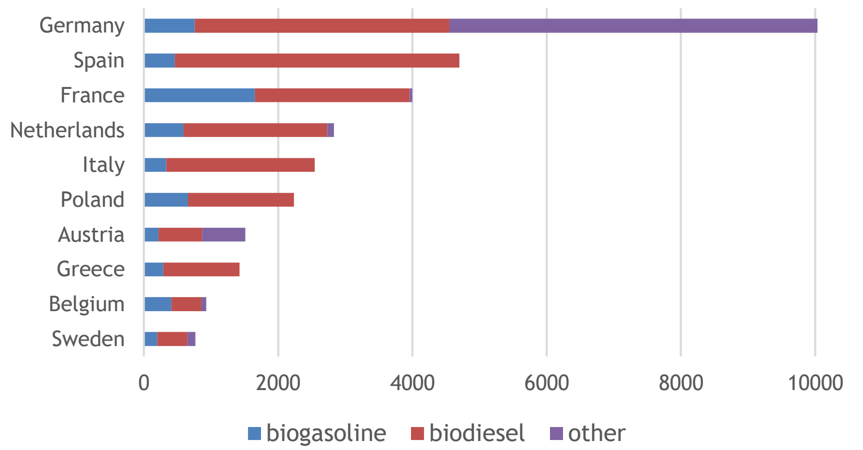


Figure 3.3. Biofuel production capacity per MS and type in the EU [2], [3]

In recent years, there has been a shift in the EU's biofuels policy towards promoting the use of more sustainable, renewable and low-carbon fuels, such as advanced biofuels. In EU, advanced biofuels are defined as biofuels listed in Annex IX part B of the RED II EU, [4]. The aim of this chapter is to provide an overview of the global production of biofuels and of the current advanced biofuels contribution to biofuel supply.

The following tables show projects and operational plants in EU for advanced biofuels. Specifically, Table 3.1 shows the current commercial plant (TRL 9, according to the H2020' Technology Readiness Level – TRL scale [5]) producing HVO and co-processed fuels inside or close oil refinery environments and stand-alone alcohol-based biorefineries. Table 3.2 shows several first-of-a-kind plants (TRL 8) producing pyrolysis oil, bioethanol and biomethanol and FT liquids. The combined production capacity of those plants is still low compared to the roughly 20 BL of bioethanol and biodiesel produced in the EU in 2020, as shown above.

Table 3.1. List of EU operational plants at TRL 9 producing advanced biofuels [3], [6]

Company	Plant	Country
Green Fuel Nordic	GNF Lieksa	Finland
St1	Etanolix Vantaa	Finland
St1	Etanolix Lahti	Finland
St1	Etanolix Hamina	Finland
Total	La Mede	France
Eni SPA	Eni Taranto refinery for co-processing	Italy
Eni SPA	HVO plants in Gela and Venice	Italy
Versalis / Eni	Crescentino Biorefinery	Italy
Twence	Hengelo	Netherlands
Borregaard Industries AS	ChemCell Ethanol	Norway
BP	Co-processing Castellon	Spain
Repsol	Co-processing Puertollano	Spain
Domsjoe Fabriker	Domsjoe Fabriker	Sweden
Honeywell UOP and Preem	Co-processing trial	Sweden

Company	Plant	Country
Preem	Preem HVO diesel and biojet	Sweden
Pyrocell (JV of Setra and Preem)	pyrolysis oil upgrading	Sweden
Sodra	Sodra biomethanol	Sweden
St1	Etanolix Gothenburg	Sweden
SunPine	SunPine HVO addition	Sweden
SunPine	SunPine HVO 100 mio liters	Sweden

Table 3.2. Advanced biofuel plants in Europe operational or planned [3], [6]

Project name	Project owner	Country	Production capacity	TRL	Technology	product	Start year
Waste to Methanol	JV controlled by ENI	Italy	300 t/d*	8	Fuel Synthesis	Biomethanol	2023
Clariant Romania	Clariant Romania	Romania	50 Kt/y	8	Fermentation	Bioethanol	2022
BioTfueL pilot	BioTfueL-consortium	France	60 t/y	4-5	Fuel Synthesis	FT liquids, SAF	2012
BioTfueL demo	Total	France	8,000 t/y	6-7	Fuel Synthesis	FT liquids, SAF	2021
Booster	TU Munich	Germany	0.15 MW	4-5	Torrefaction and HTC and Fuel Synthesis	SNG	
EMPYRO HengeloTwence	BTG-Bioliquids	Nether-land	24 kt/y	8	pyrolysis	Bio-oil	2015
Silva Green Fuels (SGF)	Statkraft & Södra	Norway	5 kl/d	4-5	Hydrothermal liquefaction	Bio-oil	2021
GFN Lieksa	GFN OY	Finland	24 kt/y	8	Fast pyrolisis	Bio-oil	
Pyrocel Gavle	Pyrocell	Sweden	24 kt/y	8	fast pyrolisis	Pyrolyis oil	2021
RenFuel Backhammer	RenFuel	Sweden		6-7	Transport fuel intermediates from thermolytic processes	bio-oil (3,200 t/y)	2016
To-Syn-Fuel	Fraunhofer UMSICHT	Germany	200 kl/y	4-5	Thermo-Catalytic Reforming TCR®	Bio-oil	2021
bioliquid project	Karlsruhe Institute of Technology (KIT)	Germany	608 t/y	8	Gasification and Fisher Thropsch	FT liquid	2021
BioMCN	BioMCN	Nether-land	200 Kt/y	8	Biogas steam reforming	Biomethanol	2010
Vaermlandsmetanol Hagfors	Vaermlandsmetanol	Sweden	92 Kt/y	8	HTW gasification and methanol synthesis	Biomethanol	2015
Sodra biomethanol	Sodra	Sweden	5.2 kt/y	8		Biomethanol	2020
Ecoplanta Molecular Recycling Solutions	Enerkem and Suez	Spain	220 kt/y	8	gasification	Biomethanol	2025
Cellulonix Pietarsaari	ST1	Finland	10 ML/y	8	fermentation	Bioethanol	2017
chempolis Oulu	Chempolis Ltd	Finland			fermentation	no	

Project name	Project owner	Country	Production capacity	TRL	Technology	product	Start year
ethanolix Ghotenburg	st1	Sweden	5 ML/y	4-5	fermentation	Bioethanol	2015
ArcelorMittal Ghent Steelanol	ArcelorMittal	Belgium	62 Kt/y	8	Fermentation	Bioethanol	

*t = tonne

As shown below, the share of renewable diesel in the total bio-derived diesel use in EU reached 23.2% in 2020, mainly deriving from UCO and other waste-based lipids. Advanced ethanol was at only 0.5%. For biofuel produced using feedstock listed in RED II Annex IX, Italy and Germany are the leaders in EU for the year 2020, Italy with 400 ktoe/yr leads Annex IX part A, and Germany with 600 ktoe/yr leads Annex IX part B (Figure 3.4 and Figure 3.5).

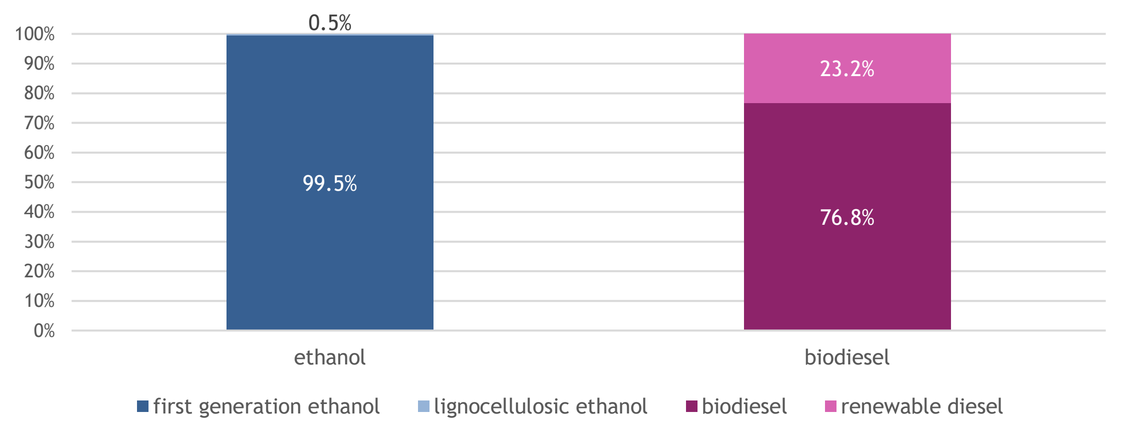
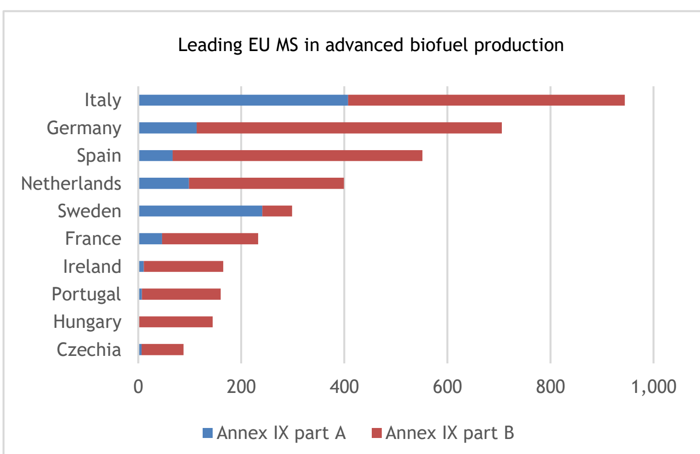


Figure 3.4. Share of advanced biofuels in biofuel use the EU in 2020 [2], [3]



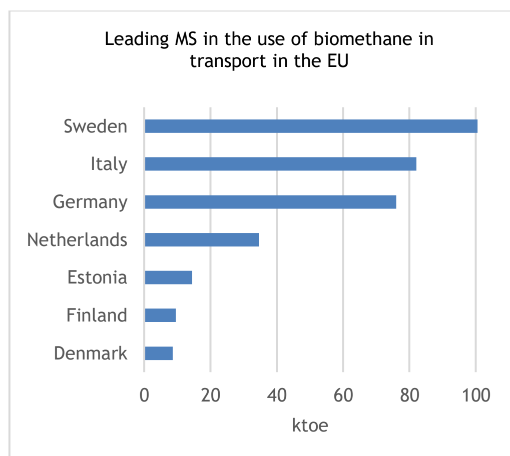


Figure 3.5. Leading EU MS in advanced biofuel production 2020 [2], [3]

3.2.2. EU biofuels consumption

The consumption data are given in tonnes of oil equivalent (toe): one toe corresponds to approximately 2,000 l of ethanol and 1,300 l of biodiesel [3]. The biofuel consumption in EU transport sector was 13 Mtoe in 2015 and increased to 16 Mtoe in 2020, with a biodiesel share of around 80% of biofuels used in transport (Figure 3.6). The use of biofuels produced from feedstock listed in Annex IX (Part A and B) is increasing in the last years and was just above 4 Mtoe in 2020 at around 25% of total biofuel consumption. Of this, 1.2 Mtoe (according to Eurostat database) were advanced biofuels (biofuels produced from feedstock listed in Annex IX Part A) (Figure 3.7). Germany was by far the main biofuel consumer in Europe in 2020, with almost 3.5 Mtoe, followed by France with more than 2.5 Mtoe consumed, while most of countries are still under 0.5 Mtoe (Figure 3.8).

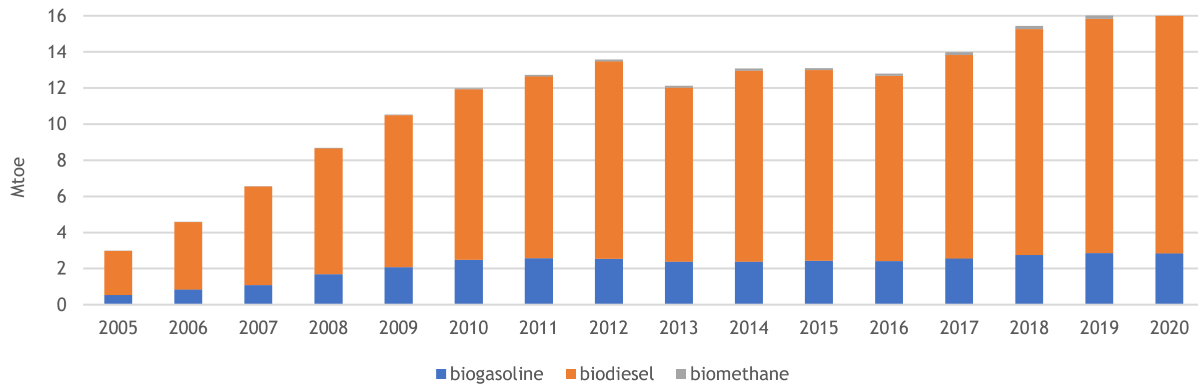


Figure 3.6. The evolution of the use of biofuels in transport in the EU [2]

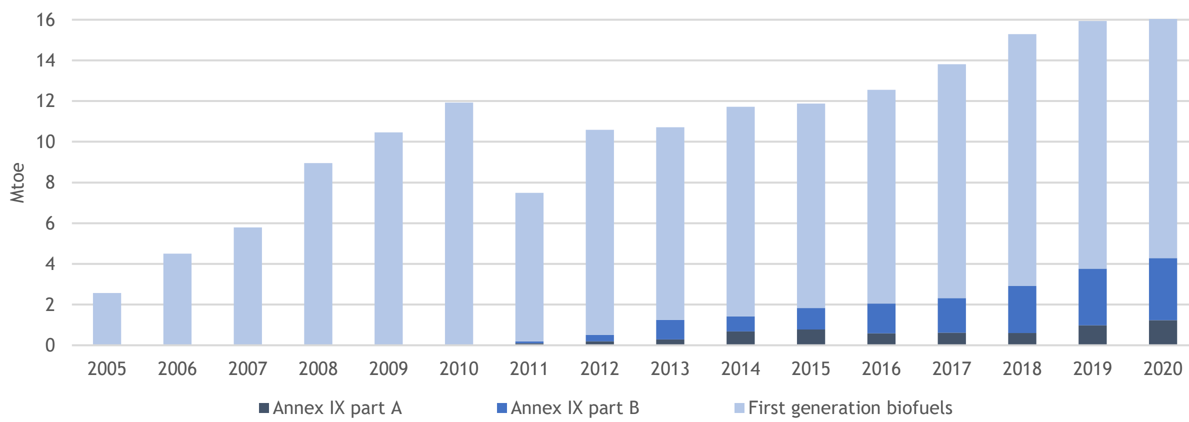


Figure 3.7. The evolution of the use of biofuel, including advanced biofuels in the EU [7]

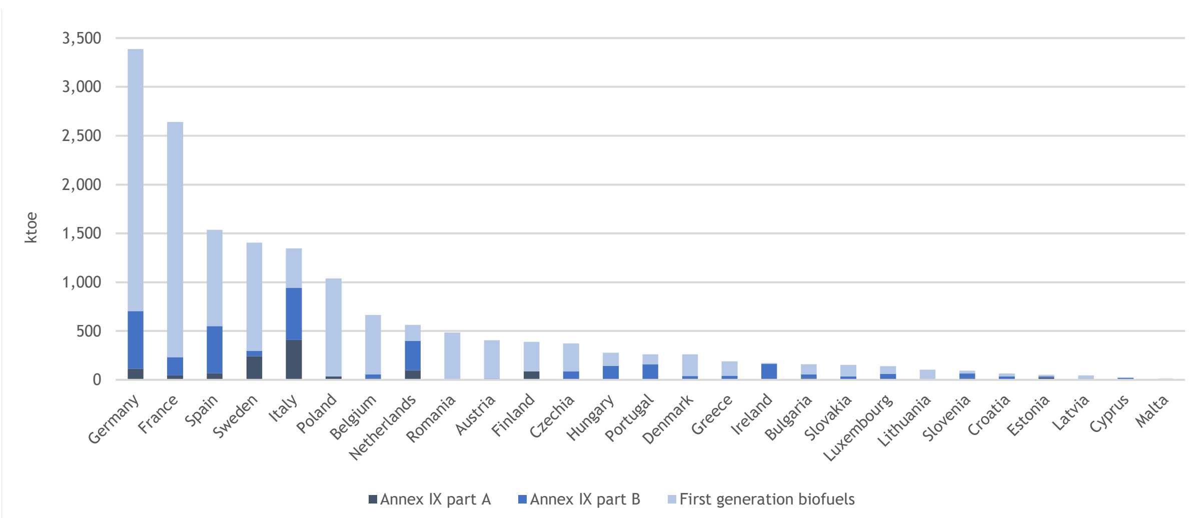


Figure 3.8. The use of biofuel, including advanced biofuels in MS of the EU [7]

Considering also the current use of renewable electricity within transport sector in EU, biodiesel still had a share of 73.8% in 2020 (Figure 3.9).

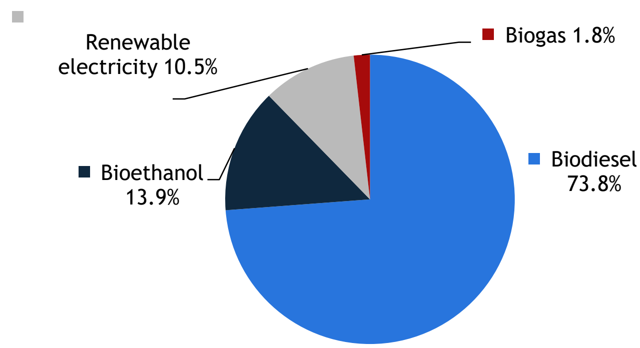


Figure 3.9. Distribution of renewable energy by fuel used in EU, 2020 [8]

3.2.3. Primary feedstock

This section provides info on the feedstock needed for the 1st generation biofuels (conventional or starch and oil-based biofuels). Considering the commercial biodiesel, globally, about 75% of FAME is based on vegetable oils (20% rapeseed oil, 25% soybean oil, and 30% palm oil) or UCOs (20%) [7]. Rapeseed oil is still the dominant biodiesel feedstock in the EU, accounting for 38% of total feedstock use in 2020 (Figure 3.10). The popularity of rapeseed oil is grounded on its domestic availability as well as in the higher winter stability of the resulting rapeseed methyl ester (RME) compared to other feedstocks. UCO was the second most important feedstock in 2020, accounting for 23% of the total feedstock. Palm oil was third in terms of feedstock source in 2020 (18%), mainly used in Spain, Italy, France, and the Netherlands, and to a much lesser extent in Belgium, Finland, Germany, and Portugal. Palm oil use will be affected by the phase-out of biofuels deriving from high-risk ILUC crops. Regarding ethanol, at world level, about 60% of ethanol is produced from maize, 25% from sugarcane, 3% from wheat, 2% from molasses and the residues from other grains, cassava or sugar beet. As for EU, the feedstocks used for bioethanol production are mainly sugar beets (38%), maize (36%), wheat (14%) and the rest from triticale, barley and rye (Figure 3.11). Advanced biofuels from cellulosic feedstock (e.g., crop residues, dedicated energy crops, or wood) account for a very small share of total biofuel production.

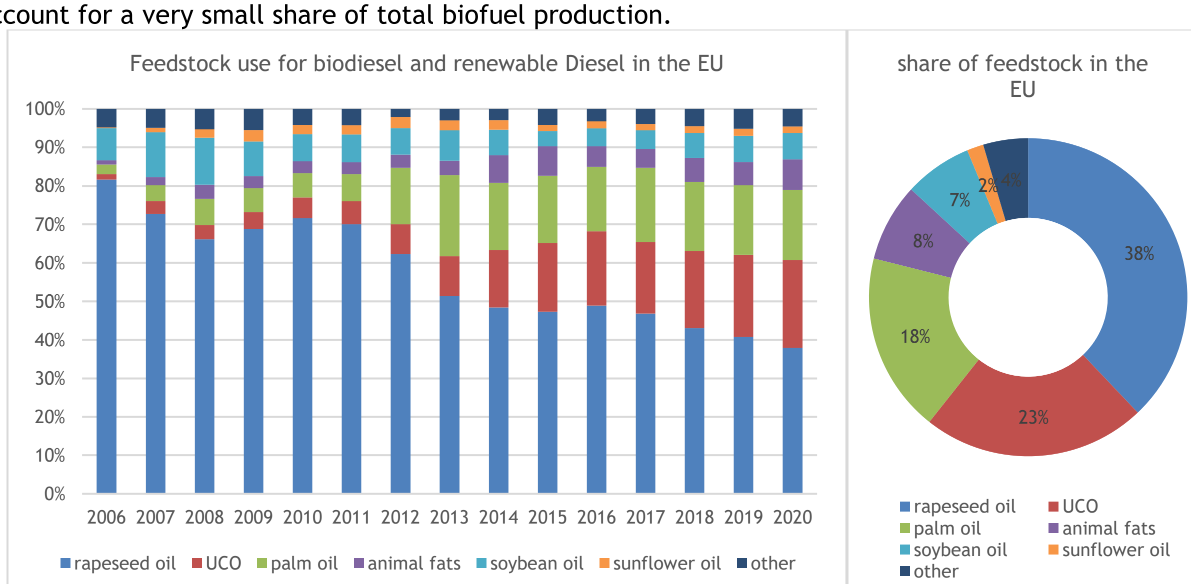


Figure 3.10. Feedstock use share, Biodiesel EU 2020 [2]

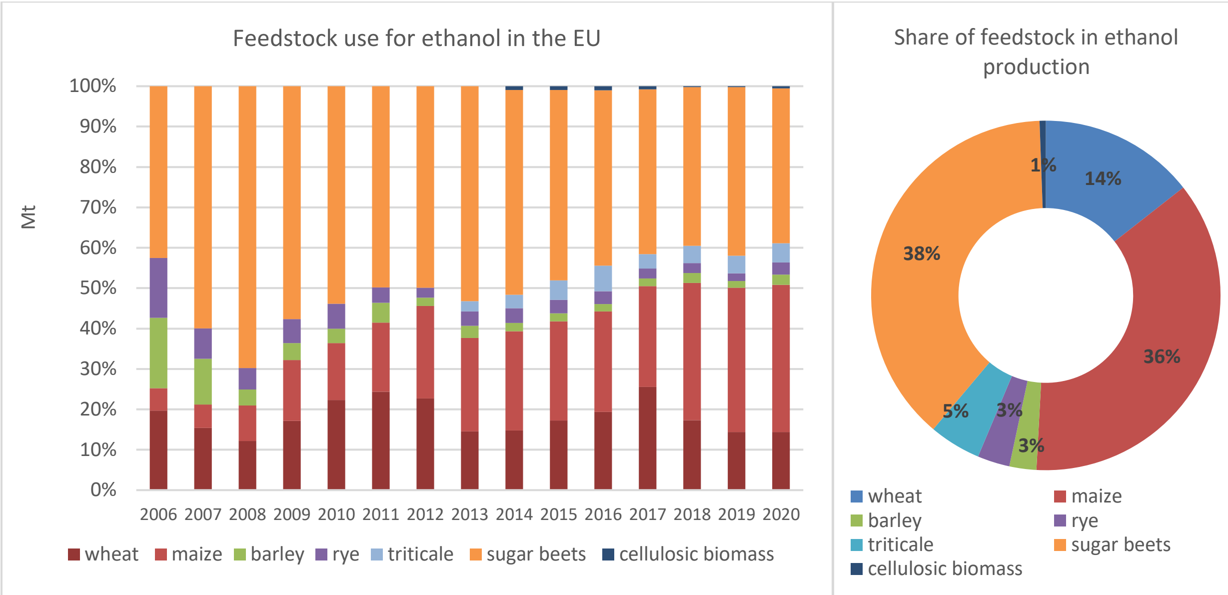


Figure 3.11. Feedstock use share, Ethanol EU 2020 [2]

3.3. Policies driving the production and use of biofuels in the EU

3.3.1. RED II, revision (Fit-for-55 package) and RePowerEU

The European Union (EU) has established a specific regulatory framework for the promotion of the production and use of renewable energy through the Renewable Energy Directive (EU) 2018/2001 (RED II) , which entered into force since 2018 and replaced the Renewable Energy Directive 2009/28/EC (RED) from 2009 [4]. RED II has set the objective to achieve a share of at least 32% of energy from renewable sources in the EU's gross final consumption of energy by 2030. Biofuels count towards the 32% renewable energy target and towards the transport target of minimum 14% of the energy used in the transport sector by 2030. The EU RED II encourages the deployment of advanced biofuels, by limiting the amount of biofuels produced from food and feed crops (starch-rich crops, sugar crops or oil crops) produced on agricultural land to max 7% of final consumption of energy in the road and rail transport sectors. This target for the transport sector includes a sub-target of 3.5% to from advanced biofuels that should increase from 0.2% in 2022 and 1% in 2025. Advanced biofuels are defined in RED II as biofuels that are produced from the feedstock listed in Part A of Annex IX. RED II includes a list of feedstocks in Annex IX Part A that can be used for the production of advanced biofuels. The biofuels produced from feedstocks listed in Part B of Annex IX (such as UCO and animal fats) are capped at 1.7% in 2030 in order to avoid distortive effects on markets for by-products, wastes or residues.

Fit-for-55 and the revision of RED II

In December 2019, the European Commission proposed the European Green Deal (EGD) [9] that set a vision of how to achieve sustainability and climate neutrality goals by 2050 to tackle climate and environmental challenges. Sustainable alternative transport fuels are an option to decarbonise the sectors in which electrification remains challenging. The European Climate Law set a legally binding target of net zero GHG emissions by 2050 of the European Green Deal and also set and the intermediate target of reducing net GHG emissions by at least 55% by 2030, compared to 1990 levels. As part of the EGD, on 14 July 2021 the EC adopted the 'Fit-for-55' package [10], which provided updates of the existing climate and energy legislation to meet the EU objective of a minimum 55% reduction in GHG emissions by 2030.

A key element of this Fit-for-55 framework is the revision of the Renewable Energy Directive (RED II) [4]. The proposal for the revision of RED II sets a minimum 40% renewable energy share in final energy consumption by 2030, accompanied by new sectoral targets. The proposal increased the ambition level for the use of renewable fuels and renewable electricity in transport and changed the approach toward reaching a GHG intensity reduction of at least 13% by 2030, compared to the baseline. The proposal also set new targets for the share of advanced biofuels and biogas produced from the feedstock listed in Part A of Annex IX to 2.2% in 2030 and added a target for the share of Renewable Fuels of Non-Biological Origin (RFNBO) is at least 2.6% in 2030. The proposal for revision of RED II removes the multipliers associated to certain renewable fuels and to renewable electricity used in transport.

REPowerEU plan

On May 2022, the Commission proposed in the REPowerEU plan [11] to further raise this RES target to a 45% share by 2030. REPowerEU is the action aiming at substituting fossil fuels and reducing the dependence on Russian fossil fuels and accelerating clean energy transition. The main focus is further deployment of renewables and promoting the renewable gases such as hydrogen and biomethane. After one year of discussions, the European Parliament adopted the regulation on 14 February 2023 and entered into force on the following day [12].

The purpose of REPowerEU is to strengthen the strategic autonomy of the EU by diversifying its energy supplies and ending its dependency on Russian fossil fuel imports. In practical terms, Member States will have to add a new REPowerEU chapter to their national recovery and resilience plans (RRPs) under the NextGenerationEU initiative [13], in order to finance key investments and reforms that will help achieve the REPowerEU objectives. REPowerEU aims at increasing the resilience, security, and sustainability of the EU's energy system through the decrease of fossil fuel dependence, diversification of energy supplies at EU level, including by increasing the uptake of renewables, energy efficiency and energy storage capacity. Biomethane and renewable hydrogen will be key to replace natural gas in industry and transport. REPowerEU has set a target of 10 Mt of domestic renewable hydrogen production and 10 Mt of renewable hydrogen imports by 2030, as well as a 35 bcm target of biomethane production by 2030.

Finally, advanced biofuels can also contribute to the targets imposed by the ReFuelEU Aviation [14] and FuelEU Maritime [15] initiatives. ReFuelEU Aviation aims at promoting SAF through a blending mandate for fossil suppliers to reach an increasingly high level of SAF into jet fuel (5% of by 2030 and 63% by 2050) and promoting the uptake of synthetic fuels (0.7% by 2030 and 28% by 2050). FuelEU Maritime Initiative sets a limit on the GHG content of the energy use in ships decreasing over time compared to the fleet average in 2020 reduced by 6% from 2030 and 75% from 2050. Biofuels, biogas, renewable fuels of non-biological origin and recycled carbon fuels are taken into account. Non-compliant new fuels and food/feed biofuels are considered to have the same emission factors as the least favorable fossil fuel pathway. These initiatives have been proposed by the European Commission as part of the "Fit-for-55" package to decarbonize the aviation and maritime sectors.

The legislative process continues at the moment of writing this report through the trialogue between the Council, the European Parliament and the European Commission. The most significant aspects to be agreed upon, and the different positions adopted by each party on the revision of the RED II, are summarised in Table 3.3.

Table 3.3. The most significant aspects to be agreed upon, and the different positions adopted by each party on the revision of the RED II [16]

Topic	European Commission proposal	EU parliamentary position	Council position
Binding EU-level target	45% of energy from renewable sources in the overall energy mix by 2030 (increased from 40% as part of the REPowerEU plan).	45% of energy from renewable sources in the overall energy mix by 2030.	40% of energy from renewable sources in the overall energy mix by 2030.

Topic	European Commission proposal	EU parliamentary position	Council position
Sub-targets for transport	13% reduction in CI of transport fuel by 2030.	16% reduction in CI of transport fuel by 2030 (gradually increased, starting from 6% in 2021).	Possibility for member states to choose between: 1. A binding target of 13% GHG intensity reduction in transport by 2030; or 2. A binding target of at least 29% renewable energy within the final consumption of energy in the transport sector by 2030.
Sub-target for advanced biofuels supplied to the transport sector	At least: 0.2% in 2022; 0.5% in 2025; and 2.2% in 2030.	At least: 0.2% in 2022; 1% in 2025; and 2.6% in 2030.	0.2% in 2022; 1% in 2025; and 4.4% in 2030, integrating the addition of a double counting for these fuels.
Sub-target for renewable fuels of non-biological origin in transport	At least 2.6% in 2030.	Agree with European Commission proposal.	Agree with European Commission proposal.
Hydrogen	50% of the hydrogen used in industry should come from renewable fuels of non-biological origin by 2030.	50% of the hydrogen used in the hard-to-abate high-temperature industry, aviation, and shipping sectors, where electrification is not a feasible solution, should come from renewable fuels of non-biological origin by 2030.	35% of the hydrogen used in industry should come from renewable fuels of non-biological origin by 2030 and 50% by 2035.

3.3.2. Sustainability criteria

Directive 2009/28/EC introduced a set of sustainability criteria for biofuels, including criteria protecting land with high biodiversity value and land with high-carbon stock. The RED II defined reinforced EU sustainability criteria for biofuels used in transport as well as for solid and gaseous biomass fuels for heat and power to deliver high GHG emission savings, do not cause deforestation or degradation of habitats or loss of biodiversity, while promoting efficient use and avoid unintended impacts on other uses.

Biofuels should not be produced from raw materials originating from high biodiversity land (primary forests; areas designated for nature protection or for the protection of rare and endangered ecosystems or species; and highly biodiverse grasslands; high carbon stock land (wetlands, continuously forested land or other forested areas); peatland (as of January 2008). A new sustainability criterion on forest biomass to ensure that it meets the following land-use, land-use change and forestry (LULUCF) criteria and that changes in carbon stock associated with biomass harvest are accounted towards the country's commitment to reduce or limit GHG emissions and that the LULUCF-sector emissions do not exceed removals. Biofuels, bioliquids and biomass fuels produced from waste and residues, other than agricultural, aquaculture, fisheries and forestry residues, are required to fulfil only the GHG emissions saving criteria. The REDII defines low ILUC-risk biofuels. The Delegated Regulation (EU) 2019/807 defines high ILUC-risk fuels and sets out criteria for the certification of low ILUC-risk fuels that should be exempt from the specific and gradually decreasing limit for food and fed based biofuels.

The EU sustainability criteria are extended to cover solid biomass and biogas: (i) plants with a total thermal input above 20 MW producing power, heating, cooling or fuels from solid biomass fuels; and (ii) plants with total thermal input capacity above 2 MW for installations using gaseous biomass fuels.
The proposal for the RED II revision includes further strengthening of the sustainability by applying the existing land criteria (e.g., no-go areas) for agricultural biomass also to forest biomass (including primary, highly diverse forests and peatlands) and further minimizing the negative impact of harvesting on soil quality and biodiversity. Those strengthened criteria are also applied to small-scale biomass-based heat and power installations above a total rated thermal capacity of 5 MW, while for power plants using gaseous biomass fuels with thermal input equal exceeding 2 MW. Sustainability criteria also apply to biomethane plants with a capacity above 200 Nm^3. The existing GHG saving thresholds for electricity, heating and cooling production from biomass fuels shall also apply to existing installations, not only new installations. Member States shall ensure that energy from biomass is produced in a way that minimizes undue distortive effects on the biomass raw material market and harmful impacts on biodiversity. The European Commission shall adopt a delegated act on how to apply the cascading principle for biomass, in particular on how to minimize the use of quality roundwood for energy production, with a focus on support schemes. When developing support schemes for bioenergy, Member States should take into consideration the available sustainable biomass for all uses, the conservation of the forest carbon sinks as well as the principles of the biomass cascading use and the waste hierarchy established in Directive 2008/98/EC.

Apart replacing the 14% target for renewable energy in transport (as set by RED with the 13% GHG intensity reduction target for 2030, the updated target for advanced biofuels also excludes the use of multipliers and ensures high volumes of renewable fuels replacing fossil fuels. The only multiplier maintained of 1.2x apply to advanced biofuels and Renewable Fuel Non-Biological Origin (RFNBOs) used in aviation and maritime sectors. Moreover, the contribution of biofuels produced from the feedstocks defined in Annex IX, part B, including UCO and category 1 and 2 animal fats, is limited to 1.7%, with an option for Member States to request higher caps depending on national feedstock availability.

3.3.3. GHG emissions calculation methodology for biofuels

In the European Union, the methodology for calculating GHG emissions (CO2, N2O and CH4) from biofuels is set out in the RED II [4] and establishes the rules for calculating the entire life cycle emissions of biofuel, from the production, transportation, and use. The emissions should include emissions from the extraction or cultivation of raw materials, from land use change, emissions from processing, emissions from transport and distribution and from the fuel in use. The calculation also includes emission savings from soil carbon accumulation via improved agricultural management, from carbon capture and storage and carbon capture and replacement. The GHG emission savings from the use of biofuels are calculated, according to the RED II, by using the pre-calculated default values reporting the CI of some biofuels and bioenergy pathways. Carbon intensities and savings can be also calculated by using a combination of actual values and disaggregated default values, calculated in accordance with the RED II methodology (reported on Annex V & VI). The emissions from the biofuel in use (combustion) are considered to be zero for biofuels, due to the biogenic origin of the fuels. The methodology takes into account all other CO2eq emissions as CH4 (e.g., from biogas fugitive emissions) and N2O (e.g., from fertilizers), and the accounting system considers how much emissions are saved by using biofuels instead of fossil fuels. Emissions from the manufacture of machinery and equipment are not be taken into account. The GHG emissions savings are calculated by comparing them to the CI of a reference fossil fuel set at 94 gCO2eq/MJ and are required to pass a GHG reduction threshold to be considered eligible: these requirements are 50-65% for biofuels, depending on the date of facility construction and 70% for RFNBOs and Recycled Carbon Fuels (RCFs). In order to certify their products, fuel suppliers can use voluntary schemes and national certification schemes available for EU countries [17], which help to ensure that biofuels, bioliquids and biomass fuels are sustainably produced by providing evidence of compliance with the EU sustainability and GHG emissions saving criteria.

3.3.4. Advanced biofuels requirements and ILUC

While biofuels are important in helping the EU meet its GHG reduction targets, the production of conventional biofuels comes from croplands that are also used (or also were previously used) for feed and food production. An increase in the demand of crops for biofuel production impacts on the other markets through price-mechanisms which both raise yields and extension of the crop area in response to the increased demand for feedstock.

The increased demand for biofuel can be fulfilled partly by the increase of crop area through the expansion of agricultural land into non-crop land, possibly into areas with high carbon stock, such as forests, wetlands and peatlands. This process is known as indirect land use change (ILUC). To address the issue, high ILUC-risk biofuels have been limited at 2019 levels, and then gradually reduced to zero by 2030 at the latest. The European Commission published in 2019 a report on the status of production expansion of relevant food and feed crops worldwide [18] to support this initiative. The Delegated Regulation on indirect land-use change [19] set down provisions to determine the high ILUC-risk feedstock for which a significant expansion of the production area into land with high carbon stock is observed. It also set out criteria to certify low ILUC-risk biofuels, bioliquids and biomass fuels. Furthermore, specific rules and methodological guidance for certification of low ILUC-risk biofuels, bioliquids and biomass fuels have been included in the Implementing Regulation on sustainability certification proposed by the Commission in line with Article 30(8) of the RED II, and entered into force on 14th June 2022 [20]. For other specific rules for certain feedstocks and their potential effect on deforestation, it is worth mentioning also the regulation on deforestation-free production [21], approved in December 2022, which set out rules to tackle deforestation and forest degradation linked to specific commodities and products placed on or exported from EU markets. This results of significant importance since most of the feedstock for bioenergy is recovered from wood processing for the production of materials.

In order to translate part of these policies into practical information for the operators producing advanced biofuels, in December 2022 the Commission released the draft Delegated Directive for the amending Annex IX (RED II) list for eligible feedstocks [22]. This list is subject to periodic review by the European Commission, following an analysis of the potential feedstock which consider the principles of the circular economy and of the waste hierarchy for avoiding significant distortive effects on markets, negative impacts on the environment and biodiversity and avoiding creating an additional demand for land. Final adoption of the revised list is highly likely to be done during the first half of 2023, followed by an 18-month transposition period for Member States. This document introduced additional sustainable feedstocks and moved some categories from list A to list B as it follows.

- in Part A, the following feedstocks are added: “(r) Alcoholic distillery residues and wastes (fusel oils) not fit for use in the food or feed chain; (s) Raw methanol from kraft pulping stemming from the production of wood pulp; (t) Non-food crops grown on severely degraded land, not suitable for food and feed crops”.

- in Part B, the following feedstocks are added: “ (c) Bakery and confectionary residues and waste not fit for use in the food and feed chain; (d) Drink production residues and waste not fit for use in the food and feed chain; (e) Fruit and vegetable residues and waste not fit for use in the food and feed chain, excluding tails, leaves, stalks and husks; (f) Starchy effluents with less than 20% starch content not fit for use in the food and feed chain; (g) Brewers’ Spent Grain not fit for use in the food and feed chain; (h) Liquid whey permeate; (i) Deoiled olive pomace; (j) Damaged crops that are not fit for use in the food or feed chain, excluding substances that have been intentionally modified or contaminated in order to meet this definition; (k) Municipal wastewater and derivatives other than sewage sludge; (l) Brown grease; (m) Cyanobacteria; (n) Vinasse excluding thin stillage and sugar beet vinasse; (o) Dextrose ultrafiltration retentate from sugar refining; (p) Intermediate crops, such as catch crops and cover crops that are grown in areas where due to a short vegetation period the production of food and feed crops is limited to one harvest and provided their use does not trigger demand for additional land and provided the soil organic matter content is maintained."

3.3.5. Non-biological fuels and co-processing

Within the RED II, also non-biological fuels (the so-called renewable fuels of non-biological origin) are included within the renewable energy targets, and the rules to determine their use have been set out in specific delegated regulations. Such fuels must be produced with renewable energy (other than biomass). On 7th February 2023 the EC proposed two Delegated Acts related to the promotion of Recycled Carbon Fuels (RCF) and Renewable Fuels of Non-Biological Origin (RFNBO).

The first Delegated Act [23] defines when hydrogen, hydrogen-based fuels or other energy carriers can be considered as a renewable fuel of non-biological origin. The rules are to ensure that these fuels can only be produced from "additional" renewable electricity generated at the same time and in the same area as their own production.

The second Delegated Act [24] sets the methodology to calculate GHG emissions savings from RFNBOs and RCF (fuels produced from non-recyclable waste of non-renewable origin or from waste processing gas and exhaust gas of non-renewable origin). The methodology takes into account the full lifecycle of the fuels to calculate the emissions and the associated savings. It also establishes that the GHG emissions savings from the use of recycled carbon fuels shall be at least 70%, compared to the fuels they are replacing.

Even if not directly linked to EU biofuels targets, these pieces of regulation may also support the market uptake of some advanced biofuels value chain adopting hydrogen as input or reagent for biofuels production (e.g., HVO, FT-fuels and bio-synthetic methane).

During 2023, the EC will also release the methodology for calculating the share of renewables in the case of co-processing in the form of a delegated regulation [25], which aims to establish the share of biofuel and biogas for transport resulting from biomass being processed with fossil fuels in the oil refineries. Following a consultation held in mid-2022, the European Commission is set to adopt a final delegated act on the EU approach to co-processing possibly during Q1 2023. Taking into consideration the final draft shared, a 14C radiocarbon testing could be the cornerstone of the system, ensuring that only the biogenic fraction of feedstocks processed in refineries are taken into consideration for the purposes of counting toward the different renewable energy targets.

3.3.6. Implementation in the Member States

While the implementation of the RED II into the EU Member States (MSs) national legislation has been already completed within June 2021, the implementation of the Fit-for-55 package will require further actions and cooperation at MS level to update the previous targets. Each Member State will need to develop and implement its own national plans and policies to achieve the required emissions reductions and meet the package's targets. The Commission has proposed a new governance framework to ensure that Member States work together and share best practices, and to monitor and assess progress towards the package's targets. Under the proposed governance framework, each Member State will be required to develop and submit a national energy and climate plan (NECP) [26] outlining its policies and measures to achieve the package's targets. The plans will be subject to review by the Commission and Member States will be required to report regularly on their progress towards meeting their targets.

3.3.7. EU Methane Strategy and the role of biomethane

On December 15th, 2021, the European Commission tabled a proposed regulation targeting methane emissions in the energy sector named EU Methane Strategy [27], which sets the framework to mitigate CH4 emissions in all sectors, especially agriculture, energy and waste. The initiative targets to improve information for all energy-related methane emissions and to mitigate such emissions with specific interventions and is complementary to other initiatives targeting the penetration of renewable and low-carbon gases to replace natural gas [28]. Few months later, the EC released a complementary communication for hydrogen and biomethane implementing a specific roadmap for a short-term market uptake [29].

Introducing the EU Methane Strategy [30] on the Governance of the Energy Union (which was part of the EU Clean Energy Package adopted in 2019), the European Commission introduced the EU Strategic plan for methane (art. 16). This strategic plan is an integral part of the EU long-term strategy aiming to reach climate-neutrality by 2050 [31], the Fit-for-55 package and the RePowerEU, which set a target of 35 bcm of biomethane to replace the Russian natural gas.

To promote biomethane market uptake, one of the key proposed actions is the creation of a biogas and biomethane industrial partnership at EU level to promote the sustainable production and use of biomethane. So, the Biomethane Industrial Partnership (BIP) was launched on 28 September 2022 with the objective to support the achievement of 35 bcm target of annual production and use of sustainable biomethane by 2030, and to create the preconditions for a further ramp-up of its potential towards 2050 [32]. The BIP will promote participatory multi-stakeholder engagement between the Commission, EU countries, industry representatives, feedstock producers, academia and NGOs.

The European Parliament adopted its position on the Gas Decarbonisation Package [33] on 9th February 2023, that implemented the biomethane binding target of 35 bcm target into the regulation. The Package also included the requirement for Member States to set-up national biomethane strategies and to ensure regional mapping of highest production potential areas. This mapping exercise should inform the national strategies and the network planning carried out by the grid operators. National biomethane strategies shall provide a long-term perspective for the biomethane sector and guidance for investors.

3.3.8. EU rules on certifying carbon removals

The European Commission adopted on 30th November 2022, a proposal for the first EU-wide voluntary framework to certify high-quality carbon removals, carbon farming activities that enhance carbon storage, carbon storage in products in long-lasting products or materials; [34]. The proposal aims to boost innovative carbon removal technologies and sustainable carbon farming solutions and contribute to the EU's climate, environmental and zero-pollution goals. It shall significantly improve, in particular, the EU's capacity to quantify, monitor, and verify carbon removals. For this purpose, the European Commission will develop specific certification methods for carbon removal activities for a proper quantification of carbon removals, guaranteeing the long-term storage and ensuring that only sustainable removals are certified.

The proposed certification framework is linked also to biofuels technologies, since an option to mitigate GHG emissions include also Bioenergy with Carbon Capture and Storage (BECCS), the potential use of biochar (still under evaluation), Direct Air Capture and Storage (DACCS), etc. This scheme shall be also in line with the rules set out in the Commission Implementing Regulation (EU) 2018/206613 [35] on the monitoring and reporting of GHG emissions under the ETS [36] and the detailed EU methodologies developed by the Commission for the quantification of GHG emission avoidance of BECCS and DACCS projects under the Innovation Fund [37]. The Commission will develop tailored certification methodologies for the different types of carbon removal activities supported by an expert group.

3.4. Advances and challenges in biofuels technologies

According to the EU's regulatory framework, technological and market research in Europe is largely focused on 'advanced' biofuels from non-food or feed feedstocks, while 'traditional' biofuels cover the largest demand even if they are limited by the cap previously described. In order to address the complexity and multi-faced character of the transition to a climate-neutral society in Europe, the EC lunched an initiative to monitor advanced energy technologies named Clean Energy Technology Observatory (CETO). This is a joint initiative between the Joint Research Centre (JRC), implementing the Observatory and DGs Research and Innovation (R&I) and Energy (ENER) on the policy side. Starting from

2022, CETO monitors the EU research and innovation activities on the clean energy technologies, including advanced biofuels [3].

3.4.1. Status of the technologies

While 'traditional' biofuels technologies easily convert vegetable oils or sugars into biodiesel or bioethanol, advanced (second generation) technologies entail high complexity and require further development for converting lignocellulosic material or wastes into drop-in biofuels. In EU, several biofuel technologies for advanced biofuels are at high TRL such as HVO and co-processing, which can cover large fuels demand. Other technologies such as biomass FT-gasification and lignocellulosic ethanol are promising technologies. Main limitations for advanced biofuel production include the need to demonstration in commercial operation, complex logistics, undeveloped non-food biomass value chains and short-term policies on biomass sustainability. Feedstock availability might also be an issue, being limited to the list of feedstocks defined in the RED II Annex IX, as well as the hydrogen supply. The EU is world leader in advanced biofuels demo and first of a kind plants, with several demo plants been built, even if overall production capacity is still marginal (see 3.2.1). New technologies are ready to exploit the potential of those waste and residues feedstocks, even if commercial pathways do exist (e.g., anaerobic digestion to biomethane, hydrogenated vegetable oil, lignocellulosic ethanol production), but without significant production (currently 1.2 Mtoe) and with limited planned production (1.85 Mt/yr).

Considering the recent REPowerEU target, the biomethane production is expected to rapidly grow in the coming years: the European biogas production has increased 6 folds from 2005 to 2020, and today it is expected an important shift from biogas to biomethane production. Currently the production of biomethane is still low (3 bcm or 32 TWh) compared the overall biogas supply (18 bcm). However, it has been recently estimated that the potential biogas and biomethane production by 2030 is between 35 and 42 bcm (according to EBA [38]). It will be fundamental to consider sustainable biomass (i.e. the feedstocks reported in the RED II Annex IX) to cover this demand, mostly industrial and agro-residues, and bio-wastes [39].

As regards other pathways, a variety of innovative technologies such as biomass gasification to Fischer-Tropsch synthetic fuels and bio-methanol production, which have been demonstrated at industrial scale, are ready to take-off and some next generation technologies are making progress. Moreover, innovative technologies as solar fuels, novel thermochemical processes, microbial fuels and micro-algae derived-fuels are mostly at lab-scale yet.

The main challenges for the market uptake of advanced biofuels are their lack of cost competitiveness with existing conventional biofuels derived from food crops and fossil fuels (estimated at 1.5 to 3 times the market price), high capital expenditures and the availability of sustainable biomass feedstock. There is a significant potential of 25-40% for cost reduction through R&I, and 50% further reduction by large scale deployment and co-processing in existing plants.

3.4.2. Fundings

In EU, different funding programs are available, ranging from low TRL research projects to large-scale commercial (high TRL) plants. European funding for research and demonstration, i.e., the Horizon 2020' program (and thereafter Horizon Europe), has been quite stable over the last years. Figure 3.12 shows that approximately 5 projects have been funded on average each year since 2015 (with data for 2022 not available at the time of writing).

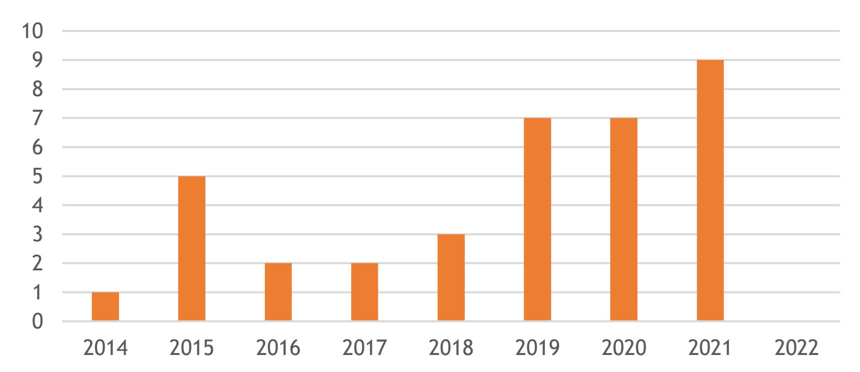


Figure 3.12. Number of H2020 projects on advanced biofuels (JRC elaboration based on JRC TIM, Cordis database [3])

Typically, an H2020 project is coordinated by one institution, but having inside the project consortium of even more than 20 partners from various Member States and countries participating in the Horizon 2020 program. As shown in Figure 3.13, the countries with the highest number of projects are those where biofuel production is strong: Germany, UK, Netherlands, Italy and Spain. But also, Finland, France, Belgium, Sweden and Austria are notably participating in projects, also due to their feedstock availability or history of biofuels production.

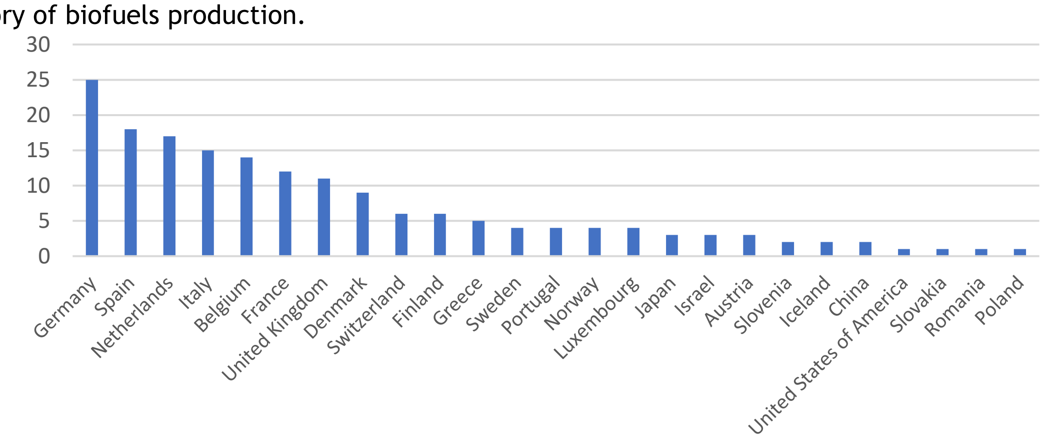


Figure 3.13. Number of H2020 projects on advanced biofuels per country (JRC elaboration based on JRC TIM, Cordis database [3])

The amount of funding received follows a similar pattern (Figure 3.14), even if some countries like Netherlands, France, Sweden and Romania received higher funding amounts per project than the average.

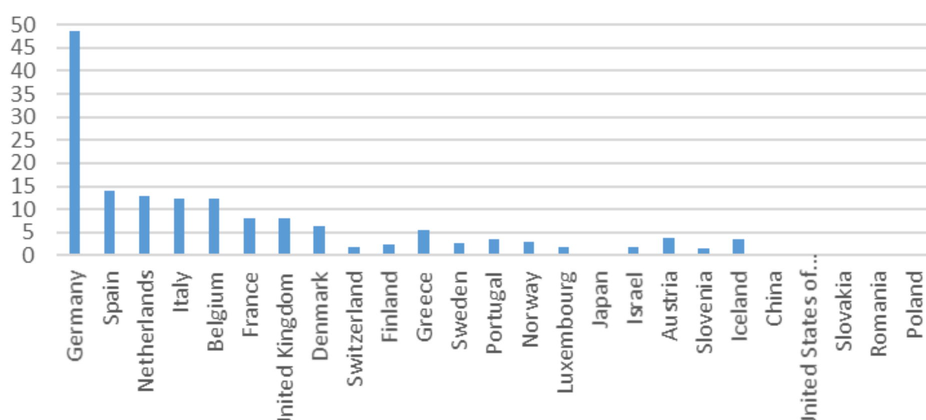


Figure 3.14. Total EU contribution to H2020 advanced biofuels projects (Million Euros) (JRC elaboration based on JRC TIM, Cordis database [3])

The projects cover most of the described technologies, with a focus on gasification and fuel synthesis, but also including biogas, pyrolysis, fermentation and hydrothermal liquefaction. The whole value chain is represented, from feedstocks like algae, oil plants and biomass from degraded land, over pre-treatment and intermediate bioenergy carrier production to liquid fuel synthesis as well as upgrading to road, maritime and aviation fuels.

The funding program available from the credit recovered by the Emission Trading System (ETS) is named "Innovation Fund" [37] supports the commercial demonstration and deployment of innovative low-carbon technologies, encompassing biofuel refineries under its energy-intensive industries focus. Across the 2020/21, small- and large-scale calls, the Innovation Fund has selected three projects for support (BECCS Stockholm, FirstBio2Shipping and Waga 4 World) with a contribution of EUR 133 million. Later new calls (now it has been just passed the 3rd round of calls) came out, and new projects are being funded.
As regards private R&I, biofuels funding in EU was on average EUR 250 million per year in the period 2010-2021, dominated by the US and Canada, with an EU share of only 6% in the last five years. However, the EU is leading with twice more high-value patents than the US.

3.4.3. Market analysis

Biofuel market analysis has been carried out in the CETO report [3] as well as in the EC report on Progresses on competitiveness of clean energy technologies [40]. EU shares roughly 7% of the global biofuel market worth EUR 100 billion in 2020, mostly generated from first generation biodiesel. In 2018 the turnover reached a peak at EUR 14.4 billion mostly generated in France, Germany and Spain. Beyond a EUR 2.3 billion direct contribution impact to the EU GDP, 250,000 direct and indirect jobs were created along the value chain. The EU shares 29% of innovation companies, while the US and Japan have the most. The sector of advanced biofuels is just emerging, the number of commercial plants is still quite low, and international trade is very limited. The EU is the world leader with 19 out of 24 operational, commercial plants of advanced biofuels, with Sweden and Finland having the highest number, i.e. 12 (example plants are taken from the IEA task 39 database [6]).

International trade concerns all biofuels and is nearly inexistent for advanced biofuels. EU biofuel imports have constantly increased since 2014, with a trade deficit above EUR 2 billion in 2021, mainly due to imports from Argentina, China and Malaysia. The Netherlands and Germany are the biggest EU and global biofuel exporters.

3.5. Conclusions

After the Covid-19 pandemic, the production of biofuels in EU-27 has been quite stable in 2020, accounting 18.5 Mtoe, which accounted for 5.5% of the total energy consumption in transport in the EU. The new policy mechanisms, considering both GHG emissions reduction and food security (so promoting biofuels production with non-food crops and wastes/residues) is promoting the production of advanced biofuels (with a current production of 1.2 Mtoe, with limited additional planned production up to 1.85 Mt/yr), which today is mostly based on "stand-alone" plants (e.g., HVO, second generation ethanol, biomethane…). Co-processed fuels, recycled carbon fuels and renewable fuels on non-biological origin are also fundamental to achieve the RED II targets, and the recently published or coming delegated acts will ensure their rules for a sustainable production. In 2021, the Fit-for-55 package updated the RED II targets, introducing a new GHG emission-based reduction target using RES, which replaced the former energy-based target in RED II. This Fit-for-55 package also introduced specific targets for non-biological fuels, aviation and maritime biofuels. On May 2022, the EC proposed in the REPowerEU plan to further raise the RES to 45% by 2030. REPowerEU is the action to decrease the EU dependence on the Russian fossil fuels by fast forwarding the clean transition and promotes the use of renewable energy and renewable gases as hydrogen and biomethane. Specifically, a target was introduced for biomethane production at 35 bcm by 2030, so it is of fundamental importance to ramp up its production on short-term, both installing new plants and retrofitting existing CHP-based biogas plant to biomethane production.

Public funding is provided especially through Horizon Europe programme for research and innovation (previously (Horizon 2020) and Innovation Fund programme for the demonstration of innovative low-carbon technologies that contribute to GHG emission reduction to support research and demo activities through specific calls on various sectors of interest. The EU share of worldwide private R&I on biofuels represents only 6% in the last five years in comparison to worldwide private R&I biofuels funding of EUR 250 million on average per year in the period 2010-2021, dominated by the US and Canada. The market analysis showed that EU share represents roughly 7% of the global biofuel market worth EUR 100 billion in 2020, mostly from first generation biodiesel market. In 2018 the turnover reached a peak at EUR 14.4 billion mostly generated in France, Germany and Spain. Apart from a EUR 2.3 billion direct contribution impact to the EU GDP, about 250,000 direct and indirect jobs were created along the value chain. The EU shares 29% of innovation companies, while the US and Japan have the most.

In conclusion, despite the fact that the installed and planned production capacity of advanced biofuels is very low compared to total fuel use, and the potential of advanced biofuels from sustainable feedstock in the EU is limited, they can contribute to the Fit-for-55 GHG emission savings targets, covering sufficiently any delay in transport electrification. A wide potential of sustainable feedstock may come from non-food crops cultivated in degraded lands, developing new value chains producing fuels in rural and remote areas with a high GHG emission reduction potential. Advanced biofuels are mostly drop-in fuels that can use existing fuel infrastructure (supple, transport and distribution and use) with little or no additional investments needed. In order to fully realize such supply chains to cover a significant part of the transport fuel demand, certain technical and economic risks must still be overcome: support for CAPEX, support to develop solid value chains for biomass supply and increase conversion technologies reliability. Since EU is the clear market leader in operational, commercial plants of advanced biofuels and high-value innovations, the next decisions and the available funding will play a crucial role in defining the 2030 scenario.

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4. Germany

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4.1. Summary

- Currently, GHG reduction in the German transport sector is mainly achieved by using biofuels. The amount of renewables used in transport was about 8% in 2021, of which 89% were biofuels.
- The European Renewable Energy Directive (REDII) was implemented in Germany by means of continuing the instrument of the GHG reduction quota. This quota instrument has been in place since 2015. From 2022 onwards, an increase from 7% to 25% by 2030 will be realized by different fulfillment options. These include, electromobility and e-fuels (especially "green" hydrogen and SAF). Advanced biofuels will be promoted by different minimum quotas and/or multi-counting. Maximum quotas are likely for conventional biofuels from crops that can also be used for food and fodder as well as biofuels based on UCO and animal fats.
- Since 2018 there has been no tax cut for pure biofuels in road transport except for biomethane. However, additional climate-related CO2 taxation has been established via the Fuel Emissions Trading Act. Driven by the GHG reduction quota and the associated trading system, there are indirect incentives for fulfillment options with minimum quotas and multi-counting. This is also true for advanced biofuels.
- There are various funding programs for R,D&D which emphasize advanced biofuels and e-fuels along the whole value chains. This aims to promote Germany's role as a technology developer and an integrator of renewable fuels into the whole energy transition.

4.2. Introduction

The 2020s are considered to be a crucial decade for reaching the targets of the Paris Climate Agreement. The global GHG budget for meeting the 1.5 °C target is rapidly dwindling. Depending on the effectiveness of the measures implemented to reduce GHG emissions, the window of opportunity is just a few years. All the while, the effects of climate change are becoming increasingly visible. When taking stock of what Germany has achieved so far in terms of climate protection in the transport sector, which it has been pursuing since the early 2000s with targets and measures like significant reduction of final energy consumption supported by renewable energies, alternative drive systems and modal shift, the status quo is sobering. There are around 60 million vehicles in use today. This represents an increase of 20% compared to 2010. The number of buses, rail vehicles and inland waterway vessels in use is stagnating or declining in some cases. The number of alternative drive systems is still low (1 million electric vehicles, 0.9 million plug-in hybrids and 0.4 million gas vehicles) (KBA, 2023). Even in the second COVID-19 year, 2021, final energy consumption was still high at around 2,350 PJ – this corresponded to 27% of the total primary energy supply of Germany with 8,667 PJ. The share of renewable energy is still low (147 PJ) (now-gmbh, 2023), mainly contributed by biofuels used in road transport and renewable electricity in rail transport. It is therefore not surprising that the country's sector specific GHG targets have not been met in recent years (Umweltbundesamt, 2023). While GHG emissions in all sectors have decreased by 40% from 1,251 to 746 MMT (metric million tonnes) CO2eq since 1990, the transport sector shows only a marginal COVID-19 related decrease of 9% from 163 to 148 MMT in 2022.

Against this background, and prompted by various debates (e.g., on banning internal combustion engines), it is surprising that there is still a serious discussion in Germany about the importance of electromobility for achieving climate targets. A paradigm shift towards electromobility based on renewable energies, complemented by renewable fuels such as hydrogen, e-fuels, advanced biofuels and some "conventional" biofuels, is still not in sight, even with the support of the current German government.

4.3. Main drivers for biofuels policy

Following the Paris Agreement, the primary driver is to fight climate change by focusing on low-carbon technologies, CO_2 use and efficient renewable products from biomass and electricity. GHG savings are the primary driver for implementing German biofuel policies, and for that reason, the national transposition of the European Renewable Energy Directive (RED II) 2018/2001 "*Directive on the Promotion of the Use of Energy from Renewable Sources*" realized as GHG reduction quota is the most relevant instrument added by CO_2 tax related instrument Fuel Emissions Trading Act (BEHG, Bundesemissionshandelsgesetz).

4.4. Transport biofuels policy

A comprehensive overview of the current political and regulatory framework for renewable fuels in Germany can be found in the DBFZ report "Monitoring Renewable Energies in Transport", Section 1. The issues presented below are a condensed summary of this section, with some recent updates updates. A graphical overview is given in Figure 4.1.

4.4.1. Legal framework for fuels from renewable sources

For more details of the legal framework set by the European Commission please refer to the respective chapter in this report. In the following, primarily the most important framework for renewable fuels based on biomass in Germany is considered.

Since 2019, the **Federal Climate Change Act** (KSG, Bundes-Klimaschutzgesetz) has formed the primary legal basis for Germany's measures for implementing the Paris Climate Agreement. The Federal Government amended the act on May 12, 2021 in light of the new European climate target for 2030 and as a result of a decision by the Federal Constitutional Court of April 29, 2021, which calls for a binding pathway to climate neutrality. This results in a target for reducing annual GHG emissions by at least 65% over 1990 levels by 2030. In addition to this overall target, specific targets have been set for individual sectors in the form of emission limits. The annual reduction targets per sector for the years 2031 to 2040 are to be determined in 2024 and the annual reduction targets for the years 2041 to 2045 (2034 per sector) are to be in place no later than 2032. Germany is then expected to achieve GHG neutrality by 2045. For the domestic transport sector, the 2030 emissions cap means that emissions will have to be reduced from 164 million tonnes (Mt) of CO2eq in 2019 to 85 Mt in the intervening years. The Climate Change Act provides a framework and acts as a control mechanism for future statutory regulations and ordinances, which have a much greater binding force than the previous provisions.

The requirements of the Renewable Energy Directive for the transport sector are transposed in Germany by Article 37a–h of the **Federal Immission Control Act** (BImSchG, Bundesimmissionsschutzgesetz) and the **lower ordinances for the implementation of the Federal Immission Control Act** (36^{th}, 37^{th}, and 38^{th} BImSchV). Table 4.1 provides an overview of the GHG reduction commitments contained therein for fuels for the years 2010 to 2030. As in the RED II, there is a sub-quota for advanced biofuels from biogenic raw materials or feedstocks defined for this purpose, in addition to the overarching target. Furthermore, a binding sub-quota will be defined for aviation starting in 2026. The fulfilment of the specified quotas is linked to further framework conditions in terms of the limiting or multiple counting of individual options. These are summarized in Table 4.2.

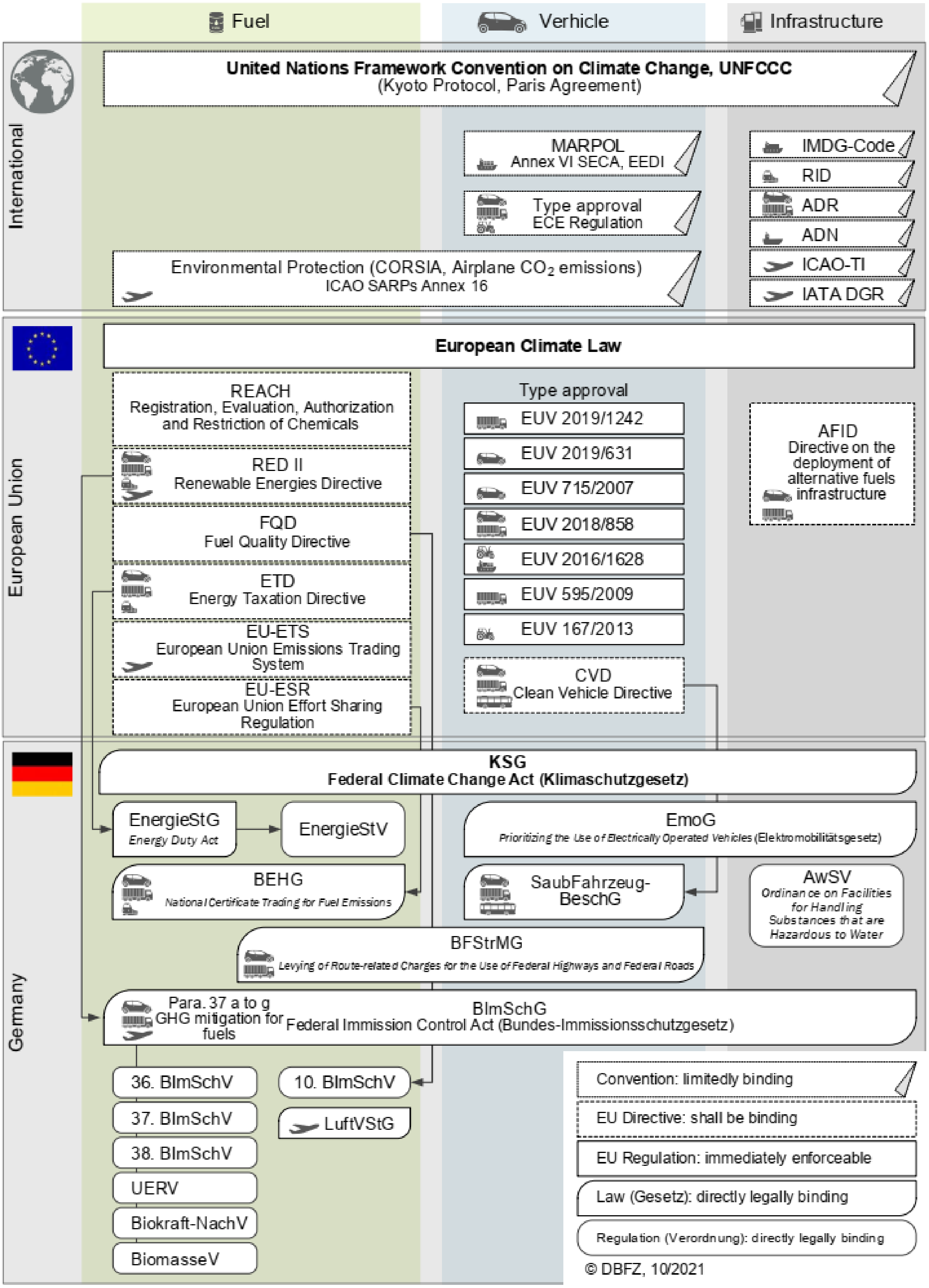

Figure 4.1. Overview of the existing regulatory framework in the transport sector

Table 4.1. Biofuel mandates in Germany

Year	Fuel quota for liquid fuels [Road energy]	GHG quota for liquid fuels [Min GHG reduction]	Advanced biofuels [Road energy]	E-fuel SAF [Air energy]
2010	6.75%			
2011	7.0%			
2012	7.25%			
2013	7.5%			
2014	7.75%			
2015		3.5%		
2016		3.5%		
2017		4.0%		
2018		4.0%		
2019		4.0%		
2020		6.0%		
2021		6.0%		
2022		7.0%	0.2%	
2023		8.0%	0.3%	
2024		9.25%	0.4%	
2025		10.5%	0.7%	
2026		12.0%	1.0%	0.5%
2027		14.5%	1.0%	0.5%
2028		17.5%	1.7%	1.0%
2029		21.0%	1.7%	1.0%
2030		25.0%	2.6%	2.0%

Table 4.2. Boundary conditions for compliance options within the GHG quota for the transposition of the RED II in Germany

Fulfillment option	Remarks	Condition
Advanced biofuels in road transport (38th BImSchV, Annex 1)	Quantities over the minimum percentage, except POME	Double counting for amounts over the minimum percentage for energy
Biofuels from UCO and animal fat (38th BImSchV, Annex 4)	Percentage for energy	Maximum 1.9%
Conventional biofuels from feedstocks that also serve the food and feed sectors	Percentage for energy	Maximum 4.4%
Biofuels from feedstocks with a high-risk of indirect land use change (palm oil)		2022: maximum 0.9% Starting in 2023: 0%
Green hydrogen and derivatives (e-fuels)	Used in refineries and road transport	Double counting
Electricity	Electricity for electric vehicles	Triple counting; adjustment mechanism
Battery-assisted electric drives and fuel cell-assisted electric drives	Factorization of electric power and hydrogen	Adjustment factor for drive efficiency: 0.4
Upstream emission reduction (UER)	GHG avoidance through UER	Until 2026: maximum 1.2% Starting in 2027: 0%

4.4.2. Excise duty reductions

The **Energy Duty Act** (Energiesteuergesetz) transposes the requirements of the ETD at a national level and regulates the taxation of fossil and renewable energy carriers. Since 2018, it no longer contains a tax cut for pure biofuels in road transport; however, additional climate-related taxation has been established via the Fuel Emissions Trading Act, which is described below. For agriculture and forestry, the act regulates the tax relief for energy products used in (diesel: 214.80 EUR/1,000 l; biodiesel (FAME): 450.33 EUR/1,000 l; vegetable oil: 450.00 EUR/1,000 l). This tax relief is granted retroactively upon application for (initially fully taxed) fuels. The use of biofuels is indirectly affected by the current preferential treatment of fossil gas fuels, such as CNG, LNG and liquified petroleum gas (LPG), as well as their biogenic substitutes, like biomethane. A reduced tax rate will apply to gaseous hydrocarbons until December 31, 2026 and to non-blended liquefied gases until December 31, 2022. However, tax rates are continuously increasing; for gaseous hydrocarbons they will rise from 13.90 EUR/MWh (until 2023) to 27.33 EUR/MWh (2026). Starting January 1, 2027, the regular tax rate of 31.80 EUR/MWh will apply. For liquefied gases, the reduced rate of 363.94 EUR/t in 2022 will be replaced by a regular tax rate of 409 EUR/t from 2023 onwards.

Starting in 2021, the Act on **National Certificate Trading for Fuel Emissions** (Fuel Emissions Trading Act – Brennstoffemissionshandelsgesetz, BEHG) aims to reduce GHG emissions in areas that are not yet covered by the European Emissions Trading Scheme (EU ETS) [BEHG (2019)]. Thus, it serves to transpose the EU Effort Sharing Regulation (ESR) [Verordnung (EU) 2018/842 (2018)], which focuses on these areas, as well as the national climate protection targets, particularly in the buildings and transport sectors, whereby European domestic aviation is already subject to the EU-ETS. In doing so, the law establishes a successively increasing price for GHG emissions from fuels and combustibles. For the duration of the sale, the fixed price per tonne of GHG emitted amounts to 25 EUR in 2021 and it will be raised to 55 EUR by 2025. From 2026 onwards, the price corridor for the auctioning of certificates is EUR 55 to 65 for one emission certificate. Note: As a tax relief, the CO_2 price was temporarily frozen in the wake of the 2022 energy crisis.

Currently, the toll on gas-powered vehicles has been reduced, resulting in an impact, albeit not an immediate one, on the use of gas fuels in transportation and thus potentially on the use of their biogenic substitutes. According to the **Act on Levying of Route-related Charges for the Use of Federal Highways and Federal Roads** (Bundesfernstraßenmautgesetz), medium and heavy commercial vehicles must pay a toll for the use of certain roads. This applies to vehicles or vehicle combinations that are intended or used to transport goods by road and whose maximum permissible weight is 7.5 metric tons or more. One exception is for vehicles powered by natural gas, which only have to pay partial toll rates to cover infrastructure costs (0.08 to 0.174 EUR/km) and to cover noise pollution costs (0.002 EUR/km). The partial toll rate to cover air pollution costs of 0.011 to 0.085 EUR/km is waived.

4.4.3. Fiscal incentives

Currently, there is no fiscal incentives by means of tax reduction for biofuels in Germany. Indirectly advanced biofuels are promoted by possibly higher GHG quota prices for the GHG certificates traded within the GHG reduction quota system. In addition to that in Germany, the Federal Ministry of Digital Affairs and Transport (BMDV) is planning a funding program for the construction of production plants from the end of 2023. Until then, the only funding available is for demonstration projects.

4.5. Promotion of advanced biofuels

In Germany, the term “advanced biofuels” follows the definition according to RED II. Following this, there are recognizable projects on advanced transport biofuels at different technology readiness levels (TRL) and fuel readiness levels (FRL). Existing commercial biodiesel (FAME), ethanol and biomethane plants principally can be used also to produce advanced biofuels based on residues or waste feedstocks as defined in the RED II. Capacities for lignocellulosic fuels remain quite low, however. This is also true for electricity-based liquid or gaseous electro-fuels (short e-fuels like e.g., hydrogen, synthetic natural gas or liquid hydrocarbon fuels).

There are different funding schemes and programs for R&D&D with different emphases (e.g., use of diversified raw materials, decentralized-centralized concepts along value chains, promoting Germany's role as a technology developer, and integration of renewable fuels based on biomass and electricity into the energy transition) which have led to a number of different pilot and demonstration plants for advanced gaseaous and liquid biofuels at universities (e.g. TU Bergakademie Freiberg, TU Darmstadt, RWTH Aachen, HAW Hamburg, University Hohenheim, TU Clausthal), R&D institutions of Max Planck, Helmholtz (e.g. KIT), Fraunhofer (e.g. IGB/CBP, UMSICHT, IME) and DBFZ as well as companies (e.g. Clariant, VERBIO, CAC Engineering, INERATEC, Thyssen).

In addition, the topic of efuels is attracting increasing interest, especially in context of the German energy transition and increasing shares of renewable electricity. Efuels- are viewed as carbon neutral and clean fuel by different OEMs. There are different projects on efuels- ongoing in Germany, an overview can be seen here.

Currently, there are important funding programs for R&D&D that are addressing renewable fuels for transport including advanced biofuels and to a major share efuels. In general, there has been a decrease in funded projects related to biofuels. Funding programs include for instance:

- Ministry of Education and Research (BMBF): "Kopernikus – projects for the energy transition" with one project on PtX with 44 partners, an Namosyn for the production of climate neutral combustion fuels with 37 partners from research and industry. Research is carried out on drop-in hydrocarbon fuels as well as on oxygenated fuel components and products from syngas fermentation. In 2022, the BMBF funded three lighthouse projects with a total funding of 700 million (H2Giga, H2Mare and TransHyDE).
- Federal Ministry of Food and Agriculture (BMEL): Renewable Resources Funding Scheme with projects related to ethanol, biodiesel, vegetable oils, biomethane, and advanced biofuels (e.g., hydrocarbons from biochemical pathways, fuels from other renewable resources like algae, and renewable oxygenates (OME) as gasoline and diesel blending components).
- Federal Ministry for Economic Affairs and Energy (BMWi): funding initiative on "energy transition in the transport sector" which also addresses advanced fuels (focus on efuels)
- Federal Ministry for Digital and Transport (BMDV), research on renewable fuels, with EUR 1.54 billion (USD 1.67 billion) available for 2021-24, consisting of resources from the Climate and Transition Fund (KTF) and the National Hydrogen Strategy. Importantly, EUR 640 Million (USD 695 million) will be used for R&D projects, to develop a technical R&D-platform and to support demonstration plant construction and operation. Moreover, there is public funding for alternative motor fuels on the national scale is supported by the Federal Ministry for Digital and Transport (BMDV,) in the areas of National Innovation Programme Hydrogen and Fuel Cell Technology, NIPII, infrastructure, e-mobility, LNG, CNG, and jet fuel.
- In addition, there are initiatives on the level of the federal states, such as the strategic dialogue for automotive industry in Baden-Württemberg which funds the reFuels and reFuels Demo project on the production and application of drop-in hydrocarbon fuels in tons-scale and on the preparation of a refinery-integrated demonstration plant based on renewable methanol.

4.6. Market development and policy effectiveness

Currently the biofuel market is mainly based on conventional biofuels, which are expected to remain dominant in the coming years if the German GHG quota will not be adapted in terms of phasing-out conventional biofuels. For advanced biofuels, there are only a few production plants for biomethane available as well as some biodiesel and ethanol plants that also use feedstocks in line with the current REDII Annex IX A. The development of production biofuels such as bioethanol, FAME, biomethane is shown in Table 4.3. Biomethane is produced in significant capacities but for different markets; just a share of roughly 4% is used for transport applications.

The first modern plants producing ethanol in Germany started operation in 2005. Ethanol is now produced in 12 plants, of which one is producing ethanol out of dairy residues (Sachsenmilch) and one is a demonstration plant for lignocellulosic ethanol (Clariant). The overall ethanol production capacity is about 1,076 ML/yr, in a production capacity ranging from 7 to 340 ML/yr. The most important companies are VERBIO AG, CropEnergies AG, Suiker Unie GmbH & Co. KG and Nordzucker AG. See below for more details on the imported and exported biofuels.

About 31 facilities with an overall combined capacity of about 4,365 ML/yr are still producing biodiesel, in a production capacity ranging from 2 to 650 ML/yr. This reflects some consolidation, as in 2012 there were about 51 production facilities in operation (Naumann et al. 2016). The most important companies are VERBIO AG, ADM, Cargill, ecoMotion GmbH, German Biofuels GmbH, Natural Energy West GmbH, REG Germany AG, and Mannheim Bio Fuel GmbH (Bunge) (Naumann et al. 2019).

Biomethane from upgraded biogas was produced by about 238 plants with a total capacity of around 1.300 MW in 2021 (EBA statistical report, 2022). The main companies producing biomethane for transport are VERBIO AG (biomethane from ethanol stillage and straw), E.ON Bioerdgas GmbH, Envitec, VNG and Berliner Stadtreinigungsbetriebe.

There are no HVO/HEFA production capacities available in Germany.

The following weblinks shows maps for production facilities for bioethanol and biomethane:

https://www.bdbe.de/biokraftstoff-bioethanol/zellulose-ethanol
https://www.gie.eu/wp-content/uploads/filr/5808/GIE_EBA_BIO_2021_A0_FULL_3D_253_online.pdf

Table 4.3. Transport biofuels actual production (ML/yr)

Year	Bioethanol (conventional)	Biodiesel (FAME)	RNG as transportation fuel
2010	960	3,181	7,500
2011	938	3,181	9,300
2012	976	2,954	33,300
2013	1,068	3,307	48,300
2014	1,176	3,808	44,900
2015	1,232	3,505	34,500
2016	1,250	3,543	37,900
2017	1,275	3,644	44,500
2018	1,123	3,799	38,900
2019	1,028	4,070	66,100
2020	1,100	3,498	88,400
2021	1,240	3,925	100,000
2022	1,140	3,408	N/A

Unit conversion: 1 MMT of biodiesel = 1.136 ML; 1 MMT of ethanol = 1.262 ML; 1 GWh of methane = 100 ML

In 2021, biofuels used avoided 11.1 MMT CO_2-eq in Germany. The fuel specific GHG mitigation are 82% biodiesel (FAME), 90% bioethanol, 83% HVO/HEFA and 93% biomethane for the main fuel options. The biofuels used consisted of 65% crops and 29% UCO. The rest were advanced fuels based on biogenic feedstocks from industrial waste, effluents from palm oil mills, crude glycerin or biogenic waste and residues from forestry (Table 4.4) (BLE, 2023).

Table 4.4. Summary of transport fuel consumption (ML) (BLE, 2023)

Year	Gasoline	Diesel fuels	Aviation fuel	Bioethanol	Biodiesel	Renewable diesel (from lipids)	RNG as transport fuel
2010	25,220	33,482	10,419	1,301	2,890	0	7,500
2011	22,461	34,328	9,967	1,456	2,667	323	9,300
2012	23,738	35,017	10,673	1,617	2,517	507	33,300
2013	23,699	36,751	10,794	1,554	2,071	605	48,300
2014	23,757	37,324	10,425	1,543	2,295	431	44,900
2015	23,232	38,814	10,432	1,479	2,239	216	34,500
2016	23,207	40,070	11,221	1,438	2,258	212	37,900
2017	23,495	40,876	12,275	1,428	2,423	42	44,500
2018	22,658	39,470	12,622	1,466	2,626	35	38,900
2019	22,836	39,913	12,543	1,467	2,717	54	66,100
2020	20,424	35,610	57,73	1,406	2,710	1,353	88,400
2021	22,200	42,145	7,567	1,460	2,569	580	100,000
2022	22,968	41,880	11,052	N/A	N/A	N/A	N/A

Unit conversion: 1 MMT gasoline = 1,351 ML; 1 MMT (renewable) diesel = 1,205 ML; 1 MMT aviation fuel = 1,235 ML.

As the consumption of bioethanol as a fuel in Germany increased, so did the volume of imports. In 2022, around 1.5 million m^3 were covered by imports. At the same time, around 0.5 million m^3 of bioethanol was exported. Imports came mainly from the Netherlands, Belgium, Hungary and Sweden. Exports within the EU were mainly to the Netherlands, Sweden, Denmark and France. The Netherlands is only considered as a transit country for exports to non-European countries via the ethanol terminal in Rotterdam. The resulting net import of 1.0 million m^3 corresponds to trade in bioethanol including industrial alcohol and potable alcohol for material use. Significant quantities of biodiesel produced or used in Germany have been and are being traded internationally. The main customers are the Netherlands (including exports via Rotterdam), Belgium, Poland, the USA and Austria. Imports come mainly from the Netherlands, Belgium, the United Kingdom and Poland. In the overall trade balance for Germany in 2020, this results in FAME exports of 3.0 million m^3 and FAME imports of 1.6 million m^3. All the HVO/HEFA diesel used in Germany was imported (Table 4.5).

Table 4.5. Import and export of bioethanol and FAME in Germany from 2010 to 2022

Year	Bioethanol		Biodiesel (FAME)	
	Import (ML/yr)	Export (ML/yr)	Import (ML/yr	Export (ML/yr)
2010	1,343	343	1,426	1,320
2011	1,402	248	1,525	1,507
2012	1,400	203	849	1,380
2013	1,290	202	640	1,774
2014	1,104	240	663	1,946
2015	1,128	351	587	1,626
2016	1,123	407	815	1,724
2017	1,115	469	899	1,829
2018	1,300	448	1,383	2,117
2019	1,485	456	1,602	2,601
2020	1,390	487	1,646	2,643
2021	1,459	416	1,257	2,410
2022	1,501	492	1,588	3,002

In order to meet the GHG emissions quota, direct or indirect effects on the amount of biofuels or renewable fuels used are expected. The main driver of competition between fuels within the quota remains the fuel-specific GHG reduction potential.

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5. Austria

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5.1. Summary

- Most of Austria's GHG emissions come from its energy sector, with a contribution of 67%. The main GHG contributor to the energy sector is the transport sector. This amount of 22 Mt CO2eq corresponds to 42% of the energy sectors emissions, or 28% of the total national emissions.
- The primary policy instrument that has encouraged the production and use of transport biofuels is a biofuel blending mandate. This biofuel volume obligation includes at least 3.4% ethanol and 6.3% biodiesel on an energy content basis. Since 2020 there has been a specific target for advanced biofuels, which rises to 3.5% in 2030. The carbon intensity or GHG emissions of fuels are currently not taken into account.
- However, for fuel producers there will be reduction targets for GHG emissions of energy carriers and fuels. From 2025 the emission reduction target will be 7.5% up to 13% in 2030.
- Note, there is a tax exemption for the biofuel content in fuels.
- There are non-compliance costs for not meeting the biofuel policy targets. For example, not achieving the substitution targets the cost is 43 €/GJ, for not achieving the GHG emission reduction targets a non-compliance cost of 600 €/t CO2eq is payable.
- The energy substitution of biofuels consumed in road transport in Austria in 2021 was 5.48%. Of these, the main contribution was from using biodiesel with only a small amount of bioethanol and HVO used.
- Although there are no specific policies promoting aviation and marine biofuels there is the intention to promote aviation biofuels. Initiatives, projects and strategy papers have been established in the recent years concerning the use of SAF.
- Austria's sustainability assessments are based on RED and EU frameworks. Companies along the biofuel production chain require certification from either a system authorized by the European Commission (EC) or a national or bilateral acknowledged system to be registered in the national monitoring system (elNa).
- One large bioethanol production facility and eight FAME (biodiesel) production facilities were operating in Austria in 2021. Other fuels, which are produced in smaller production facilities, are pure plant oils and biomethane. Since January 2021 one facility for the production of ethanol from brown liquor has been operational at a pulp mill. Since 2022 an oil refinery in Austria is operating a co-processing unit.
- Austria is a net importer of biofuels. In particular, more FAME is imported than exported. This is contrary to the case of bioethanol, where 3 times more is exported than imported.

5.2. Introduction and main drivers for transport biofuels in this country

The total primary energy supply (TPES) in Austria was 1363 PJ in the year 2021. Renewable energy accounts for about 33.5% of Austria's total primary energy supply, in the form of biofuels, combustible waste, hydropower and solar. The main part of the energy supply comes from oil, natural gas and coal. Figure 5.1 shows the total energy supply for Austria from 1990-2021.

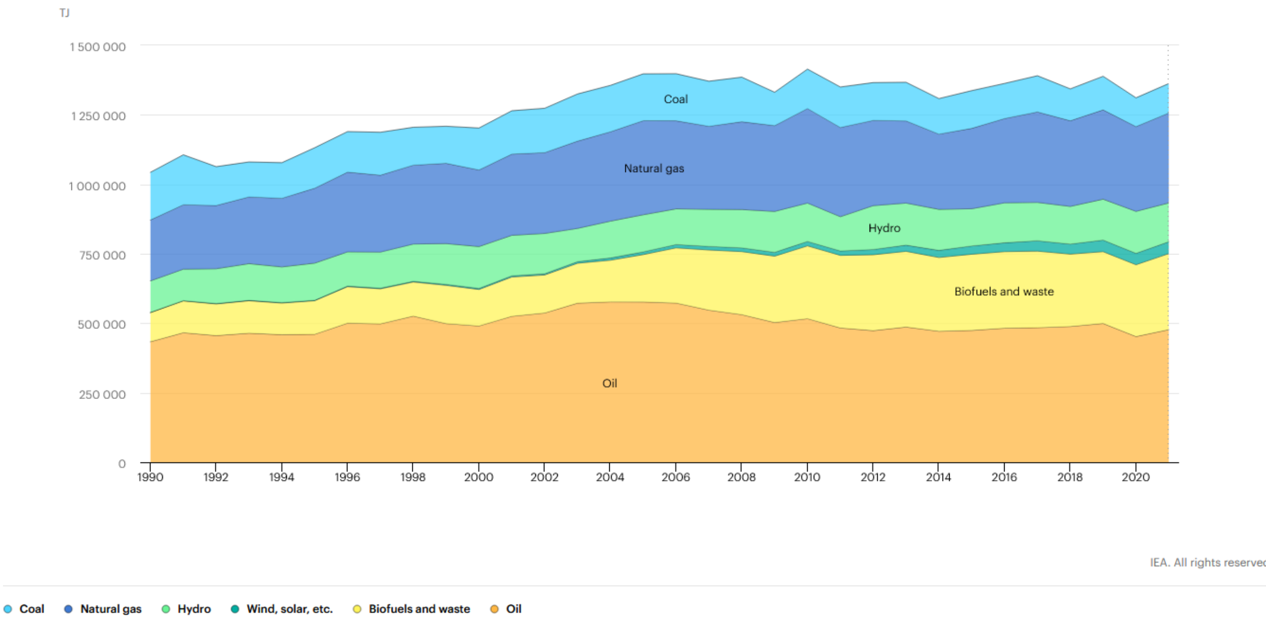

Figure 5.1. Total energy supply by source for Austria from 1990-2021 (graph from IEA)

The total GHG emissions in Austria amounted to 77.5 Mio tCO2eq in the year 2021 (UBA, 2023). In Austria, the transport sector causes about 28.3% of this annual CO_2 emissions of the country. The Austrian transport sector showed a sharp rise of 57% in GHG emissions from 1990 (14 Mio tCO2eq) to 2021 (22 Mio tCO2eq) (UBA 2023). The reason was mainly the long-term trend of increased annual mileage in freight and passenger transport. In addition, the fuel export increased considerably since 1990, caused by lower fuel prices in Austria compared to neighbouring countries. The drop of transport caused GHG emissions in 2020 is caused by the effects of the Covid-19 pandemic with travel restrictions and restricted mobility.

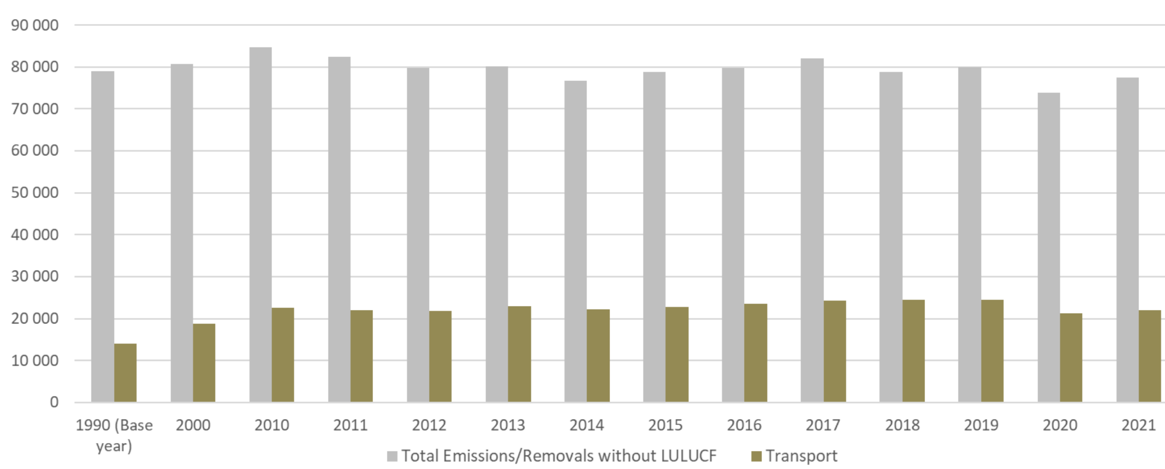

Figure 5.2. GHG emission trends in total and for transport (ktCO2eq) in Austria

LULUCF (Land Use, Land-Use Change and Forestry); Data from UBA 2023

The main part of the total GHG emissions in Austria in 2021 came from the energy sector with a contribution of 67%. The origin of 99% of these emissions is fuel combustion. The most important sub-category of the energy sector is the transport sector with 22 million tonnes CO2eq (MtCO2eq) which corresponds to 42% of emissions in the energy sector or 28% of total national emissions.

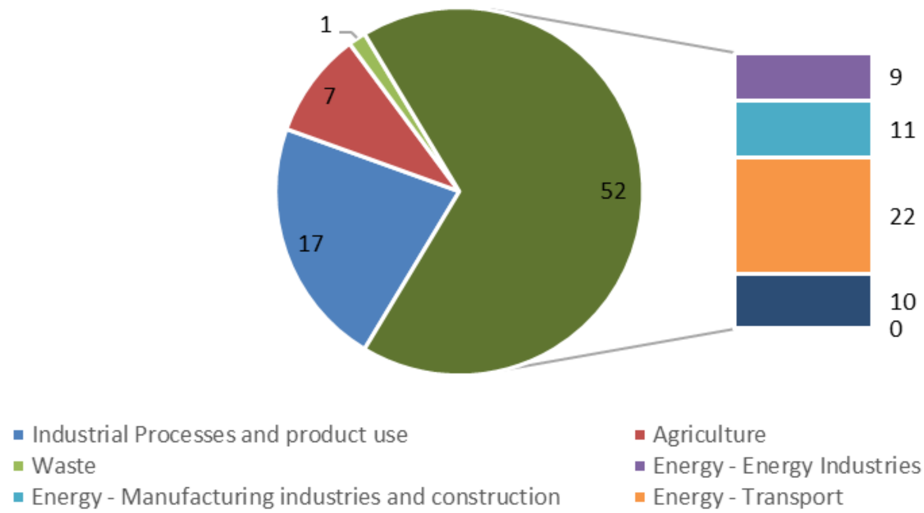

Figure 5.3. GHG emissions per sector (Mt CO2eq) in Austria 2021 (data from UBA, 2023)

In Austria the biofuel policies – implementing the respective EU Directives - led to a relatively stable production and use of biofuels in the country since 2005. The biofuel blending obligation leads to the use of biofuels in the common diesel and petrol fuels, but there are virtually no dedicated vehicles for higher blends of biofuels. Apart from the biofuel blending obligation there are no attempts to further increase the biofuel use in the Austrian transport sector.

The main driver for biofuels production in Austria is EU legislation for the promotion of renewable energy. The rationale behind the EU legislation is a combination of concerns regarding energy supply security, the need for climate change mitigation, and the wish for rural development and job creation. While rural development and job creation were the main drivers in the beginning, the importance of climate change mitigation has increased and is reflected by ongoing discussions on the GHG emission benefits of biofuels.

The EU has established a legal framework concerning transport fuels. These include the Renewable Energy Directive (RED) 2009/28/EC on the promotion and use of energy from renewable sources and the Fuel Quality Directive (FQD) 2009/30/EC. The RED has set a goal of 20% final energy consumption from renewable sources by 2020, and a specific sub-target of 10% share of renewable energy in the transportation sector by 2020; the FQD requires a minimum 6% reduction in GHGs per energy unit of transport fuel by 2020.

Both directives include sustainability criteria for biofuels, requiring at least 35% savings in GHG emissions as compared to fossil fuels by 2013. This requirement increased to at least 50% by 2017, and 60% by 2018 for biofuels produced by new facilities. These EU Directives are binding for all member states and have been implemented into the respective national laws.

Post 2020 targets for renewable energy are a minimum of 27% of final energy consumption in the EU as a whole by 2030. In December 2018, the revised Renewable Energy Directive (RED II) 2018/2001/EU entered into force, and new targets and also sub-targets for the transport sector have been defined. In RED II, the overall EU target for renewable sources share by 2030 has been raised to 32% in gross final energy consumption. For the transport sector, the overall goal is to reach 14% renewable energy by 2030; advanced biofuels may be double-counted for reaching this target, and renewable electricity used in vehicles may be quadruple-counted. Advanced biofuels should contribute a minimum share of 0.2% of biofuels by 2022, 1% by 2025, and 3.5% by 2030. The contribution of conventional biofuels is capped at 7% or lower, depending on the level of current consumption in the respective member state.

In 2023 the Renewable Energy Directive has been revised (RED III). The provisional agreement is to raise the share of renewable energy in the EU's overall energy consumption to 42.5% by 2030. The negotiations led to new targets for the transport sector with the possibility for member states to choose between:

- a binding target of 14.5% reduction of GHG intensity in transport from the use of renewables by 2030
- or a binding share of at least 29% of renewables within the final consumption of energy in the transport sector by 2030

The provisional agreement sets a binding combined sub-target of 5.5% for advanced biofuels (generally derived from non-food-based feedstocks) and renewable fuels of non-biological origin (mostly renewable hydrogen and hydrogen-based synthetic fuels) in the share of renewable energies supplied to the transport sector. Within this target, there is a minimum requirement of 1% of renewable fuels of non-biological origin (RFNBOs) in the share of renewable energies supplied to the transport sector in 2030.

Those targets have to be transferred into national law. Before this revision Austria defined targets in the National Energy and Climate Plan in 2019. The national targets and objectives in the Integrated National Energy and Climate Plan for Austria (2019) could be divided into 5 dimensions: decarbonisation, energy efficiency, security of energy supply, internal energy market, and research, innovation and competitiveness. Beside the objectives of the European climate and energy policy framework, Austria defined some specific targets for the years 2021-2030 in NECP:

- Reduction of GHG emissions (non-ETS) by 36% compared to 2005
- GHG contribution in transport sector: -7.2 Mt CO2eq compared to 2016 (total contribution)
- Increase the share of renewable energy in gross final energy consumption of energy to 46-50%, and source 100% of electricity consumption from renewables (nationally/balanced)
- Increase the share of renewable energy in transport in 2030 to at least 14% by using biofuels and increasing the share of e-mobility

The historical development of biofuels policy in Austria is shaped by European legislation and national implementation. The following Figure 5.4 shows the timeline of the biofuel policies that have been introduced in Austria to encourage the production and use of biofuels in the country since 1995. Biofuel blending mandate has been the key policy instrument in Austria to support the development and deployment of transport biofuels markets.

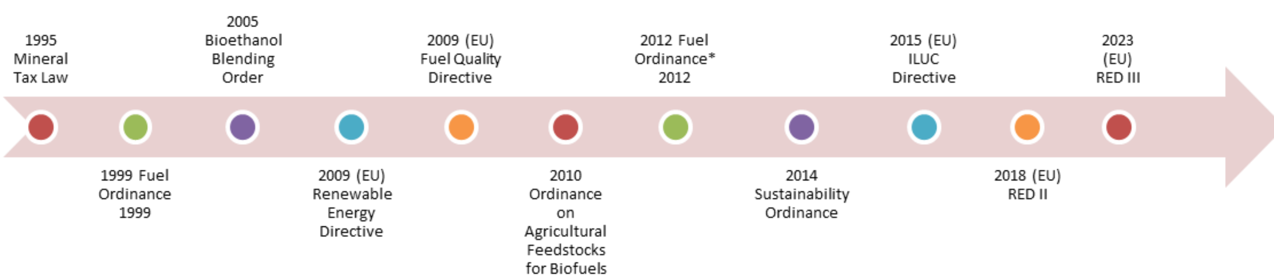

Figure 5.4. Timeline of biofuel policies development in Austria to encourage the production and use of biofuels

Note: There are several amendments of the fuel ordinance – the last in the end of 2022.

5.3. Transport Biofuels policies

The main legislations that have impacted the biofuels production and use in Austria include European legislation and national legislation:

- EU Renewable Energy Directive (RED) 2009/28/EC
- EU Renewable Energy directive (RED II) 2018/2001/EU
- EU Renewable Energy directive (RED III) – in preparation 2023
- EU Fuel Quality Directive (FQD) 2009/30/EC
- EU ILUC Directive (EU) 2015/1513
- Fuel Ordinance BGBl. II Nr. 398/2012 idF BGBl. II Nr. 452/2022
- Sustainability Ordinance BGBl. II Nr. 157/2014
- Ordinance on Agricultural Feedstocks for Biofuels BGBl. II 250/2010
- Mineral Oil Tax Law BGBl. I Nr. 630/1994 idF BGBl. I Nr. 104/2018
- Bioethanol Blending Order BGBl. II Nr. 378/2005 idF BGBl. II Nr. 63/2016

In Austria, the EU transport biofuels directive 2003/30/EG was transposed to national law with an amendment of the fuel ordinance (BGBl.II Nr.209/2004). Since 1.10.2005, 2.5% (energetic) of the fossil fuels in the transport sector have to be substituted by biofuels. This goal has been reached by blending of diesel fuel with 5% FAME. The percentage of substitution increased from 1.10.2007 to 4.3% due to the admixture of ethanol to petrol fuels. With 1.10.2008 the substitution obligation according to the fuel ordinance was increased to 5.75%.

In 2009 another amendment of the fuel ordinance (BGBl. II Nr. 168/2009) introduced specific sub-goals for the different type of fuels. From 1.1.2009 there was the obligation to substitute 5.75% (energy) with biofuels, 3.4% (energy) of gasoline and 6.3% (energy) of diesel. The Austrian regulation defines values as percentage by energy content. These values can be fulfilled by adding 5% by volume of ethanol to gasoline and 7% by volume of biodiesel to diesel. The contribution of conventional biofuels is capped at 7% or lower, depending on the level of current consumption in the respective member state. With the amendment of the fuel ordinance in 2018 (BGBl. II Nr. 86/2018) additionally a sub-goal for advanced biofuels was created with a substitution obligation of 0.5% (energetic) with advanced biofuels from 1.1.2020. The target was reduced from 0.5% to 0.05% for 2020 because of limited availability of this advanced fuel at cost-efficient prices in the market.

The Fuel Quality Directive requires a reduction of the GHG intensity of transport fuels by a minimum of 6% by 2020. In the recent amendment the value rises from 6% in 2023 to 13% in 2030. Together with the Renewable Energy Directive, it also regulates the sustainability of biofuels. A summary of Austrian targets for the transport sector is given in Table 5.1.

Table 5.1. Austrian targets in the transport sector

Reduction of GHG emissions – by at least 6% from 2023, rising about 1% per year to at least 13% in 2030
Cap for first generation biofuels of 7%
Substitution target (% energy content) – 3.4% Ethanol, 6.3% Biodiesel
Target for Advanced Biofuels – 0.2% from 2023, 1% from 2025, 3.5% from 2030

Fuels can only be counted towards these targets if they fulfil the sustainability criteria (same thresholds and requirements as in RED and FQD). Any feedstock produced in Austria must comply with EU regulations. Imported feedstocks or biofuels must be certified by another Member State or a voluntary scheme approved by the EC or Austrian control bodies. Since 2021 palm-oil based fuels cannot be counted towards these targets. A summary of Austrian policies for the transport sector is given in Table 5.2.

Table 5.2. A summary of Austrian policies for the transport sector

Type of policy	Details
Market pull policies for transportation fuels and targets	Biofuel blending mandates: At least 3.4% (energy content) of ethanol to be added to gasoline – which corresponds to E5. The use of E10 is possible since the current amendment of the fuel ordinance. At least 6.3% (energy content) of biodiesel to be added to diesel – which corresponds to B7 Emission reduction targets: Fuel producers have to reduce the life cycle GHG emissions per unit of energy of fuels or energy carriers for transport use compared to the fuel baseline of 94.1 CO2eq as follows: - from 2023 by 6% - from 2024 by 7% - from 2025 by 7.5% - from 2026 by 8% - from 2027 by 9% - from 2028 by 10% - from 2029 by 11% - from 2030 by 13%
Market-pull policies target the entire transport sector or specific transport sectors	This is for the entire transport sector.
LCA model to measure the CI of biofuels	Sustainability criteria in line with the EU sustainability criteria. According to the KVO, biofuels and other renewable fuels may only be counted towards the GHG reduction and substitution targets since 2012 if they meet the sustainability criteria. The calculation of the savings in life cycle GHG emissions achieved through the use of biofuels is carried out in accordance with § 19a KVO.
Sustainability requirements/criteria within biofuel policies that are used to assess environmental performance	GHG emission reduction : Fuel producers have to reduce the life cycle GHG emissions per unit of energy of fuels or energy carriers for transport use compared to the fuel baseline of 94.1 CO2eq as follows: - from 2023 by 6% - from 2024 by 7% - from 2025 by 7.5% - from 2026 by 8% - from 2027 by 9% - from 2028 by 10% - from 2029 by 11% - from 2030 by 13%

Type of policy	Details
Approved sustainability certification and/or verification schemes for transport biofuels and their feedstocks	In Austria, all companies along the biofuel production chain have to be in charge of a certification either from a system authorized from the European Commission (EC) or a national or bilateral acknowledged system to be registered in the national monitoring system, elNa. The following certification systems are used by Austrian producers: • 2BSvs • AACS (AMA) • BLE • Bonsucro EU • ISCC DE • ISCC EU • Red Cert DE • Red Cert EU • Slovakian National System
Technology-push policies for transportation fuels	There is a tax exemption for the biofuel content in fuels. At the moment in the transport sector funding is available for electromobility, not for other alternative fuel vehicles. Financial assistance: Funding for research and development is available. In some cases, grants are available for the construction of plants for the production of sustainable liquid or gaseous fuels which haven non-food feedstock.
Specific technology push policies to promote the use of biofuels for long-distance transport sector	Current legislation does not contain specific policies to promote aviation or marine fuels. But there are incentives to promote sustainable aviation fuels.
Specific technology push and/or market pull policies that are used to promote the production and use of drop-in or advanced (e.g., cellulosic ethanol) fuels	There are blending mandates for advanced biofuels. From 2023 0.2% From 2025 1% From 2030 3.5%
The primary challenges for new biofuels to enter the market and/or earn incentives	To enter the biofuels market in Austria, the biofuel producers and importers have to register with elNa. Biofuel specifications have to match the existing standards for Diesel or Otto fuels. The production chain has to comply with the sustainability criteria, and this has to be certified.
The non-compliance cost of not meeting transport biofuel policies requirements for the obligated parties	In case of not achieving the targets for substitution of fossil petrol and fossil diesel, as well as the specific targets for advanced biofuels a non-compliance cost of 43 €/GJ is payable. In case of not achieving the goals for GHG emission reduction a non-compliance cost of 600 € per tonne CO2eq has to be raised. For the year 2023 the amount of 600 €/t accounts for the first 5% GHG reduction target, for the last 1% the amount is 15 €/t.

The substitution target for the Austrian transport sector is 5.75% based on energy content since 2009 – a detailed list of targets for different biofuel types is given in Table 5.3. The Austrian regulation defines values as percentage by energy content. For diesel fuels the substitution with renewable fuels has to be at least 6.3% and for gasoline fuels 3.4%. These values can be fulfilled by adding 5% by volume of ethanol to gasoline and 7% by volume of biodiesel to diesel. Since 2020 there is a specific goal for advanced biofuels – 0.5% of the energy content has to be replaced by advanced biofuels. But this target was reduced for the years 2020 to 0.05% and 2021 to 0.1% due to limited availability in the market.

Table 5.3. Biofuels mandates percentage by energy content since 2010

Year	Ethanol	Biodiesel	HVO/ Renewable Diesel	Others (specify e.g., Biojet/SAF, RNG)
2010	3.4	6.3		
2011	3.4	6.3		
2012	3.4	6.3		
2013	3.4	6.3		
2014	3.4	6.3		
2015	3.4	6.3		
2016	3.4	6.3		
2017	3.4	6.3		
2018	3.4	6.3		
2019	3.4	6.3		
2020	3.4	6.3		Advanced biofuels: - original target 0.5 - reduced target 0.05
2021	3.4	6.3		Advanced biofuels: - original target 0.5 - reduced target 0.1
2022	3.4	6.3		Advanced biofuels: - original target 0.5 - reduced target 0.1
2023	3.4	6.3		Advanced biofuels: 0.2

5.4. Market development and policy effectiveness

Austria has targets mandating the blending of biofuels, introduced by BGBl. II Nr. 398/2012. In 2015, the overall biofuels target was a minimum 5.75% biofuel in transport fuel (by energy content). In addition, there are separate targets (by energy content) of at least 3.4% biofuel in petrol and at least 6.3% biofuel in diesel. These targets directly influence the Austrian market and production of biofuels which can be seen in Table 5.4.

Table 5.4. Transport biofuels actual production (ML/yr) in Austria

Year	Bioethanol (conventional)	Cellulosic ethanol	Biodiesel (FAME)	Renewable diesel/HVO (from lipids)	RNG as transportation fuel	Other advanced biofuels (specify, e.g., biojet/SAF)
2010	202		378			
2011	220		348		0.0	
2012	220		297		0.7	
2013	226		243		1.0	
2014	234		327		0.8	
2015	226		381		0.6	
2016	228		345		0.4	
2017	239		331	7.0	0.3	
2018	254		322		0.4	
2019	259		336		0.4	
2020	225	0.4	327		0.4	Advanced biofuel FAME: 1.5
2021	241	8.3	327		0.4	Advanced biofuel FAME: 4

The production of conventional biofuels in Austria remained relatively stable in the past ten years. The historical biofuel production can be seen in Figure 5.5. In the last years the production of advanced biofuels in dedicated facilities started in Austria – in the year 2021 about 12.7 ML of advanced biofuels have been produced (Cellulosic ethanol, FAME and biomethane), this was a 6-fold increase compared to 2020.

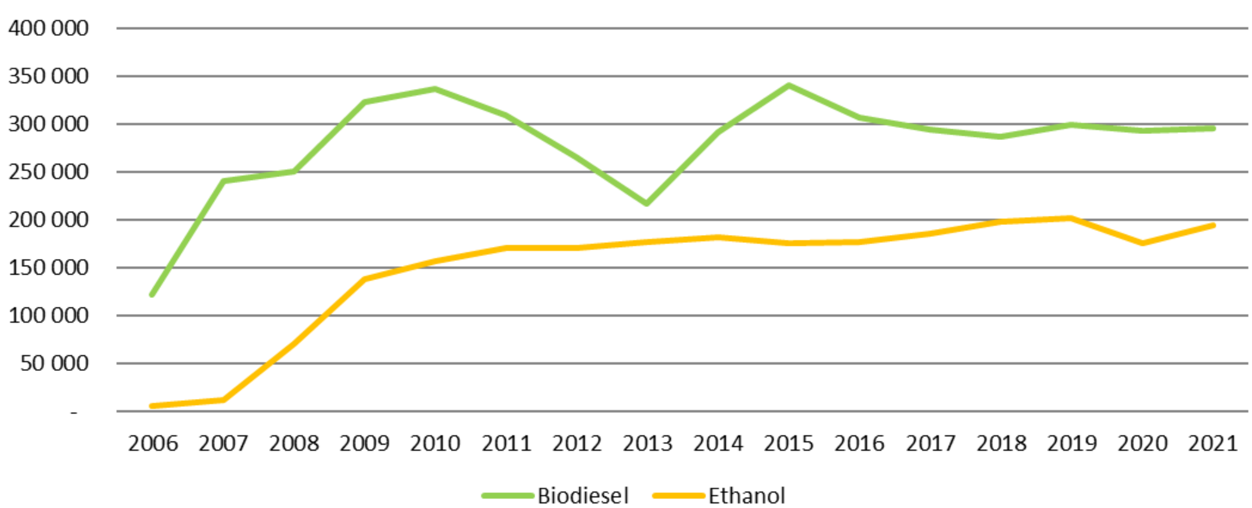

Figure 5.5. National production of FAME and ethanol over time (tonnes) (2006-2021)

Source: Data BMK 2022

The fuel consumption in Austria is depicted in the following table in ML for the past decade. The biofuels used in the Austrian transport sector are biodiesel (FAME), bioethanol, HVO, pure plant oil and biogas either as blending component or for direct use (Table 5.5).

Table 5.5. Summary of transport fuel consumption (ML) in Austria

Year	Gasoline (fossil)	Diesel fuels (fossil)	Biodiesel	Bioethanol	Pure plant oil	HVO	Biomethane
2010	2 340	6 878	562	107	19	-	-
2011	2 259	6 678	568	100	18	-	-
2012	2 163	6 754	559	108	18	-	0.7
2013	2 119	6 789	553	87	19	15	1.0
2014	2 065	6 803	646	113	17	53	0.8
2015	2 091	7 032	682	116	15	102	0.6
2016	2 046	7 319	572	112	17	66	0.4
2017	2 052	7 415	523	110	17	31	0.3
2018	2 096	7 522	569	114	0.3	23	0.4
2019	2 112	7 665	544	111	0.1	28	0.4
2020	1 703	6 806	465	106	0.1	12	0.4
2021	1 813	7 265	483	98	0.1	15	0.4

Figure 5.6 gives the percentages of different fuels used in Austria in the year 2021. The road transport in Austria caused fuel sales of 338 PJ in the year 2021, which is nearly 20 PJ more than in the year 2020. But that year the consumption was very low due to the Covid-19 pandemic. Before 2020 the fuel consumption increased in the last years, along with a rising consumption of diesel. The petrol consumption decreases since the 90s. Diesel fuel has the biggest share of 77% in fuel sales compared to petrol fuel with 17% and fuels with biogenic origin with 5.5% (BMK 2022).

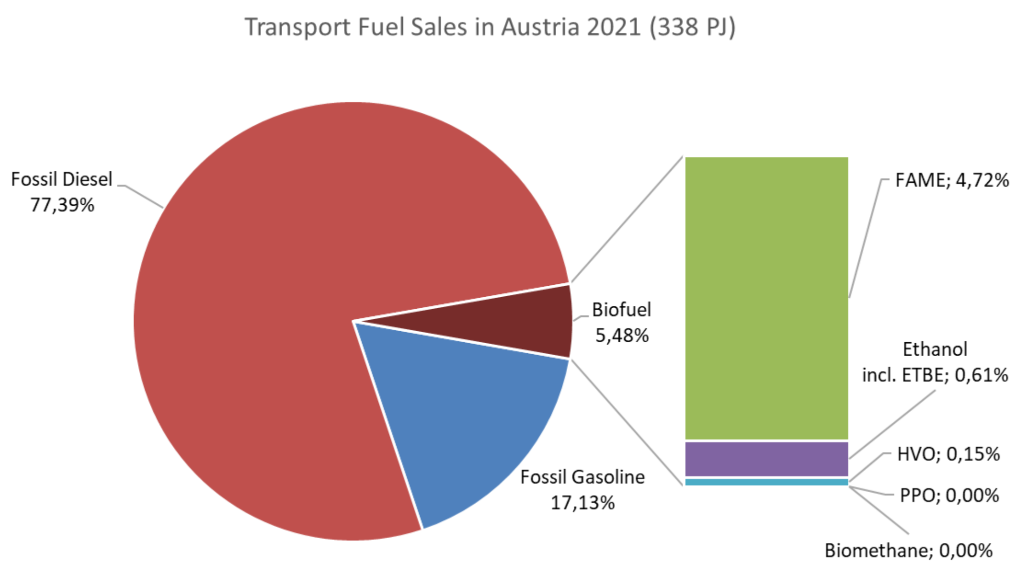

Figure 5.6. Transport Fuel Sales in Austria 2021

Source: Data BMK 2022

5.5. Biofuels facilities and main companies

Biofuels produced in Austria are bioethanol, biodiesel, HVO, pure plant oil, RNG and advanced biofuels. In Austria, one large bioethanol production facility, one production facility producing ethanol from brown liquor, eight smaller FAME (biodiesel) production facilities and co-processing in a refinery were operating in 2021. Other fuels, which are produced in smaller production facilities with no relevant values available, are pure plant oils and biomethane.

The conventional bioethanol plant has a capacity of 246 ML/yr located in Pischelsdorf. In 2021, 241 ML of ethanol was produced in Austria. This plant's GHG emission reductions of 50% have been certified by Joanneum Research. The other bioethanol plant produces advanced ethanol from brown liquor at the pulp mill of AustroCel Hallein in Hallein. The capacity is 30 ML/yr. The ethanol production is fully integrated into the mill that produces dissolving pulp for textile applications as the major product. Currently the facility represents Austria´s only production facility for advanced ethanol with an actual production of 8.3 ML in 2021 (Table 5.6).

Table 5.6. Bioethanol production plants in Austria

Company	City	Capacity (ML/yr)
AGRANA Bioethanol GmbH	Pischelsdorf	246
AustroCel Hallein GmbH	Hallein	30

According to the Austrian biofuels register elNa, eight companies are registered in 2021 as biodiesel producers. Biodiesel is the main biofuel produced in Austria. Biodiesel production capacity in Austria is ~ 430 ML/yr from 8 production facilities (Table 5.7). Production reached its peak in 2015 with nearly 381 ML of biodiesel produced, with a current production (2021) of 327 ML. Total biodiesel consumption in 2021 was 483 ML.

Table 5.7. Austrian biodiesel producers

Company	City	Capacity (ML/yr)
Biodiesel Süd GmbH	Bleiburg	22
Münzer Bioindustrie GmbH	Wien	157
Bio oil GmbH	Krems	56
HPF Biokraft Hirtl GmbH	Fehring	5
Abid Biotreibstoffe GmbH	Hohenau	56
Biodiesel Kärnten GmbH	Arnoldstein	56
Münzer Paltental	Gaishorn am See	67
Bioraffinerie Mureck GmbH	Mureck	17
Total capacity		437

In Austria HVO is produced as co-processing HVO in the fossil refinery of OMV in Schwechat. In first trials in 2016 and 2017 about 7 ML of HVO had been produced. In the year 2022 the production began as co-processing with a production of 2 ML of HVO which has been used as SAF for Austrian Airlines.

Pure plant oil (PPO) was used in recent years directly as fuel, in particular by agricultural vehicles Since 2018 the use of PPO decreased sharply. The reason for that might be the low diesel price and additionally the loss of converted tractors due to the rising age. Austria's co-processing plants and plants for the production of advanced biofuels are summarized in Table 5.8.

Biogas produced in Austria is mainly used on site for heat and power production. Beside the direct conversion into electricity processed biogas is fed into the national gas grid. In three biogas plants in Austria the processed biogas is used as biomethane for refueling vehicles in decentralised fuel stations.

Table 5.8. Co-processing plants and plants for the production of advanced biofuels

Name of company	Status (planned; operational; closed)	Technology	Production capacity (ML/yr)
OMV AG	Operational	Co-Processing HVO/SAF	
AustroCel Hallein GmbH	Operational	Ethanol from brown liquor	30

5.6. Biofuels and feedstocks: imports and exports

Austria is a net importer of biofuels. 2021 548,000 tons of biofuels were imported, whereas 525,000 tons were exported. Detailed information on imports and exports for the last years is given in Table 5.9.

Table 5.9. Imports and exports of biofuels in Austria

Year	FAME		Bioethanol		HVO	
	Import (ML/yr)	Export (ML/yr)	Import (ML/yr)	Export (ML/yr)	Import (ML/yr)	Export (ML/yr)
2014	425	N/A	57	N/A	58	N/A
2015	559	267	74	195	104	7
2016	501	335	100	227	148	9
2017	482	122	73	198	46	12
2018	657	355	100	222	35	9
2019	616	402	79	231	61	4
2020	529	382	78	199	12	4
2021	533	379	69	235	24	5

Almost all raw materials for biodiesel production comes from the European Union. Austria is not self-sufficient in terms of vegetable oils in general (not only for biodiesel production) and UCO for biodiesel production. Most of the feedstock comes from Austria (23.5%) followed by the surrounding countries like Hungary, Slovakia, Czech Republic and Italy. Feedstock used for producing FAME are UCO, rapeseed, animal fat, fatty matter, soy and fatty acids (Figure 5.7).

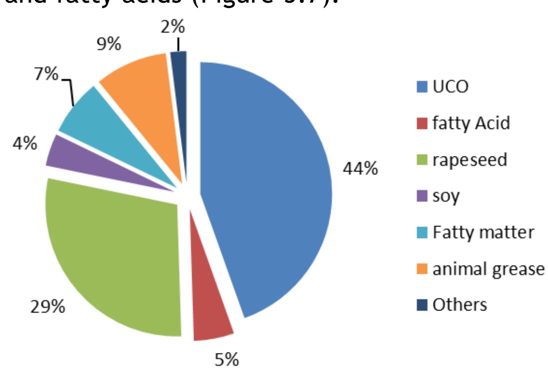

Figure 5.7. Feedstock for FAME production

The main feedstock for ethanol production is starch sludge and maize, followed by wheat, triticale and brown liquor (Figure 5.8). Feedstock for ethanol production is partly imported, as Austria is a small country and the production facility is close to the Czech border and close to a Danube port.

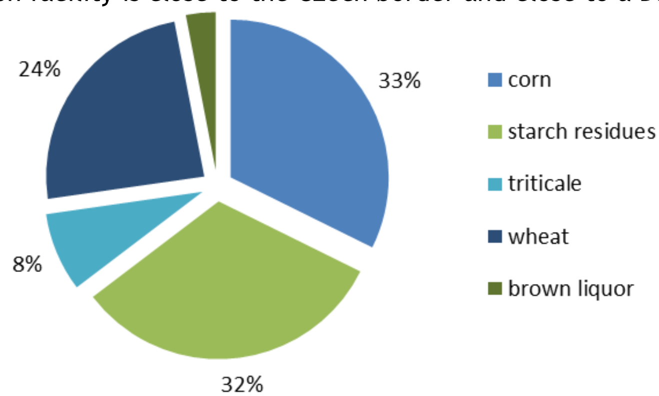

Figure 5.8. Feedstock Ethanol Production

For the production of biomethane only residues and waste streams were used (Figure 5.9), the residue based raw materials all originated from Austria.

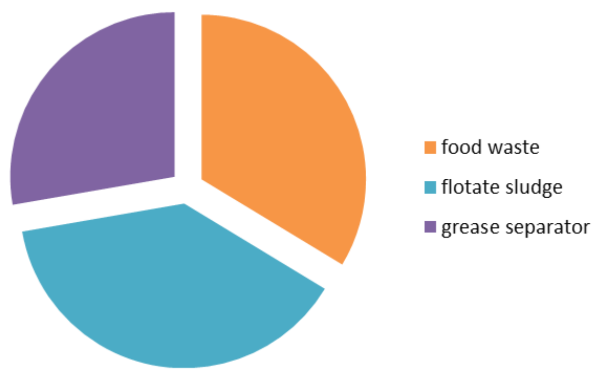

Figure 5.9. Feedstock Biomethane Production

5.7. Co-processing at oil refineries/Repurposing Oil refineries

Co-processing is done in Austria, in the single one oil refinery – the company OMV operates a refinery in Schwechat close to Vienna and its airport. The Schwechat Refinery is one of the most modern and one of the largest refineries in Europe. OMV uses new technologies to increase the quality and stability of fuels with biogenic components through what is known as co-processing. In 2016 and 2017, OMV successfully conducted the first field trials of co-processing. In 2022 operation of the co-processing at the refinery started with 2 ML of HVO which was used as SAF for Austrian Airlines. OMV sets a goal of producing 700,000 tons of SAF in 2030 (not only in Austria, but in the European facilities).

5.8. Research and Development and Additional information

National R&D funding programs include instruments that are open to all fields of research (to fund fundamental research, applied research and build-up of research infrastructure) and thematic calls (such as the energy research program and the IEA Research Cooperation). The Austrian Research Promotion Agency (FFG) is the national funding agency for industrial research and development in Austria. Owners and providers of funds for the research programs are the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) and the Federal Ministry of Labour and Economy (BMAW).

Fundamental research is funded by the Austrian Science Fund FWF. The Austrian Science Fund (FWF) is Austria's central funding organization for basic research.
KPC Kommunal Kredit Public Consulting is considered the specialist for funding climate and environmental protection projects.

The Climate and Energy Fund was established by the Federal Government in 2007 (Federal Act on the Establishment of the Climate and Energy Fund - Climate and Energy Fund Act). The strategies of the Austrian Federal Government in the areas of research and technology, climate protection as well as energy and provide the essential foundations that are reflected in the programs of the Climate and Energy Fund.

EU funding is available through the Horizon Europe Program.
The Austrian Energy Agency evaluates each year the funding for energy research in Austria (AEA 2022). In the year 2021 about 8.5 Mio Euro were used for research projects on bioenergy, which was a decrease compared to the last years. Most of the funds were given to the topics hydrogen, hybrid and electric vehicles, storage technologies and energy efficiency.

Funded R&D projects in Austria area dealing with a wide range of different topics and types of fuels. The Austrian energy research arena has a strong focus on energy efficiency, and therein on e-mobility. A small part of the budget is used for renewable energy research and research on biofuels. Those projects are dealing with biomass gasification and synthesis to FT-diesel, lignocellulosic ethanol and hydrogen. A selection of important projects is listed here:

- **Waste2Value:** In the course of the €9 million COMET project "Waste2Value, the use of residual materials from which a hydrogen-rich synthesis gas is produced is being advanced. The focus is on residual materials such as sewage sludge, residues from the paper industry and mixtures with hazardous wood. In a further process step, the gas is synthesised into liquid fuels.

- **Bluetifuel**: Blue flames for low-emission combustion using non-carbon eco-fuels: this project is especially concerned with carbon-free eco-fuels, which burn without any CO_2, such as hydrogen H_2, ammonia NH_3. The team wants to develop a completely digitalised combustion technology that works on the basis of a precisely controlled, forced flame turbulence.

- **IFE - Innovation Liquid Energy:** a system for the highly efficient generation of CO_2-neutral synthetic fuels is being designed and subsystems are being developed. A Solid Oxide Co-Electrolysis (Co-SOEC) is combined with an efficient carbon dioxide (CO_2) extraction and a Fischer-Tropsch (FT) process. The plant produces synthetic diesel, naphtha and waxes from water and carbon dioxide.

- **EvEmBi**: Evaluation and reduction of methane emissions from different European biogas plant concepts: The EvEmBi project aims to evaluate different biogas plant concepts (e.g., agricultural biogas and bio-waste or waste water treatment plants) used in the EU with respect to their methane EFs.

- **AMF Task Sustainable Aviation Fuels**: This is the first AMF project on this topic. The project is led by Austria, participants so far are Austria, Denmark and Germany, and a number of other AMF member countries are currently examining the possibility of participation.

- **UpHy I:** Upscaling of green hydrogen for mobility and industry: UpHy I is addressing an important white spot of by developing solutions for large scale green hydrogen production, hydrogen distribution, HRS technologies and the required measurement techniques for official calibration of HRS regarding mass and gas quality.

Beside the R&D Projects also strategy papers and initiatives are active in Austria:

- Aviation Strategy - Luftfahrtstrategie 2040+ (2022)
  - This Aviation Strategy, published by BMK, is focusing on four thematic areas, namely: environmental protection and introduction of SAF, integration into the overall transport system, development of a level-playing field and innovation and technological change.
  - FTI Strategie für Luftfahrt 2040+ (2022) is part of the Aviation Strategy and puts the Federal Government's Research, Technology and Innovation Strategy 2030 into concrete terms for aviation-related topics.
- Hydrogen Strategy - Wasserstoffstrategie für Österreich (2022)
  - Hydrogen will be one solution for decarbonizing the industry, but only if produced with renewable energy. Austria´s plan foresees 1 GW electrolysis capacity by 2030 and the development of a supportive framework to integrate hydrogen in the energy system. The focus of using hydrogen will be on industries which are hard to decarbonize, e.g., chemical industry, steel industry, maritime and aviation. Gas infrastructure will be transformed to hydrogen infrastructure and incentives, such as investments in research and networking (e.g., Hydrogen platform H2Austria), will be created.
- Mobility Master Plan Mobilitätsmasterplan 2030 für Österreich (2021)
  - The Austrian mobility master plan foresees a promotion of e-fuels as well as innovative propulsion systems based on hydrogen and battery, an introduction of blending mandates, compliance with international approval criteria, the participation in CORSIA, climate neutral transport by 2040 and a transport sector covered by 100% renewable energy from Austria (except for aviation). Biofuels which are now used exclusively in road transport should, up to a certain extent, also be used for aviation, if there is no other more efficient application.
- Further, a SAF Roadmap is under development by the Federal Environmental Agency.
- Additionally, ZOVI (Zukunftsoffensive Verkehr & Infrastruktur) a non-partisan alliance of leading Austrian infrastructure providers, presented an action plan for the introduction of SAF in Austria.

5.9. Sources

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6. The Netherlands

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6.1. Summary

- National implementation of REDII, as of January 1st 2022. Within RED II, the overall EU target for Renewable Energy Sources consumption by 2030 has been raised to 32%. Member States must require fuel suppliers to supply renewable energy at a minimum of 14% of the energy consumed in road and rail transport by 2030.
- On January 1st, 2022, the updated Energy for Transport legislation and regulations entered into force. This implemented parts of the updated European Renewable Energy Directive (RED II) and the Dutch Climate Agreement. Companies that deliver fuels in the Netherlands are subject to obligations based on the *Energy for Transport* legislation and regulations. This consists of an annual obligation and a reduction obligation. The annual obligation is a mandatory share of renewable energy in a company's fuel deliveries, which will increase annually. The mandatory share will increase incrementally from 17.9% in 2022 to 28.0% in 2030.There is 18.3% biofuels mandate (both ethanol and biodiesel), mainly for road transport, based on energy content.
- The Dutch regulation includes a sub-target for the use of advanced biofuels at a 2.4% level in 2023 (including double counting). This will increase annually to a 7.0% level in 2030.
- Implementation of the European Commission *Fit-for-55* package which has a goal of 55% CO2-reduction by 2030. This package includes (among other things) revisions to REDII (REDIII), ReFuel Aviation, FuelEU Maritime, FQD, ETS, ETD. (Fit-for-55 – The EU's plan for a green transition – Consilium (europa.eu))
- There are production facilities for bioethanol, biokerosene, biodiesel, HVO and biomethanol in the Netherlands.
- However, in the Netherlands, there are not separate market-based mechanism aimed at reducing CO_2 emissions for transport (such as a carbon tax or emissions trading (cap-and-trade).
- A mandate for SAF in aviation is in preparation. Until then an opt-in system for aviation biofuels can be used to generate tradable units, as part of the contribution to the mandate for road transport
- No financial incentives (e.g., subsidies, credits, incentives) are provided for the uptake of biofuels. The blending of biofuels is encouraged with the quota obligation for fuel suppliers.

6.2. Introduction

The total energy supply (TES) of the Netherlands in 2021 amounted to 2955 PJ. It is still for around 90% dominated by fossil fuels, particularly gas and oil, which represent around 45% (1262 PJ) and 42% (1065 PJ) of total energy supply respectively. Coal represents around 5% of TES (236 PJ). Renewable energy sources have a share of around 8% or 350 PJ. Around 70% of renewable energy supply in 2021 came from biomass (235 PJ), followed by wind and solar energy (together 114 PJ) (Figure 6.1).

Overall TES slightly declined in the past decade. Natural gas is the main source of energy – its consumption was fairly stable between 1400 and 1500 PJ up to 2011, which was around 45% of TES. After that there was a temporary decline to 1200 PJ in 2015. However, in recent years natural gas use increased again up to 1262 PJ in 2021. Oil products have been relatively stable around 1000-1200 EJ in the past decade, representing around 37% of TES. An important share of oil products (~360 PJ) is consumed for non-energy use. Coal used to be quite stable around 350 PJ up to 2013 (10% of TES). With the building of new coal power plants, it increased to a level of 460 PJ (15% of TES) in 2015. Meanwhile the use of coal has started to decline, to a level of 236 PJ (5% of TES) in 2019. Nuclear energy only had a modest role in the Netherlands around 1.5% of TES (40 PJ), which has been quite stable in the past decades (Figure 6.2).

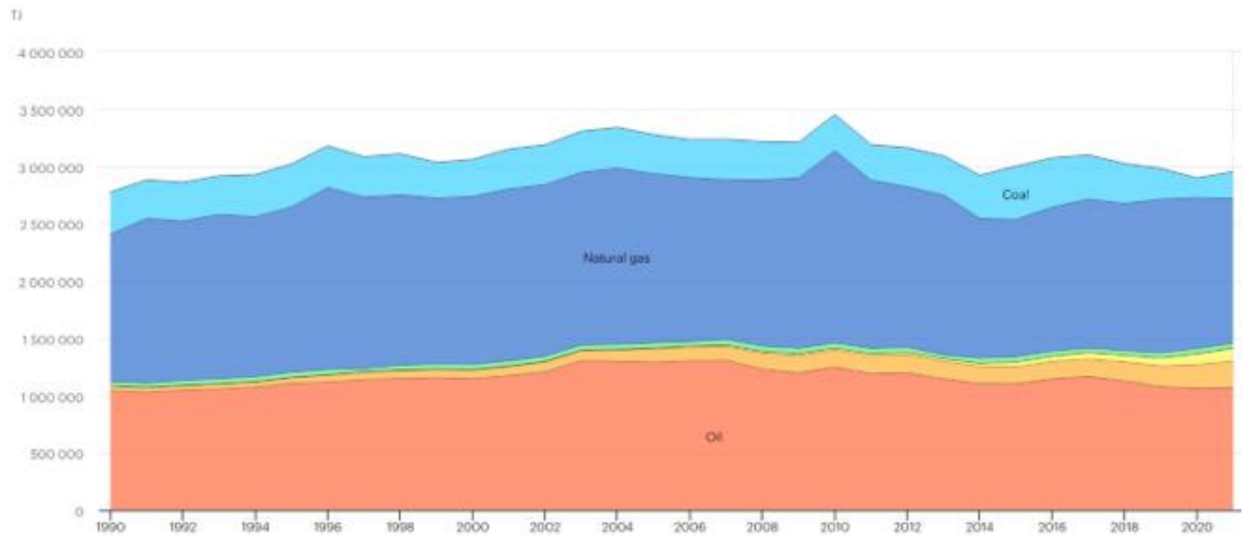

Figure 6.1. Total energy supply[1] (TES) and the contribution of different energy sources in The Netherlands, (1990-2021) (Source: IEA (2023)

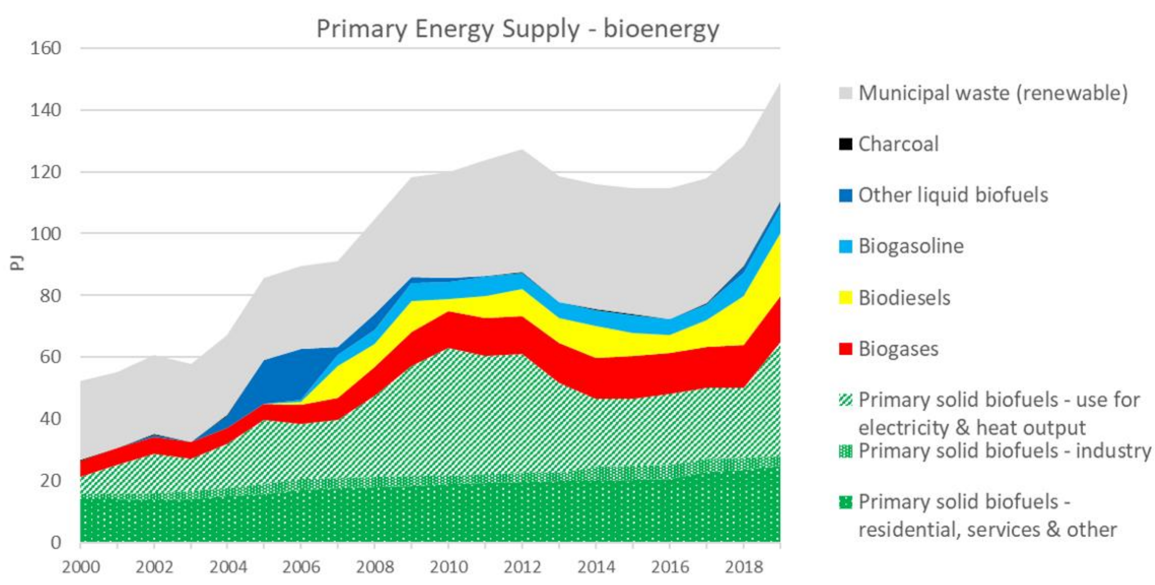

Figure 6.2. Development of total energy supply from bioenergy in The Netherlands 2000 – 2019 (Source: IEA (2021) World Energy Balances and Renewables Information). The share of renewable energy continuously increased from 2005, albeit at fairly modest levels.

[1] Total energy supply refers to the use of resources. In terms of the role in the energy system this distribution overestimates the role of resources producing electricity with a high share of unused waste heat (like nuclear plants).

Since 2017 there is a clear acceleration of renewable energy, mainly in bioenergy, wind and solar energy. The share of renewable energy is expected to continue to grow in coming years. The European Renewable Energy Directive (REDII) targets are at least 32% renewable energy overall and 14% share of renewable energy in final consumption of energy in transport by 2030 (including double counting). The two biggest sources of bioenergy in the Netherlands are solid biomass (65 PJ or 44% of bioenergy supply) and renewable municipal waste (39 PJ or 26%). 20% of bioenergy comes from liquid biofuels (30 PJ) and 10% from biogas (15 PJ).

Energy policies in the Netherlands focus on developing a mix of resources that will assure reliable, affordable supply while recognizing the need to reduce reliance on carbon-intensive resources. There are two recent developments that can have major impact on the energy policy. First, the decision to reduce the extraction of natural gas out of the Groningen field (the main source of natural gas in recent decennia). Depending on the geopolitical situation, the Groningen field will likely be closed in 2024. Second, the targets of the Rutte IV administration to reduce GHG emissions 55% by 2030. In June 2019, this was implemented in the Dutch Climate Agreement between the government and stakeholders, as a follow up of the earlier National Energy Agreement (September 2013).

The government supports deployment of renewables, energy efficiency, nuclear power, and relies on biomass co-firing (with restrictions for use for low-temperature heat) and carbon capture and sequestration (CCS) to curb carbon emissions from coal and gas-fired generators. The Dutch government has in place a number of policies and programs to support decarbonization.

The Renewable Energy Directives obliges member states of the EU to produce a certain amount of renewable energy. The Netherlands is implementing the EU-RED by gradually raising its share of energy from renewable sources such as biofuels, biogas, and electricity for road transport. The 10% target of renewable energy in the final consumption of energy in transport contributed 36 PJ to final renewable energy use in 2020. As of January 1st 2022, the EU-RED recast (REDII) with tightened targets towards 2030 has been implemented in the Netherlands.

6.3. Main drivers for biofuels policy

The main driver for biofuel consumption in the Netherlands is the national annual mandate for renewable energy in transport (Jaarverplichting Energie Vervoer). The mandate is designed to cover the obligatory share of renewable energy in transport as defined in the European Renewable Energy Directive (RED), the mandatory percentage of GHG reduction as defined in the European Fuel Quality Directive (FQD) and the National Energy Agreement for 2023. A revision of the national mandate by 2021 has implemented the REDII, continued the FQD mandate and implemented the policy for reducing GHG emissions from transport as part of the Dutch Climate Agreement.

6.4. Biofuels policy

The biofuel policy in the Netherlands is closely linked to European policy and the Paris agreement. The Ministry of Infrastructure and Water Management (IenW) is responsible for biofuels policy. In 2007, a quota obligation for fuel suppliers was introduced, which became later part of implementation of the RED (2009/28/EC). For this directive, it provides a contribution to an overall target for renewable energy and the specific target for 10% renewable energy in transport in 2020. The implementation of the original RED and the Fuel Quality Directive (2009/30/EC) was completed in 2011. In the same year, the Dutch Emissions Authority (NEa) was appointed as the authority in charge of monitoring compliance with national legislation. In 2015, the RED was changed, partly because of the discussion on the land use change impact of biofuels. Renewable Energy Directive (2009/28) and Fuel Quality Directive (2009/30) (both revised in iLUC directive (2015/1513)) implemented in Besluit energie vervoer 2015 (and under revision as part of implementation the iLUC directive). The revised RED (ILUC Directive) from 2015 included a cap on crop-based fuels (7%) and a sub-target for advanced biofuels (0.5%). This was implemented in "Besluit energie vervoer", published June 2018. Through the Annual Obligation [2] fuel suppliers are obliged to achieve a minimum blending level or else face financial sanctions for non-compliance. The obligation mirrors the EU wide scheme, allowing "double-counting" for biofuels based on wastes and residues and other non-food cellulosic and hemi-cellulosic feedstocks as specified in Annex IX of the RED. There are also limits on the proportion that can come from "food and feed crop-based biofuels" and from feedstocks listed in Annex IX Part B (principally UCO), and a mandatory level for" advanced biofuels". The levels of the obligation were being set through to 2030, providing market certainty.

In the coalition agreement (January 2022) of the Rutte IV administration, new targets were set for emission reduction in 2030 (55%). Implementation of this agreement formed the basis of new regulation., which has entered into force in 2022. As the revised national mandate came into force in 2022, the preceding mandate was extended to 2021 with a proposed increased target of 17.5%. As of 2022, the RED II is in force in the Netherlands. In RED II, the overall EU target for Renewable Energy Sources consumption by 2030 has been raised to 32%. Member States must require fuel suppliers to supply a minimum of 14% of the energy consumed in road and rail transport by 2030 as renewable energy (double counting included).

In 2019 the Climate Agreement was signed by a number of parties and lays down the future transition to a sustainable electricity from solar, wind, smart grids and storage of energy (e.g., in H2). It is expected that wind and solar can grow a 10-fold (wind from the 1 GW in 2020 to 10 – 14 GW in 2030). This requires an improved infrastructure and flexibility. Innovation is crucial to realize this. Coal fired power plants will be closed and biomass for power will also fade out.

A sustainability framework for high value use of biobased raw materials was developed in 2019 – 2020 and agreed upon with the Parliament in 2020. This lays down a preference for cascading use of bioresources: First for chemicals and materials, Secondly for (transport) fuels, heavy road, aviation, shipping. Additionally, it is recommended to reduce the use of biomass for heating and power. The sustainability governance of biofuels in the Netherlands is based on the comprehensive EU RED (II) framework. This defines a series of sustainability and GHG emission criteria that transport biofuels must meet in order be counted towards targets and to be eligible for financial support by public authorities. In particular RED II reinforces the measures aimed at reducing ILUC effects and strengthens supervision on sustainability (both public and private). Figure 6.3 shows timeline of biofuels policy development in the Netherlands (2010-2022).

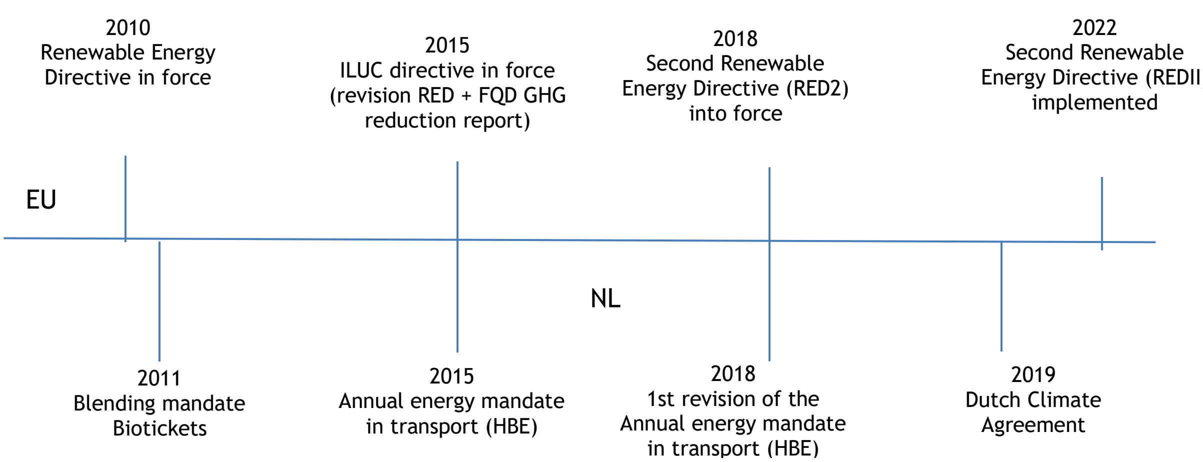

Figure 6.3. Timeline of biofuels policy development in the Netherlands (2010-2022)

[2] Annual obligation | Obligations - Energy for Transport | Dutch Emissions Authority

The industry sectors in the Netherlands made the largest steps to GHG emission reduction in the last decades, followed by electricity production and mobility. Agriculture and housing made a more moderate progress to reduction.

In 2021 the Fit-for-55 package was presented by the European Commission. This is a set of proposals to revise and update EU legislation and to put in place new initiatives with the aim of ensuring that EU policies are in line with the climate goals agreed by the Council and the European Parliament. Fit-for-55 comprises several regulations to reduce CO2-emissions by 55% in 2030. The policy package consists of more general regulations like the Energy Taxation Directive (ETD) and the Emission Trading Scheme (ETS) to target fossil fuel prices and emissions from multiple sectors. Fit-for-55 also has more sector specific plans, like ReFuel Aviation and FuelEU Maritime, that set targets for the deployment of renewable fuels in the aviation and maritime sectors respectively. We will conduct research on the interdependence and interaction between ReFuel and FuelEU, and how to organize legislation to achieve the goals of both regulations.

Furthermore, negotiations for the revision of the REDII (REDIII) are currently ongoing. The Netherlands aims to change from an energy-based approach to an emission reduction-based approach in 2025. This means switching the 2030 target from a share of 14% renewable energy to a minimum of 13% CO2-reduction well-to-wheels in 2030. A sub-target for the use of renewable fuels of non-biological origin (RFNBO, e.g., renewable hydrogen or e-fuels) from 2025 is currently under debate. Changes in the GHG emissions in different sectors over the period of 1990-2021 and 2030 target are shown in Figure 6.4.

In addition to the policy work, the Netherlands has also started the National Energy Program (NPE). This program aims to create an overarching view of the entire energy system in the Netherlands towards 2050. On the one hand it identifies the amount of renewable energy in the system based on current established and intended policy. And on the other hand, it tries to identify a final image of 2050 in which all of the energy needed is renewable. The NPE contains transition paths for sectors (mobility, industry, agriculture and the built environment) and development paths for energy chains (renewable carbon, hydrogen and electricity) and looks at these in relation to each other. The NPE creates clarity about the development direction of the energy system, the system change that this requires and links long-term vision with short-term choices. The NPE will be updated every five years and the first edition is intended to be completed at the end of 2023.

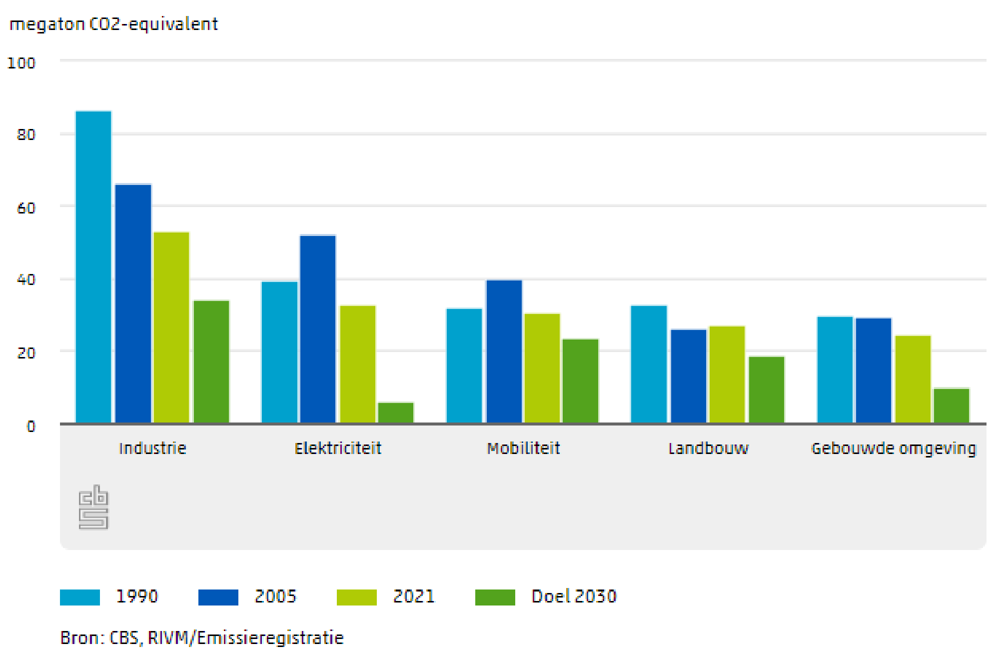

Figure 6.4. Changes in the GHG emissions in different sectors over the period of 1990-2021 and 2030 target (Source: CBS, GHG emissions (cbs.nl))

In the last decade, the CO2 emissions of road traffic declined with some 75 Ktonnes CO2eq. Mainly due to the growing share of renewables and more recent by electric vehicles. Main part of the emissions is still the result of passenger cars (
Figure 6.5).

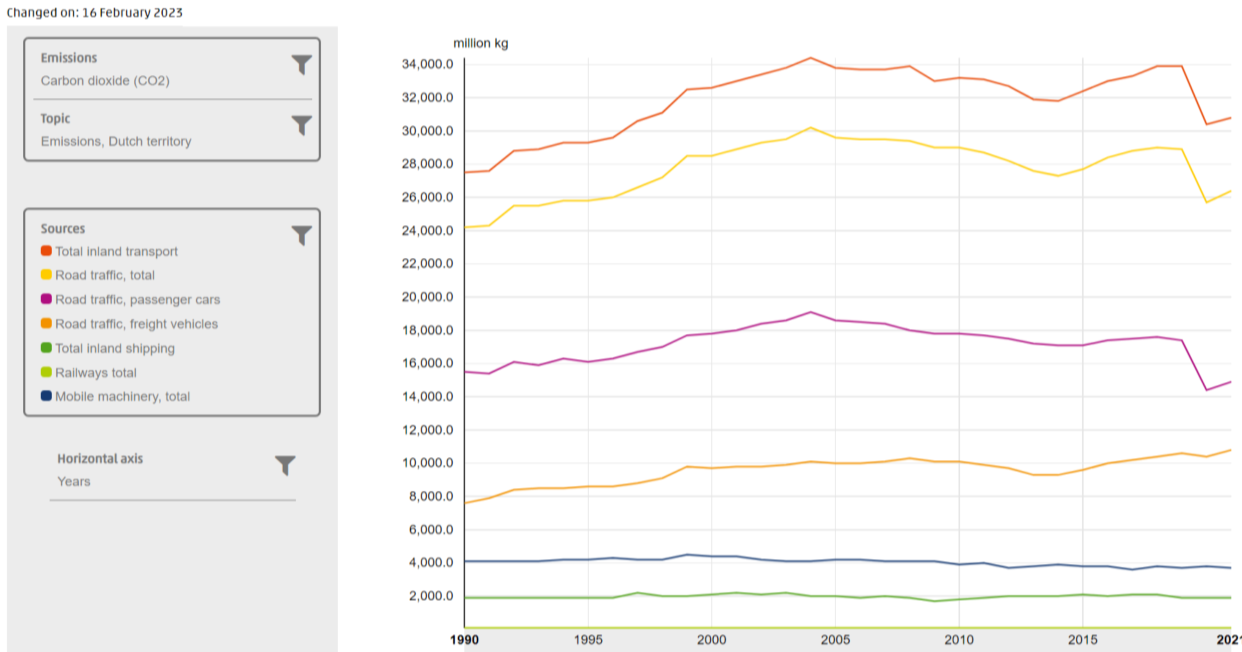

Figure 6.5. Transport emissions in the Netherlands (ton)
Source: [StatLine - Emissions to air on Dutch territory; mobile sources (cbs.nl)].

Order in Council for the Dutch annual energy mandate Besluit energie vervoer (in Dutch)
http://wetten.overheid.nl/BWBR0040922/2018-07-01

The paragraph on climate and energy in the coalition agreement (in Dutch).
https://www.rijksoverheid.nl/regering/regeerakkoord-vertrouwen-in-de-toekomst/3.-nederland-wordt-duurzaam/3.1-klimaat-en-energie

- A summary of the intended post 2022 policy on renewable fuels in the Netherlands are:
- 2030 blending biofuels mandate in road (60 PJ) leading to a physical contribution of 60 PJ
- Focused on energy targets REDII and Tank-to-Wheels (WTW) CO2 emissions contributing to the Paris agreement
- Politic claim all growth in advanced biofuels
- Sustainability demands beyond RED according to Bio-feedstock approach government
- Temporary opt-in on aviation and advanced marine fuels until 2025, in anticipation to a separate national target on Aviation (14% by 2030). Maritime shipping will get a separate target on marine fuels after 2025 (see next section). Looking at more instruments to support investments in advanced biofuel production

6.4.1. Biofuels obligations

Mandatory targets to blend at least 3.5% biofuels in both the petrol and diesel segment of the transport fuel market were removed by the legislation that came into force in 2015. This legislation sets an annual energy obligation ("Jaarverplichting Hernieuwbare Energie Vervoer") in transport fuels that requires fuel suppliers to ensure a minimum level of renewable energy (on energy basis) used in transport fuels. In

2015, fuel suppliers were obliged to blend fossil fuels with at least 6.25% biofuels in energy content ascending to 16.4% in 2020. During 2021 there was an extension of the preceding regulation which resulted in a target share of 17.5%. A fuel suppler that fails to fulfill the quota obligation is liable to pay a penalty. The enforcement of the annual obligation has a legal basis. Next to this pump owners are obliged to supply E10 since October 2019.

From 2022 the EU-REDII was transposed in national legislation. The levels of the national obligation are being set through to 2030. There is a 1.4% cap for first generation biofuels and a 10% cap for biofuels produced from waste oils and fats. Furthermore, there is a sub-target for advanced biofuels that will increase annually to 7% in 2030 as part of the national implementation of the EU RED II directive. Emissions of biofuels are also taken into account based on the European Fuel Quality Directive (2009/30/EC) that requires well to wheel emission reduction (WTW) of 6% in 2020 compared to 2005. For transport in the Netherlands, there are currently no market-based mechanisms for reducing CO_2-emissions in transport such as a carbon tax or emissions trading (cap-and-trade). The NL Climate Agreement sets the intention to additionally reduce emissions in transport, compared to the 2030 projection of the National Energy Exploration 2017. The Climate Agreement demands a limit to the first-generation biofuels from food and feed crops on the level of 2020 in the revision of the annual obligation. In addition, the Agreement aims to maximize the share of biofuels in road transport. This has been effectuated in the revision of the annual energy mandate of 2022.

A summary of the Climate Agreement related to the transportation include:

- 49% CO2 reduction by 2030 (Paris agreement),
- Multistakeholder process including Urban environment, Mobility, Industry, Agriculture and land use, and Electricity,
- Mobility, additional CO2-reduction (Electrification (2 millions EV); Biofuels 27 PJ (2.0 Mton CO2) plus; and various efficiency measures,
- 27 PJ from biofuels is additional to the estimated 33 PJ from the EU obligation (2.5 Mton CO2).
- 5 PJ additional biofuels in inland shipping (0.4 Mton CO2),
- € 200 millions subsidy to stimulate the production of advanced biofuels in the Netherlands ,
- Transport levy contributes to CO2 reduction measures taken by transport companies,
- Separate appointments on aviation and shipping outside the 27 PJ (not part of Paris Agreement),
- Integral sustainability requirements on bio-feedstock;

Since 2011, fuels from wastes/residues and lignocellulosic materials count double in the Netherlands. As part of implementing the EU ILUC directive (2015/1513/EC), a specific sub-target stimulates advanced fuels. In the Netherlands, double counting remains part of the regulation up to 2025. In REDI, sustainability criteria for biofuels were defined in article 17, mass balance and governance demand in article 18, and advanced fuels in Annex IX A. In REDII the sustainability criteria as well as requirements concerning the governance are laid down in Articles 29 and 30.

In the Netherlands, fuel suppliers that sell fuels to the aviation and marine industry have no obligation to supply a certain percentage of biofuel. However, these sectors can contribute voluntarily (opt-in system) to the realisation of the target in the annual obligation for road transport by generating tradable renewable energy units (HBEs). This opt-in is under discussion for the new national mandate because the CO_2 reductions achieved in the aviation and maritime sectors do not contribute to the national obligation resulting from the Paris agreement. Until 2025, deliveries of biofuels to the marine shipping sector only qualify as tradable renewable energy units (HBEs) if the biofuels have been produced from feedstocks listed in Annex IX Part A of the Renewable Energy Directive or in the Dutch industrial waste list (Annex 5 of the Dutch Energy for Transport Regulations). From 2022, in addition to this feedstock-based double-counting, a multiplier of 0.8 will also apply to registered deliveries to the marine shipping sector, so as to regulate the effect of the number of HBEs from marine shipping in the HBE market. The Ministry of Infrastructure and Water Management may revise this multiplier from year to year. A multiplier of 1.2 applies to fuel deliveries to the aviation sector that have been produced from biofuels that do not result in the creation of HBE-Cs.

In 2018, 3 types of tradable units were introduced, HBE-C (conventional), HBE-A (advanced) and HBE-O (others), to facilitate meeting the sub-target for advanced biofuels and limiting conventional biofuels. In the coming national mandate, an extra HBE unit will be introduced to regulate the cap resulting from the REDII for Annex IX-B biofuels, i.e., UCO and animal fats (HBE-B) (Figure 6.6).

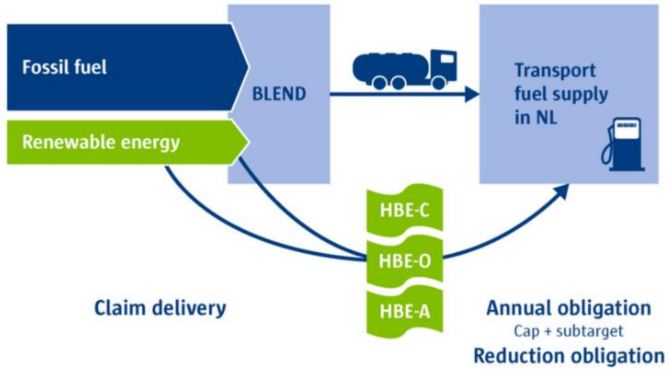

Figure 6.6. Overview of the HBE-system in the Netherlands (Source: Dutch Emissions Authority)

Table 6.1 provides information on current obligations for biofuels in the Netherlands. Obliged parties are oil companies that bring petrol and diesel from excise warehouses into the Dutch fuel market. All biofuels that are proven to be sustainable and fuels or energy demonstratable from renewable sources are eligible to meet the obligation. Sustainability can be proven by using one of the EU accepted voluntary schemes (see link to European Commission website).

For this obligation, biofuels produced from wastes/residues as well as non-food cellulosic and hemicellulosic materials count double. A list of materials counting double is part of RED Annex IX (A and B). The category "industrial waste" is specified with a specific Dutch list of materials. Verification of double counted material is obliged. A protocol for verifying double counting of eligible biofuels is made available by the government. Companies wishing to enter a claim for a biofuel to be eligible for double-counting must have a double-counting declaration for this biofuel. This declaration proves that the double counting has been confirmed by an authorized independent verifier to meet legal conditions.

Table 6.1. Biofuel obligations/mandates (% by energy content)

Year	Total % renewable energy in the transport market, obligation to market parties		Subtarget advanced biofuels (Annex IX A)	Limit conventional	Cap (Annex IX B)
	Target	Achieved			
2010	4%	Unknown			
2011	4.25%	4.31%			
2012	4.5%	4.54%			
2013	5%	5.05%			
2014	5.5%	5.54%			
2015	6.25%	6.25%			
2016	7%	7.0%			
2017	7.75%	7.75%			
2018	8.5%	8.9%	0.3%	3.0%	
2019	12.5%	12.7%	0.4%	4.0%	
2020	16.4%	16.5%	0.5%	5.0%	
2021	17.5%	17.5%	0.6%	5.0%	
2022	17.9%	Not yet known	1.8%	1.4%	10%
2023	18.9%	Not yet known	2.4%	1.4%	10%

From January 2015, administration of obligations has been through an automated digital register managed by NEa. Companies in non-compliance with their obligation are subject to a financial penalty according to the act on economic crimes.

Companies that supply renewable energy to the Dutch transport sector can claim the delivered renewable energy in their account in the Energy for Transport Registry (REV), and receive Renewable Energy Units (HBEs) in return. Renewable energy encompasses liquid biofuels, gaseous biofuels, renewable liquid fuels and electricity. Eligibility conditions apply to both the claiming operators and the renewable energy to be claimed.

In addition, obligated companies can comply with their mandated GHG intensity reductions by purchasing HBEs. The legislation sets a maximum to the administrative transfer of biofuels supplied in a previous year, with the objective of selling HBEs to others for the purpose of using them to meet their obligation in a subsequent year ("carry-over"). This restriction does not apply to physical biofuel stocks. Physical and administrative biofuel stocks transferred to a subsequent year must still comply with sustainability requirements in force in that year. To demonstrate the sustainability of biofuels, companies must use one of the voluntary schemes (for instance ISCC or Better Biomass) that has been recognized by the European Commission.

6.4.2. Excise duty reductions

There is no excise duty reduction for biofuels in the Netherlands.

6.4.3. Fiscal incentives

No financial incentives (e.g., subsidies or credits) are provided for biofuel uptake. The blending of biofuels is encouraged within the quota obligation for fuel suppliers.
The Climate Agreement includes the intention to support the production of advanced biofuels for the Dutch market. This has been implemented since 2021.

6.4.4. Investment subsidies

The Energy Investment Deduction scheme (EIA), the Environmental Investment Deduction scheme (MIA) and the Random Depreciation Environmental Investment scheme (VAMIL) all provide tax incentives for investment in renewable energy projects. These schemes support various renewable energy technologies, including biomass processing equipment, pyrolysis installations for recycling of residues, production facilities for algae, etc.

6.4.5. Other measures stimulating the implementation of biofuels

Since 2017, the Demonstration Scheme for Climate Technologies and Innovations in Transport (DKTI Transport) has provided subsidies for: 1) technology and innovation development at pre-commercial phase; 2) reduction of CO_2, NOx, fine dust emissions and noise; and 3) transport of alternative fuels, including accelerated roll-out or use of infrastructure for alternative fuels.

Both the MIA and VAMIL schemes are applicable to natural gas cars, hydrogen cars, fully electric and plug-in hybrid cars. Cars with diesel engines are excluded from MIA and VAMIL.

6.5. Promotion of advanced biofuels

The Dutch regulation includes a sub-target for the use of advanced biofuels at 2,4% level in 2023. With the implementation of REDII, an increase of advanced biofuels up to 1.75% (3.5% with double counting) is needed. The Dutch Climate Agreement aims for an additional 2 Mt CO2 reduction in 2030 on top of the reductions achieved by the REDII mandate, mainly to be achieved with advanced and renewable fuels of non-biological origin. The new national mandate proposes a sub-target for advanced biofuels of 3.5% (7% with double counting) in 2030 which reflects that ambition.

6.6. Market development and policy effectiveness

Figure 6.7 and Table 6.2 show the biofuel production facilities in the Netherlands with installed and planned production capacity and their consumption in transport.

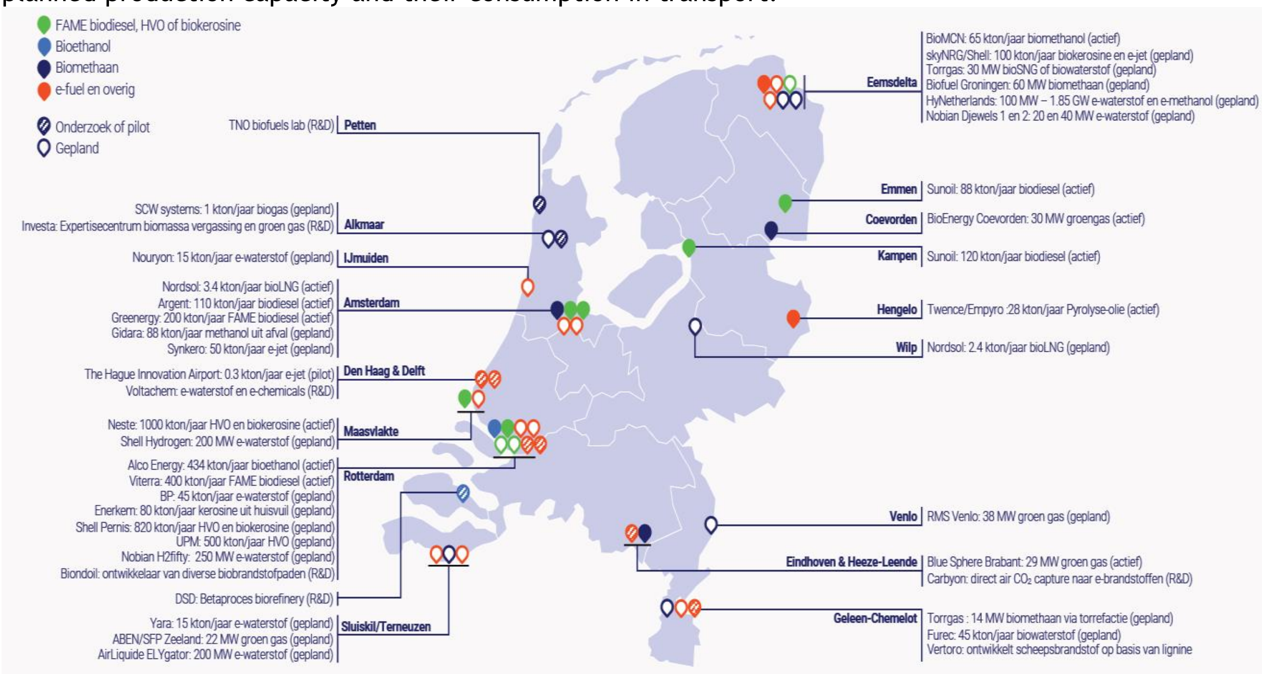

Figure 6.7. Map with biofuel production locations in the Netherlands– installed and planned production capacity (Kt/yr and MW/yr)

Table 6.2. Biofuel production and consumption in transport (TJ) (Preliminary data source: CBS)

Year	Production Installed production capacity (TJ/yr)		Consumption in transport (pure and blended) (TJ/yr)	
	Biogasoline	Biodiesel	Biogasoline	Biodiesel
2006	314	684	798	968
2007	293	3,145	3,687	9,344
2008	186	3,071	4,524	7,524
2009	-	10,138	5,771	9,835
2010		14,114	5,614	3,963
2011		18,167	6,231	7,207
2012		43,549	5,211	8,806
2013	11,178	50,875	5,238	8,140
2014		63,640	5,379	10,307
2015		60,273	5,950	7,488
2016		54,094	5,049	5,698
2017		71,373	5,399	8,493
2018		68,034	7,146	15,846
2019		72,832	8,321	20,116
2020		73,266	9,481	14,848
2021		75,575	9,766	17,973

An increasing portion of the biofuels on the Dutch transport market is produced from waste streams; in 2021 the share of these feedstocks amounted to 86%, with UCO accounting for a share of 44%. It is attractive to use waste-based biofuels because their energy content may be counted twice to achieving the targets. Particularly in the case of the petrol substitute bioethanol, the use of waste streams is increasing, resulting in fewer agricultural crops are used. The other 15% of biofuels are produced from agricultural crops, mainly corn and wheat.

The feedstocks of the biofuels that were used in the Netherlands in 2021 originate from 90 different countries. 15 countries account for almost 83% of the total feedstock volume. This top 15 consists mainly of countries from Europe and Asia. Less than 7% of the biofuels used in Dutch transport are produced from feedstocks that originate in the country itself.

6.7. Co-processing in refineries

As a delta region, the Netherlands is an excellent location to receive, process and transport oil products to the European mainland. With 7 refineries, mainly located in the Rotterdam area, Netherlands has a share of about 10% in the European market. Co-processing in refineries does not take place in the Netherlands yet.

6.8. Conclusions

The Netherlands was one of the first European countries to implement the annual obligation and the double counting policy on fuels form wastes and residues and are very successful with that reaching a share of share of 89% of biofuels from UCO and animal fats. The share of renewables that could be reported to the European Commission in 2021 was 13,8% of the total use of gasoline, diesel and renewable electricity in transport in the Netherlands, and exceeded the obligatory share of 10% by 2020.

Strengths of the Dutch approach are the national trading system that supports the market in an efficient uptake of the obligation, ambitious goals set in a national Climate Agreement and the announcement of a separate obligation on aviation fuels. High ambitions on a fast growing share of biofuels from wastes and residues with a consistent share of UCO and animal fats. As points, a low limit on the share of feedstock from food and feed crops and the influence of large volumes of marine fuels on HBE-prices are points of attention that need to be solved.

6.9. Sources

Dutch Climate agreement:
https://www.klimaatakkoord.nl/

Netherlands- Energy System Overview.
The Netherlands - Countries & Regions - IEA

A platform for sustainable biofuels in the Netherlands: Platform Hernieuwbare Brandstoffen

Website EC with background of EU policy : https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/

Background policy in the Netherlands: https://www.rijksoverheid.nl/onderwerpen/milieuvriendelijke-brandstoffen-voor-vervoer/biobrandstoffen

Subsidie DKTI-transport: https://www.rvo.nl/subsidies-regelingen/DKTI-Transport

Statistics on energy, fuels and biofuels: http://statline.cbs.nl/statweb/

Reports regarding the obligation results:
General - Renewable Energy for Transport 2022-2030 | Dutch Emissions Authority

Biofuel policies in the Netherlands http://saee.gov.ua/sites/default/files/Kvant_0.pdf

The Netherlands

Netherlands- Energy https://www.export.gov/article?id=Netherlands-Energy

- Tax law, article 72a on biofuels ("Wet op de accijns m.b.t. biobrandstoffen, art. 72a)
- Policy letter on biofuels of Government to parliament - March 2006.
- www.biofuel-cities.eu
- National Renewable Energy Action Plan – The Netherlands: http://ec.europa.eu/energy/renewables/transparency_platform/doc/national_renewable_energy_action_plan_Netherlands_en.zip
- GAVE website: Hernieuwbare energie vervoer
- https://www.emissionsauthority.nl/topics/themes/energy-for-transport (website of the Dutch Emissions Authority (NEa) in English)

https://www.emissionsauthority.nl/topics/themes/energy-for-transport

7. Belgium

Drafted and submitted by Robert Malina (Hasselt University, Belgium);

7.1. Overview on current energy status

Belgium, a country with a population of approx. 11.5 million people and an area of 30,690 km^2, was the 8th largest energy consumer in the European Union in 2020, consuming 1,597 PJ. The country consumed about 76% of its gross available energy, similar to the European Union average (74%). In terms of energy productivity, Belgium was in the 15th position, lying, inter alia, behind Germany, France, and the whole European Union, and the Netherlands. Figure 7.1 illustrates these and other key energy indicators in Belgium, in comparison to other European countries.

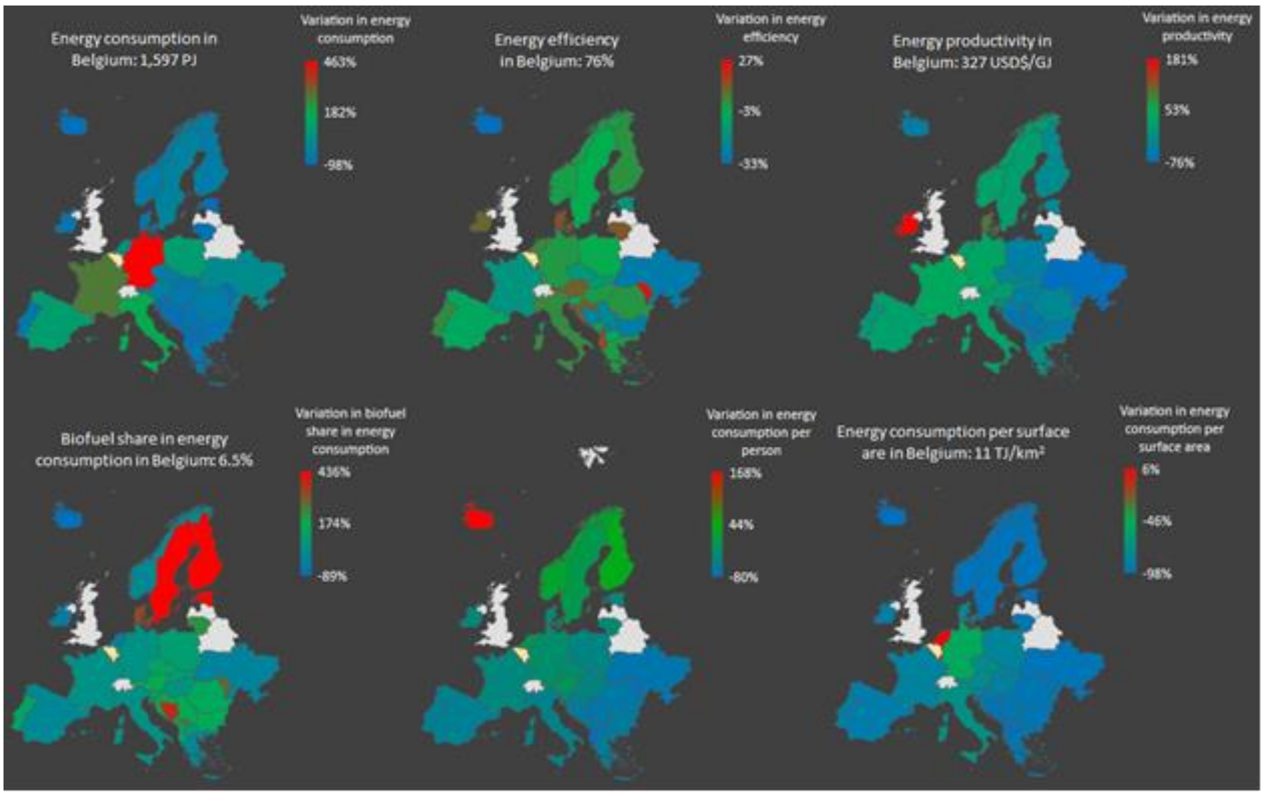

Figure 7.1. Variation in energy indicators in Europe compared to Belgium [1, 2] (White areas denote regions without available data)

7.2. The role of biofuels in BELGIUM

Figure 7.2 shows the breakdown of energy consumption in Belgium in the year 2020 excluding bunker fuels (any fuel used on board an ocean ship or planes on international routes). With 104 PJ, biofuels covered about 6.5% of the final energy consumed in Belgium, while other renewable sources, excluding nuclear, covered 7.2 PJ, which highlights the great dependency of the country on fossil sources. The transport sector represented about 20% of total energy consumption in Belgium in 2020, dominated by the road transport sector. Biofuels' energy contribution to this sector is lower than 10%, with biodiesel the highest contributor (83% of road transport bioenergy consumption). The energy consumption of other non-road transport sectors (aviation, in-land navigation, and rail) represents less than 5% of the total energy consumed by the transport sector and is currently covered almost entirely with fossil resources. For instance, the rail sector covered about 86% of its energy requirements (6 PJ) using electricity generated from nuclear sources (39%), natural gas (34%), biofuels (6%), and other renewable sources (21%, mostly wind and solar) [2]. Thus, biofuels contributed less than 0.4 PJ to the energy requirements of this sector.

Figure 7.2. Disaggregated energy consumption in Belgium excluding bunker fuels [2]

Biofuels´ contribution to the industry sector and other energy sectors is also relatively low (8.3%, and 6.7%, respectively), with primary solid biofuels (PSBs) being the dominant biofuel. No biofuels were used in other non-energy sectors. The contribution of PSB and other biofuels to the transport sector is negligible (≈0.1%). If bunker fuels are included, the total energy consumption in Belgium in 2020 would increase by 294 PJ, which is almost the energy consumed by non-energy sectors in the country by the same year [3]. This is due to the outsized importance of the Port of Antwerp.

Putting Belgian biofuels consumption in perspective

In 2019, the household energy consumption in Belgium reached about 331 PJ, that is, about 21% of the total energy consumption of the country [2]. Furthermore, Belgium had about 5 million houses by that year [5]. Thus, the average energy consumption of households reached about 67 GJ/yr, used mostly (73%) for space heating. The energy contribution of biofuels equals then the annual energy consumption of about 1.6 million households, almost the whole of all households in the Walloon region.

7.3. Where do biofuels in Belgium come from?

Figure 7.3 shows the energy balance of biofuels in Belgium in 2020. In this year, biofuels production in the country was about 1.7 times as high as biofuels imports. On the other hand, exports amounted to about 18% of domestic biofuels production. PSBs are the most important biofuel, contributing more than half of the total biofuel energy input in the country. Biodiesel is the second most important biofuel with 22% of contribution. The total biofuel energy inputs in Belgium reached 151.87 PJ. About 12% of biofuels inputs in Belgium were exported, leaving 134.29 PJ available.

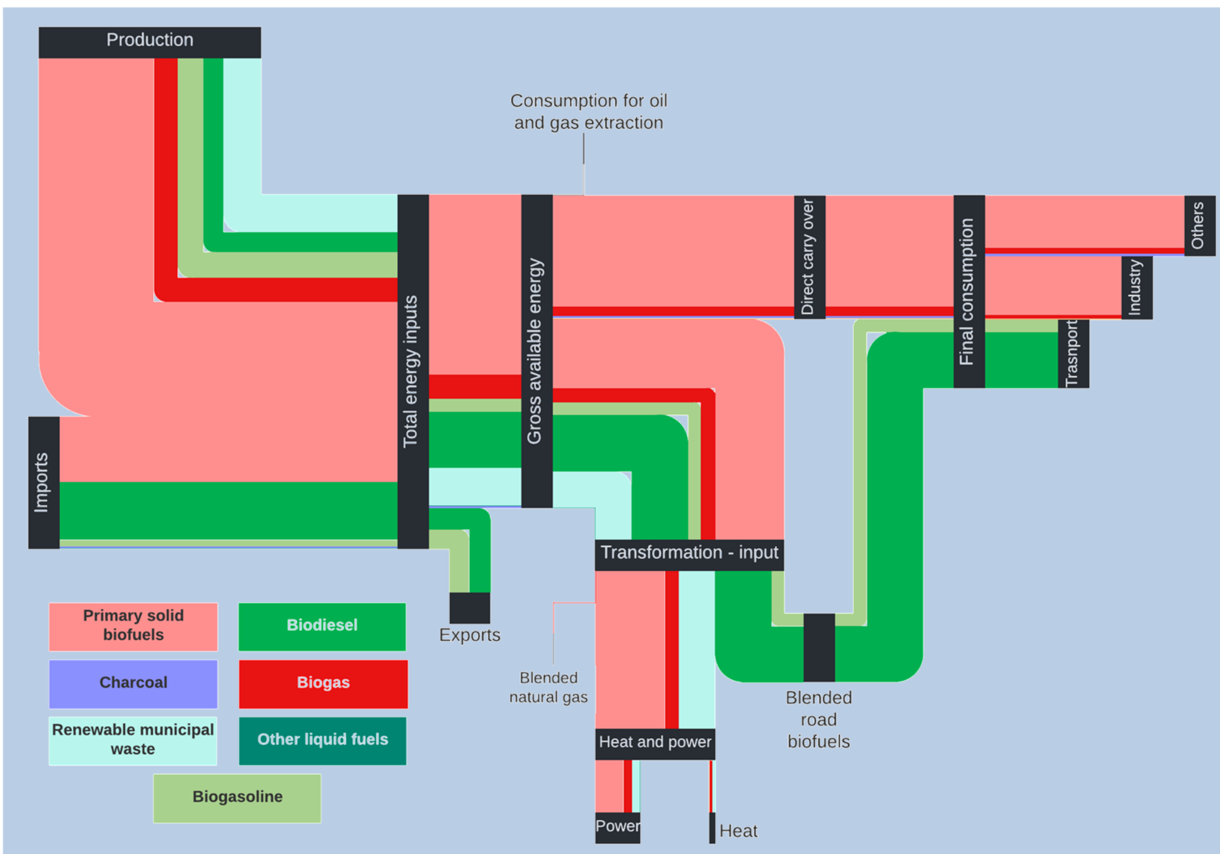

Figure 7.3. Energy balance of biofuels production in Belgium [1, 2]

About 60% of the gross available biofuels (81 PJ) were transformed prior final consumption. Thus, biogasoline (liquid biofuels suitable to replace gasoline or be blended with it) and biodiesel were blended with conventional fossil fuels almost entirely (>99%) and used for the road transportation sector. Biodiesel and biogasoline contributed 24 PJ and 5 PJ to the road transportation sector, respectively. On the other hand, almost 30 PJ, 15.5 PJ, 6 PJ, and 0.25 PJ of PSB, renewable municipal waste (RMW), biogases, and OLF were used to generate heat and power. Moreover, only a small portion of biogas for transformation (<1%, 49 TJ) is blended with natural gas. The biofuel-based generated heat and power (21.7 PJ) covers about 6.4% of the total heat and power generation in the country. In Belgium, about half of the entire generated heat and power is used by the industry sector, about half is used by other energy sectors, and <2% for the transport sector.

About 47.6 PJ of PSB (62%) was directly used and divided almost equally to be used by the industry and other sectors. On the other hand, about 40% of the gross available biogas (4 PJ) was also directly used by the industry (1.6 PJ) and other (2.4 PJ) sectors.

Figure 7.4 shows the evolution of liquid biofuels production capacity in Belgium. From 2011 to 2020, production capacity has decreased from 48 PJ to 33 PJ. Biodiesel contributes the most to total production capacity (54%), followed by biogasoline (38%). Comparing liquid biofuels production capacities with primary production in 2020, biodiesel and biogasoline, facilities were operating at 48%, and 88% of production capacity, respectively.

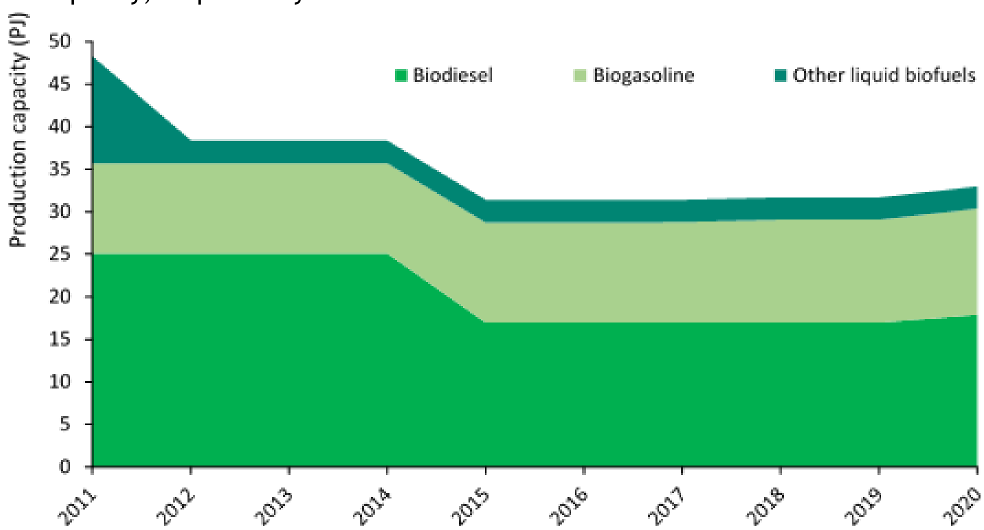

Figure 7.4. Liquid biofuels production capacity in Belgium [2]

Figure 7.5 shows a breakdown of biodiesel and bioethanol in Belgium by feedstock in 2014 and 2018. Most of the biodiesel in Belgium is derived from rapeseed. However, its contribution has decreased from 2014 to 2018. For bioethanol, wheat is the highest-used feedstock, followed by corn [6].

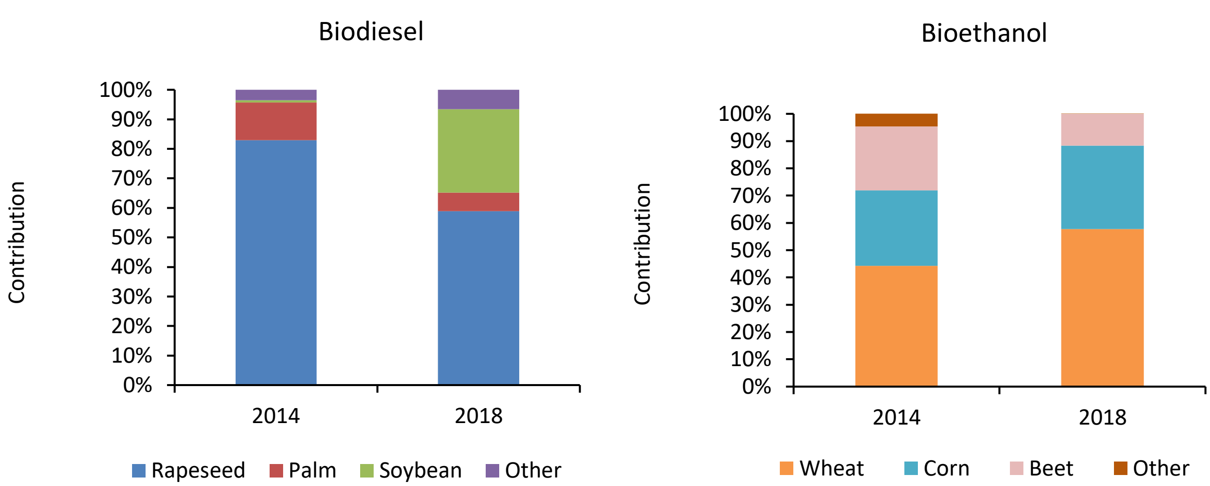

Figure 7.5. Breakdown of liquid biofuels in Belgium [6]

About 59% of the liquids biofuels inputs in Belgium are imported. Most of biodiesel and biogasoline imports come from Switzerland and the Netherlands, respectively (Figure 7.6) [1].

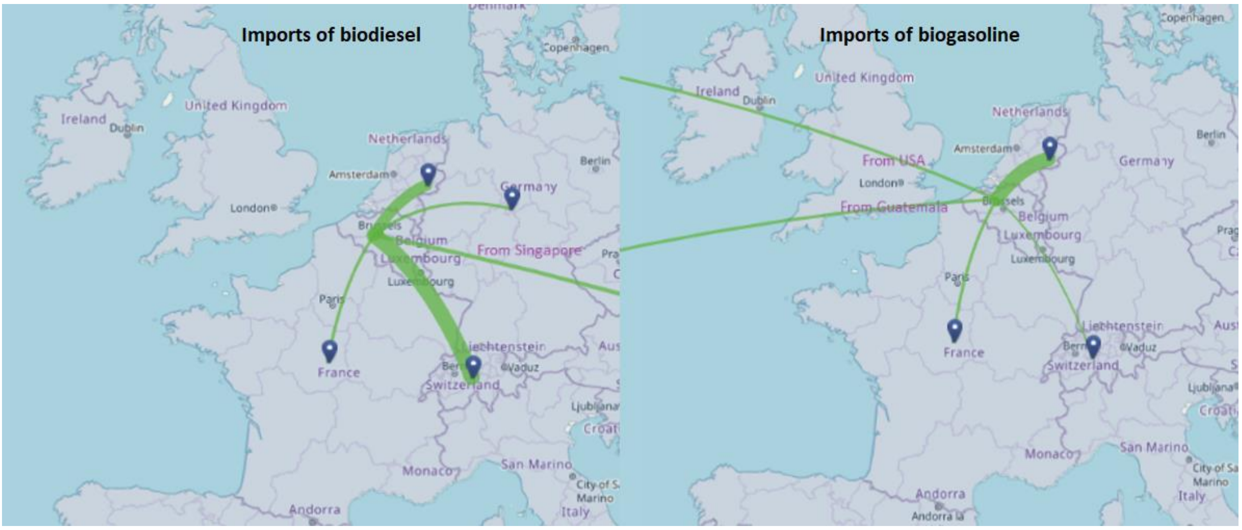

Figure 7.6. The road of biofuels into Belgium

7.4. The GHG emissions impact of biofuels in Belgium

Biofuels are used in order to reduce carbon dioxide emissions of human activity by replacing conventional fossil-based fuels. Therefore, biofuels must have lower lifecycle carbon emissions than their conventional, fossil-derived counter-parts. An existing assessment of the CO2 emissions of the road transport sector and the biofuel consumption in Belgium indicates that GHG emissions decreased by 6% from 2008 to 2019. In the same period, the share of biofuel consumption in this sector increased from 0 to 5.5% (Figure 7.7).

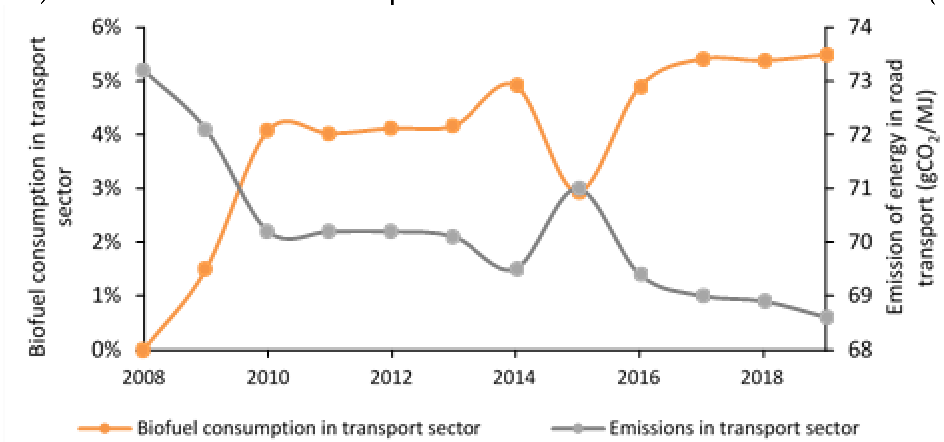

Figure 7.7. Carbon dioxide emissions of the transport sector and the contribution of biofuels in it [2]

7.5. Policies towards biofuels in Belgium

Belgium has developed 98 energy-related policies, out of which 49 are oriented for renewable energies. Nine of these laws are ended, 39 are in force, and 1 is being planned. Table 7.1 summarizes the policies focusing on the use of liquid biofuels for the transport sector in Belgium. The "*law of obligation for the incorporation of biofuels in fossil fuels*" and the "*blending mandate 2017 and 2020*" are important laws as they set targets for the incorporation of biofuels in line with the 10% minimum target to be achieved by all EU member States for the share of biofuels in transport petrol and diesel consumption. The available biogasoline and biodiesel in Belgium in 2020 was enough to cover 8% and 10% of the energy needs of motor gasoline and gas/diesel in the road-transport sector, respectively. Overall, both biofuels covered 9.3% of the total gasoline and diesel energy requirements, which means that the country requires a small effort to fulfill with the European Union target (Figure 7.8).

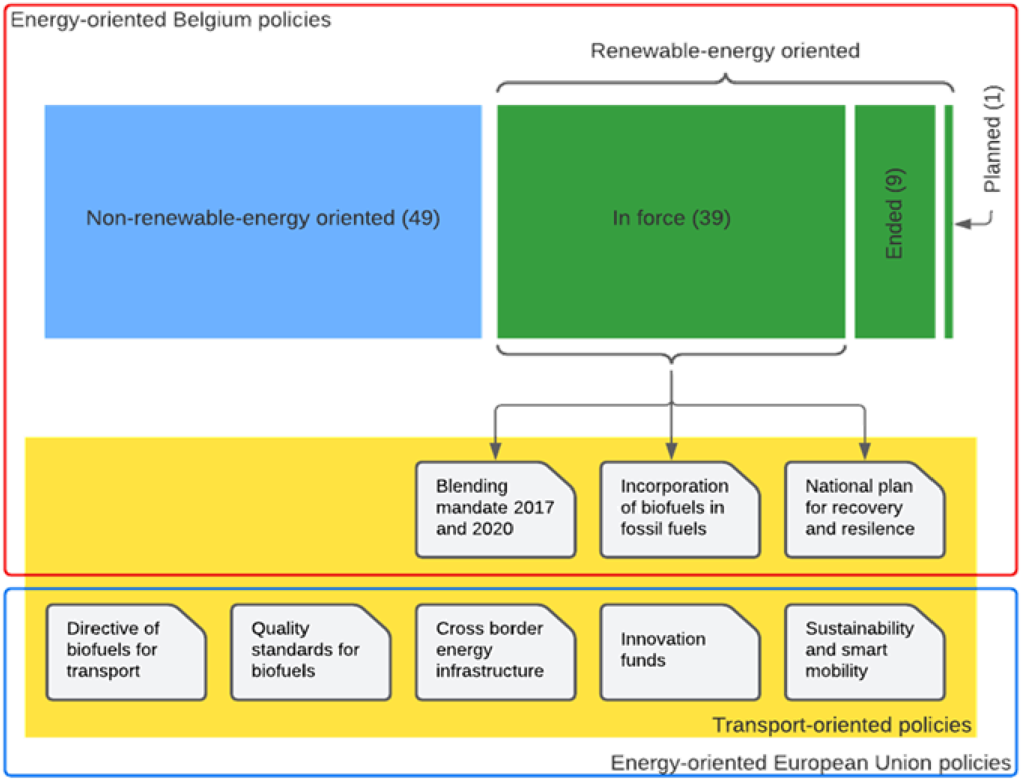

Figure 7.8. Policies regarding the use of renewable energy in the transport sector in Belgium [7]

Recently, Belgium joined Denmark, France, and the Netherlands to ban biofuels derived from palm oil or soy from 2022 onwards due to issues related to deforestation, loss of biodiversity, and human rights violations [8]. Unlike palm oil, the soybean restriction could compromise the biodiesel availability in the country (Figure 7.5) and hinder the fulfilment of targets stated by the European Union. Regarding advanced biofuels, legislation in Belgium allows for double counting of those fuels when using them in the transport sector and established a target for covering 0.1% of its total transport energy with them from 2020 onwards [9].

Table 7.1. Summary of Belgium policies focusing on the use of liquid biofuels for the transport sector [7]

Law	Year	Status	Description
Excise Tax Reduction for Biofuels	2006	Ended	Tax reduction for diesel oil containing at least 3.37% biodiesel and on gasoline containing at least 7% ethanol of non-chemical nature
Law of obligation for the incorporation of biofuels in fossil fuels	2009	In force	Fossil fuel companies in Belgium must incorporate at least 8.5% bioethanol and 6% biodiesel
Blending mandate 2017 and 2020	2017	In force	Set the binding target for blending biofuels in petrol to 8.5% vol/vol. The update in 2020 set the target to 8.5% MJ/MJ.

7.6. Biofuels technology development and deployment

In 2020, Belgium committed to the objectives set out in Lisbon and the European 2020 strategy to invest 3% of its GDP on research and development. One-third of the R&D budget is supposed to be funded by public agencies while the remaining by private sectors [10]. About 5% - 10% of the total is aimed to be spent on climate and energy projects by means of the federal Energy Transition Fund.

Figure 7.9 maps some research projects on bioenergy in Belgium [11]. In the region of Flanders in the north of Belgium, there is a focus on bio-based value chains from available ligno-based raw materials with projects such as the Flanders Biobased Valley or the Lignin-based Biorefinery. Other projects, such as the BIG-Cluster, collaborate with institutions from other countries. Furthermore, the research centers Interuniversity Microelectronics Centre (IMEC) and VITO, together with industrial partners Bekaert, Colruyt Group, DEME and John Cockerill undertake research projects related to green hydrogen production [12].

Research projects in the region of Wallonia include renewable hydrogen generation (H2GREEN, HYSTACK, HYDEAI, HYFLUX, WallonHY H2Hub Wallonia), waste recovery (LOOP FC, AGRIWASTE VALUE), local renewable energy integration (INTERESTS, TTCOGEN, ENERBIO), microorganism-based biofuel generation (ALGOTECH, PERSEPHONE, COOPILOT BIOMGT), or energy-oriented technologies (OPTI-AGV, CLEARPOWER, PEPSE). In the region of Brussels, the TTCogen project aims to valorize biomass though gasification and cogeneration. As a Belgian-wide collaboration, BE-HyFE is aiming to enhance the expertise in Belgium with regard to addressing key hydrogen challenges, including the transition to green hydrogen [14].

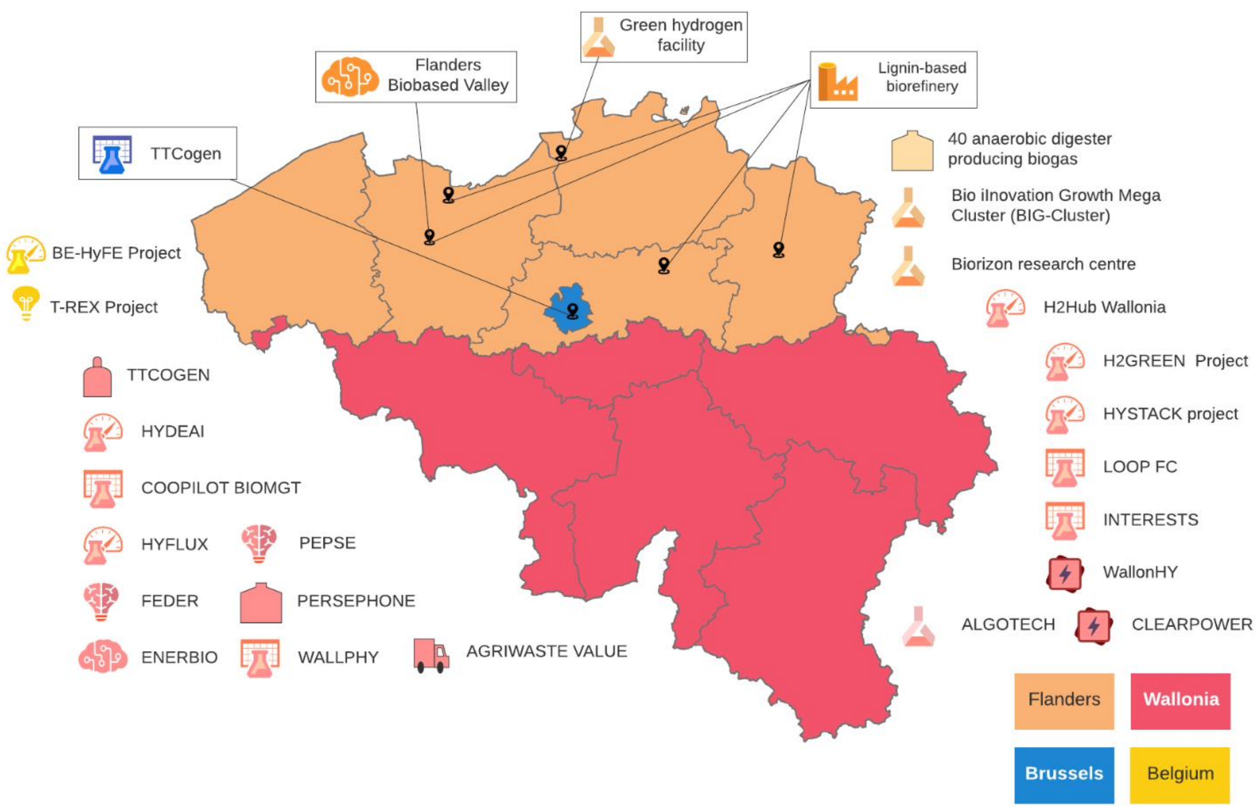

Figure 7.9. Research projects on biofuels in Belgium. Data taken from [11-14]

7.7. Sources

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8. Brazil

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8.1. Summary

- Brazil has been a pioneer in the implementation of biofuels, particularly ethanol, as a sustainable and renewable alternative to fossil fuels. With its abundant sugarcane production, the country has successfully developed a robust biofuel industry. The establishment of the National Alcohol Program in the 1970s, because of the oil crisis, facilitated this evolution. Brazil's commitment to biofuels can be seen in its extensive ethanol production and infrastructure. This includes the widespread use of flex-fuel vehicles capable of running on both gasoline and ethanol.
- Recently, there has been rapid growth in corn ethanol production. It is already responsible for a large market share.
- The biodiesel industry has been growing steadily, with blending targets established up to 2026.
- The widespread adoption of biofuels has not only reduced Brazil's dependence on imported oil, it has also contributed significantly to mitigating GHG emissions.
- The Brazilian government has recently implemented policies and incentives to encourage the expansion of biofuel production such as the RenovaBio program, ensuring the sustainability and economic viability of the sector.
- Developments in the production of advanced biofuels such as sustainable aviation fuels are expected in the near team.
- Brazil's successful implementation of biofuels stands is a good example of how governments can prioritize environmental sustainability while simultaneously promoting energy security and economic growth.

8.2. Introduction and main drivers for transport biofuels in Brazil

In 2021, the Brazilian energy supply (total energy available in the country) reached 301.5 Mtoe, registering an increase of 4.5% compared to the previous year (EPE, 2022b). The country has a significant portion of its internal energy supply from renewable sources, which corresponded to 44.7% in 2021. Public policies adopted by Federal Government over the years, associated with the country's natural conditions, have enabled Brazil to present a great diversity of renewable sources in its energy mix. Such a variety comprises liquid biofuels, predominantly ethanol, and biodiesel; solid biofuels, the most relevant being sugarcane bagasse; and gaseous, with a still incipient participation of biogas. Biogas has shown an increasingly significant production in the national energy scenario. The share of biogas in the domestic energy supply is still small (0.12%), but it has shown rapid growth, of 22% CAGR (compound annual growth rate) in the last five years (EPE, 2022a). Sugarcane products (16.4%) are the second main source in the internal energy supply, behind oil and its products (47.7%) (EPE, 2022b).

According to the Brazilian Energy Balance report (EPE, 2022b), the final energy consumption was 255 Mtoe, with contributions between different sources as seen in Figure 8.1. Sugarcane products have a relevant share in several sectors of the economic activity: in the transport sector, they provide 17.4% of the energy consumed (18.5% for road transport), and in the industrial, 18.2% (in the food and beverage segment, 70.4%) (EPE, 2022b). Ethanol (straight [hydrous] and blended [anhydrous] with gasoline, E27) is used in Otto cycle engines and bagasse is an energy source for steam production in the manufacturing of ethanol and sugar. Also, sugarcane biomass is used to generate electricity, part of which is consumed in the sugarcane mills and part is injected into the national grid (National Interconnected System – SIN).

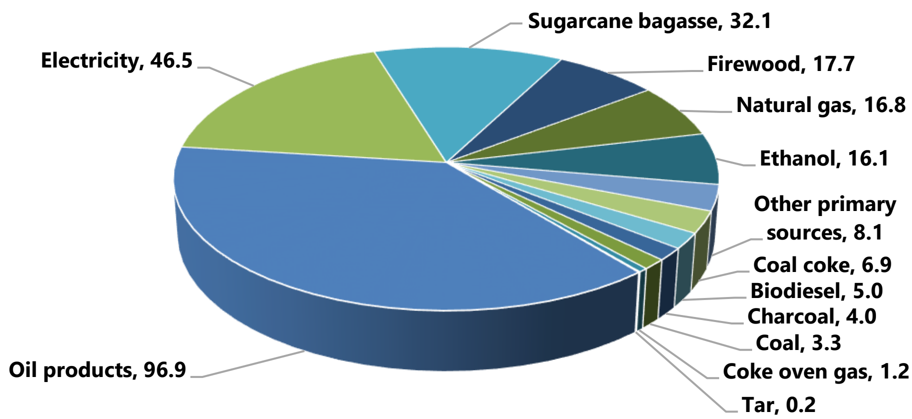

Figure 8.1. Final energy consumption of energy by source in Brazil in 2021 (Mtoe) (EPE, 2022b)

In 2021, the final energy consumption in the transport sector was 85.1 Mtoe and represents 24.1% of the total (EPE, 2022b). For road transport, the amount consumed was 80.2 Mtoe, 30.6% of the total. Brazil is itself a case of success in the biofuel demand for the transport sector. Its participation increased from 16.7% in 2011 to 22.6% in 2021. The share of biodiesel increased from 2.2% to 5.2% of the transport energy consumption in the period (EPE, 2022b).

Figure 8.2 shows the evolution of GHG emissions in Brazil from 1990 to 2020. In 2005, GHG emissions in Brazil were 2,450 MtCO2eq, with Forest and Land Use as the main emitter, responsible for 64% of the total (considering net emissions from forests and land use). In a later survey, GHG emissions fell to 1,676 MtCO2eq in 2020, with Forest and Land Use (38%) being the main responsible for this reduction. In the same year, the energy sector emitted 389.5 MtCO2eq (23% of the total) (MCTI, 2022).

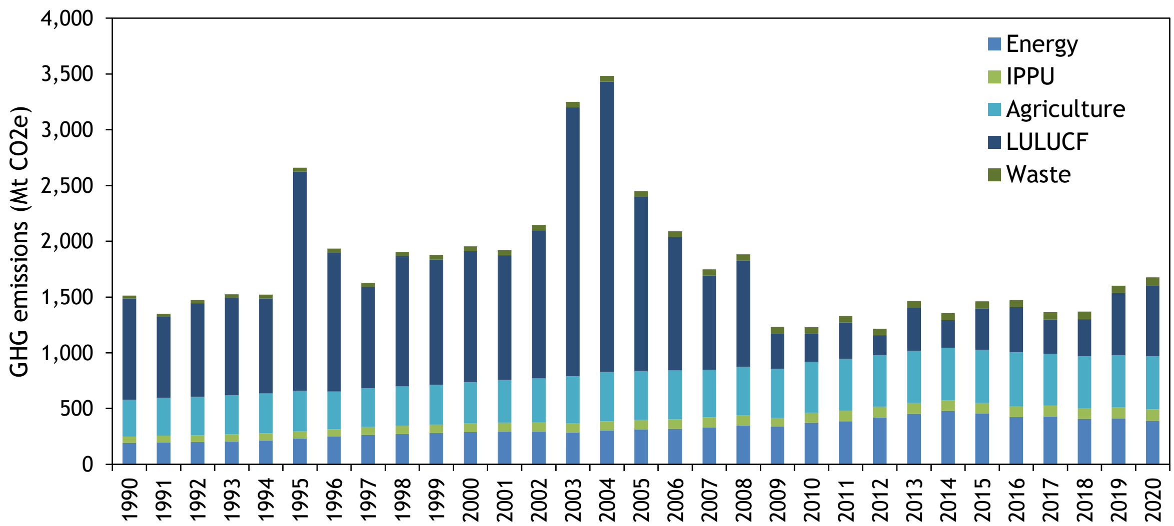

Figure 8.2. Brazilian GHG emissions divided by sectors, from 1990 to 2020. IPPU: industrial processes and product use, LULUCF: land use, land-use change, and forestry (MCTI, 2022)

In 2021, total anthropogenic emissions associated with the Brazilian energy mix reached 445.4 MtCO2eq. The main responsible for GHG emissions in energy production and consumption are the transport (197.8 MtCO2eq) and industrial (77.8 MtCO2eq) sectors, which accounted for 44.4% and 17.5% of total emissions, respectively (EPE, 2022b).

There are several benefits from biofuels use in the Brazilian national energy mix, which can be observed in the economic, social and environmental spheres. Since Brazilian production of gasoline and diesel is not sufficient to meet domestic demand, the use of ethanol and biodiesel reduces the risks related to the instability of the international oil market and increases the security of energy supply. The absence of these biofuels could result in an increase in imports of fossil analogues, thus affecting Brazil's trade balance.

The most evident social impacts of using biofuels are related to the creation of jobs and income, whether in the agricultural or industrial phase of their production, with benefits to the far countryside. In the case of biodiesel, a standout initiative is the Social Fuel Seal (in Portuguese: “Selo Combustível Social”), which benefits small farmers with family farming participation in the biofuel production process. Indirectly, jobs are also created in the agricultural machinery industry and its business and related services, with most trading occurring in rural areas of the country. Besides, it is possible to identify positive impacts on infrastructure, improvements in motorways and railways, in food production and in quality of life of people living in the neighbouring areas.

The environmental benefits of biofuels are due to the reduction of GHG emissions, lower generation of air pollutants, liquid effluents, and solid waste compared to fossil fuels. In general, biofuels produced in Brazil have lower GHG emissions compared to other biofuel technologies used worldwide, with further potential for further reduction if new technologies are developed or better management is used.

Today, the official document driving Brazil’s national policy framework for renewable energy is its Nationally Determined Contribution (NDC) towards achieving the goals of the United Nations framework convention on climate change. This document, announced in December 2015 during the Paris Conference (COP 21), forecasts the Brazilian energy use and emissions on next years and provides background for the main energy planning document. The Ten Year’s Energy Expansion Plan (PDE, in Portuguese: “*Plano Decenal de Expansão de Energia*”), is elaborated by Brazil’s Energy Research Office (EPE) and published every year by the Ministry of Mines and Energy (MME). In addition, all policies, measures and actions to implement Brazil’s NDC are carried out under the National Policy on Climate Change (Law 12,187/2009), the Law on the Protection of Native Forests (Law 12,651/2012, hereinafter referred to as the Forest Code), the Law on the National System of Conservation Units (Law 9,985/2000) as well as related legislation following established processes. The Brazilian government is committed to implement its NDC with full respect to human rights, in particular the rights of vulnerable communities, including indigenous populations, traditional communities and workers in affected sectors, and to also promote gender-responsive measures.

As a result of COP 21, Brazil is committed to reduce its domestic GHG emissions by 37% by 2025 and by 43% by 2030, both compared to 2005 levels. The country also intends to adopt further measures that are consistent with the goal of 2°C maximum temperature rise, in particular:

- Increase the share of sustainable bioenergy in the Brazilian energy matrix to approximately 18% by 2030, by expanding biofuel consumption, increasing ethanol supply — including a greater proportion of advanced biofuels, cellulosic ethanol in the gasoline fuel blend and more biodiesel in the diesel blend.
- Achieve an estimated 45% share of renewables in the energy mix by 2030.
- Obtain at least a 66% share of hydropower in electricity generation by 2030, not considering self-produced electricity.

- Expand the use of renewable energy sources other than hydropower in the total energy mix to 28–33% by 2030.
- Expand the use of non-fossil energy sources domestically in the electricity mix by increasing the share of renewables (other than hydropower) in the power supply to at least 23% by 2030, by increasing the share of wind, biomass, and solar energy; and achieve 10% efficiency gains in the electricity sector by 2030.

Still under this topic, it is important to add that the Glasgow Climate Pact was signed in 2021. IN this new agreement, Brazil has indicated the intention to reduce 50% of its emissions by 2030 and as a long-term commitment, become carbon neutral by 2050 (UNFCCC, 2021).

In 2017, Brazil launched the RenovaBio program (Law 13,576/2017), which is a state policy recognizing the strategic role of all types of biofuels in national energy mix, both for energy security and for mitigation of GHG emissions, effective from 2020. After the first operating year of commercialization of decarbonization credits (called CBIO — further explained in the next section) in an organized market and because of COVID-19 Pandemic impacts, there was a revision of the annual goals of RenovaBio. According to the law, the total CBIO to be marketed in 2022 is 36.0 million and, for 2031, 95.7 million. By March 2023, there are 318 certified producer plants for CBIO awarding (ANP, 2023). The RenovaBio program does not include the creation of carbon taxes or any kind of subsidy to biofuels; instead, it creates a market-based incentive by issuing GHG emissions reduction certificates, which fuel distributors are required to purchase.

The framework of the Rota 2030 program – Law 13,755/2018 – was approved by the Brazilian federal government in December 2018 (BRAZIL, 2018) to foster efficiency and safety in vehicles produced in Brazil. Specific measures have been put forward to promote ethanol and biodiesel as solutions to meet progressively strict vehicle emissions regulations.

8.3. Historical Development of Biofuel Policy and Industry in Brazil

In 1931, the Brazilian government implemented a compulsory blend of at least 5% anhydrous ethanol in gasoline, aimed at reducing dependence on imported petroleum and absorbing excess production of the sugar industry. In 1975, in response to the impacts of the oil shocks during the 1970s, the Brazilian government created the National Alcohol Program (*Pro-álcool* in Portuguese), increasing the ethanol blending level up to 25% in gasoline (E25) and introducing hydrous ethanol ("E100", approximately 95% ethanol and 5% water) for use in ethanol-dedicated vehicles. The use of ethanol-dedicated vehicles was eventually phased out and replaced by mandatory blends of ethanol in gasoline, starting with E10. The ethanol content in Brazilian gasoline has varied over successive decades and it is currently 27%. For over 80 years, all Brazilian cars have been using blends of ethanol and gasoline with good performance and without any remarkable problems (BNDES, 2008).

The second phase of expansion took place because of a new market opportunity. In 2003, flex-fuel cars were launched, offering drivers the option of using both gasoline (containing 20–27% anhydrous ethanol) and hydrous ethanol, at any proportion. As a result, the consumption of hydrous ethanol in Brazil's domestic market made a comeback, creating new opportunities for expanding the sugarcane industry in Brazil, as well as the possibility of exporting more ethanol to meet the world's biofuel demand. During 2003–2008, the Brazilian sugarcane industry expanded rapidly, with many new and more efficient sugar-ethanol mills commissioned (SCOPE, 2015a) and several of them exporting electricity to the national grid. As of 2008, the sector has experienced great difficulties due to the petroleum crisis and the rise of the American dollar, which has considerably increased their debts that were tied to this currency, and led to a consolidation phase within the industry. Thus, the production increased by only 1.8% between 2008 and 2017. In 2019, ethanol production was 36 BL and the share of ethanol in the fuel mix used by light vehicles (Otto Cycle — in gasoline eq.) reached 54.8%, the highest in history.

Brazil's biodiesel program started in 1980 with the Plan for the Production of Vegetable Oils for Energy Purposes initiative (*PRO-OLEO* in Portuguese). A blend level of 30% vegetable oils or derivatives in fossil diesel was mandated and, in the long run, a total substitution. The proposed technological alternative to produce biofuels was the transesterification of vegetable oils. The main motivation was the oil crisis and the sharp increase in the prices of fuels it caused. After the fall in international oil prices in 1986, the PRO-OLEO program was abandoned.

At the end of the 20th century, several studies were carried out by inter-ministerial commissions in partnership with universities and research centers, and, in 2002, ethanolysis of vegetable oils was chosen as the main route to initiate a substitution program for petroleum diesel, the PROBIODIESEL program. As Brazil is a large ethanol producer, ethanolysis was chosen as the production route instead of methanolysis. The National Program for Production and Use of Biodiesel – PNPB – was created in 2005 to further stimulate energy, economic and social objectives as well as foster feedstock production by small farmers. This program has evolved gradually, with soybean oil and tallow proving to be the most relevant feedstocks for production, adopting a transesterification process with methanol. There was also the objective of reducing dependence on fossil diesel. This program mandated a B5 blending in 2005. In April 2023, the blending mandate for biodiesel was increased from 10% to 12%, and successive yearly increases of 1 p.p. will lead to a 15% blend by 2026.

The normative acts regarding the specification of biodiesel are:

- ANP Resolution No. 798/2019 – amends ANP Resolution No. 45/2014, which establishes the biodiesel quality specifications, to determine the mandatory addition of biodiesel with antioxidants and establishes a new specification limit for the oxidation stability characteristic;
- ANP Resolution No. 30/2016 – establishes the specification of diesel oil BX to B30, in an authoritative nature, under the terms of items I, II, and III of art. 1 of CNPE Resolution No. 03, of September 21, 2015;
- ANP Resolution No. 45/2014 – establishes the biodiesel specification contained in ANP Technical Regulation No. 3/2014 and the quality control obligations to be met by the various economic agents that sell the product throughout the national territory.

In 2017, Brazil established the National Policy for Biofuels – RENOVABIO, by Law #13,576/2017. The RENOVABIO program creates a regulatory framework to revitalize the biofuels sector, encouraging energy efficiency gains in biofuels production and use. It recognizes that different biofuels have different capacities to contribute to the decarbonization of the economy. The policy aims to meet the annual decarbonization targets set by the government for a minimum 10-year period. Through this program, biofuels production is being certified through life cycle assessment (LCA) with the issuance of GHG emissions reduction certificates, named CBIO (an acronym for "*Crédito de Descarbonização*" – Portuguese for Decarbonization Credit, equivalent to 1 t of CO2 avoided GHG emissions), to producers that can be traded in the stock market and purchased by fuel distributors. One CBIO corresponds to a reduction of one ton of CO2eq in comparison to fossil fuel emissions. With RenovaBio, the government plans to increase ethanol and biodiesel production (MME, 2020c). Figure 8.3 shows the governance structure of RenovaBio.

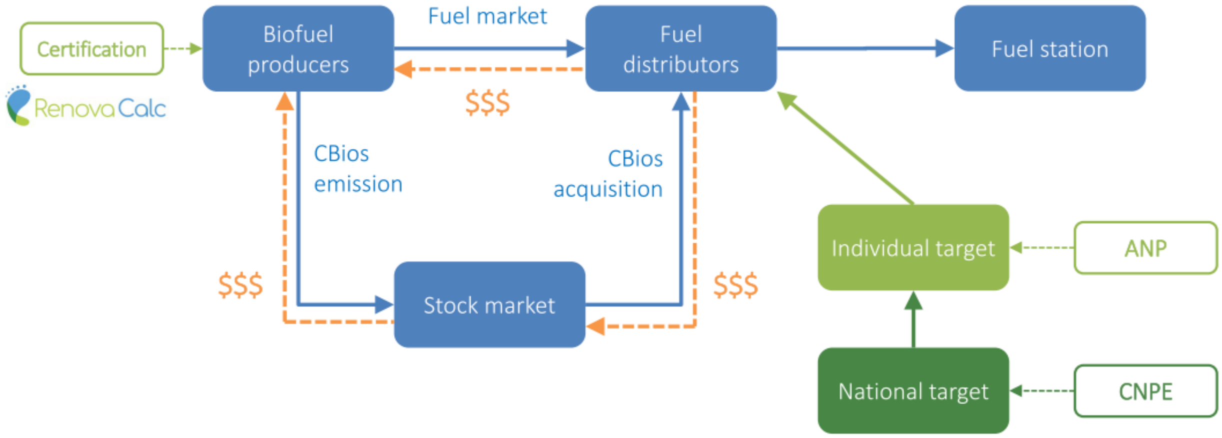

Figure 8.3. Governance structure of RenovaBio

In 2019, the MME, through resolution CNPE #12/2019, called for studies to support the formulation of measures aimed at promoting free competition in the supply of fuels, other petroleum products, and biofuels. That year, the Brazilian Government launched the "*Abastece Brasil*" (Portuguese for "Refuel Brazil") Program, an initiative led by the MME and a support base for the National Energy Policy Council (CNPE), that seeks to develop the fuel market and secure its supply, with a focus on promoting free competition in the sector (MME, 2019). The main instrument for carrying out the work of the initiative is the Integrated Technical Committee for the Development of the Market of Fuels, Other Petroleum Derivatives and Biofuels (CT-CB), established by Decree #9,928, of July 22nd, 2019, and it is responsible for (1) preparing studies to support the formulation of public policies aimed at guaranteeing the national supply of fuel; (2) prepare studies to help improve regulatory standards for activities ranging from production to sale of both fossil fuels and biofuels; and (3) propose actions and measures aimed at developing the fuel market, other petroleum products and biofuels.

In 2020, ANP approved the start of a public hearing on the specification of green diesel, a renewable fuel for diesel cycle combustion engines, produced via hydroprocessing of renewable raw materials, such as vegetable oil, animal fats, sugarcane, alcohol, and biomass. The new fuel will be added to diesel of fossil origin, which currently has mandatory 12% biodiesel. The new biofuel consists predominantly of paraffinic, straight-chain hydrocarbons, having properties similar to diesel from fossil sources and differs from biodiesel, which is a mixture of fatty acid esters with similar properties. The regulation of green diesel may also make feasible the production and commercialization of aviation biokerosene (sustainable aviation fuel, SAF), already regulated by ANP Resolution #778/2019, because the hydroprocessing of renewable feedstock to producing green diesel also produces hydrocarbons suitable for aviation fuel. The initiative is the result of the ANP carrying out an analysis of the regulatory impact brought about by the insertion of this new biofuel in the Brazilian market, as well as studies of the international specifications of green diesel sold internationally.

The MME, through Resolution #13/2020, instituted a working group to study the inclusion of biofuels for use in diesel cycle engines under the Brazilian Energy Policy, in compliance with the guidelines of the Brazilian Biofuels Policy – RenovaBio (BRASIL, 2020). This working group was coordinated by MME and composed of representatives of several government bodies. Its conclusion was on October 17th, 2021 and the results were presented as a Report in 2022, analyzing the increase of biofuel use in diesel cycle engines (MME, 2022).

On April 7th, 2021, under the CNPE Resolution 07/2021, the Future Fuel Program was created to propose measures to increase the use of sustainable and low-carbon fuels, as well as national vehicle technology, to decarbonize the national transport energy mix (BRAZIL, 2021). The Resolution also created the Future Fuel Technical Committee (CT-CF), which is composed of fifteen government bodies and coordinated by the MME. This committee must provide proposals of methodologies for evaluating the complete fuels life cycle analysis; recommend measures to bring the reference fuels closer to the used fuels; and suggest actions to provide the citizen with adequate information for the conscious choice of the vehicle concerning aspects of energy and environmental efficiency, among others.

On May 13th, 2021, ANP presented Resolution #842 / 2021, which defines the specification and obligations regarding the quality control of green diesel. As a result, the regulation of biofuels used in diesel engines start to incorporate current technological advances and allows the use of other biofuels in addition to FAME biodiesel (ANP, 2021a).

A specific public policy and a legal framework for SAF in Brazil is under development, which includes quality and specification standards that allow renewable fuels to be used in airplanes. This can be considered the first step to the creation of a domestic market for SAF. The timeline for important regulations concerning SAF is shown in Figure 8.4.

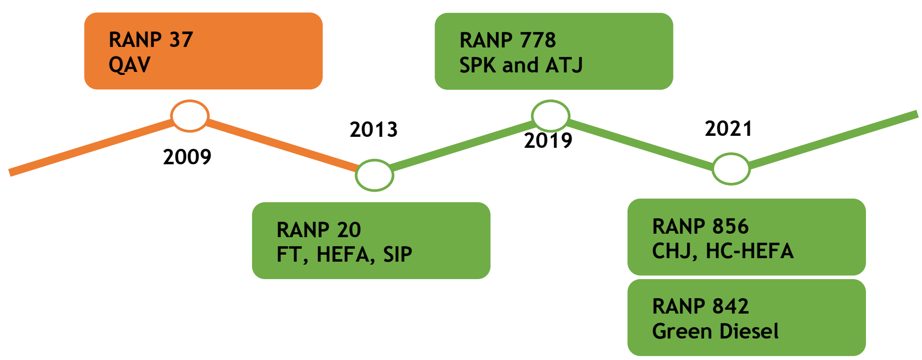

Figure 8.4. Timeline of ANP Resolutions for Aviation Kerosene. Adapted from (GIZ, 2022)

In terms of directives and standards, ANP has issued the following Resolutions:

- RANP 37/2009 QAV — The ANP Resolution #37/2009 dealt with the specification of kerosene as aviation fuel (QAV, "*querosene de aviação*", aviation kerosene in Portuguese), intended exclusively for consumption in aircraft turbines, marketed by producers, importers, distributors, and resellers throughout the national territory (ANP, 2009).
- RANP 20/2013 FT; HEFA; SIP – It established the specifications of alternative aviation kerosene (also known as SAF), and their mixtures with conventional aviation kerosene (QAV-1), as well as the obligations regarding quality control to be served by the various economic agents that sell these products throughout the national territory. It also set alternative aviation kerosene may be added to aviation kerosene (QAV-1) up to the maximum limit of 50% by volume for consumption in aircraft turbines (ANP, 2013).
- RANP 778/2019 – It incorporated the routes of paraffinic kerosene synthesized from aromatics (SPK/A) and paraffinic kerosene synthesized from ethanol (SPK-ATJ) that had been approved by ASTM in 2015 and 2016 respectively. The standard provided that aviation kerosene type C (QAV-C) was the mixture of QAV (QAV-1) with the alternative kerosene, obeying mixing percentages of 50% for the SPK-FT, SPK-HEFA, SPK/A, and SPK-ATJ routes and 10% for SIP (ANP, 2019).
- RANP 856/2021 - Establishes the specifications of JET A and JET A-1 aviation kerosene, alternative aviation kerosene, and aviation kerosene C (JET C), as well as the obligations regarding quality control

to be met by economic agents that sell these products on national territory. Based on ASTM D7566, as per Annex Table A.1. (ANP, 2021b).

   - Annex to ANP Resolution - RANP 856/2021 - Product quality specification table, as per Annex Table A.2.

- ANP Resolution 842/2021: It establishes the specification of green diesel, as well as the obligations regarding quality control to be met by the economic agents that sell it in the national territory. The green diesel covered by the Resolution is obtained from the hydroprocessing of vegetable oils (in natura or residual), oils from algae, microalgae, and animal fats, fatty acids from biomass, synthesis gases obtained from the gasification of organic waste, such as biomass, oligomerization of ethyl alcohol (ethanol) or isobutyl alcohol (isobutanol) and from catalytic hydro thermolysis of vegetable oil (in natura or residual) (please see EPE, 2020 (TN – Green Diesel) Green diesel routes (ANP, 2021a).

Besides ANP, some more crucial regulatory developments for SAF in Brazil include:

- CT CF – The Fuel of the Future Program (CF) has created several sub-committees to study and develop the different aspects of this policy, among them the ProBioQAV CT-CF, which is dedicated to BioQAV (bio-aviation kerosene) and SAF (MME, 2021a).
- Brazil is a signatory of CORSIA (ICAO) (MME, 2021b)
- SAC/ANAC - routes – The ProBioQAV Subcommittee has studied several SAF routes (MME, 2021b).
- PROQR - MITCI – Project to support the planning, financing, construction, and operation of small, decentralized power plants that produce fuel for aviation from renewable electricity in remote locations, integrating various Brazilian ministries, authorities, universities, and other public institutions (GIZ, 2022).

There is also the bill PL 1873/2021, issued on November 24th, 2021, that establishes a federal program to encourage research, production, and consumption of advanced biofuels in Brazil. The text also establishes a schedule for the mandatory addition of advanced biofuels to diesel oil and aviation kerosene. The proposal gives special emphasis to green diesel and alternative aviation kerosene, gradually determining their blend with fossil fuels from 2027 to 2030 (CÂMARA, 2022).

Table 8.1 presents an overview of important landmarks in the development of the Brazilian biofuels market. This includes early developments for the implementation of ethanol as a gasoline additive since the 1930s, the rise of biodiesel in the early 2000s, and the recent developments regarding SAF, biogas, and the RenovaBio program.

Table 8.1. Research and development landmarks in the development of biofuels in Brazil

Year	Landmark
1920s	Studies and tests with ethanol/gasoline mixtures and ethanol use demonstration programs.
1931	Mandatory addition of 5% ethanol to gasoline of foreign origin.
1938	Mandatory addition of 5% ethanol to all national gasoline.
1969	Creation of the Copersucar Technology Center (CTC)
1971	Launch of the National Sugarcane Improvement Plan (Planalsucar)
1975	Launch of the National Alcohol Program (Proálcool), initially determining the mandatory use of the addition of 10% ethanol to gasoline, progressively increased up to 20% in 1980.
1978	Goldemberg et al. publish the Energy Balance for Ethyl Alcohol Production from Crops, Science, 1978, evidencing the advantages of sugarcane for bioenergy production.
1979	Introduction of light-duty vehicles fueled by pure hydrous ethanol (96% ethanol).

Year	Landmark
1979	The nutrient cycle is now widely adopted in sugarcane cultivation through fertigation with vinasse.
1985	Loss of competitiveness of sugarcane ethanol and reduction of the use of hydrated ethanol, maintaining the addition of ethanol to gasoline.
1986	Creation of the Motor Vehicle Air Pollution Control Program (PROCONVE), which progressively set limits for vehicle emissions and reinforced interest in ethanol.
1989	Operation of the pilot unit of the Dedini Rapid Hydrolysis project for acid hydrolysis of lignocellulosic biomass.
1998	Beginning of the Genome Project for genetic sequencing of sugarcane.
1998	Implementation of the sugarcane payment system based on its quality (sugar content).
2002	Starting with the State of São Paulo, the harvest of green sugarcane (without burning) is adopted throughout the country, accelerating the adoption of mechanized harvesting.
2002	Creation of the Network of Research and Technological Development in Biodiesel (Probiodiesel)
2003	Through the Green Ethanol Protocol and support from the Canasat project, the adoption of good management practices and the evaluation of sustainability indicators in sugarcane crops are monitored with satellite images.
2003	Introduction of flex-fuel vehicles capable of using any mixture of hydrated ethanol and gasoline (E25), fuels available at all dealer stations in the country.
2003	Launch of the Biodiesel Production and Use Program, initially authorizing the addition of up to 2% of biodiesel in mineral diesel (B2).
2005	Embraer launches the Ipanema agricultural plane powered by hydrated ethanol.
2006	Creation of EMBRAPA Agroenergy Center.
2007	The EPA recognizes that sugarcane ethanol, due to its smaller carbon footprint, can be considered an advanced biofuel.
2008	The mixture of 2% biodiesel to diesel is made mandatory, with a plan to increase to up to 10% (B10) in ten years.
2009	FAPESP launches the FAPESP Bioenergy Research Program — BIOEN.
2009	EMBRAPA edits the Agroecological Zoning of Sugarcane.
2009	Inauguration of the National Laboratory of Bioethanol Science and Technology (CTBE) - renamed to National Laboratory of Biorenewables (LNBR) in 2019.
2010	The Brazilian Land Use Model (Blum) demonstrates that the indirect effects of ethanol production on land use changes are reduced.
2010	EMBRAPA edits the Agroecological Zoning of Palm oil for the Deforested Areas of the Legal Amazon.
2011	Launch of the BNDES-FINEP Plan to Support Industrial Technological Innovation in the Sugar and Sugarcane Sectors (PAISS).
2014	FAPESP BIOEN organizes the SCOPE Bioenergy & Sustainability Report: bridging the gaps, involving 137 researchers from 24 countries.
2014	FAPESP Sustainable Biofuels Roadmap Project for Aviation in Brazil identifies opportunities and constraints in raw materials and technologies for aviation biofuels.
2014	Start of pre-commercial operation of Granbio, a lignocellulosic biomass ethanol plant in the state of Alagoas, with a capacity of 80 ML/y.
2015	Logum logistics project comes into operation, combining ethanol pipelines and waterways to move up to 21 million m^3 of ethanol per year.
2015	Beginning of corn ethanol production, complementing sugarcane as raw material for biofuels.
2015	Introduction of varieties of sugarcane with high energy productivity.
2015	Start of pre-commercial operation of Raizen lignocellulosic biomass ethanol producing unit in São Paulo, for 40 ML/y of lignocellulosic ethanol
2015	Authorization of the use of higher levels of biodiesel (B20 in captive fleet; B30 in river transport; B30 and agricultural and industrial use), by the ANP.

Year	Landmark
2016	Regulation of the production and use of SAF by the ANP, in line with ICAO recommendations.
2017	Launch of the National Biofuels Policy (RenovaBio), valuing the environmental externalities of biofuels, through the issuance of Certified Decarbonization Credits (CBIO) to biofuel producers.
2017	Specification of biomethane (produced from biogas) by ANP.
2018	The FAPESP LACAf Project identifies and evaluates the potential for sugarcane bioenergy production in Latin America and Africa.
2019	Review and consolidation of the specification of vehicular fuels (anhydrous and hydrated ethanol, gasoline, and diesel) by ANP.
2019	The genome sequence of a commercial sugarcane cultivar is completed.
2020	In all fuel stations in the country, one can find hydrated ethanol, gasoline with anhydrous ethanol (E27), and diesel with biodiesel (B12).
2020	Start of the commercialization of CBIOs.
2020	The SUCRE Project, developed by LNBR, concludes the evaluation of the potential and conditioning factors of the use of straw (tips and leaves) of sugarcane harvested without burning.
2020	Establishment of a multidisciplinary working group to study the increase of biofuel use in diesel engines under the Brazilian Energy Policy, in compliance with the guidelines of the RenovaBio.
2021	Establishment of the Future Fuel Program to promote sustainable and low-carbon fuels and vehicle technology, to decarbonize the Brazilian transport energy mix.
2021	Definition of the technical specification of green diesel, as well as the obligations regarding quality control, allowing the use of other biofuels suitable for diesel engines in addition to FAME biodiesel.
2022	The first green hydrogen plant in Brazil starts to be built. Located at the Port of Pecem, state of Ceará, this pilot plant will produce hydrogen from water electrolysis, using renewable electricity.
2022	FAPESP launches the Amazon +10 Initiative, a subnational partnership involving 10 federal states in Brazil to promote ST&I in the Legal Amazon Region with a goal for funding of US$ 100 million in cooperation with FAPs and CNPq.
2022	Shell Brazil, Raízen, Hytron, the University of São Paulo (USP), and the National Industrial Learning Service (Senai) sign a cooperation agreement for the construction of an ethanol reformer to produce hydrogen in two pilot units and the implementation of a plant with a capacity of 44.5 kg/h. The agreement includes a vehicular supply station to supply fuel for USP buses equipped with fuel cells.
2023	The Brazilian government increases the biodiesel content in diesel to 12% and set yearly increases of 1 p.p. until 2026 when the biodiesel content in diesel will reach 15%.

8.4. Transport Biofuels policies

National Policy for Biofuels - RENOVABIO (link)

- National Biofuels Policy, instituted by Law No 13,576/2017, whose objective is to expand the production of biofuels in Brazil, based on predictability, environmental, economic, and social sustainability, and compatibility with the market growth. Biofuels play an important role in this policy to reduce CI in the transport sector.
- The policy program is based on strategic axes: 1) decarbonization goals; 2) biofuel production certification; and 3) decarbonization credit (CBIO).

National Program for Production and Use of Biodiesel – PNPB

- Created by Law 11,097/2005 to stimulate energy, economic and social objectives as well as more feedstock production by small farmers.

Mandatory Anhydrous Ethanol Blend with Regular Gasoline

- Created by Federal Decree 19,717/1931, makes the addition of anhydrous ethanol to gasoline consumed in Brazil mandatory.
- Law 13,033/2014 increased the anhydrous ethanol mandatory blend limit in gasoline from 18% (by volume) up to 27.5%.

Table 8.2 presents a summary of these transport biofuel policies in the Brazilian market, with their impact on the market and GHG emissions in the country.

Table 8.2. Summary of transport biofuel policies in Brazil

Type of policy	Details and comments
Biofuel blending mandate	Blending mandates: - Anhydrous ethanol mandatory blend in gasoline level increased from 18% (by volume) up to 27.5% - Law 13,033/2014. The current mandatory blending level is 27% (E27). 100% ethanol (hydrous ethanol) is also commercialized in all gas stations in Brazil. - Biodiesel mandatory blend level increased from 5% (by volume) up to 15% - Laws 11,097/2005 and 13,263/2016. The current mandatory blending level is 12% (April 2023).
Emissions trading scheme	National Biofuel Policy – RenovaBio – Law 13,576/2017: - The objective is to expand the production of biofuels in Brazil, based on predictability, environmental, economic, and social sustainability, and compatibility with market growth. Biofuels play an important role in this policy to reduce CI in the transport sector. - The policy program is based on strategic axes: 1) decarbonization goals; 2) biofuel production certification; and 3) decarbonization credit (CBIO). - Art. 7 - The national mandatory annual targets will be broken down into individual ones, applied to all fuel distributors, proportional to their respective market share in the sales of fossil fuels from the previous year.
Specific emission reduction targets	Federal Decree 9,888/2019 (link) - Provides for the definition of national mandatory annual targets for the reduction of GHG emissions in the transport sector, effective beginning in 2020. - These reduction targets are the basis for the decarbonization goals of the RENOVABIO program. CNPE Resolution No. 13/2022 (link) - Sets national mandatory targets to reduce GHG emissions in fuel sales.

Type of policy	Details and comments
Market-pull policies targeted specific transport sectors	Law 13,755/2018 – ROTA Program (link) - Establishes obligatory requirements for the commercialization of vehicles in Brazil to foster efficiency and safety. Specific measures have been put forward to promote ethanol and biodiesel as solutions to meet progressively stringent vehicle emissions regulations.
Use of life cycle assessment (LCA) to measure the CI of biofuels	National Biofuel Policy – RenovaBio (link) - Certification of biofuels production: eligible producers will have to go through a certification process (life cycle assessment), in which an inspecting firm evaluates aspects related to the production/import of biofuels, under Resolution No. 758/2018 (link). The RenovaBio uses the RenovaCalc, which was developed by researchers and is made available to all biofuel producers. RenovaCalc is a cradle-to-grave LCA, including all steps required in the production of biofuels, transportation, and final use. It is an attributional LCA with allocation among co-products based on energy content.
Sustainability requirements and criteria within your Brazil's biofuel policies to assess the environmental performance	National Biofuel Policy – RenovaBio (link) - The policy aims to meet the annual decarbonization targets set by the government for a minimum 10-year period. Under RenovaBio, biofuels production is certified through LCA and attending sustainability criteria (ex. no deforestation), with the issuance of GHG emissions reduction certificates, named CBIO (Decarbonization Credit), which corresponds to a reduction of one ton of CO2eq in comparison to fossil fuel emissions.
Sustainability certification and/or verification scheme for transport biofuels and their feedstocks to prove compliance under the policy frameworks	National Biofuel Policy – RenovaBio (link) - The LCA process certification of the biofuels from eligible producers will be carried out by an inspecting firm that will evaluate aspects related to the production/import, under Resolution #758/2018 (link).
Financial incentive to biofuel producers and blenders	National Biofuel Policy – RenovaBio (link) - The program does not include the creation of carbon taxes or any kind of subsidy for biofuels. The created CBIOs, issued by biofuel producers, are traded on the stock exchange and the fuel distributors are obliged to acquire a quantity of this credit, established in a resolution.
Financial incentive to biofuel consumer	Internal Revenue Service - IRS Normative Instruction No. 1,911/2019 (link). - Different state taxes for the circulation of goods and services (ICMS) for ethanol and gasoline. - Preferential treatment for ethanol compared to gasoline under Contribution for Intervention in Economic Domain (CIDE)- Law No. 10,336/2001 (link) - and Contribution to Social Integration/Contribution for Financing Social Security (PIS/COFINS) programs. - Tax exemptions and incentives for biodiesel, according to the nature of the raw material, size of the producer, and region of production, encourage the production of biodiesel and promote social inclusion.

Type of policy	Details and comments
Tax incentive	Resolution GECEX #317/2022 - Ethanol import tax is zeroed by the end of 2022.
R&D on biofuels production plants	Ordinances MME 252/2019 (link) and MME 348/2019 (link). - Ordinances that regulate the process of framing priority projects in the oil, natural gas, and biofuels sectors for the issuance of incentive debentures. - Financing programs associated with bioenergy and sustainability to further reduce the CI of biofuels: Fundo Clima and RenovaBio Line
Promotion of the production of advanced or drop-on biofuels	National Program for Sustainable Aviation Fuel, Law 14,248/2021 (link). - It aims to foster the production and use of SAF in the Brazilian energy matrix and reduce carbon dioxide emissions by air operators.
Policies to promote the decarbonization of the long-distance transport sector (trucking, rail, aviation, and maritime)	CONAMA Resolution #13/86 (link) Establishes the Vehicle Emissions Control Program – PROCONVE, with the aim of: - Reduce emission levels to meet Air Quality Standards, especially in urban centers. - Promote national technological development both in automobile engineering and in methods and equipment for testing and measuring pollutant emissions. - Create inspection and maintenance programs for motor vehicles in use. - Promote public awareness of air pollution from motor vehicles. - Promote the improvement of the technical characteristics of the liquid fuels available for the national fleet, aiming at the reduction of air pollutants, and. - Establish conditions for evaluating the achieved results. - The CONAMA Resolution was reinforced by Law 8,723, of October 28, 1993 (link), which established the emission levels reductions of polluting compounds in the vehicles sold in the country.
New biofuels: ease of market access, incentives, and primary challenges.	New biofuels need regulation, technical standards, and mandatory and/or cost competitiveness to achieve relevant participation in the market. If they are drop-in fuels, the current infrastructure is sufficient. If not, adaptation and/or new infrastructure are necessary. Nevertheless, it is mandatory to observe the existence of the whole value chain. If the feedstock is not already used, its logistics should be an important point to evaluate because of country.

Type of policy	Details and comments
Promotion of biofuel production and consumption	Resolution CNPE 07/2021 (link). - Establishes the Fuel of the Future Program to propose measures to increase the use of sustainable fuels with low-CI, as well as national vehicle technology to decarbonize the energy matrix of national transport. - The measure also creates the Fuel of the Future Technical Committee - CT-CF, intending to propose measures for integration between the National Biofuels Policy (RenovaBio), the National Biodiesel Production and Use Program (PNPB), the Air Pollution Control Program for Motor Vehicles (Proconve), among others. - The Program finished in 2022 and left a series of proposals for landmarks and legal reforms. Between then, there is a draft bill to review Rota 2030 with the integration of RenovaBio, a legal framework for carbon capture and storage (CCS), and a mandate for SAF.
Penalties for non-compliance to transport biofuel policies requirements for the obligated parties	National Biofuel Policy – RenovaBio (link) - Art. 9. Failure to meet the individual target will subject the fuel distributor to a fine, proportional to the amount of not complied Decarbonization Credit, without prejudice to others administrative and pecuniary sanctions in this Law and Law No. 9,847, of 26 October 1999. - The referred fine may vary, under the terms of the regulation, between R$ 50 million and R$ 100 million. RANP791/2019, Art. 11 (Link) - When the fine in Art. 9 of Law No. 13,576, of 2017, does not correspond to the obtained advantage of non-compliance with the target obligation, a temporary, total, or partial suspension of the distributor's facilities operation will be applied, under the terms of item I of art. 8 of Law No. 9,847, of 1999.

Table 8.3 presents a history of the blending mandates for ethanol and biodiesel since 2010. The ethanol blending mandate has remained almost constant through the years. Overall, total ethanol production has remained almost constant through the years (Table 8.4) despite the decrease in the land area used for the production of sugarcane, as a reflection of better agricultural and industrial efficiencies. The biodiesel blending mandate has increased substantially in the same period, but during the COVID-19 pandemic, it was decreased amid a surge in vegetable oil prices.

Table 8.3. Biofuel blending mandates by volume for ethanol (anhydrous, in gasoline) and biodiesel (FAME, in diesel) (MAPA, 2020)

Year	Ethanol	Biodiesel
2010	E25	B5
2011	E25	B5
2012	E25	B5
2013	E25	B5
2014	E25	B5 (JAN-JUN), B6 (JUL-NOV), B7 (NOV-DEC)
2015	E25 (JAN-MAR), E27 (MAR-DEC)	B7
2016	E27	B7
2017	E27	B8
2018	E27	B10
2019	E27	B11
2020	E27	B11 (JAN-FEB), B12 (MAR-SEP), B10 (SEP-NOV), B11 (DEC)
2021	E27	B11 (JAN-FEB), B13 (MAR-MAY), B10 (JUN-SEP), B12 (OCT-NOV), B10 (DEC)
2022	E27	B10
2023	E27	B10 (JAN-MAR), B12 (APR-to date)

8.5. Market development and policy effectiveness

Table 8.4 presents the size of biofuel markets in Brazil, including ethanol, biodiesel, and cellulosic ethanol. These values represent the actual production of these biofuels. Currently, a large portion of the biodiesel capacity is idle.

Table 8.4. Annual production of transport biofuels in Brazil, in BL (EPE, 2022a) (EPE, 2022b)

Year	Biodiesel	Bioethanol	Cellulosic ethanol
2010	2.4	28.0	-
2011	2.5	22.9	-
2012	2.8	23.6	-
2013	2.9	27.7	-
2014	3.4	28.5	-
2015	3.9	30.2	-
2016	3.8	28.1	-
2017	4.3	27.3	0.01
2018	5.4	31.6	0.02
2019	5.9	34.7	0.02
2020	6.4	30.2	0.02
2021	6.8	26.6	0.03

Table 8.5 presents the country's consumption of fossil fuels and biofuel.

Table 8.5. Annual transport fuel consumption (fossil fuel and biofuel) in Brazil, in BL (EPE, 2022a) (EPE, 2022b)

Year	Gasoline	Diesel	Aviation fuel	Biodiesel	Bioethanol
2010	22.8	51.5	3.9	2.4	23.3
2011	27.1	53.8	4.3	2.5	20.7
2012	31.8	57.6	4.6	2.8	19.1
2013	31.8	60.7	4.4	2.9	22.9
2014	33.4	62.8	4.4	3.4	25.0
2015	30.3	59.6	4.4	3.9	29.7
2016	31.5	56.1	4.0	3.8	26.7
2017	32.3	56.4	4.0	4.3	26.6
2018	28.0	57.1	4.1	5.4	30.3
2019	27.9	58.8	4.0	5.9	33.8
2020	26.2	58.9	2.3	6.4	29.6
2021	28.7	63.5	3.1	6.8	28.2

8.6. Biofuels facilities and main companies

By the end of December 2021, 359 conventional ethanol units were able to produce anhydrous and hydrous ethanol, whose production capacities were 132 ML/day and 246 ML/day, respectively (Figure 8.5). The crushing capacity was around 735 million tonnes /yr. On the same date, there were 53 licensed plants of FAME biodiesel, with a production capacity of 12.3 BL. The main raw materials were soybean oil (72.1%) followed by tallow (11%) (EPE, 2022a) (EPE, 2022c). Most of the ethanol production capacity is located in the states of São Paulo, Goiás, Minas Gerais, and Paraná, and several mills of small capacity are distributed along the coast of the Northeast region of Brazil. Biodiesel plants are located closer to the main soybean and cattle producers in the states of Mato Grosso, Mato Grosso do Sul, and Goiás. Today, there is no production facility for HVO/HEFA in the country, but there are some projects in planning/development, as shown in Table 8.6 in a summary of projects for the production of advanced biofuels in the country.

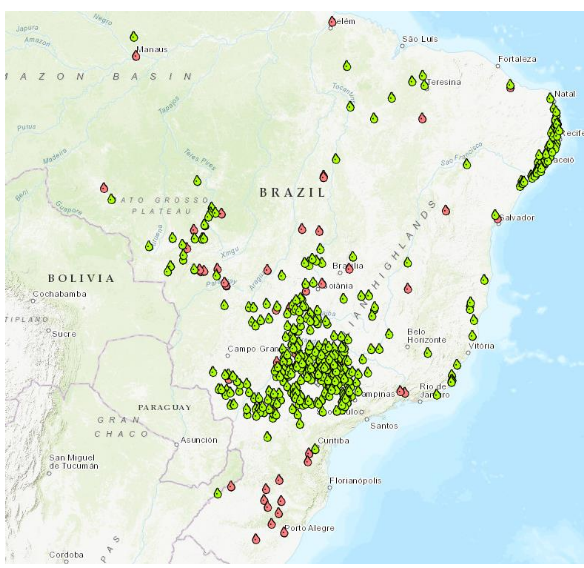

Figure 8.5. Geographic distribution of ethanol and biodiesel production facilities in Brazil (EPE, 2022c)

Table 8.6. Summary of projects to produce advanced biofuels in Brazil (operational of planned) (EPE, 2022a) (ANP, 2023)

Name of company	Location	Status	Technology	Production capacity
Raízen	Piracicaba - SP	operational	lignocellulosic ethanol	42 ML/yr
Granbio	São Miguel dos Campos - AL	operational	lignocellulosic ethanol	60 ML/yr
Raízen	Guariba – SP	planned	lignocellulosic ethanol	82 ML/yr
Raízen	Valparaíso – SP	planned	lignocellulosic ethanol	82 ML/yr
Raízen	Barra Bonita - SP	planned	lignocellulosic ethanol	82 ML/yr
Raízen (5 facilities)	Non-Identified	planned	lignocellulosic ethanol	410 ML/yr
BBF / Vibra	Manaus - AM	planned	SAF	500 ML/yr
Partnership between Brazilian government, German government, and private companies	CE	planned	SAF	-
GNR Fortaleza Valorização de Biogás Ltda.	Fortaleza - CE	operational	biogas	110 thousand Nm^3/day
GNR Dois Arcos	São Pedro da Aldeia - RJ	operational	biogas	16 thousand Nm^3/day
Gás Verde S.A.	Seropédica - RJ	operational	biogas	204 thousand Nm^3/day
COCAL ENERGIA S.A.	Narandiba - SP	operational	biogas	27 thousand Nm^3/day
METAGÁS BIOGÁS E ENERGIA S.A	São Paulo - SP	operational	biogas	30 thousand Nm^3/day

8.7. Biofuels and feedstocks: imports and exports

Table 8.7 presents the history of exports and imports of biofuels and biofuel feedstock in Brazil. Brazil is a net importer of methanol, feedstock for the production of FAME (biodiesel). Ethanol exports and imports vary through the years, and it depends on the harvest season because sugarcane ethanol is majorly produced only during the months of autumn and winter. Therefore, in these months, part of the ethanol is exported, and in other months, ethanol is imported.

Table 8.7. Biofuel and biofuel feedstocks imports and exports over the year (ME, 2022)

Year	Ethanol		Methanol imports (Mt)
	Exports (ML)	Imports (ML)	
2010	1.9	0.1	0.6
2011	2.0	1.1	0.7
2012	3.1	0.6	0.6
2013	2.9	0.1	0.8
2014	1.4	0.5	0.9
2015	1.9	0.5	0.8
2016	1.8	0.8	1.1
2017	1.4	2.5	1.2
2018	1.7	1.8	1.2
2019	1.9	1.5	1.2
2020	2.7	1.0	1.3
2021	1.9	0.4	1.4

8.8. Co-processing at oil refineries

In 2021, the installed capacity of 19 oil refineries in Brazil was 366 ML/day. The location of these oil refineries is shown in Figure 8.6 (ANP, 2022) (EPE, 2022c).

Figure 8.6. Oil refineries facilities in Brazil, December 2022 (EPE, 2022c)

Petrobras, the state oil company of Brazil, has developed a technology to produce diesel oil from vegetable oils (HBio technology), which involves the catalytic hydrogenation of a mixture of fractions of diesel oil and vegetable oil in a hydrotreatment reactor (HDT), under controlled conditions of high temperature and hydrogen pressure. The high conversion yield stands out, at least 95% v/v in diesel oil, without waste generation and a small production of propane as a by-product (ZOTIN, 2020). This process produces diesel oil with renewable fuel content, named Diesel RX.

According to Petrobras, it is feasible to use part of the hydrotreating equipment, adding a diesel R5 production capacity of around 1 million m^3/month. In the future, with the phasing out of diesel S500 (500 ppm of sulfur) and full replacement by diesel S10 (10 ppm of sulfur), there may be a reduction in this availability (MME, 2020b) because of the hydroprocessing requirement in the production of ultra-low sulfur diesel.

8.9. Research and Development and Additional information

Table 8.8 lists the funding agencies and major programs in Brazil that have been financing the development of the biofuel industry in Brazil. This includes banks, research institutes, and countrywide and statewide research funding agencies. Table 8.9 lists the major programs that support the development of biofuels in Brazil.

Table 8.8. Funding agencies supporting the development of biofuels in Brazil

Agency	Program
BNDES (link)	The National Bank for Economic and Social Development (in Portugues: *Banco Nacional de Desenvolvimento Econômico e Social* – BNDES) is a development bank structured as a federal public company associated with the Ministry of Development, Industry, and Trade of Brazil. The stated goal is to provide long-term financing for endeavors that contribute to the country's development. Here are some financed programs associated with bioenergy and sustainability: • BNDES ABC Program; • BNDES-PAISS (with FINEP) (see below); • BNDES-PRORENOVA; • Credit lines to the sugarcane industry • Fundo Clima • RenovaBio Line
CNPq (link)	The Brazilian National Council for Scientific and Technological Development (in Portuguese: *Conselho Nacional de Desenvolvimento Científico e Tecnológico* – CNPq) is an organization of the Brazilian federal government under the Ministry of Science and Technology, dedicated to the promotion of scientific and technological research and the formation of human resources for research in the country.
CTC (link)	The Sugarcane Technology Center (in Portuguese: *Centro de Tecnologia Canavieira* - CTC) is a research institute that focuses on research and development for the Brazilian ethanol industry. The Company is engaged in the development of new varieties and technologies in the production of sugarcane and ethanol including genetic improvement (new varieties), biotechnology, and second-generation biofuels.
EMBRAPA (link)	The Brazilian Agricultural Research Corporation (in Portuguese: *Empresa Brasileira de Pesquisa Agropecuária* – EMBRAPA) is a state-owned research corporation affiliated with the Brazilian Ministry of Agriculture, dedicated to developing technologies, knowledge, and technical-scientific information aimed at Brazilian agriculture, including livestock.
FAPESP (link) BIOEN (link)	The São Paulo Research Foundation (in Portuguese: *Fundação de Amparo à Pesquisa do Estado de São Paulo* – FAPESP) is a public foundation located in São Paulo, Brazil, to provide grants, funds, and programs to support research, education, and innovation of private and public institutions and companies in the state of São Paulo, Brazil. FAPESP has a dedicated Program for Bioenergy Research, BIOEN. BIOEN aims to integrate comprehensive research on sugarcane and other plants that can be used as biofuel sources, thus assuring Brazil's position among the leaders in the area of Bioenergy. The research includes biomass improvement, production and processing, biofuel production, biorefineries, engines, sustainability, and impacts.
FINEP (link)	The Financier of Studies and Projects (in Portuguese: *Financiadora de Estudos e Projetos* - FINEP), is a Brazilian public company, linked to the Brazilian Ministry of Science and Technology and Innovation, that promotes science, technology, and innovation in companies, universities, technological institutes, and other public or private institutions, headquartered in Rio de Janeiro.

Agency	Program
LNBR (link)	The Brazilian Biorenewables National Laboratory (in Portuguese: *Laboratório Nacional de Biorrenováveis* – LNBR) is one of the four laboratories that compose the Brazilian Center for Research in Energy and Materials (CNPEM), a non-profit private institution funded by the Brazilian Ministry of Science and Technology and Innovation to integrate unique skills for scientific and technological development and support innovation in energy, materials, and biosciences. LNBR aims to accelerate the transition from an industrial production based on fossil resources to a bio-based and renewable industry, which promotes Brazil's technological independence and reduces environmental impacts.

Table 8.9. Major programs that support the development of biofuels in Brazil

Program	
BNDES PAISS (link).	The Joint Plan for Supporting Industrial Technological Innovation in the Sugar-based Energy and Chemical Sectors (in Portuguese: *Plano Conjunto BNDES-Finep de apoio à inovação tecnológica industrial dos setores sucroenergético e sucroquímico – PAISS*) is a joint initiative of BNDES and FINEP intended for sugarcane rural producer and its cooperatives to select business plans and promote projects that contemplate the development, production, and commercialization of new industrial technologies for sugarcane biomass (second generation ethanol, gasification, etc.). The BNDES PAISS operates in a few thematic lines, including: • thematic line 1 – second generation (lignocellulosic ethanol): ○ Development of technologies for collecting and transporting sugarcane; ○ Optimization of pre-treatment processes for hydrolysis of sugarcane biomass; ○ Development of enzyme production processes and/or hydrolysis processes of lignocellulosic material from sugarcane biomass; ○ Development of microorganisms and/or pentose fermentation processes; and ○ Process integration and scheduling for cellulosic ethanol production. • thematic line 2 – new products of sugarcane: ○ Development of new products directly obtained from sugarcane biomass through biotechnological processes. ○ Integration and scheduling of processes to produce new products directly obtained from sugarcane biomass.
BNDES ProRenova (link).	The Program to Support the Renovation and Implementation of New Sugarcane Plantations (in Portuguese: *Programa de Apoio à Renovação e Implantação de Novos Canaviais* – BNDES Prorenova) is a financing program to renew and implant new sugarcane fields and promote sugarcane production in the country.
BNDES ABC Program (link).	The ABC program seeks to encourage investment in agricultural projects that reduce GHG emissions and deforestation, in addition to expanding the area of cultivated forests, stimulating the recovery of degraded areas, increasing agricultural production on a sustainable basis, and adapting rural properties to environmental legislation.

Program	
BNDES Fundo Clima	The Climate Fund Program is intended to apply the portion of refundable resources from the National Fund on Climate Change, or Climate Fund, created by Law 12,114/2009, regulated by Decree 7,343/2010, and currently governed by Decree 10.143/2019. The Climate Fund is one of the instruments of the National Policy on Climate Change and constitutes an accounting fund, linked to the Ministry of the Environment with the purpose of guaranteeing resources to support projects or studies and financing of businesses that have as objective the mitigation of climate change impacts.
BNDES RenovaBio (link)	BNDES offers direct support through ESG (Environmental, Social, and Governance) financial credit for the biofuels sector, within the scope of the RenovaBio Policy, with incentives to improve energy-environmental efficiency and production certification. Biofuel-producing companies that are participants of the RenovaBio Policy can be eligible and the financing amount available is between 20 and 100 million Brazilian Reais per participant.
EMBRAPA INOVABio (link)	The INOVABio Program aims to establish partnerships with agents in the productive sector to elaborate open-innovation project proposals for the development of technologies for biofuels and bioproducts production. Embrapa Agroenergia will provide the selected partner with laboratory infrastructure, technical staff with multidisciplinary work, and financial resources.

There are many major recent/ongoing research projects focusing on biofuels technology development and deployment, including the following examples:

- Universidade Federal de Minas Gerais (UFMG) - Laboratório de Ensaios de Combustíveis (link)
- Universidade Federal de Goiás (UFG) – Laboratórios de biocombustíveis e biodiesel (link)
- Universidade Federal do Paraná (UFPR) – Laboratório de Produção de Biocombustíveis (link)
- Rede de bioquerosene e hidrocarbonetos sustentáveis para aviação (Rede BioQav) (link)
- Universidade de São Paulo (USP) – Research Center for GHG Innovation (RCGI) (link)

8.10. Additional comments

The entire Brazilian strategy for the introduction of SAF in the energy mix is being developed within the scope of the Fuel of the Future Program, in its ProBioQAV subcommittee. The program follows the guidelines of Resolution #7/2021, of the National Energy Policy Council (CNPE), aiming at proposing a legal framework on the subject.

In the ProBioQAV subcommittee, the strategy is to build a public policy with broad social participation, giving legitimacy to the process. For this reason, the subcommittee is attended by a wide range of actors, involving representatives of government bodies and entities, airlines, airport operators, and civil society. Producers and distributors of fossil fuels and biofuels, representative associations, consultants and specialized agencies, aircraft manufacturers, quality certification laboratories, universities, regional and national initiatives, international organizations, and representatives of the raw materials sector also participate (MME, 2021b).

Since 2016, almost 20 corn-based ethanol units have been built, leading to a 20-fold increase in production between 2016 and 2022, reaching 4.1 BL (26% more than 2021) (EPE, 2022a) (MAPA, 2023). In 2022, 7.5 M tonnes of corn were processed for ethanol production (ANP, 2023). Sugarcane, with its contribution of 282 million tons, is still the predominant raw material.

About two years are needed for corn plants to start operation, which is relatively shorter than sugarcane units. Additionally, the raw material can be purchased directly from grain producers, therefore the plant does not need to have its area. Unlike the sugarcane crop, corn has two annual harvests, and may come as a second rotation with soybeans (EPE, 2022e) with many benefits because of the nitrogen-fixing bacteria of the soybean crop. In the next decade, the construction of 34 new corn ethanol plants is expected, with the prospect of production of around 10 BL (EPE, 2022d).

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9. New Zealand

Drafted and submitted by Paul Bennett (Scion Research);

9.1. Summary

- The government aims to reduce national GHG emissions to net zero by 2050. It has implemented new Zero Carbon legislation to meet the 2050 goal.
- Work is also underway to define best options to meet Paris GHG reduction targets such as buying international credits, emissions reductions and forest plantations.
- An emissions trading scheme (ETS) is the country's key tool for reducing carbon emissions. It is based on tradable units and includes most sectors of the economy, including transport.
- There is currently no mandate for biofuel use or for any type of biofuel volume obligations.
- Ethanol, including imported ethanol, is exempt from excise duty (NZD 0.595/liter vs retail petrol price of NZD 2.3/liter). This exemption does not apply to biodiesel or other biofuels.
- A biodiesel grants scheme ran from July 2009 to June 2012. This was designed to support the growth of a biodiesel manufacturing industry by providing a grant of up to 42.5 cents per liter for biodiesel production, subject to certain conditions. This scheme resulted in a steady increase in domestic biodiesel production, however since the scheme ended in June 2012 biodiesel production has plummeted.
- There are no investment subsidies supporting biofuel deployment.
- There are currently no specific policies promoting advanced biofuels deployment. Although, there seems to be a market pull for aviation and marine biofuels.
- There is growing awareness amongst international transport operators and exporter about the potential risk to their markets.

9.2. Introduction

New Zealand is a geographically-isolated country with a long skinny geography, a land area of 268,000 km^2, and a comparatively small population (5.1 M). It has a temperate climate, with an export-focused economy which is highly dependent on agriculture, particularly dairy products, meat, forestry and horticulture. Per-capita use of transport fuels is also relatively high due to the country's low population density and the nature of the economy.

In March 2022, Marsden Point, in Northland, New Zealand's only oil refinery closed. In April 2022, a new company, Channel Infrastructure, began operating as a fuel import terminal at Marsden Point. Most oil products are imported from refineries in Singapore, South Korea and Japan. Channel Infrastructure focuses on supplying the Auckland and Northland fuel markets, handling between 3 and 3.5 BL of transport fuels annually, which is about 40% of New Zealand's fuel demand. The rest of our transport fuels, except for a small amount of biofuels, are imported through other terminals across the country.

New Zealand has a fairly unique GHG emissions profile that heavily skewed towards agricultural emissions. Figure 9.1 shows the breakdown of New Zealand's gross GHG emissions by sector and gas type by 2020.

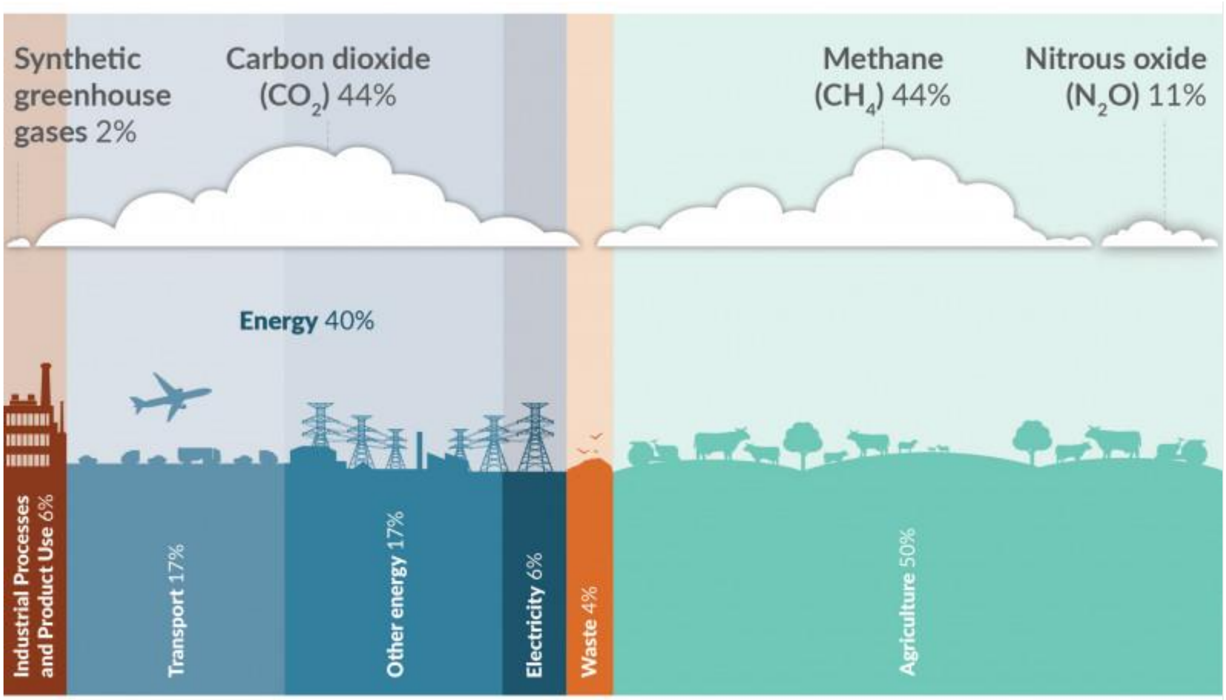

Figure 9.1. The breakdown of New Zealand's gross GHG emissions by sector and gas type by 2020
Source: https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/emissions-reduction-targets/greenhouse-gas-emissions-targets-and-reporting/

New Zealand has committed to reduce its GHG emissions by 30% below 2005 levels by 2030 and also has a further longer-term target to reduce emissions. In 2019, the Climate Change Response (Zero Carbon) Amendment Act set into law a new domestic 2050 target:

- net zero emissions of all GHGs other than biogenic methane by 2050
- 24 to 47% reduction below 2017 biogenic methane emissions by 2050, including 10% reduction below 2017 biogenic methane emissions by 2030.

The Act also will:

- establish a system of emissions budgets to act as stepping stones towards the long-term target
- require the Government to develop and implement policies for climate change adaptation and mitigation
- establish a new, independent Climate Change Commission to provide expert advice and monitoring to help keep successive governments on track to meeting long-term goals.

New Zealand's GHG emissions amounted to 78.8 MtCO2eq, of which 44% is methane and 11% is nitrous oxide, predominantly from the agricultural sector. Carbon dioxide emissions amount to 31.5 MtCO2eq. Whilst transport accounted for 16.7% of the total GHGs in 2020, 39% of the total CO2 emissions were from this sector (estimated from 2019 GHG emissions inventory). Emissions from road transport were the fastest growing sector between 1990 and 2020 with an increase of 76%.

Reducing emissions from liquid fossil fuel use, particularly for transport, represent one of the few options to significantly reduce the country's carbon dioxide emissions and to meet the net zero target, especially given the two targets for biogenic methane and other long-lived emission. The country already has a high proportion of renewable electricity (85% in 2019), a growing population and almost half the country's emissions come from agriculture where ways to significantly reduce emissions without reducing production are challenging.

9.3. Main drivers for biofuels policy

While all the main drivers for global growth of biofuels - environmental benefits, rural economic development and security of fuel supply- exist in New Zealand, to date only limited encouragement has been given to large-scale deployment and use of biofuels, with biofuels still making up less than 0.1% of the country's liquid fuel use. The New Zealand Energy Strategy 2011-2021 sets the strategic direction for the energy sector and energy will play role in the New Zealand economy. This strategy has been developing renewable energy resources, as one of its two key focus areas, and biomass is recognised as a resource having considerable potential.

However, the current government, which came into power in October 2017, sees taking decisive action on climate change as one of its priorities, and has initiated a comprehensive re-look at how New Zealand can transition to a low-carbon economy. This include introducing Zero Carbon legislation to provide a long-term and stable policy environment, with a clear emissions reduction target and a strategy to reach this target, as well as required changes to the ETS and other policies. A programme of work is underway to develop the actions and make the necessary legislative changes, which may influence future policy around biofuels.

In November 2019, the Climate Change Commission was formed to provide advice on how to achieve country's climate targets. The targets were legislated under the Climate Change Response (Zero Carbon) Amendment Act, which was passed with multi-party support. The Commission's advice is based on research and analysis of different factors that can affect our emissions and the potential impacts and effects of climate change. It helps the government make decisions to transition to a thriving climate-resilient and low-emissions Aotearoa New Zealand. The first Advice to Government document was published in June 2021, key statements on transport included;

Developing low-carbon fuel markets through measures that include a low-carbon fuel standard or mandate to increase demand for low-carbon fuels. Undertaking a detailed study into the use of low-carbon fuels for aviation and shipping in Aotearoa New Zealand.

Emissions from international aviation and shipping are not currently part of the 2050 targets in Aotearoa. The Commission will review whether these should be included in the 2050 targets in 2024.

In May 2022, responding to the Commission's advice, the Ministry for the Environment published Aotearoa New Zealand's first emissions reduction plan which sets the direction for climate action for the next 15 years. Key proposed actions that pertain to transport were;

Initiate work to decarbonise heavy transport and freight including by supporting the uptake of low-carbon liquid fuels by implementing a SAF mandate and a sustainable biofuels obligation.

There are enough woody residues or low-value exported wood to kick-start a sustainable biofuels industry in NZ while, at the same time, removing coal from the process heat sector and deliver feedstock to support the growth of a new circular bioeconomy.

Scion's 2018 New Zealand Biofuels Roadmap study illustrates what large-scale production and use of biofuels in New Zealand could look like and identifies key issues, decisions and actions needed for large scale biofuel deployment.

9.4. Biofuels policy

The main policy incentives for biofuels in New Zealand are the New Zealand Emissions Trading Scheme (ETS), the excise tax exemption for bioethanol and some R&D support to research institutions, such as Scion.

The ETS zero-rates the biofuel component of transport fuels. The current carbon price translates to around 9 cents per liter for diesel, and 7.8 cents for petrol.

The petrol excise duty is 70.024 cents per liter, which translates to a tax advantage of 7 cents per liter for 10 per cent bioethanol blend (E10) over petrol.

Carbon emissions from international aviation and international use of marine fuels are not currently covered by the ETS, so this policy provides no incentive for biofuel substitution into these sectors.

9.5. Biofuels obligations

There is currently (April 2023) no mandate on biofuel use or any biofuel volume obligations. A Biofuel bill, enacted in September 2008, introduced a mandated Biofuel Sales Obligation from October 2008. This required all oil companies to include liquid biofuels as a fixed percentage of their total sales. Under the obligation, liquid biofuels were to have made up 0.5% of oil companies' sales in 2008, with obligation levels rising by 0.5% increments to 2.5% in 2012. However, as a result of a change in government, the Biofuel Sales Obligation and associated regulations were repealed in December 2008, and since then there have been no biofuel blending targets or mandates.

Over the last two years the New Zealand Government have been developing a Sustainable biofuels obligation for transport fuel use, excluding aviation fuels. The obligation was to be placed on fuel providers to ensure increasing GHG reductions in the fuels that they are supplying over time. Implementation was delayed to 1st April 2024 with a 2.4% reduction in GHG emissions required, ramping up to a provisional target of 9.0% by 2035. Due to concerns around the increasing cost of living in New Zealand, and difficulties in ensuring the sustainability of import, the obligation was scrapped in February 2023. Despite the withdrawal of the sustainable biofuels obligation, a separate mandate for SAF is currently in development by Government.

9.5.1. Excise duty reductions

Ethanol (including imported ethanol) is exempt from excise duty (NZD 0.595/L vs current retail petrol price of NZD 2.3/ L). This exemption does not apply to biodiesel or other biofuels. Biofuels are zero-rated under the ETS.

9.5.2. Fiscal incentives

A biodiesel grants scheme ran from July 2009 to June 2012. This was designed to support the growth of a biodiesel manufacturing industry within New Zealand by providing a grant of up to 42.5 cents per liter for biodiesel production, subject to certain conditions. This did lead to a steady increase in biodiesel production in New Zealand, however since the scheme ended in June 2012, due a change in Government, domestic biodiesel production has plummeted.

9.5.3. Investment subsidies

There are currently no investment subsidies supporting biofuel deployment.

9.5.4. Other measures stimulating the implementation of biofuels

In spite of a limited amount of government support, a number of potential end-users remain interested in using biofuels. These include Air New Zealand, the national airline, and New Zealand Rail, the operator of the main ferry service between the two islands.

Air New Zealand have been sponsoring the development of the domestic production of SAF. It published a request for proposals for domestic SAF production, and have received several responses which are being pursued.

With New Zealand being an export focused, key product exporters are become concerned about the embedded carbon in their products when they reach the international markets. Marine fuel combustion makes a significant contribution to the embedded carbon.

While not a policy measure, such end-user interest may well stimulate biofuel production and use within New Zealand.

9.6. Promotion of advanced biofuels

There are currently no specific policies promoting advanced biofuels deployment. However, other Government funding mechanisms (e.g., Endeavour Programme, Sustainable Food and Fibers Fund) can be used to support biofuel research and development (R&D) if other criteria for that fund are satisfied.

The government, via its Ministry of Business Innovation and Employment, supports a number of Crown Research Institutes, particularly Scion, to undertake R&D projects aimed at the production of advanced biofuels. The Universities of Auckland and Canterbury also have or have had research programs in this area. LanzaTech, a NZ Startup company, previously received over $10 M in government grants to fund process development and scale-up of their proprietary process to ferment CO-rich industrial waste gases into ethanol and other products. The company has subsequently re-located to the US.

9.7. Market development and policy effectiveness

The bulk of the ethanol produced in New Zealand has been produced at 3 plants, all owned by Fonterra Anchor Ethanol Ltd, by fermentation of whey, a by-product of cheese making. Recently Fonterra has stopped ethanol production at 2 of the 3 plants to start more profitable co-products, such as whey permeate for lactose.

DB Breweries and Gull (an independent fuel distributor) have entered into a partnership to produce small volumes of ethanol from a by-product of beer production.

Domestic biodiesel production was 0.5 ML in 2018. The largest current domestic producer of biodiesel is Green Fuels, which produces biodiesel from recycled vegetable oil.

In November 2018, New Zealand's first commercial scale biofuels plant, built by energy retailer Z Energy, began supplying high quality biodiesel to commercial customers, using tallow as feedstock. The plant, named Te Kora Hou has produced high-quality biodiesel that meets European, New Zealand and Z Energy's own stringent specifications. The nameplate capacity of 20 ML per annum was never achieved, a maximum production of 7 ML of biodiesel was made.

In May 2020, Z Energy announced that the plant would be temporarily hibernated due to rising global tallow prices combined with escalating construction costs to bring the plant to an acceptable scale. In July 2022, Z announced that the production plant would be closed permanently, but the site will continue to use as an import terminal to meet customer biodiesel demand.

Table 9.1 shows the amount of biofuels produced and therefore consumed in New Zealand. These are all domestic production figures. In 2019, Government start reporting total biofuels use in PJs rather than volumes of ethanol and biodiesel. Very little of cellulosic ethanol, renewable diesel or lignocellulosic ethanol is used in New Zealand. However, one ML of SAF were imported in 2022 into New Zealand from Neste in Singapore for use in Air New Zealand trials.

Table 9.1. Biofuel production

Year	Biodiesel (ML/yr)	Ethanol (ML/yr)	Combined biofuels (PJ)
2007	1.20	0.30	0.05
2008	1.20	0.11	0.12
2009	1.15	3.70	0.12
2010	1.61	3.10	0.18
2011	2.35	4.81	0.23
2012	1.27	5.67	0.28
2013	0.24	4.97	0.10
2014	0.90	3.25	0.12
2015	0.56	2.87	0.12
2016	0.47	4.84	0.13
2017	0.46	3.64	0.10
2018	0.45	5.25	0.13
2019			0.18
2020			0.32
2021			0.25

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Table 9.2 summarizes fuel consumption for transport since 2000. Biofuels contribute to about <0.1% of total transportation fuels in New Zealand with bioethanol produced from Whey and Biodiesel produced from UCO and Tallow.

Table 9.2. Transport Fuel consumption (ML/ yr)

Year	Gasoline	Diesel fuels	Aviation fuel
2000	2,914	2,250	1,165
2001	2,941	2,268	1,237
2002	3,041	2,431	1,203
2003	3,129	2,526	1,273
2004	3,257	2,609	1,379
2005	3,181	2,803	1,403
2006	3,206	2,800	1,363
2007	3,264	2,883	1,296
2008	3,196	2,855	1,354
2009	3,143	2,725	1,273
2010	3,147	2,760	1,281
2011	3,103	2,877	1,340
2012	3,027	2,911	1,303
2013	3,032	3,026	1,323
2014	3,031	3,134	1,343
2015	3,123	3,186	1,413
2016	3,193	3,295	1,660
2017	3,288	3,502	1,839
2018	3,218	3,610	1,948
2019	3,223	3,686	1,920
2020	2,862	3,531	896
2021	2,905	3,754	683
2022	2,900	3,834	918

The volumes for Aviation fuel shown above are for domestic and international traffic. In the last full pre-Covid year, 2019, there were 1,522 ML of aviation fuels used on international routes departing New Zealand. By 2021, the consumption of international aviation fuel, Jet A1, dropped by 76% to 362 ML.

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9.8. Conclusions

Due to a lack of policy support biofuels production and consumption in New Zealand has been very limited. More recent Government initiatives, such as setting up the Climate Change Commission, Ministry of Transports focus on Green Freight, and the Ministry for Primary Industries focusing on the use of forest harvesting waste has refocused attention onto biofuels. Biofuels are again being evaluated as a potential part of the energy solution in New Zealand's future particularly in heavy goods, aviation and maritime transportation, where there is a market pull from operators (CORSIA and the IMO) and from produce exporters.

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10. Canada

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10.1. Summary

- In 2020, Canada's transport sector was the second largest source of GHG emissions, accounting for 24% of total national emissions. The main drivers for developing effective biofuel policies include economic diversification of rural and remote communities, GHG emissions reductions and legislation.
- The Canadian *Net-Zero Emissions Accountability* Act, which became law on June 29, 2021,established a legally binding process to set five-year national emissions-reduction targets as well as developing credible, science-based emissions-reduction plans to achieve each target. Under the Act, current and future governments must plan, report, and course-correct on the path to net-zero emissions by 2050.
- On July 2022, the Government of Canada published the final Clean Fuel Regulations (CFR). The first carbon intensity (CI) reduction requirements took effect on July 1, 2023, providing approximately 12 months of early credit creation. The CFR is expected to deliver up to 26 million tonnes (Mt) of GHG emissions reductions in 2030. To drive innovation at the lowest cost, the CFR will establish a credit market. Regulated parties (producers and importers of gasoline and diesel) must create or buy credits to comply with national reduction requirements. While aviation and non-diesel marine fuels are not obligated under the CFR, supplying low-carbon liquid transportation fuels for aviation applications (e.g., sustainable aviation fuel), is eligible to generate credits.
- The CFR will use the Fuel LCA Model, an OpenLCA software-based model developed by ECCC, to calculate the CI of fuels and determine compliance and credit creation. The model was released in June 2022 and revised in January 2023. It will continue to be populated with additional pathways, data and updates.
- Federal and provincial-level renewable fuels programs continue to support conventional biofuels production and use across Canada. Federal blending mandates require at least 5% of the volume of a primary supplier's pool of gasoline and 2% of its diesel pool be displaced by an equivalent volume of a liquid low-CI fuel. Provincial minimum blending mandates range from 5% to 15% in the gasoline pool and 2% to 5% in the diesel pool (volume basis).
- The Province of British Columbia is leading Canada's transport related emissions reductions with the British Columbia Low Carbon Fuel Standard (BC-LCFS). The BC-LCFS mandates a minimum 5% annual average renewable fuel content in gasoline and 4% renewable fuel content in diesel (Government of British Columbia, 2022). The BC-LCFS requires fuel suppliers to reduce the average CI of their fuels annually to achieve a 30% reduction by 2030 compared to 2010 levels. The LCFS is the largest contributor to CleanBC goals and is expected to lead to a reduction of 5 Mt of GHG emissions by 2030.
- The Government strengthened its minimum national standards for pollution pricing (federal benchmark). These standards updated the Pan-Canadian Approach to Pricing Carbon Pollution for the 2023 to 2030 time period. The standards contain two components. (1) A regulatory charge on fossil fuels such as gasoline and natural gas, known as the fuel charge, which as of fall 2022 applies in Ontario, Manitoba, Yukon, Alberta, Saskatchewan and Nunavut. (2) A performance-based system for industries, known as the federal Output-Based Pricing System (OBPS) which as of late 2022 applies in Manitoba, Prince Edward Island, Yukon, Nunavut, and partially in Saskatchewan.

- The Canadian Government continues to support research and development in biofuels production through the allocation of funding. For example, the recent $53 million Clean Fuels and Industrial Fuel Switching (CFIFS) call for proposals was announced in 2021 under Natural Resources' Canada's (NRCan's) Energy Innovation Program. This targets industrial update of low-carbon fuels and production of low-carbon fuels for use in hard-to-abate sectors. Selected projects are expected to be announced soon.
- Budget 2022 proposed establishing a $15 billion Canada Growth Fund to attract substantial private sector investment to help meet important national economic and climate policy goals. The late 2022 Economic Statement clarified that the Canada Growth Fund would utilize a broad suite of project financing tools, including contracts for difference.
- Budget 2023 proposed providing an additional $500 million over ten years to the Strategic Innovation Fund to support the development and application of clean technologies in Canada. The Strategic Innovation Fund will also direct up to $1.5 billion of its existing resources towards projects in sectors including clean technologies, critical minerals, and industrial transformation.
- Canada's biofuel production capacity has grown modestly over the last decade, largely driven by growth in biodiesel production capacity. Ethanol production in Canada has remained relatively constant at around 1,700 ML/y from its 14 operational facilities. Canada currently has five operational biodiesel facilities with a total capacity of more than 590 ML/yr. Two refineries, Tidewater and Parkland, are also co-processing renewable fuels. Further growth in biofuel production capacity is expected, as several announcements for new facilities have been made.
- Both the BC-LCFS and the federal CFR will encourage Canadian oil refineries to consider co-processing as an economically attractive compliance pathway. Canada has 17 refineries with a total capacity of approximately 2.0 million barrels per day (Mb/d), as of 2020. Alberta has the largest share of refining capacity (27%), followed by Ontario (20%), Quebec (19%), New Brunswick (16%), Saskatchewan (8%), Newfoundland and Labrador (7%), and British Columbia (3%). In 2020, Canadian refineries operated on average at 76% capacity, and consumed 1.5 Mb/d of crude oil, a decrease from 2019, resulting from weaker demand during the pandemic.

10.2. Introduction

Among the three sectors (electricity, heat and transport) where renewable energy is used at scale, the global contribution of renewables to energy used in transport is the lowest: 3.4% in 2017 and expected to grow to only 3.8% in 2023 (International Energy Agency, 2018). Of the renewable energy used in transport, biofuels[3] are still anticipated to make up almost 90% in 2023, the remainder being renewable electricity for rail and road use (International Energy Agency, 2018). Despite the small contribution of renewables to transport energy needs, biofuels continue to be one of the most important methods used to decarbonize the transport sector.

From 2005 to 2020, Canada's domestic GHG emissions decreased by 9.3% (69 Mt of CO2eq), from 741 Mt CO2eq to 672 Mt CO2eq, mainly due to emissions reductions from the electricity and heavy industry sectors (ECCC, 2022; Figure 10.1). Over this period, GHG emissions also decreased for the transport (-1%) and the waste and others (-9%) sectors, while emissions from the oil and gas, buildings and agriculture sectors increased (ECCC, 2022). In 2020, the oil and gas and transport sectors were the largest GHG emitters in Canada, accounting for 27% and 24% of total emissions, respectively (ECCC, 2022). These increases were partially offset by the electricity and the heavy industry sectors (ECCC, 2022).

[3] **Biofuels**: liquid fuels derived from biomass, and used as an alternative to fossil fuel based liquid transportation fuels such as gasoline, diesel and aviation fuels.

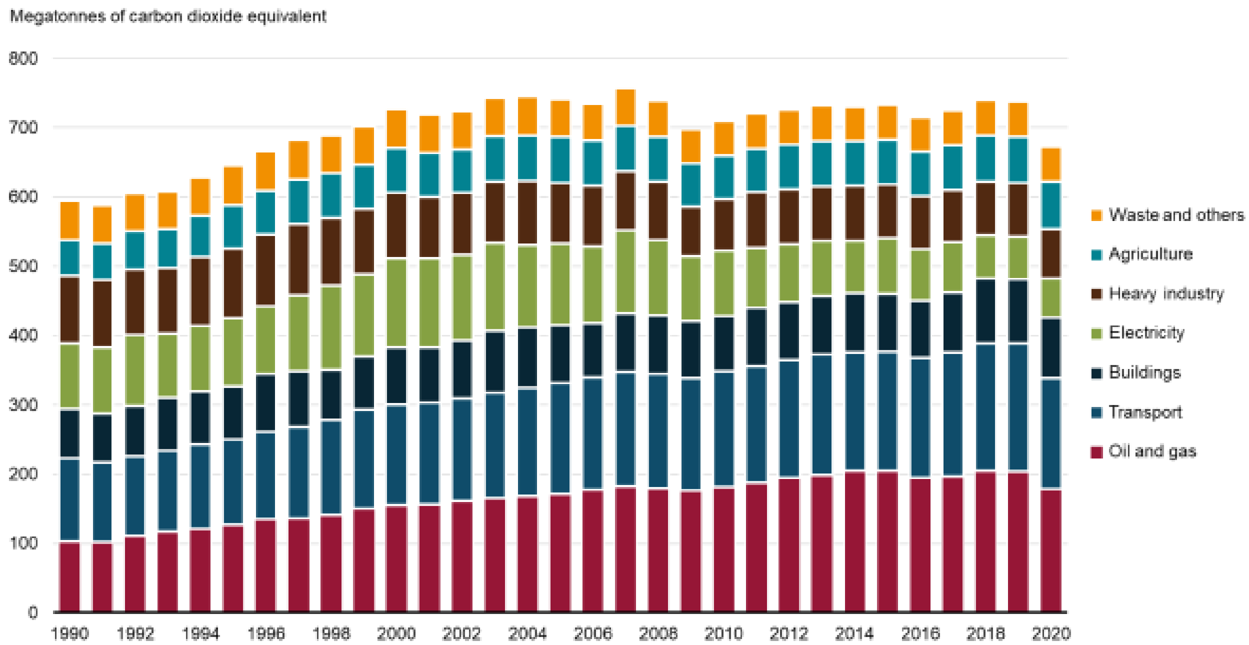

Figure 10.1. GHG Emissions by Economic Sector, Canada, 1990 to 2020 (ECCC, 2022)

Based on lifecycle CI reported by government contacts, government compliance reporting and GHGenius 4.03a, renewable fuel consumption and light-duty plug-in electric vehicles (PEVs) have avoided a total of 60 Mt CO2eq in Canada between 2010 and 2020 (Navius, 2022). Despite lower overall biofuel consumption in 2020 due to the pandemic, annual avoided GHG emissions increased slightly to about 5.9 Mt CO2eq/yr from 2019 to 2020, while emissions avoided by light-duty PEVs increased to 0.6 Mt CO2eq/yr (Navius, 2022; Figure 10.2).

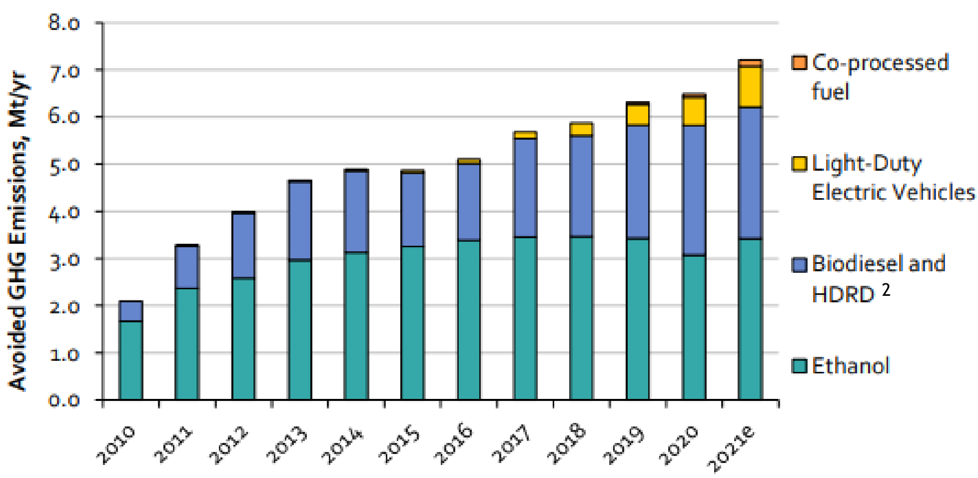

Figure 10.2. Avoided Lifecycle GHG Emissions, Canada, 2010 to 2020, with an Estimate for 2021 (Navius, 2022)

10.3. Main drivers for biofuels policy

Canada has the world's third largest proven oil reserves, after Venezuela and Saudi Arabia, is the fifth-largest oil producer and is the world's fourth largest crude oil exporter (Government of Canada, 2020a). Energy security is therefore not the main driving force for Canada's renewable fuel industry. Canada's overall GHG emissions have grown by 13.1% (78 Mt CO2eq) over the 1990 to 2020 period, driven primarily by increased emissions from oil and gas extraction and transport (ECCC, 2022).The main drivers for renewable fuel mandates include economic diversification of rural and remote communities and GHG emissions reductions, with the latter being the primary driver for policy implementation.

Legislation has also been one of the main driving forces behind the creation of policy. The Canadian Net-Zero Emissions Accountability Act enshrines in legislation the Government of Canada's commitment to achieve net-zero GHG emissions by 2050, and provides a framework of accountability and transparency to deliver on it (Government of Canada, 2022c; 2023c). The Act, which became law on June 29, 2021, establishes a legally binding process to set five-year national emissions-reduction targets as well as develop credible, science-based emissions-reduction plans to achieve each target (Government of Canada, 2022c). It establishes the 2030 GHG emissions target as Canada's Nationally Determined Contribution (NDC) under the Paris Agreement emissions reductions of 40-45% below 2005 levels by 2030 (Government of Canada, 2022c). Under the Act, current and future governments must plan, report, and course-correct on the path to net-zero emissions (Government of Canada, 2022c).

10.4. Biofuels policy

Enabling technology-push and market-pull policies in the form of blending mandates, tax exemptions and incentives play an essential role in the growth of biofuel markets. The Government of Canada Renewable Fuels Strategy consisted of four key pillars to support the expansion of Canadian production and use of clean fuels: the Renewable Fuels Regulations (RFR), the ecoENERGY for Biofuels (ecoEBF) program, the ecoAgriculture Biofuels Capital (ecoABC) program, and the NextGen Biofuels Fund. The RFR mandated a blend of 5% and 2% renewable content in gasoline and diesel, respectively. This demand driver was paired with a $1.5 billion ecoEBF program, which provided an operating incentive on a per liter basis, based on the volume of renewable fuels produced in Canada and sold by the successful recipients of the program, until 2017 when the program ended. These measures, in tandem with provincial measures, have grown Canada's biofuels industry from a production capacity of just over 115 ML of biodiesel in 2010, to approximately 416 ML of biodiesel production capacity in 2021, a 262% increase (Statista, 2023).

The first CI reduction requirement of the Clean Fuels Regulation (CFR) takes effect on July 1, 2023 providing for approximately 12 months of early credit creation. The Government of Canada published on July 6, 2022 the final Clean Fuel Regulations, under the Canadian Environmental Protection Act, with a goal of significantly reducing pollution by making the fuels we use every day cleaner over time (Government of Canada, 2022b). The CFR focus on reducing the CI of liquid fuels and is an important part of Canada's climate plan to reduce emissions, accelerate the use of clean technologies and fuels, and support sustainable jobs in a diversified economy (Government of Canada, 2022b). The CFR will help drive innovation and create job opportunities across multiple sectors, including clean technology, agriculture, and low-carbon energy sectors, such as biofuels and hydrogen (Government of Canada, 2022b). The CFR will also look to deliver up to 26 Mt of GHG emissions reductions in 2030. This is equivalent to removing approximately 4% of GHG emissions from the Canadian economy annually (Government of Canada, 2022b).

The CFR require primary liquid fossil fuel suppliers (i.e., producers and importers) to gradually reduce the CI of the gasoline and diesel that they produce and sell for use in Canada from 2016 CI levels (95 gCO2eq/MJ for gasoline and 93 gCO2eq/MJ for diesel) (Government of Canada, 2022b; Canada Gazette, 2022). The CI of a fuel is a measure of the GHG emissions from the extraction, refining, distribution, and use of the fuel. In 2023, the CI reduction requirement starts at 3.5 g CO2eq/MJ. This will increase by 1.5 gCO2eq/MJ each year, reaching 14 gCO2eq/MJ in 2030 (Table 10.1) (Government of Canada, 2022b; Canada Gazette, 2022).

Table 10.1. Clean Fuel Regulations CI Limits for Different Fuel Classes (gCO2eq/MJ) (Canada Gazette, 2022)

Fuel	2023	2024	2025	2026	2027	2028	2029	2030 and after
Diesel	89.5	88	86.5	85	83.5	82	80.5	79
Gasoline	91.5	90	88.5	87	85.5	84	82.5	81

To drive innovation at the lowest cost, the CFR will establish a credit market. Regulated parties (producers and importers of gasoline and diesel) must create or buy credits to comply with the national reduction requirements. Parties with extra credits can bank them, for use in later years, or sell them (Government of Canada, 2022b). The three compliance categories for generating credits are: (1) actions that reduce the CI of the fossil fuel throughout its lifecycle, (2) supplying low-carbon fuels and (3) supplying fuel and energy in advanced vehicle technologies (Canada Gazette, 2022). Parties that are not primary suppliers of fossil fuels are able to participate in the credit market as voluntary credit creators, creating a market opportunity for low-carbon fuel producers and importers. While aviation and non-diesel marine fuels are not obligated under the CFR, supplying low-carbon liquid transportation fuels for aviation applications (e.g., sustainable aviation fuel), for example, is eligible to generate credits.

The above policies are complemented by technology-push program funding (See Section 1.3.4). The timelines below provide an overview to the implementation of frameworks, plans, regulations and policies in the Canadian context (Figure 10.3 and Figure 10.4).

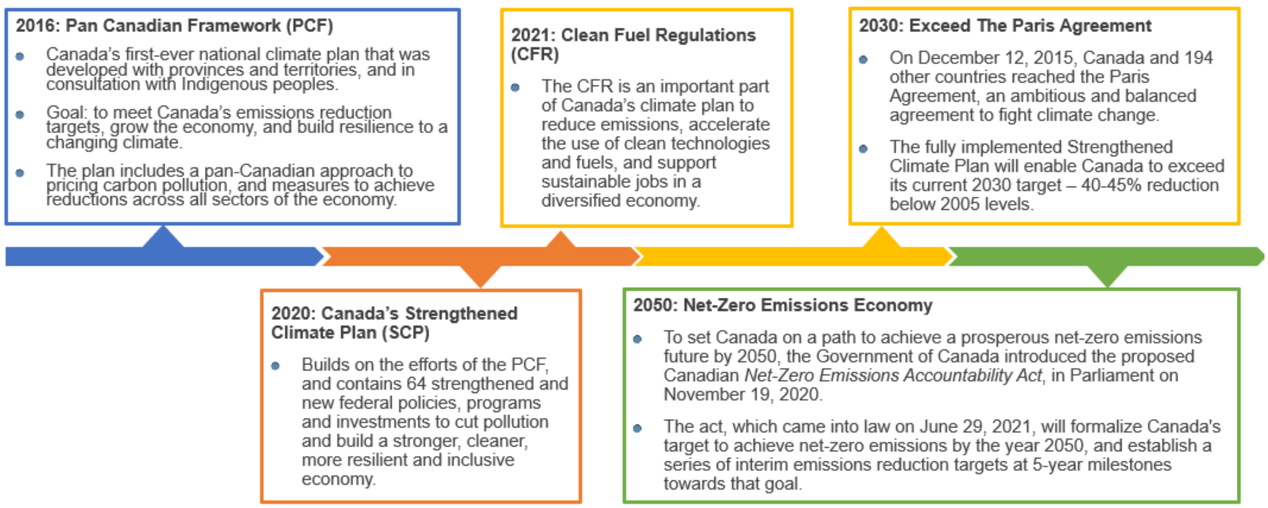

Figure 10.3. TimeLine to a Net-Zero Economy by 2050, Canada.

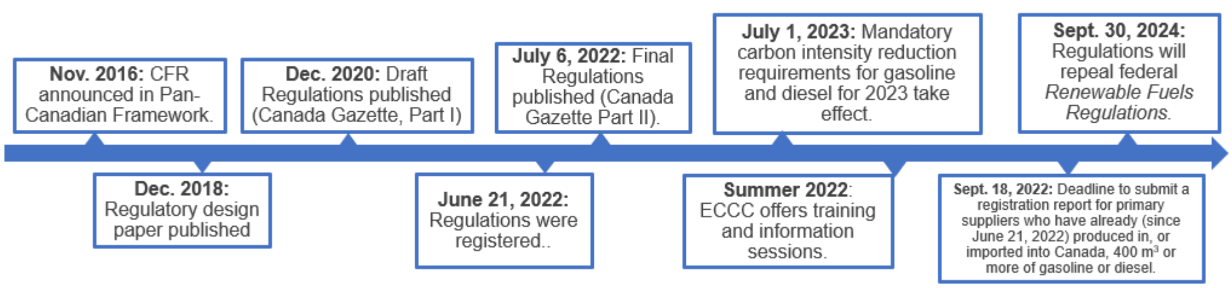

Figure 10.4. Clean Fuel Regulations Timeline, Canada

Unlike regulations such as the United States Renewable Fuel Standard (RFS), which specifies low-carbon fuel volumes based on feedstock (e.g., "conventional" starch-based ethanol vs. cellulosic ethanol) (United States Environmental Protection Agency, 2023), the CFR take a performance-based approach and rewards credits based on the CI of the fuel. Only biofuels made from biomass feedstock that adhere to land use and biodiversity criteria will be eligible for CFR credit creation. These criteria ensure the financial incentives created by the CFR do not result in loss of biodiversity from growing and harvesting biofuel feedstock.

Figure 10.5 shows the estimated lifecycle CI (i.e., well to wheels or farm to wheels) of transportation fuels in Canada between 2010 and 2020, with an estimate for 2021.

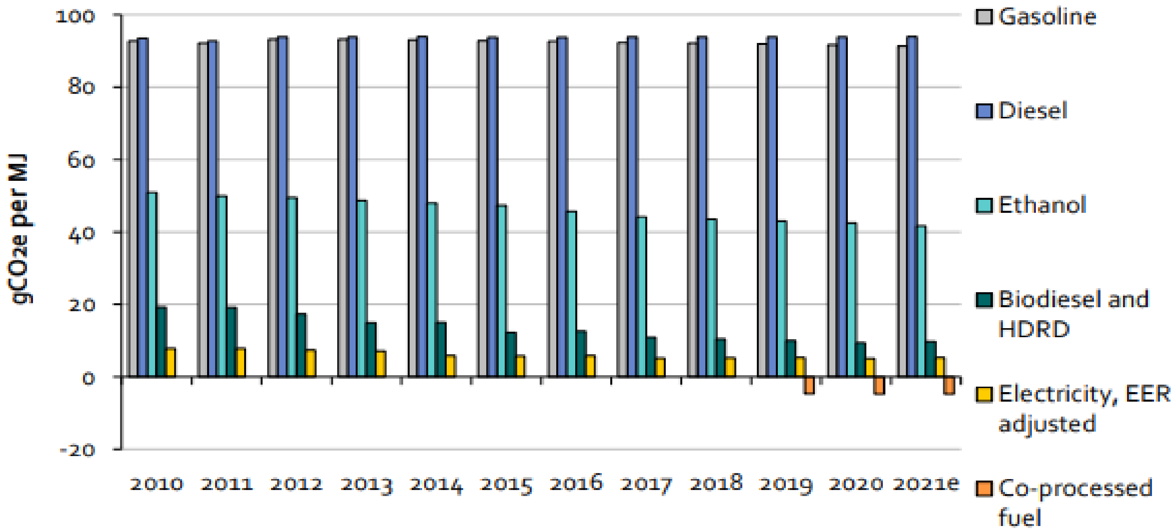

Figure 10.5. Indicative Lifecycle Carbon Intensities by Fuel Type, Canada, 2010 to 2020, with an Estimate for 2021 (Navius, 2022)

10.4.1. Provincial level policies

Summarized below are some examples of Canadian jurisdictions that have low carbon fuel policies (such as renewable fuel mandates or a fuel standard).

British Columbia's Low Carbon Fuel Standard (BC-LCFS): Bruce Ralston, Minister of Energy, Mines and Low Carbon Innovation for British Columbia highlighted that the BC-LCFS is an incredibly successful program and is the single largest contributor to reducing GHG emissions in the province (BC Gov News, 2022a). The BC-LCFS mandates a minimum 5% annual average renewable fuel content in gasoline and 4% renewable fuel content in diesel (Government of British Columbia, 2022). Further, the BC-LCFS aims to achieve a 30% CI reduction target for the diesel and gasoline fuel pools by 2030, following a reductions schedule that came into effect January 1, 2023 (Government of British Columbia, 2022). A fuel supplier can generate credits for fuels supplied in British Columbia with a CI below the target, and accrue debits for fuels having a CI over the target. Each credit or debit is equivalent to 1 tonne of CO2eq and a supplier's balance must either be zero or carry a credit to avoid non-compliance penalties of $600/debit (Government of British Columbia, 2022). British Columbia's fuel suppliers can comply with the LCFS by either supplying low-CI fuels, buying credits from other fuel suppliers, or earning credits through Part 3 agreements, i.e., agreements between a fuel supplier and the Ministry of Energy, Mines and Low Carbon Innovation, (Government of British Columbia, 2022). From 2010 to 2021, actions taken to comply with the LCFS have resulted in a reduction of more than 15.7 Mt of GHG emissions (BC Gov News, 2022b). The BC-LCFS has proven to be an effective "market-based mechanism". The LCFS is important as it targets the transportation sector, which contributed 36% of British Columbia's GHG emissions in 2020 (BC Gov news, 2022b).The BC-LCFS is the largest contributor to CleanBC goals and is expected to lead to a reduction of 5 Mt of GHG emissions by 2030, 31% of the amount required to meet CleanBC Roadmap climate targets (BC Gov News, 2022a). In the future, British Columbia plans to modify its LCFS to also include aviation and marine fuels (BC Gov News, 2022a).

Alberta: The Renewable Fuels Standard requires a minimum annual average of 5% renewable alcohol in gasoline and 2% renewable content in diesel fuel sold in Alberta by fuel suppliers. To meet the Renewable Fuels Standard, renewable fuels must demonstrate at least 25% fewer GHG emissions than the equivalent petroleum fuel (Government of Alberta, 2023).

Manitoba: Since their introduction, the Manitoba Ethanol Mandate and the Biodiesel Mandate have ensured that renewable energy is used in transportation fuels sold for use within the province. The annual compliance with these mandates has required fuel suppliers to replace at least on average 9.3% of gasoline blended with ethanol, and 2.4% renewable content in both on- and off-road diesel fuel, although there is flexibility in both blending season and renewable fuel types to meet the Biodiesel Mandate. (Government of Manitoba, 2020). Effective January 1, 2021, the province required 9.25% ethanol content in gasoline. The requirement grew to 10% on January 1, 2022. The biodiesel requirement increased to 3.5% on January. 1, 2021 and 5% on January 1, 2022 (Biodiesel Magazine, 2020).

Ontario: The Cleaner Transportation Fuels regulation requires that fuel suppliers blend 10% of renewable content in gasoline from 2020 to 2024. The renewable content requirement will increase to 11% in 2025, 13% in 2028, and 15% in 2030 and onwards. The renewable content must emit fewer GHG emissions than fossil gasoline on a lifecycle basis by 45% before 2030 and 50% from 2030 onward. The regulation also requires fuel suppliers to continue to blend 4% renewable content in diesel. This renewable content must emit 70% fewer GHG emissions than fossil diesel on a lifecycle basis (Government of Ontario, 2021).

Saskatchewan: The Renewable Diesel Act requires fuel distributors to include 2% renewable content in diesel fuel sold in Saskatchewan on an annual average basis (Government of Saskatchewan, 2012). The province also has an Ethanol Fuel Regulation that requires distributors in the province to blend ethanol with unleaded gasoline fuel of 7.5% annual as of January 1, 2008 (Government of Saskatchewan, 2002).

Quebec: Effective January 1, 2023, Quebec requires 10% low-CI fuel content in gasoline and 3% in diesel. These requirements will increase to 15% for gasoline and 10% for diesel by 2030. In both fuel pools, the percentages by volume of low-CI fuel content are established on the basis of the reduction in CI over the period of one calendar year (Légis Québec, 2022).

Nova Scotia: The Environmental Goals and Climate Change Reduction Act highlights the Government's targets in relation to GHG emissions reductions and that GHG emissions in the province are, by 2030, at least 53% below the levels that were emitted in 2005; and by 2050, at net-zero, accomplished by balancing GHG emissions with GHG removals and other offsetting measures (Nova Scotia Legislature, 2021).

Prince Edward Island (PEI): The PEI government is encouraging business and community organizations across the province to install electric vehicle (EV) charging stations targeted for business and public use through its PEI EV Charging Funding Program (Government of PEI, 2023a). The PEI government has phased out fossil fuel rebates as of December 31, 2022 (Government of PEI, 2023b). The province offers a wide variety of rebates and financial incentives to help reduce energy use through its Net-Zero Navigator. The Path to Net-Zero serves to highlight PEI’s goals of achieving net-zero emissions by 2040.

Yukon: Although not officially established, the territory of Yukon has had extensive consultations to the creation of a Clean Energy Act by 2023 to legislate GHG commitments, provide the Government of Yukon with the regulatory tools needed to meet those GHG commitments, and ensure long-term climate change accountability through public reporting. The Government of Yukon is committed to reducing the Yukon’s GHG emissions, with the exception of mining emissions, by 45% by 2030, reaching net-zero emissions across the Yukon’s entire economy by 2050 as part of its Clean Future.

Figure 10.6 summarizes the percentage of renewable content to be blended with gasoline and diesel as mandated by current provincial regulations.

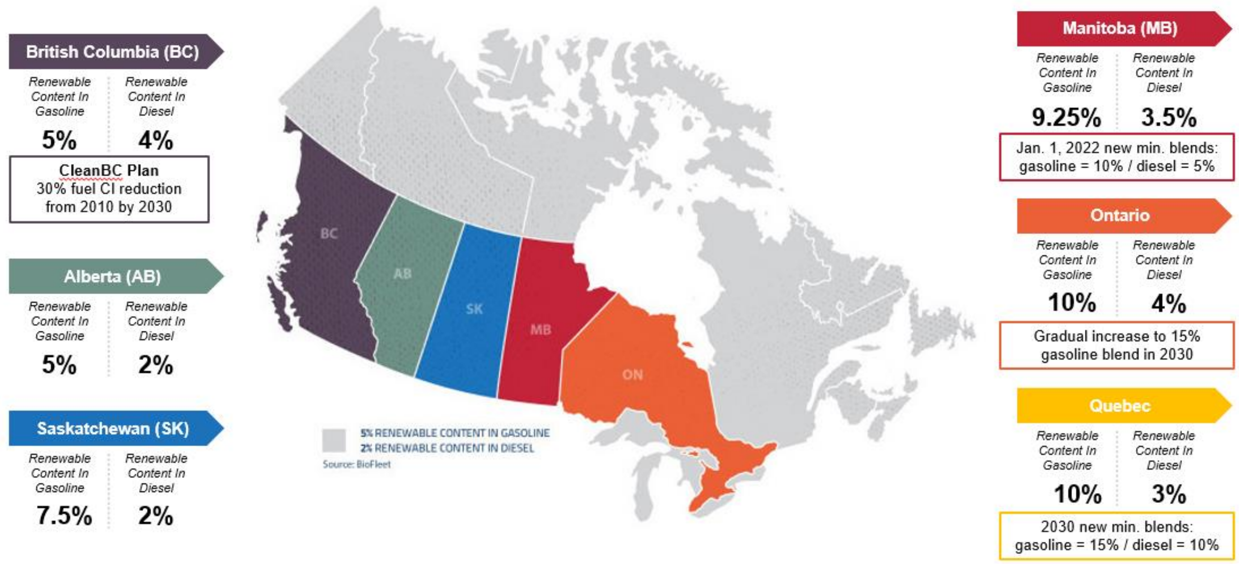

Figure 10.6. Renewable Fuel Regulations, Canada, 2023

10.4.2. The use of Life Cycle Assessment to assess the CI of a fuel

The CFR and BC-LCFS require fuels to contain a minimum volumetric amount of renewable fuel content, but also require fuel suppliers to gradually reduce the CI of their fuels. Life Cycle Assessment (LCA) is used to determine the CI of fuels and whether fuel suppliers are complying with the regulation.

The ECCC Fuel LCA model, an OpenLCA software-based model, will be used to assess the CI of fuels under the CFR and determine compliance and credit creation. It was first released in June 2022 and revised in January 2023, and will continue to be populated with additional pathways, data and updates. The model's database/datasets were collected from sources including scientific articles, science and technology experts, consultants, California Energy and Environment Protection Agency, National Energy Board, National Inventory report, Statistics Canada, US Environment Protection Agency, US Energy Information Agency, International Energy Agency, etc.

The goal of the ECCC Fuel LCA Model is to quantify carbon emission reductions in Canada's transport sector, based on an Open LCA, which is a more "wide-spread" software based on policies at the national level. The CFR take a lifecycle approach for each pathway, meaning it considers the emissions associated with all stages of fuel production and use, including extraction, transportation, conversion, distribution and end-use. A combination of enabling policies and effective LCAs can bring fuel suppliers, feedstock/technology providers, most components of the transport sector, etc., together, with the goal of successfully decarbonising transport, particularly long-distance transport.

Ongoing development and maintenance activities to the ECCC Fuel LCA Model will be prioritized based on engagement with the Stakeholder Technical Advisory Committee (STAC), comments received from stakeholders and other governmental departments as well as issues identified by ECCC. The STAC includes representatives from the following sectors (industry or associations): fossil fuel, low carbon fuel, electricity, agriculture, forestry and hydrogen. It also includes representatives from environmental non-governmental organizations and academia or independent LCA experts. All members of the STAC have expertise in LCA, GHG quantification or GHG credit trading schemes (Government of Canada, 2022g).

Established, complex LCA models such as GREET (US RFS, California LCFS) and GHGenius (BC-LCFS) have proven effective for evaluating the CI of fuels in other jurisdictions. However, unlike GREET and

GHGenius, which are owned and maintained by the US government and a private company, respectively, the ECCC Fuel LCA Model will provide centralized Canadian control and focus on Canada-relevant data. While the associated database is controlled by ECCC, use of the popular open source OpenLCA software is intended to increase the performance and robustness of the package. Comparison of LCA modelling results between models is complex and challenging for modelers, regulators and regulated parties, and is a particular challenge for exportable products such as biofuels. The ECCC Fuel LCA Model results and those of other tools such as GREET and GHGenius are highly dependent on various assumptions/default values, pathways, feedstocks, direct/indirect land use change, regional source of electricity/feedstock, local conditions, etc. Work is ongoing to improve standardization of LCA modelling across jurisdictions but will continue to be imperfect.

10.4.3. Carbon Pricing

The Canadian federal government has introduced CI benchmarks that require all provinces and territories to have a carbon pricing plan. Putting a price on carbon pollution is recognized as an efficient way to reduce GHG emissions while also driving innovation. Since 2019, every jurisdiction in Canada has had a price on carbon pollution. Canada's approach is flexible: any province or territory can design its own pricing system tailored to local needs, or can choose the federal pricing system. The federal government sets minimum national stringency standards (the federal 'benchmark'), that all systems must meet to ensure they are comparable and effective in reducing GHG emissions. If a province or territory decides not to price pollution, or proposes a system that does not meet these standards, the federal system is put in place (Government of Canada, 2021b).

In order to accelerate the market adoption of the technologies and practices needed to reduce emissions and to build a prosperous low carbon economy, Canada proposed in a Healthy Environment and a Healthy Economy to increase the price on carbon pollution annually at a rate of $15 per tonne from 2023-2030. Following engagement with provinces, territories and Indigenous leaders, the minimum price on carbon pollution (for direct pricing systems) will increase by $15 per tonne per year starting in 2023 through to 2030.

Drawing on engagement and review process of the carbon pricing system, in August 2021 the Government published strengthened minimum national standards (federal benchmark) for the 2023 to 2030 period to make sure they are fair, consistent and effective. The standards contain two components: (1) A regulatory charge on fossil fuels like gasoline and natural gas, known as the fuel charge, which as of fall 2022 applies in Ontario, Manitoba, Yukon, Alberta, Saskatchewan and Nunavut, and (2) A performance-based system for industries, known as the federal Output-Based Pricing System (OBPS) which as of fall 2022 applies in Manitoba, Prince Edward Island, Yukon, Nunavut, and partially in Saskatchewan.

Carbon pollution pricing systems in Quebec, Nova Scotia, Newfoundland and Labrador, the Northwest Territories, British Columbia and New Brunswick continue to meet the federal benchmark stringency requirements. Provincial systems in place in Prince Edward Island, Alberta, Saskatchewan and Ontario meet the federal benchmark stringency requirements for the emission sources they cover. The federal backstop applies in these provinces to emission sources not covered by the provincial systems. In Prince Edward Island, the federal OBPS applies alongside the provincial fuel charge. In Alberta, Saskatchewan and Ontario, as of January 1, 2022, provincial output-based performance standards systems apply alongside the federal fuel charge (Government of Canada, 2021b, Government of Canada, 2022d).

Figure 10.7 shows a snapshot of the various carbon pricing regimes across Canada. The provinces and territories are highlighted in three colors depending on whether the federal backstop applies in full, in part or not at all.

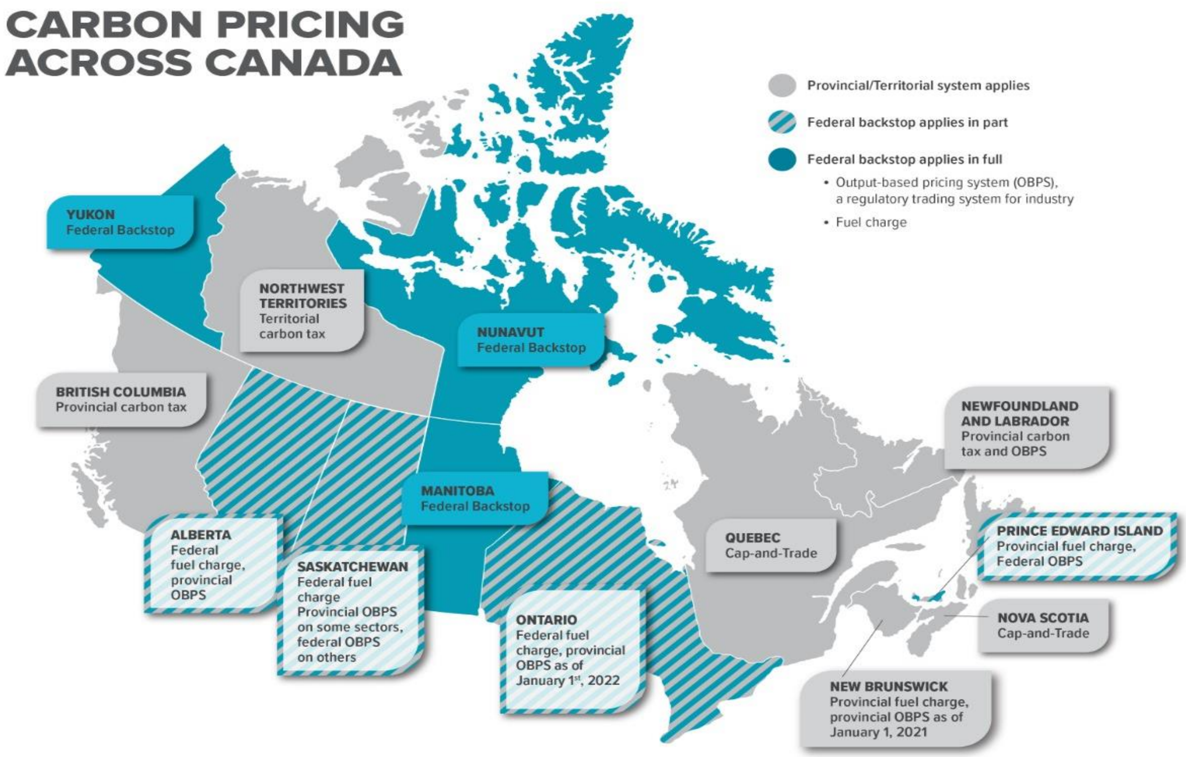

Figure 10.7. Snapshot of the Various Carbon Pricing Regimes Across Canada (Government of Canada, 2021b)

Canada's minimum national price on carbon pollution for explicit price-based systems (i.e., systems that directly set a price on emissions) is $65 per tonne of GHG emissions (CO2eq) in 2023, and this is expected to increase by $15 per year to $170 per tonne CO2eq in 2030 (Table 10.2; Government of Canada, 2022d). Carbon prices on specific fuel or emission sources must be calculated based on recognized global warming potential factors, such as those used for reporting requirements under the United Nations Framework Convention on Climate Change. As cap-and-trade systems set maximum emission levels rather than minimum carbon prices, the minimum carbon pollution price is translated into an equivalent cap on emissions (Government of Canada, 2022d). Cap-and-trade systems must have declined (more stringent) annual GHG emissions caps from 2023 to at least 2030 that correspond, at a minimum, to the projected emissions levels that would result from the application of the minimum national carbon pollution price that year in explicit price-based systems (Government of Canada, 2022d).

Table 10.2. Minimum National Carbon Pollution Price Schedule, Canada, 2023 to 2030 (Government of Canada, 2022d)

Year	2023	2024	2025	2026	2027	2028	2029	2030
Minimum Carbon Pollution Price ($ CAD/tonne CO2eq)	$65	$80	$95	$110	$125	$140	$155	$170

10.4.4. Fiscal incentives and Investment subsidies

Bioenergy related research is being conducted across Canada, at universities/colleges, within federal and provincial laboratories as well as in industry. Research, Development and Demonstration (RD&D) has been supported at both the federal and provincial/territorial levels. There are various types of government supports, spanning across all stages of the biorefining process. The types of support available includes: RD&D, business planning, plant construction, production, price support (e.g., tariffs), distribution and consumption (e.g., tax-breaks for the purchase of biofuel-consuming vehicles).

In 2018, Canada launched The Sky's the Limit Challenge. This program expanded the SAF network in Canada and contributed to cross-sectoral consortia building. It also helped identify existing expertise and capacities to help further scale-up SAF in Canada. In March 2022, it was announced that Enerkem, based in Montreal, was awarded the $5 million grand prize. Enerkem develops and uses advanced biochemical processes to convert municipal solid waste (MSW), as well as forestry and agricultural biomass, into sustainable chemicals and advanced biofuels, including SAF.

Various other types of federal and provincial government policies have been developed to encourage the production and use of biofuels. These span all stages of the biorefining process including low-interest loans, grants for feasibility studies and market development, grants for storage and distribution infrastructure and tax-breaks and rebates for the purchase of biofuel-consuming vehicles. Government support aimed at growing the clean fuel market across Canada includes: the $1.5 billion Clean Fuels Fund over five years, $8 billion in funding for the Net-Zero Accelerator Initiative (under the Strategic Innovation Fund), $67.2 million to support the implementation of the CFR, government procurement of SAF and sustainable marine fuel, and preferential tax treatment (Accelerated Investment Incentive) for low-carbon fuels used in energy generation applications.

Natural Resources Canada’s Office of Energy Research and Development (OERD) administers the Energy Innovation Program (EIP), advancing clean energy technologies that will help Canada meet its climate change targets and supporting the transition to a low-carbon economy. OERD funds research, development and demonstration projects, and other related scientific activities. The $53 million Clean Fuels and Industrial Fuel Switching (CFIFS) call for proposals was announced in 2021 under the EIP, and targets industrial fuel switching and production of clean fuels for use in hard-to-abate sectors. Selected projects are expected to be announced in the coming months.

Budget 2022 recognized Canada will need between $125 billion and $140 billion of investment every year from now until 2050 to achieve net-zero emissions, and that today’s annual investment in the climate transition is only between $15 billion and $25 billion, through a multitude of initiatives. Budget 2022 proposed establishing the $15 billion Canada Growth Fund to attract substantial private sector investment to help meet important national economic and climate policy goals. The 2022 Fall Economic Statement clarified that the Canada Growth Fund would utilize a broad suite of project financing tools, including contracts for difference.

Budget 2023 proposes to provide $500 million over ten years to the Strategic Innovation Fund to support the development and application of clean technologies in Canada. The Strategic Innovation Fund will also direct up to $1.5 billion of its existing resources towards projects in sectors including clean technologies, critical minerals, and industrial transformation (Government of Canada, 2023b).

In addition to Federal programs, Canadian Provinces have been proving financial supports to develop biofuels technologies and markets such as British Columbia’s Innovative Clean Energy Fund, Alberta Bioenergy Producer Program and Emissions Reduction Alberta.

Canada is also incentivising Canadians to switch to EVs through additional funding of $400 million for zero-emission vehicles (ZEVs) charging stations, announced in Budget 2022. Complemented by $500 million that Canada’s Infrastructure Bank will invest in large-scale ZEV charging and refueling infrastructure that is revenue generating and in the public interest, the funding will support the Government’s targets of deploying 84,500 chargers and 25 hydrogen stations by 2029. Budget 2022 also provided $1.7 billion to extend the Incentives for the ZEV program to March 2025. To accelerate the manufacturing and adoption of cleaner cars, the federal government, as announced in Budget 2022, will put in place a sales mandate to ensure at least 20% of new light-duty vehicle sales will be ZEVs by 2026, at least 60% by 2030 and 100% by 2035. To reduce emissions from medium- and heavy-duty vehicles (MHDVs), the federal government will aim to achieve 35% of total MHDV sales being ZEVs by 2030.

Although Canada's production of advanced biofuels is currently limited, federal and provincial policy incentives that favour low-CI biofuels will increase feedstock demand, requiring biofuel producers to utilize abundant feedstocks, e.g., lignocellulosic, ultimately increasing the production of advanced biofuels in Canada.

10.4.5. Other international measures stimulating the development and uptake of biofuels

In addition to national initiatives which encourage the development of biofuel technologies and markets, Canada is heavily engaged in several international initiatives:

Mission Innovation

- Canada played a leadership role in the first phase of Mission Innovation (MI). From 2016-2020, Canada co-led the Sustainable Biofuels Innovation Challenge ('IC4'). In this phase, 16 countries made progress towards implementing affordable advanced biofuels for transportation and industrial applications. Currently, Canada is exploring opportunities to contribute to the next phase of Mission Innovation ('MI 2.0').
- Replacing fossil fuel-based fuels, chemicals and materials with sustainable bio-based alternatives from residues and wastes could reduce GHG emissions, providing a renewable alternative for hard-to-abate sectors and support rural jobs. To realize this potential and to make sustainable bio-based alternatives from residues and wastes cost-competitive, Mission members are collaborating through the Integrated Biorefineries Mission. In September 2022, the Integrated Biorefineries Mission launched an Integrated Biorefineries Mission Roadmap in which the gaps and challenges in current biorefining value chains have been identified and key actions to support the Mission have been prioritized.

Biofuture Platform

- Canada is one of 20 countries participating in the Biofuture Platform, a government-led international effort to promote accelerated development of advanced low carbon fuels, biochemicals and biomaterials. Canada co-leads the Clean Energy Ministerial Biofuture Campaign, which formally launched the 11 Clean Energy Ministerial (CEM11). The intent of this platform is to accelerate the deployment of bio- and waste-based products and showcase how they can and will benefit society.

Global Bioenergy Partnership

- Canada is one of 23 countries participating in the Global Bioenergy Partnership (GBEP). GBEP brings together public, private and civil society stakeholders in a joint commitment to promote bioenergy for sustainable development. GBEP provides a mechanism for Partners to organize, coordinate and implement targeted international research, development, demonstration and commercial activities related to production, delivery, conversion and use of biomass for energy, with a focus on developing countries.

International Renewable Energy Agency

- In 2019, Canada officially joined the International Renewable Energy Agency (IRENA). IRENA is an intergovernmental organization that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a center of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy.

10.5. Promotion of advanced biofuels

Canada is uniquely positioned to be a leader in the production of advanced[4] drop-in[5] biofuels, such as renewable diesel produced from forestry residues. Federal and provincial/territorial governments are either considering, have implemented, and/or will continue to implement additional supports to achieve pre-commercial-scale plants and to encourage the development of technologies that will convert non-food-based feedstocks to biofuels.

A few examples of companies in Canada that are either developing technologies or have achieved pre-commercial-scale or commercial-scale plants for the production of biofuels:

- Hydrogen Naturally uses proven technology, sustainable forest waste fiber, and in-depth knowledge of carbon sequestration to build a reliable long lasting hydrogen supply source.
- Greenfield Global is Canada's largest ethanol producer at four facilities located in Ontario and Quebec. Farmers from within a 75-kilometre radius of the plants provide grain that is used to make ethanol, animal feed, and corn oil. The ethanol they produce Is made from renewable crops and resources, reduces lifecycle GHG emissions from transportation fuels, supports local agriculture by providing a value-added market for grains and provides consumers with an affordable, more environmentally friendly fuel at the pump.
- Arbios Biotech (Arbios), and the Lheidli T'enneh First Nation have recently named the Arbios commercial scale facility in Prince George, British Columbia, Arbios Biotech Chuntoh Ghuna which means "The Forest Lives". The Lheidli T'enneh First Nation and Arbios Biotech have been working in close partnership to develop the renewable biofuels facility, including the site preparation. The facility is located on the unceded and traditional territory of the Lheidli T'enneh.
- Vyterra deploys Ensyn's platform thermal conversion technologies to produce biochemicals and low carbon fuel products. Energy projects focus initially on the production of Low Carbon Fuel Oil for institutional heating and industrial processes, to be followed by production of biocrude for refinery co-processing and marine fuels.
- Varennes Carbon Recycling, a biofuels facility under construction in Varennes, Quebec built by Montreal-based Enerkem, will be used to produce biofuels and renewable chemicals out of landfill waste and wood waste. The plant will also incorporate one of the world's largest electrolyzers, which will split water molecules into oxygen and green hydrogen for use in its biofuel-making process. Once completed in 2025, the facility will be the largest biofuels facility in the country.

10.6. Market development and policy effectiveness

"Conventional"[6] biofuels, including ethanol and biodiesel (FAME)) and, to a (much) smaller extent, renewable natural gas (RNG), have been produced and used in Canada to decarbonize the road transportation sector.

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[4] **Advanced Biofuels**: pre-commercial technologies using non-food crops, agricultural and forest residues which can either be blended with petroleum-based fuels, combusted in existing internal combustion engines, and distributed through existing infrastructure or is dedicated for the use in slightly adapted vehicles with internal combustion engines. Advanced fuels can be produced from waste materials, stalks of wheat and corn, wood and dedicated energy crops.

[5] **Drop-in Fuel**: a completely interchangeable substitute for conventional petroleum-derived hydrocarbons (gasoline, jet fuel, and diesel). It can be used "as is" in currently available engines either in pure form and/or blended in any amount with other drop-in neat, drop-in blend, or conventional fuels.

[6] **Conentional Biofuels**: include sugarcane ethanol, starch-based or 'corn' ethanol, biodiesel and Pure Plant Oil. Feedstock used in the production of conventional biofuels can consist of sugars, starches, oil bearing crops, and animal fats – in some cases these can be used as food or animal feed. Conventional biofuels are characterized either by their ability to be blended with petroleum-based fuels, combusted in existing internal combustion engines, and distributed through existing infrastructure, or by the use in existing alternative vehicle technology.

10.6.1. Biofuels consumption in Canada

As demonstrated in Table 10.3 and Figure 10.8 (Navius, 2022):

- Renewable fuel consumption declined somewhat in 2020 relative to previous years due to the reduction in overall fuel consumption during the COVID-19 pandemic (-6% renewable fuels in 2020 relative to 2019). This change is a function of lower total gasoline consumption leading to less ethanol consumption.
- The volume of ethanol consumed in 2020 declined by over 300 ML/yr relative to 2019 (-11%).
- The quantity of diesel consumption was less impacted by the pandemic and biomass-based diesel consumption actually increased from 2019 to 2020, rising by more than 100 ML/yr (-13%).
- Total biomass-based diesel consumption was almost 900 ML/yr. Growth in HDRD consumption continued to drive the increase in biomass-based diesel, while biodiesel consumption remained relatively constant from 2019 to 2020.
- An estimated 15 ML/yr of co-processed renewable fuel was produced at Parkland's Burnaby refinery in 2019, rising to 20 ML/yr in 2020 and an estimated 44 ML/yr in 2021, although the 2021 highlights from Parkland indicate that the refinery actually co-processed 86 ML. The 2022 fourth quarter and year end results indicates that the refinery co-processed over 111 ML of bio-feedstocks in 2022,
- Electricity as a transportation fuel has been growing rapidly over the past few years, with a compound annual growth rate averaging roughly 64% between 2015 and 2021.

Table 10.3. Fuel Consumption (ML/yr), Canada, 2015 to 2020, with an Estimate for 2021 (Navius, 2022).

Fuel type	2015	2016	2017	2018	2019	2020	2021e
HDRD	194	215	323	344	432	547	507
Biodiesel	334	341	376	367	360	351	413
Ethanol	3,041	3,069	3,047	3,034	2,985	2,665	2,933
Co-processed					15	20	44
Electricity	19	31	49	93	153	212	305
Diesel (Pure)	26,752	25,831	27,732	27,550	27,039	24,106	24,284
Gasoline (Pure)	41,697	42,367	42,955	43,148	43,081	35,432	37,331

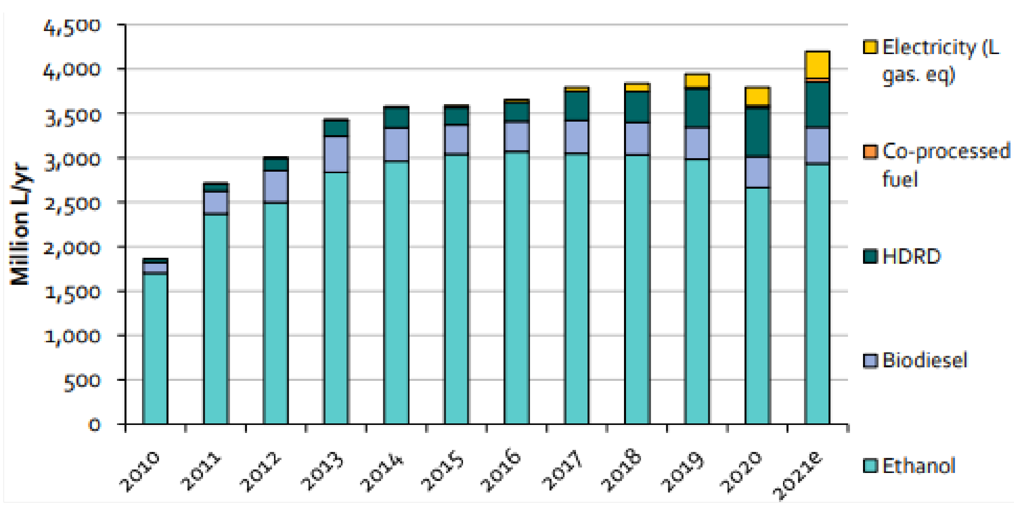

Figure 10.8. Renewable and Low-Carbon Transportation Energy Consumption, Canada, 2010 to 2020, with an Estimate for 2021 (Navius, 2022).

Although ethanol consumption declined in 2020, gasoline consumption declined proportionally more. Consequently, the blend rate of renewable fuels in gasoline increased to 7% by volume in 2020, up from about 6.5% in 2019 (Navius, 2022; Figure 10.9). Additionally, blend rates were expected to reach 7.3% in the gasoline pool and 3.7% in the diesel pool in 2021. In 2020, Co-processed fuel accounted for a volume equivalent of about 0.1% of the gasoline pool, while light-duty PEVs offset a quantity of fuel consumption equivalent to about 0.5% of the gasoline pool. The fraction of biodiesel and HDRD in diesel increased to 3.6% in 2020, up from 2.9% in 2019 (Navius, 2022).

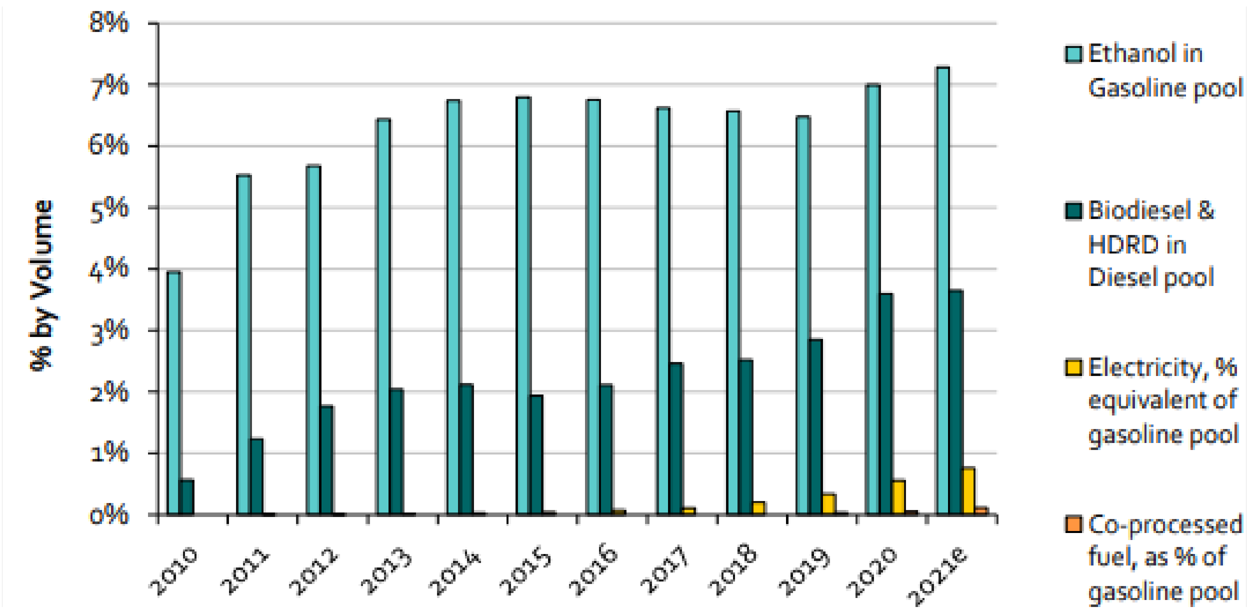

Figure 10.9. Renewable Fuel Content by Fuel Pool, Canada, 2010 to 2020, with an Estimate for 2021 (Navius, 2022)

10.6.2. Biofuels production in Canada

Canada's biofuel production capacity has grown modestly over the last decade, largely driven by growth in biodiesel production capacity. Further growth in biofuel production capacity is expected, as several announcements for new facilities have been made. A map of current ethanol and biodiesel plants in Canada can be found in the Canadian Renewable Biofuel Producers, Blenders and Distributors map.

Ethanol

Ethanol fuel consumption in Canada has increased from roughly 1,700 ML/yr in 2010 to 2,665 ML/yr in 2020 (Navius, 2022). Ethanol production in Canada has remained relatively constant at around 1,700 ML/y (Statista, 2023; Figure 10.10). There are currently 14 plants operating at or near full capacity, with a production capacity of more than 2 BL/yr (Ethanol Producer Magazine, 2023). In Canada, ethanol is presently made principally from corn and wheat, with more than 50% of the facilities using corn as their feedstock (Government of Canada, 2020b; Ethanol Producer Magazine, 2023). Facilities that produce ethanol include Enerkem Alberta Biofuels, Greenfield Global in Ontario and Quebec and North West Pure Alcohol & Spirits in Saskatchewan.

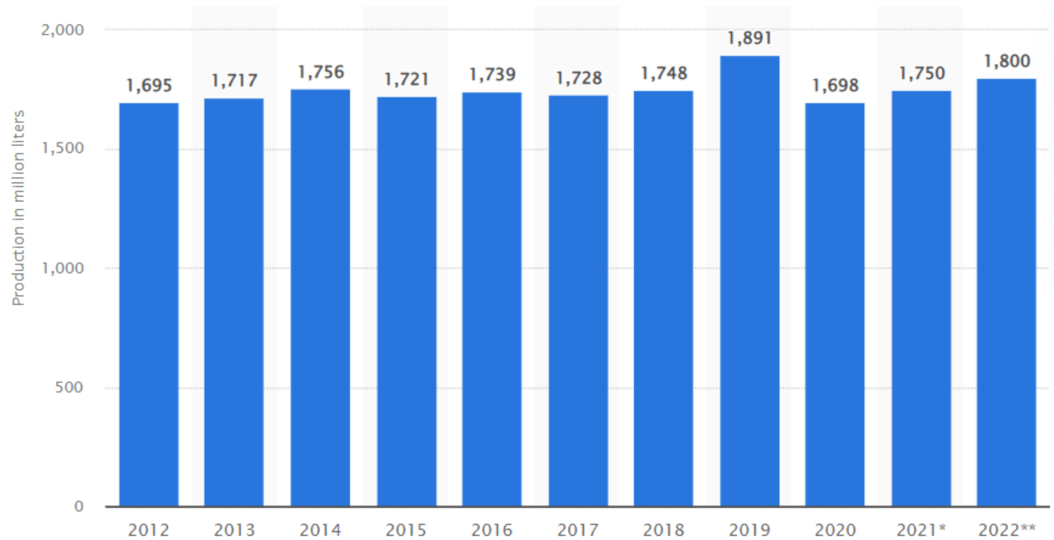

Figure 10.10. Bioethanol Fuel Production, Canada, 2012 to 2021, with an Estimate for 2022 (Statista, 2023)

Biodiesel

Canada currently has five operational biodiesel facilities with a total capacity of more than 590 ML/yr (Biodiesel Magazine, 2023). In November 2017, Innoltek Inc. acquired the assets of QFI biodiesel, including a biodiesel facility in Saint-Jean-sur-Richelieu, Quebec that has a production capacity of 12 ML/yr. The St-Jean-sur-Richelieu plant had never reached full production capacity when operating on UCO, but Innoltek CEO said the capital investment will help achieve full nameplate capacity to manufacture biodiesel from animal fats by third quarter of 2018 (Biodiesel Magazine, 2018).

Renewable Diesel

Tidewater will develop a plant on the refinery site at its Prince George Refinery, British Columbia that is intended to convert vegetable oils, UCO and animal fats into renewable diesel (RD); once complete it is expected to produce 150 ML/yr RD, which is nearly 25% of the provinces target to achieving 650 ML of renewable fuel by 2030 (Prince George Citezen, 2021).

Imperial's Strathcona refinery near Edmonton, Alberta will invest $720 M CAD to build the largest RD facility in the country. It will produce more than one BL of RD annually, primarily from locally sourced feedstocks, helping reduce GHG emissions by 3 MT/yr (Imperial Oil, 2023).

Federated Co-operatives Ltd plans to build a canola crushing and RD production complex at its Regina refinery. The RD plant will have a production capacity of about 15,000 barrels per day (bpd), which adds up to about one BL/yr. The canola crushing facility is expected to use 1.1 MT of canola seed to make 450,000 tonnes of oil (CTV News, 2022).

Braya Renewable Fuels is converting the Come By Chance refinery in Newfoundland and Labrador into a world-class RD and SAF refining facility. The refinery's location enables it to source low-CI feedstocks from anywhere in the world while delivering sustainable fuels to low-carbon markets along both US coasts. Phase 1 will retrofit a portion of the refinery to process feedstocks, which include soybean oil and distiller's corn oil, into 18,000 bpd of RD. Minor additional equipment may be added to produce SAF. Phase 2 will add facilities to convert less expensive feedstocks for additional hydrogen production, which will in turn increase renewable diesel production to 24,000 bpd. (Braya, 2023).

Renewable Natural Gas

The Canadian 2020 Biogas Market Report highlights that Canada is using only 13% of its easily accessible biogas potential, with 16% of the biogas produced upgraded to RNG (Canadian Biogas Association, 2021).

With the right incentives, policies and funding, there is opportunity for growth to complement the increasing demand for RNG in certain regions across Canada. More than 270 biogas projects currently operate across Canada: in 2020 alone, the sector produced 6 MGJ of energy through RNG, 260 Mm^3 of biogas for heat and direct use, and 196 MW of clean electricity capacity, the equivalent of roughly 400 Mm^2 of solar panels (Canadian Biogas Association, 2021).

A few provinces have installed specific regulations to encourage the growth of the biogas market (Canadian Biogas Association, 2021):

- **British Columbia**: Government of BC's CleanBC climate plan has committed to a minimum of 15% renewable gases (RNG and hydrogen) in the province's total gas supply by 2030.
- **Québec**: In November 2020, the Québec government unveiled its 2030 Plan for a Green Economy, which, among other things, aims to require a 10% share of RNG in the natural gas network by 2030 and a 50% increase in bioenergy production by 2030. Québec has also recently enacted a regulation that requires the natural gas distributor (Énergir) to increase annually the quantity of RNG to 2% in 2022, and 5% in 2025. In addition, the Québec government announced in July 2020 its commitment to provide $70 million in funding for RNG projects.
- **Ontario**: The Ontario government has established a number of specific programs to aid in the development of the RNG/biogas market. This includes a voluntary $2 monthly RNG charge that was approved in September 2020 by the Ontario Energy Board that would allow Embridge Gas to procure Rng as part of its system gas portfolio.

In addition, there are a number of broad-based federal infrastructure and climate-related funding programs that support biogas and RNG. These have included the Green Infrastructure Fund, the Low Carbon Economy Fund, the Agricultural Clean Technology Fund, the Federal Gas Tax Fund, and the $1.5-billion Low Carbon and Net-Zero Emission Fuels Fund.

10.6.3. Biofuels Imports and Exports in Canada

In 2021, 422 ML of biodiesel and 471 ML of RD were imported to Canada, mostly from the US, to meet blending mandates. In addition, 1,400 ML of ethanol was imported, mostly from the US, to meet blending mandates (ECCC, 2021c). In 2022, Canadian imports of US fuel ethanol were forecasted to reach a record 1.5 BL with further expansion of the fuel pool and an upward trend in the average nationwide blend level anticipated (USDA, 2022). The increase, up from 1.4 BL in 2021, was expected to be driven by higher Canadian fuel usage and an increased share of domestic supply going to exports. However, as government-imposed pandemic-related travel restrictions began to lift, the relatively low-priced US fuel ethanol imports are "backfilling" Canada's higher-priced undenatured fuel and non-fuel ethanol exports to Europe.

Canada's biodiesel plants are export-oriented with only part of their business focused on the domestic market. In any given year, Canada exports the majority of its biodiesel to the US. The US market nets higher returns than domestic outlets due to the US biomass-based diesel (BBD) blenders tax credit, Renewable Identification Numbers (RINs), and the California LCFS credits.

However, in recent years, Canadian exports of fuel ethanol have been on the rise, reaching record levels in 2020 and increasing further to about 100 ML in 2021 and 2022. Higher fuel ethanol prices and the somewhat stronger demand for ethanol is due to even higher gasoline prices and increasing sales of E10 (gasoline with 10% ethanol content) and E85 (gasoline that may contain up to 85% fuel ethanol). It is possible that some Canadian product being shipped under the harmonized system code for undenatured fuel ethanol is used for non-fuel purposes such as hand sanitizer (USDA, 2022).

On May 18, 2022, although the Canadian government announced that China has reinstated access to its market for Viterra and Richardson, the two companies that China Customs had suspended from exporting canola seed to China since March 2019, China still has a restrictive 1% dockage requirement in place on Canadian canola imports. Even with export licenses reinstated, exports are not expected to return to the pre-pandemic levels. Consequently, there is a high likelihood that Canadian companies will only export to China as a last resort. International canola oil sale opportunities have expanded immensely since China suspended imports from Canada, both domestically and abroad (USDA, 2022).

10.6.4. Feedstock

The principal agriculture feedstocks for producing ethanol in Canada are starches such as corn (ECCC, 2021c). Canada is a major world producer and exporter of grains. The main feedstocks used to produce biodiesel include vegetable oils, such as canola oil and corn oil, oilseeds and soy oil (ECCC, 2021c). Figure 10.11 and Figure 10.12 summarize the feedstocks used to produce the biofuels sold, from those both imported and domestically sold, in Canada from 2010 to 2020, with an estimate for 2021 (Navius, 2022) showing that:

- Most of Canada's biodiesel consumption is produced from vegetable oils, including canola oil and soy oil, followed by tallow, UCO and corn oil.
- Most HDRD consumed is from palm oil by-products and tallow.
- Most of the ethanol consumed in Canada is produced from corn although 10-15% is produced from wheat.

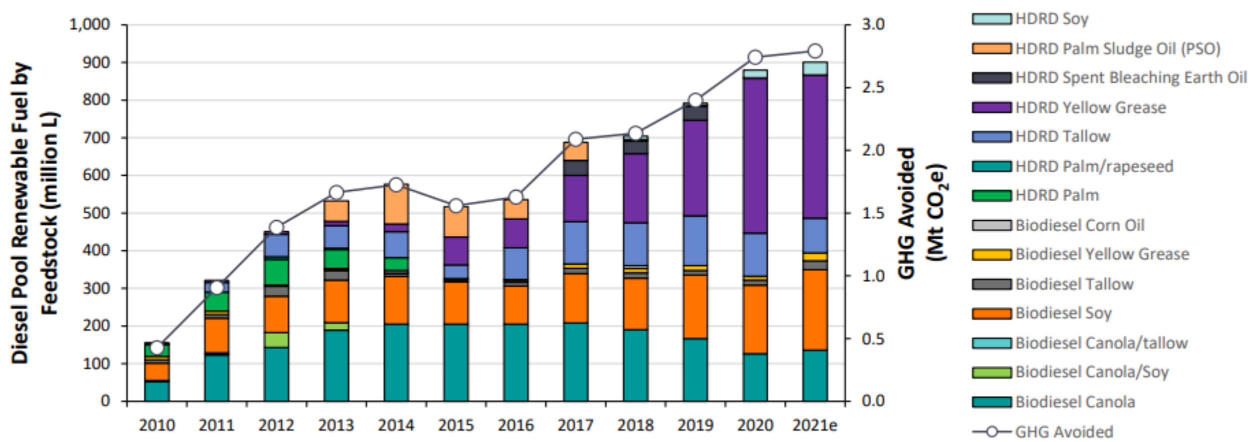

Figure 10.11. National Results for Renewable Fuel Consumption of Diesel Pool by Fuel Type and Feedstock, Canada, 2010 to 2020, with an Estimate for 2021 (Navius, 2022).

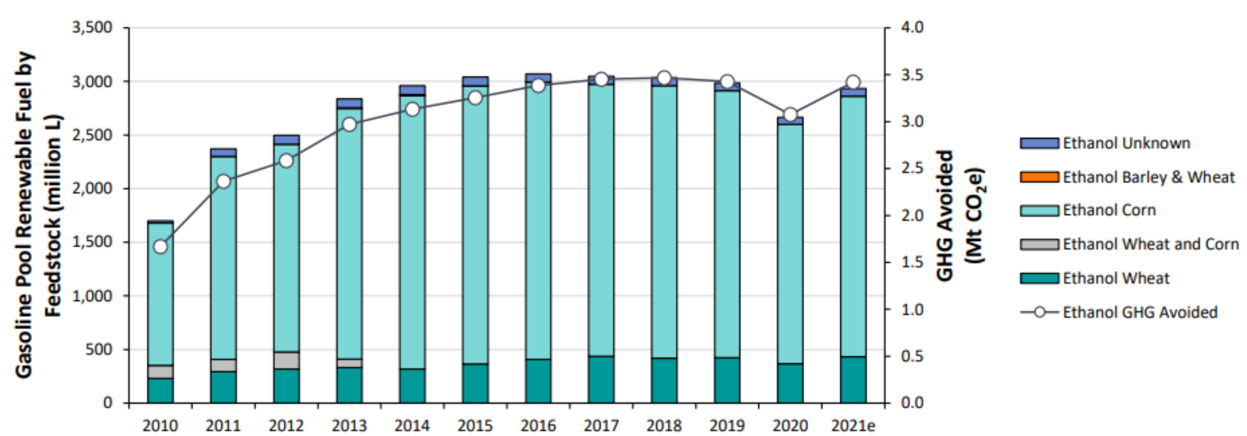

Figure 10.12. National Results for Renewable Fuel Consumption of Gasoline Pool by Fuel Type and Feedstock, Canada, 2010 to 2020, with an Estimate for 2021 (Navius, 2022).

The 14 oil seed crushing and refining plants across Canada have the capacity to crush about 11 MTof canola seed each year (Canola Council of Canada, 2023). In 2021 and early 2022, four major announcements were made to add 5.7 MT of processing capacity by 2025 – representing more than a 50% increase from the current capacity (Canola Council of Canada, 2023).

In Canada, the increased biofuel demand for canola oil is expected to increase price volatility for the commodity moving forward. As demand for biofuel increases, the Canadian Oilseed Processors Association expects canola demand for biofuels to jump to 6.5 MT/yr by 2030, up from just 1.8 MT/yr in 2020. Production is projected to increase to 29 MT/yr in 2030 from 20 MT/yr in 2020. This would make the biofuel market responsible for 23% of canola demand by the end of the decade, a significant increase from just 9% in 2020 (Western Producer, 2022).

10.7. Co-processing[7] and refined petroleum products

Both the BC-LCFS and the federal CFR encourage Canadian oil refineries to consider co-processing[7] as an economically attractive compliance pathway. Canada has 17 refineries with a total capacity of approximately 2.0 million barrels per day (Mb/d), as of 2020. Alberta has the largest share of refining capacity (27%), followed by Ontario (20%), Quebec (19%), New Brunswick (16%), Saskatchewan (8%), Newfoundland and Labrador (7%), and British Columbia (3%). In 2020, Canadian refineries operated on average at 76% capacity, and consumed 1.5 Mb/d of crude oil, a decrease from 2019, resulting from weaker demand during the pandemic (Government of Canada, 2022a).

British Columbia has two oil refineries with a total processing capacity of 67,000 b/d. The Parkland refinery in Burnaby is a Canadian leader in this approach with a capacity of 55,000 b/d. The facility is able to co-process bio-feedstocks such as canola oil, and oil derived from animal fats (tallow) alongside crude oil to produce low carbon fuels. The Tidewater refinery in Prince George, British Columbia is in the early stages of developing co-processing with a capacity of 12,000 b/d. The company recently announced its plans to build RD and renewable hydrogen facilities utlizing Topsoe's HydroFlex™ and H_2bridge™ technologies.

10.8. Conclusions

Biofuels are expected to play an integral role in reducing transportation sector emissions and helping Canada achieve its goal of net-zero emissions by 2050. Legislation, funding and informed policy changes have supported the development and deployment of transportation biofuels to date. The Canadian Net-Zero Emissions Accountability Act establishes legally binding targets that hold the government accountable. The Clean Fuel Regulations further support the emissions reductions targets by incentivizing producers and importers of gasoline and diesel to comply with national reduction requirements. Funding, through programs like the Energy Innovation Program, deliver innovation and support research, development and demonstration and encourage investment leaders in the Canadian biofuels industry. While Canadian biofuel production has grown modestly over the past few years, Canada is well positioned to achieve improved production capacity, commercial scale facilities, and regulatory compliance in the coming decades.

[7] Co-processing: simultaneous recycling of mineral materials and recovery of energy within one single industrial process

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11. United States

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11.1. Summary

- Renewable Fuel Standards (RFS) for 2023, 2024, and 2025 demonstrate a continued and increased commitment to cellulosic and advanced biofuels, biomass-based diesel, and renewable fuel over multiple years. The proposed changes also aim to include using credits for renewable electricity derived from biomass.
- The Inflation Reduction Act (IRA) of 2022 established two new credits: 1) the Sustainable Aviation Fuel (SAF) Credit for the sale or use of qualifying SAF meeting a minimum of 50% lifecycle greenhouse gas (GHG) emission reduction, and 2) the Clean Fuel Credit for the production of biofuels or SAF, and which include lifecycle GHG emission reduction considerations in biofuel credits and minimum requirements for SAF.
- The 2022 IRA further also extends existing credits for biodiesel, renewable diesel, and alternative fuels through 2024, and second generation biofuels through 2025.
- A growing number of states have adopted and proposed clean fuel standards which are based around carbon intensity, and which make SAF eligible for credits..
- Planning and funding mechanisms provide increased support for biofuels generation and utilization, including through the SAF Grand Challenge (2021) and IRA (2022). These types of programs support research to develop innovative biofuel pathways and the infrastructure necessary for the production, storage and delivery of biofuels, including SAF.

11.2. Introduction

With transportation fuels as a significant contributor to GHG emissions, accounting for 37% of CO2 emissions from end-use sectors globally in 2021 (International Energy Agency, 2022a), policies supportive of the increased production and consumption of biofuels are essential for overall decarbonization strategies. In the U.S., growth in the demand for biofuels increased in 2021-2022 (826.17 MG/yr), leading the growth in total biofuel demand globally (International Energy Agency, 2022b). In 2022, biofuels accounted for 18% of total renewable energy consumption in the U.S. (Figure 11.1), with the transportation sector accounting for 36% of total end-use energy consumption (U.S. Energy Information Administration, 2023a; U.S. Energy Information Administration, 2023b).

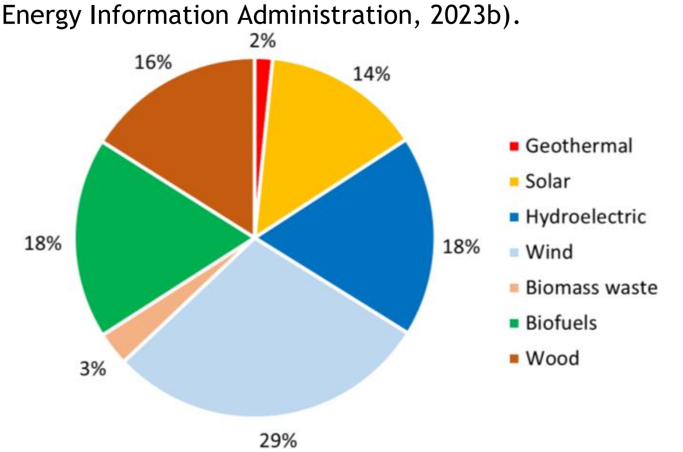

Figure 11.1. Sources of renewable energy consumption in the U.S. in 2022, with types of sources as percentages of total renewable energy (U.S. Energy Information Administration, 2023a; U.S. Energy Information Administration, 2023b).

Biofuel production and consumption levels for 2022 and 2027 show overall increases, although potential decreased consumption of ethanol (Table 11.1), with recent federal policies acting as key contributing mechanisms (International Energy Agency, 2022b).

Table 11.1. Production and consumption of biofuels in the US for 2021 and 2027 (main to accelerated projections), MG/yr (International Energy Agency, 2022b).

	Biodiesel	Biojet	Ethanol	Renewable Diesel
Production				
2022	1,566.5	60.2	15,015.0	1,577.4
2027	4,750 - 7,037	1,930 - 3,475	54,137 - 58,415	13,545 - 14,899
Consumption				
2022	1,566.5	59.2	14,043.9	1,898.9
2027	4,750 - 7,037	1,961 - 3,923	10,373 - 58,937	15,305 - 16,712

Figure 11.2 and Figure 11.3 summarise that biofuels contributed to 18% of the United States' primary energy consumption in 2022, with renewable energy accounting for a total of 13%. Additionally, Figure 11.3 highlights that 36% of the US's energy was used by the country's transportation sector.

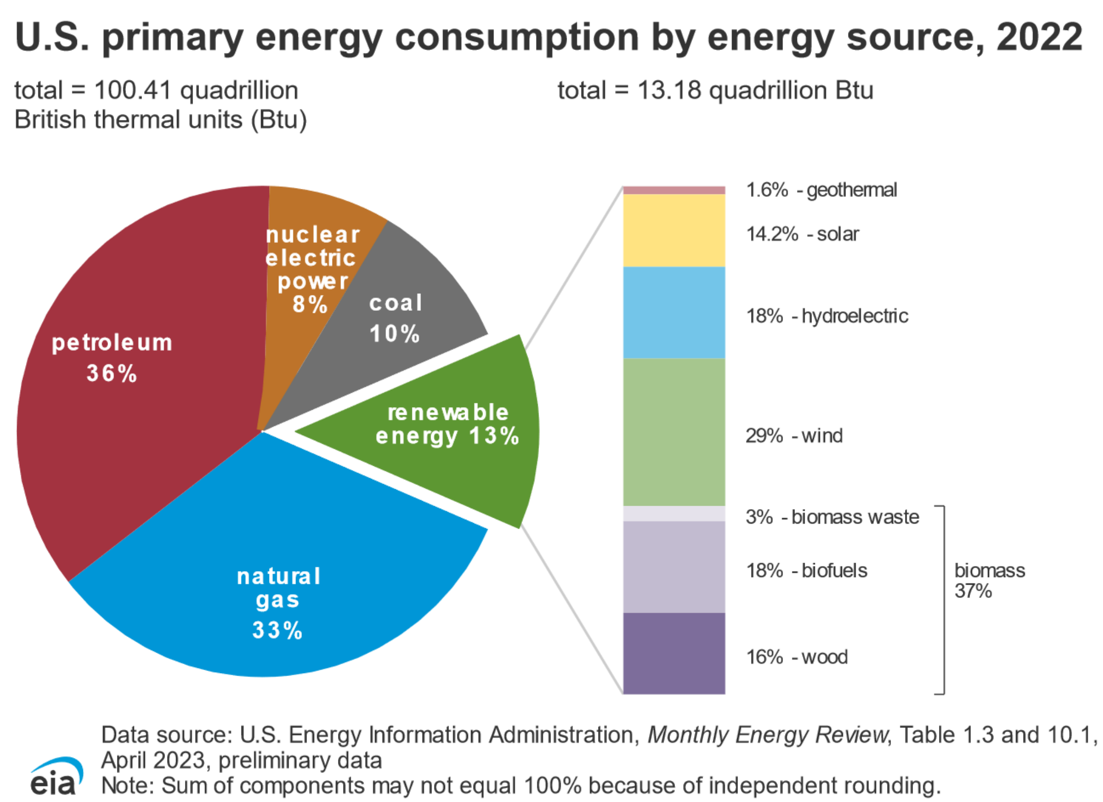

Figure 11.2. U.S. primary energy consumption by energy source, 2022. From: U.S. Energy Information Administration. (April 2023). Monthly Energy Review. Table 1.3 and 10.1.

- U.S. Energy Information Administration. (August 16, 2023). U.S. energy facts explained. https://www.eia.gov/energyexplained/us-energy-facts/
- U.S. Energy Information Agency. (August 28, 2023). Monthly energy review. Available from: https://www.eia.gov/totalenergy/data/monthly/

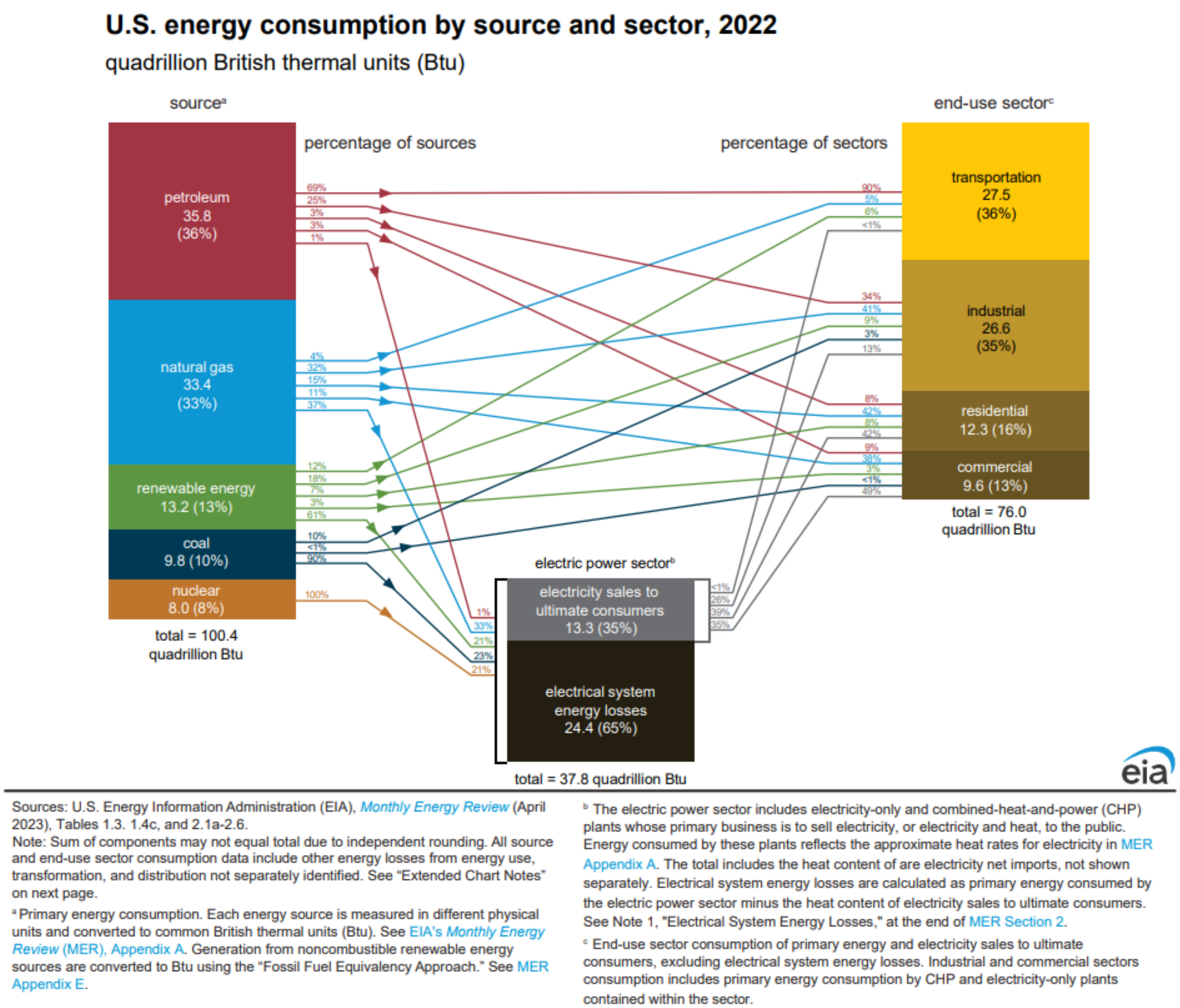

Figure 11.3. U.S. energy consumption by source and sector, 2022. From: U.S. Energy Information Administration. (April 2023). Monthly Energy Review. Tables 1.3, 1.4c, and 2.1a-2.6.

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11.3. Key Drivers and Targets

Drivers: 1) reduction of GHG emissions, 2) increase biofuel production

- Energy Policy Act (EPAct) (2005) established requirement for Renewable Fuel Standard
  - U.S. Environmental Protection Agency. (January 18, 2023). Summary of energy policy act. https://www.epa.gov/laws-regulations/summary-energy-policy-act
  - Public Law 109-58 – Energy Policy Act of 2005. (2005). PL 109-58 – 109th Congress (2005-2007): Energy Policy Act of 2005. Available from: https://www.govinfo.gov/app/details/PLAW-109publ58

Drivers: 1) Increased energy independence and security, 2) increased production of renewable fuels

- Energy Independence and Security Act (EISA) (2007) expanded Renewable Fuel Standard
  - U.S. Environmental Protection Agency (April 25, 2023). Summary of the energy independence and security act. https://www.epa.gov/laws-regulations/summary-energy-independence-and-security-act
  - Public Law 110-140 – Energy Independence and Security Act of 2007. (2007). PL 110-140 – 110th Congress (2007-2009): Energy Independence and Security Act of 2007. Available from: (http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf

Targets: Volumetric targets for biofuels production

To fulfill the goals of the EPAct (2005) and EISA (2007), the Renewable Fuel Standard (RFS) program has set volumetric requirements for biofuels, which were updated in 2022 for 2023, 2024, 2025. Targets include cellulosic biofuel, biomass-based diesel, advanced biofuels and renewable fuels.

Driver: decarbonization of aviation fuel

Targets: 1) achieving a minimum 50% reduction in lifecycle GHG emissions of SAF compared to conventional aviation fuel, 2) supplying SAF to meet 100% of aviation fuel demand by 2050:

Sustainable Aviation Fuel Grand Challenge (2021)

- U.S. Department of Energy, U.S. Department of Transportation, U.S. Department of Agriculture, U.S. Environmental Proetection Agency. (2021). Sustainable Aviation Fuel Grand Challenge Roadmap. Available from: https://www.energy.gov/eere/bioenergy/articles/sustainable-aviation-fuel-grand-challenge-roadmap-flight-plan-sustainable

Drivers: 1) Address climate change, 2) create jobs, 3) just transition to sustainable economy, 4) protect public health, 5) progress on environmental justice

Target: Net-zero emissions by 2050 for federal operations (2021):

1) net-zero carbon emissions for electricity by 2030 on net annual basis and 50% 24/7

2) 100% net-zero emission vehicle acquisition by 2025 including 100% zero-emission light-duty vehicle acquisition by 2027.

3) net-zero emissions building portfolio by 2045, including 50% reduction in emissions by 2032

4) 65% reduction in scope 1 and 2 GHG emissions (defined by Federal Greenhouse Gas Accounting and Reporting Guidance, from federal operations by 2030 from 2008 levels)

5) net-zero emissions from federal procurement

- Federal Register. (December 13, 2021). Executive Order 14057, Catalyzing clean energy industries and jobs through sustainability. 86 FR 70935. https://www.federalregister.gov/documents/2021/12/13/2021-27114/catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability

11.4. U.S. Biofuels Policies

Recent advancements in policies within the U.S., primarily at the federal level, provide strengthened support for the increased production and consumption of biofuels by providing demand- and supply-side pressures and encouragement. These include commitments for increased biofuel production and utilization, as well as support inclusive of or focused on SAF. A combination of incentives and multiple funding programs to provide support, including for innovative research and the infrastructure for pilot plants, production, storage, and the overall supply chain. This report provides an overview of recent advancements in U.S. biofuel policies, including SAF, at the federal and state levels. A number of these policies provide support SAF, demonstrating the increased recognition of the value in expanding decarbonization efforts beyond land-based transportation.

A historical overview of key federal biofuels legislation (from oldest to most recent) includes:

- Clean Air Act, 1970: Authorized development of federal and state regulations to control emissions sources, and established the National Ambient Air Quality Standards, and defined the EPA's role in protecting air quality.
- Energy Policy and Conservation Act, 1975: Established Corporate Average Fuel Economy (CAFE) standards for road vehicles.
- Alternative Motor Fuels Act, 1988: Established CAFE incentives for vehicle manufacturers
- Clean Air Act Amendments, 1990: Increased the EPA's authority and established initiatives for mobile source pollutants
- Energy Policy Act, 1992: Addressed energy supply and demand to increase energy independence, encouraging alternative fuel use through mandatory and voluntary actions
- Energy Policy Act, 2005: Established Renewable Fuel Standard (RFS)
- Energy Independence and Security Act, 2007: Expanded RFS
- American Recovery and Reinvestment Act, 2009: Provided funding for renewable energy technologies
- Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act, 2010: Extended and established alternative fuel tax credits
- American Taxpayer Relief Act, 2012: extended and reinstated alternative fuel incentives
- Tax Increase Prevention Act, 2014: Reinstated alternative fuel tax incentives
- Consolidated Appropriations Act (2016, 2020, 2021): extended and reinstated alternative fuel tax incentives.
- Bipartisan Infrastructure Law, 2021: Authorization and appropriation of funding, including for alternative fuel and advanced vehicle technologies.
- Inflation Reduction Act, 2022: Extended multiple alternative fuel tax incentives through 2024 and 2025, created a SAF tax credit (2023-2024), and created a Clean Fuel Production Credit for biofuels, including SAF.

Source: U.S. Department of Energy. (n.d.). Key federal legislation.
https://afdc.energy.gov/laws/key_legislation#conap2016

11.4.1. U.S. Federal Renewable Fuel Standard

The Renewable Fuel Standard (RFS), which sets volumetric requirements for biofuels, was first established in 2005 by the Energy Policy Act (RFS1). It was later expanded by the Energy Independence and Security Act in 2007 (RFS2) to increase the proportion of biofuels in fuels nationwide (U.S. Environmental Protection Agency, 2023a). The RFS program uses Renewable Identification Numbers (RINs) as credits which are generated by producers, bought and sold, and ultimately used to track compliance with fuel requirements (U.S. Environmental Protection Agency, 2023b).

In 2023, RFS for 2023, 2024, and 2025 were finalized for cellulosic biofuel, biomass-based diesel, advanced biofuel and renewable fuel (Table 11.2 and Table 11.3), continuing with a multi-year approach to reduce market uncertainties (U.S. Environmental Protection Agency, 2023c; U.S. Environmental Protection Agency, 2023d). Furthermore, the proposed RFS aims to expand the scope of relevant fuel pathways by addressing the use of renewable electricity from biomass using RINs. This may also enable increased growth in cellulosic biofuel.

The RFS includes renewable fuels and electricity derived from renewable biomass sources for transportation, heating oil, or jet applications (U.S. Environmental Protection Agency, 2023e). The RFS also established requirements for minimum lifecycle GHG emission reductions, and approved pathways and feedstocks for each eligible category (U.S. Environmental Protection Agency, 2023d; U.S. Environmental Agency,2023e; U.S. Environmental Protection Agency, 2023f). SAF is eligible for the generation of RIN credits as biomass-based diesel (D4), advanced biofuel (D5), or cellulosic biofuel (D3, D7) (U.S. Environmental Protection Agency, 2023e).

By setting volumetric requirements for renewable fuels, the RFS has been a primary factor in supporting the market for biofuels (U.S. Environmental Protection Agency, 2023g). However, additional factors have contributed to shaping the biofuels market, including state policies such as California's Low Carbon Fuel Standard (LCFS) which has served as a model for a limited number of additional states, prices for traditional fuels, infrastructure capacity and feedstock prices. RIN pricing for cellulosic biofuel has been more variable, with biomass-based diesel, advanced biofuels, and renewable fuels showing overall increases (U.S. Environmental Protection Agency, n.d.e). Increased prices for soybean oil and corn have contributed to increases in corn ethanol and biodiesel (U.S. Energy Information Agency, 2021).

Table 11.2. RFS volumetric requirements for biofuels for 2023, 2024 and 2025 as billion RINs (U.S. Environmental Protection Agency, 2023c; U.S. Environmental Protection Agency, 2023e).

Renewable fuel	Cellulosic biofuel	Biomass-based diesel	Advanced biofuel	Renewable fuel
D-code	3 or 7	4	5	6
Lifecycle GHG emission reduction (minimum)	60%	50%	50%	20%
2023	0.84	2.82	5.94	20.94
2024	1.09	3.04	6.54	21.54
2025	1.38	3.35	7.33	22.33

Table 11.3. RFS fuel types, feedstocks, and pathways, adapted from (U.S. Protection Agency, 2023f).

Category	D-code	Fuel types	Feedstocks	Pathways
Cellulosic biofuel	3	Ethanol	Agricultural or forestry residue, switchgrass, miscanthus, energy cane, *A. Donax*, *P. Purpreum*, yard waste, biogenic materials of municipal waste, cellulosic food waste, cellulosic annual covercrops material	Any
		Renewable gasoline and blendstock, co-processed celluolosic diesel, jet fuel, heating oil	Crop and forestry residue, yard waste, bio materials of municipal waste, cellulosic food waste, cellulosic annual cover crops material	Any process using biogas or biomass as the only energy source for processing
		Naptha	Switchgrass, miscanthus, energy cane, *A. Donax*, *P. Purpureum*	Gasification and upgrading
		Renewable compressed natural gas, renewable LNG, renewable electricity	Biogas from landfills; municipal wastewater, municipal waste, and/or agricultural digestors; cellulosic material from waste digesters	Any
	7	Cellulosic diesel, jet fuel, heating oil	crop and forestry residue, yard waste, municipal waste biogenic material, cellulosic food waste, cellulosic annual cover crop material	Any
Biomass-based diesel	4	Biodiesel, renewable diesel, jet fuel, heating oil	Oils from soybeans, annual covercrops, algae, waste bio-oils and fats, distillers corn and sorghum oils	Transesterification (with or without esterification pretreatment) or hydrotreating, excluding co-processing renewable biomass and petroleum
			Oil from canola, rapeseed	Transesterification using biomass or natural gas for process energy, or hydrotreating, excluding co-processing renewable biomass and petroleum
Advanced biofuel	5	Biodiesel, jet fuel, heating oil	Oils from soybeans, annual covercrops, algae, canola, rapeseed, waste bio-oils and fats, distillers corn and sorghum oils	Transesterification (with or without esterification pretreatment) or hydrotreating, excluding co-processing renewable biomass and petroleum
		Ethanol	Grain sorghum	Dry mill processing, using biogas from landfills, waste treatment, waste digesters for process and on-site production of electricity
			Sugarcane	Fermentation
		Ethanol, renewable diesel, jet fuel, heating oil, naptha	Non-cellulosic annual cover crops or food waste material	Any
		Renewable compressed natural gas, renewable LNG, renewable electricity	Biogas from waste digesters	Any
		LPG, naptha	Canola, rapeseed, distillers corn and sorghum oils	hydrotreatment

Category	D-code	Fuel types	Feedstocks	Pathways
Renewable fuel	6	Ethanol	Corn starch	Dry mill process using natural gas, biomass, or biogas for process energy, and: • Minimum two advanced technologies, or • Drying maximum 50% or 65% of distillers grains with solubles
				Wet mill process using biogas or biomass for process energy
			Starch from crop residue and annual overcrops	
			Grain Sorghum	Dry mill process using biogas from waste treatment plants or waste digesters, or natural gas for process energy
		Butanol	Corn starch	Fermentation, or dry mill processing using natural gas, biogas, biomass for process energy

11.4.2. Sustainability requirements

The Federal RFS evaluates and sets requirements for lifecycle GHG emissions reductions for qualifying fuels. The RFS are determined using an EPA 2010 LCA framework, which combines three models including the GREET[8] Model developed by Argonne National Laboratory (ANL), the Forest and Agricultural Sector Optimization Model with Greenhouse Gases model (FASOM), and the Food and Agricultural Policy Research Institute international model developed by the Center for Agriculture and Rural Development at Iowa State University (FAPRI-CARD model or FAPRI). This approach considers land use changes (U.S. Energy Information Agency, June 2023a).

The Federal RFS evaluation of and requirements for lifecycle GHG emission reductions considers land use change (U.S. Environmental Protection Agency, 2023d).

- U.S. Environmental Protection Agency. (July 12, 2023). Final rule: Renewable fuel standard (RFS) program: Standards for 2023-2025. https://www.govinfo.gov/content/pkg/FR-2023-07-12/pdf/2023-13462.pdf

The U.S. Environmental Protection Agency is required to analyze environmental factors in setting volumetric targets, including air quality, water quality, and soil quality. The agency is also required to assess environmental justice impacts of its policies, as "high and adverse human health or environmental effects".

- U.S. Environmental Protection Agency. (June 2023b). Regulatory Impact Analysis. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1017OW2.pdf

The Federal RFS uses renewable identification numbers (RINs) as traded credits for compliance.

- U.S. Environmental Protection Agency. (February 10, 2023a). Overview for renewable fuel standard. https://www.epa.gov/renewable-fuel-standard-program/overview-renewable-fuel-standard
- U.S. Environmental Protection Agency. (February 10, 2023b). Renewable Identification Numbers (RINs) under the Renewable Fuel Standard Program. https://www.epa.gov/renewable-fuel-standard-program/renewable-identification-numbers-rins-under-renewable-fuel-standard

The California LCFS is based on credits derived by the lifecycle GHG emission reductions of fuels. The program also provides tools for a standard lifecycle emissions analysis. These include tools for direct

[8] Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies Model

impacts: the California GREET and Oil Production Greenhouse Analysis Project (OPGEE) models; and tools for indirect impacts: the Global Trade Analysis Project (GTAP) and Agro-Ecological Zone Emissions Factor (AEZ-EF). This "set of tools" ensures the impacts of fuel production and consumption, transportation, and land-uses are included. The use of standards based on lifecycle GHG emission reductions makes California a front-runner. This has been achieved through the adoption of non-volumetric measures, which have since been mirrored by the lifecycle GHG emission reductions requirements for SAF in the 2022 IRA, as well as other state policies.

11.4.3. Financial incentives to support the transportation biofuels

Below is a summary of some of the financial incentives used to support transportation biofuels:

1. Inflation Reduction Act tax credits (HR 5376 Inflation Reduction Act, 2022):

- HR5376 Inflation Reduction Act. (2022). HR5376 – 117th Congress (2021-2022): Inflation Reduction Act of 2022.
    - Available from: https://www.congress.gov/bill/117th-congress/house-bill/5376/text

2. Sustainable Aviation Fuel Grand Challenge (2021) :Goal of supplying SAF to meet 100% of aviation fuel demand by 2050.
    - U.S. Department of Energy, U.S. Department of Transportation, U.S. Department of Agriculture, U.S. Environmental Proetection Agency. (2021). Sustainable Aviation Fuel Grand Challenge Roadmap. Available from: https://www.energy.gov/eere/bioenergy/articles/sustainable-aviation-fuel-grand-challenge-roadmap-flight-plan-sustainable

3. States with Low Carbon Fuel Standards or Clean Fuel Standards:

- California: Low Carbon Fuel Standard (LCFS), 20% reduction in CI of transportation fuels by 2030. SAF is eligible for credits.
    - California Air Resources Board. (n.d.). Low Carbon Fuel Standard. Available from: https://ww2.arb.ca.gov/resources/documents/lcfs-basics

- Oregon: Clean Fuels Program, 20% reduction in CI of transportation fuels by 2030, 37% by 2035, compared to 2015 levels. SAF is eligible for credits.
    - Department of Environmental Quality. (n.d.). Clean Fuels Program Overview. https://www.oregon.gov/deq/ghgp/cfp/pages/cfp-overview.asps
    - Department of Environmental Quality. (2022). Clean Fuels Program Expansion. https://www.oregon.gov/deq/rulemaking/Pages/cfp2022.aspx

- Washington: Clean Fuel Standard, 20% reduction in CI of transportation fuels from 2017 levels by 2034. Beginning in 2023, Washington state provides a credit for SAF, through State Senate Bill 5447.
    - Department of Ecology. (n.d.) Clean Fuel Standard. https://ecology.wa.gov/Air-Climate/Reducing-Greenhouse-Gas-Emissions/Clean-Fuel-Standard
    - Washington State Legislature. (2023). SB 5447 – 2023-24, Promoting the alternative jet fuel industry in Washington. https://app.leg.wa.gov/billsummary?BillNumber=5447&Year=2023&Initiative=False

4. Recent updates in federal planning and funding:

- HR5376 Inflation Reduction Act. (2022). HR5376 – 117th Congress (2021-2022): Inflation Reduction Act of 2022. Available from: https://www.congress.gov/bill/117th-congress/house-bill/5376/text
    - U.S. Department of Energy, U.S. Department of Transportation, U.S. Department of Agriculture, U.S. Environmental Proetection Agency. (2021). Sustainable Aviation Fuel Grand Challenge Roadmap. Available from: https://www.energy.gov/eere/bioenergy/articles/sustainable-aviation-fuel-grand-challenge-roadmap-flight-plan-sustainable

11.4.4. U.S. Federal Biofuel Incentives – Inflation Reduction Act of 2022 (IRA)

The Inflation Reduction Act of 2022 has extended existing tax credits for renewable fuels and established new tax credits for renewable fuels (which include SAF-specific credits (HR5376 Inflation Reduction Act, 2022)), and which are structured to act as overlapping or staggered incentives (Figure 11.4).

The 2022 IRA extends tax credits, which was previously scheduled to expire at the end of 2022, was extended via the Extension of Incentives for Biodiesel, Renewable Diesel, and Alternative Fuels through to 2024 (Sec. 13201), (extending incentives for a range of biofuels).

- The Biodiesel and Renewable Diesel Credit provides a credit of $1.00 per gallon.
- The Biodiesel Mixture Credit offers $1.00 per gallon for the production, sale, and use of pure biodiesel, agri-biodiesel, and renewable diesel blended with petroleum-based diesel, and is eligible for SAF. (So not just limited to road vehicle applications).
- An Alternative Fuel Credit, at $0.50 per gallon (for natural gas, liquified hydrogen, propane, P-series fuels, liquid fuel from coal, and compressed or liquified gas from biomass), which are for sale or use in motor vehicles.
- An Alternative Fuel Mixture Credit, at $0.50 per gallon of alternative fuel used in mixtures of at least 0.1% gasoline, diesel, or kerosene (However, not applicable if ethanol/biodiesel tax credit applied).

Additionally, the Extension of Second Generation Biofuel Incentives through 2025 (Sec. 13202) provides for $1.01 per gallon of second generation biofuel produced, sold, or used, and is derived from lignocellulosic renewable materials, cyanobacterial or algal cultivation.

The 2022 IRA introduced two new credits, the Sustainable Aviation Fuel Credit as a SAF-specific credit in effect 2023 and 2024, and the Clean Fuel Production Credit for renewable fuels including SAF in effect 2025 through 2027.

- The Sustainable Aviation Fuel Credit directly incentivizes SAF by providing a $1.25 per gal credit for the sale or consumption of a qualifying SAF mixture, requiring a minimum of 50% of lifecycle greenhouse gas (GHG) emission reduction compared to traditional petroleum jet fuel. A supplemental credit of $0.01 per gal for each additional percentage point of emission reduction. Qualifying SAF mixtures are required to meet a minimum of a 50% reduction in lifecycle GHG emissions compared to conventional jet fuel, and are further required to meet the requirements of ASTM International Standards D7566 or the Fischer Tropsch provisions of D1655, and to exclude palm fatty acid materials.
- The Clean Fuel Production Credit (CFPC) establishes incentives for biofuels, determined by a base or alternative credit multiplied by an emissions factor based on lifecycle GHG emissions. For non-SAF biofuels, the base credit is $0.20 per gallon, or $1.00 per gallon if produced by a qualifying facility. The CFPC also provides a SAF-specific credit with a higher base of $0.35 or alternative credit of $1.75 per gallon, based on the requirements for qualifying facilities, also multiplied by an emissions factor.

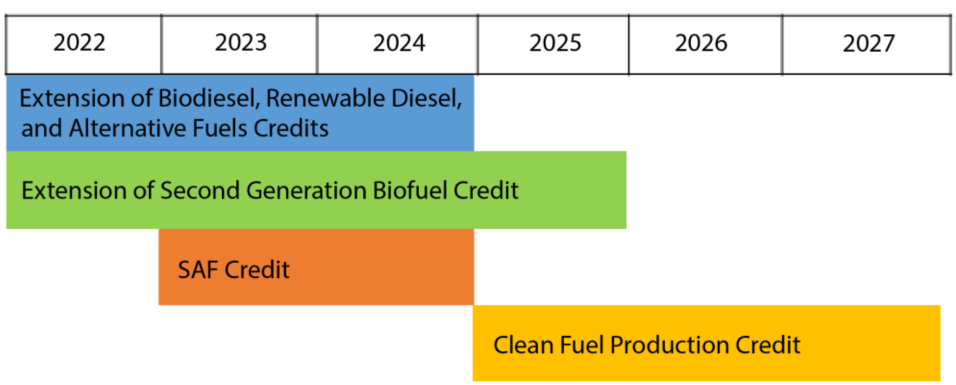

Figure 11.4. Timeline of incentives in Inflation Reduction Act of 2022 (HR5376 Inflation Reduction Act, 2022).

Table 11.4. Tax credits provided by the 2022 IRA (HR5376 Inflation Reduction Act, 2022).

IRA Credit	Details
Sec. 13201, Extension of Incentives for Biodiesel, Renewable Diesel, and Alternative Fuels, to Dec. 31, 2024	Biodiesel and Renewable Diesel Credit, $1.00 per gal., for motor vehicle, not in a mixture
	Biodiesel Mixture Credit: $1.00 per gal of pure biodiesel, agri-biodiesel, renewable diesel blended with petroleum diesel resulting in minimum 0.1% diesel fuel mixture
	Alternative Fuel Credit: – $0.50 credit per gal, for sale or use for motor vehicle – Natural gas, liquified H2, propane, P-Series fuel, liquid fuel from coal (Fischer-Tropsch), compressed or liquified gas derived from biomass
	Alternative Fuel Mixture Credit: – $0.50 per gal of alternative fuel used in mixtures of at least 0.1% gasoline, diesel, or kerosene (not allowed if ethanol/biodiesel tax credit applied)
	Payments for alternative fuels
Sec. 13202, Extension of Second-Generation Biofuel Incentives, to Dec. 31, 2025	$1.01 per gal credit for production of qualified feedstocks: – includes lignocellulose, hemicellulose, cyanobacterial and algal biomass
Sec. 13203, 40B, SAF Credit (Jan. 1, 2023 – Dec 31, 2024)	$1.25 per gal for sale or use of qualifying SAF mixture, minimum of 50% lifecycle GHG emission reduction – Supplemental credit of $0.01 per gal for each additional percentage in lifecycle GHG emission reduction (up to $0.50)
Sec. 13704, 45Z, Clean Fuel Production Credit (Jan 1, 2025 – Dec. 31, 2027)	45Z, Production credit determined by a base or alternative credit per gal of qualifying biofuels, multiplied by an emissions factor based on lifecycle GHG emissions – Base credit $0.20 – Alternative credit: $1.00 (for qualifying facilities)
	– SAF production base credit: $0.35 (for qualifying facilities) – SAF alternative credit: $1.75 (for qualifying facilities)

11.4.5. State Biofuel Standards and SAF-Specific Incentives

A growing number of states have clean fuel standards, which are supportive of biofuels broadly, and which are increasingly supportive of SAF through voluntary inclusion in standards or direct SAF-specific incentives (Table 11.5). California leads state-level biofuel policies with a Low-Carbon Fuel Standard (LCFS). This has served as a model for other states. The California LCFS, first adopted in 2009 and most recently updated in 2018, established a target of reducing the CI of transportation fuels by a minimum of 20% by 2030 (Table 11.5) (California Air Resources Board, n.d.).The amendments in 2018 aligned the LCFS carbon intensity benchmarks through 2030 with the state-level target for GHG emissions through 2030 (SB32). The LCFS is designed to be one of a suite of state policies aligned with California's Global Warming Solutions Act of 2006 (AB 32) and complement other policies targeting improving air quality and energy independence.

The California LCFS is based on credits dependent on the lifecycle GHG emission reductions of fuels, and the program also provides tools for a standard lifecycle emissions analysis. These include tools for direct impacts: the California GREET and Oil Production Greenhouse Analysis Project (OPGEE) models; and tools for indirect impacts: the Global Trade Analysis Project (GTAP) and Agro-Ecological Zone Emissions Factor (AEZ-EF). This standard set of tools ensures the impacts of fuel production and consumption, transportation, and land-uses are included. The use of standards based on lifecycle GHG emission reductions makes California a front-runner in the U.S. in the adoption of non-volumetric measures, which have since been mirrored by the lifecycle GHG emission reductions requirements for SAF in the 2022 IRA, as well as other state policies.

Oregon adopted a similar Clean Fuels Program in 2016, with rules updated in 2022 to expand annual CI reduction targets to 20% below 2015 levels by 2030, and 37% by 2035, in addition to updated enforcement measures (Department of Environmental Quality, n.d.; Department of Environmental Quality, 2022). The program requires the participation of importers of gasoline, diesel, ethanol, biodiesel, and renewable diesel, while voluntary participation includes alternative jet fuel (SAF) producers or importers (Department of Environmental Quality, n.d.).

Washington state adopted a Clean Fuel Standard which went into effect January 2023, targeting a 20% reduction in the CI of transportation fuels, from 2017 levels, by 2038 ((Department of Ecology, n.d). The state further passed a SAF-specific credit of $1.00 per gallon SAF with a 50% reduction in GHG emissions, with an additional $0.02 per gallon for each additional percentage point in GHG emission reduction to a max of $2.00, dependent on a minimum of one facility in the state providing a capacity of 20M gallons of SAF per year (Washington State Legislature, 2023). This credit is applicable to the sale and purchase of SAF for use on flights departing Washington, and is only eligible for local businesses in a county with a population less than 650,000 or for designative SAF blender facilities in the state. This reflects a commitment to develop and support SAF production with the state.

The collection of state-level biofuel policies in the western U.S. demonstrates the value of regional collaboratives such as the Pacific Coast Collaborative (Pacific Coast Collaborative, n.d.) in facilitating biofuel policy adoption across different governments. Additionally, a SAF-specific incentive is provided by the state of Illinois for SAF sold to or used by air carriers for use in Illinois, at $1.50 per whole gallon of SAF (Illinois Department of Revenue, 2023). Both Illinois and Minnesota have proposed clean fuel standards aimed to reduce the CI of transportation fuels (Illinois General Assembly, 2023; Minnesota Department of Transportation, 2023). New York state proposed fuel standards in 2023, similarly based on the reduction of the CI of transportation fuels, and with the eligibility of SAF to generate credits (New York State Senate, 2023).

Table 11.5. State clean fuel standards and SAF incentives.

State-level renewable fuel standards and SAF incentives	
Adopted	
California	Low-Carbon Fuel Standard (LCFS) (adopted 2009, most recent amendment 2018): • 20% reduction in CI by 2030 • SAF eligible for credits (production, importation)
Illinois	SAF Credit (adopted 2023): • Credit of $1.50 per gallon SAF purchased for use in state
Oregon	Clean Fuels Program (2016, 2021): • 20% reduction in CI of transportation fuels from 2015 levels by 2030, 37% by 2035 • SAF eligible for credits
Washington	Clean Fuel Standard (2019): • 20% reduction in CI of transportation fuels from 2017 levels by 2034 SAF credit (2023): • Credit of $1.00 per gallon of SAF for minimum of 50% reduction in GHG emission reduction, with additional credit of $0.02 per additional percentage of GHG emission reduction.
Proposed	
Illinois	Clean Transport Standard (2023): • 20% reduction of CI from on-road transportation by 2038
Minnesota	Clean Transportation Fuel Standard (2023): • Reduction in CI of transportation fuel supplied to state: 25% below 2018 level by end of 2030, 75% by end of 2040, 100% by end of 2050
New York	Clean Fuel Standards (2023): • Reduction of CI of road transportation fuels by 2031 SAF eligible for credits

11.4.6. Federal Planning and Support for Infrastructure and Innovation - Planning, Grants, Loans

Recent federal policies provide funding for the fundamental innovation in fuel pathways and technologies and infrastructure for the production, storage, and delivery of biofuels which are necessary to realize the commitments for biofuel use (Table 11.6, Figure 11.5). First, the SAF Grand Challenge established a multi-agency agreement and plan to support all aspects of aviation biofuel development, production, and utilization, to help realize a federal target of 100% SAF use by 2050 (U.S. Department of Energy, U.S. Department of Transportation, U.S. Department of Agriculture, U.S. Environmental Protection Agency, 2021). Areas of focus included research support to enable the development of innovative feedstock and fuel pathways. Support is further designed to improve infrastructure for fuel production, storage and delivery through federal loans and loan guarantees. Additional efforts address regulatory practices for efficient fuel testing and approval. The study regional feedstocks are designed support regional supply chains that benefit rural communities and minimize distances from production points to airports. The collective effort across several federal agencies targeting the complete SAF supply chain demonstrate a commitment to accelerating the domestic supply and consumption of SAF.

The 2022 IRA provides $812M in funding supportive of biofuels broadly and SAF directly, in part aiming to realize the SAF Grand Challenge strategy. The Biofuel Infrastructure and Agriculture Product Market Expansion (**Sec 22003**) which provides $500M in grants for biofuel infrastructure through 2031. These grants allow for a maximum of 75% of costs for projects focused on improving infrastructure for blending, storing, supplying, or distributing agricultural biomass-based biofuels.

The 2022 Act also allocated to the EPA (**Sec. 60108**) $5M for testing and protocol development, including analyses of the lifecycle GHG emissions of biofuels, and $10M to support investments in advanced biofuels. Further, the policy also provides an Alternative Fuel and Low-Emission Aviation Technology Program (**Sec. 40007**) for projects providing SAF production, blending, storage, or transport ($244M), and low-emission aviation technology projects ($46.5M). Policies and programs in some states provide funding through programs supporting biofuel use directly or more broadly among a range of alternative fuel vehicles. These include grants for the purchase of alternative fuel fleet vehicles (Alternative Fuel Vehicle Grants, Maryland) (U.S. Department of Energy, n.d.a) and grants to support advanced transportation technology industries including biofuels (Advanced Industries Accelerator Program Grants, Colorado) (U.S. Department of Energy, n.d.b). These forms of state-level policies augment federal mechanisms supporting elements of the chain from biofuel development to consumption.

Table 11.6. Federal planning, grant, and loan instruments to support biofuel innovation and infrastructure, through the SAF Grand Challenge (U.S. Department of Energy, U.S. Department of Transportation, U.S. Department of Agriculture, U.S. Environmental Protection Agency, 2021) and 2022 IRA (H.R. 5376 Inflation Reduction Act, 2022).

Policy	Date adopted or updated	Planning and funding instruments
SAF Grand Challenge	**2021**	Multi-agency agreement to provide planning and support across multiple dimensions of SAF development, production, storage, delivery, consumption: • Feedstock innovation • Conversion technology innovation • Building supply chains • Policy and valuation analysis • Enabling end use • Communicating progress and support Target: 3B gallons per year of domestically-produced SAF, 100% SAF use by 2050 (SAF fuels with a minimum 50% reduction in lifecycle GHG emissions)

Policy	Date adopted or updated	Planning and funding instruments
IRA	**2022**	Sec. 22003, Biofuel Infrastructure and Agriculture Product Market Expansion: • $500M in grants through 2031 for biofuel infrastructure • Up to 75% project costs Sec. 40007, Alternative Fuel and Low-Emission Aviation Technology Program: • $244.5M in grants for SAF production, blending, storage, transport projects • $46.5M in grants for low-emission technology projects • Further development of methodology for lifecycle GHG emission reduction determination • Up to 75% project costs, or 90% for small hub/non-hub airport Sec. 60108, Funding for Section 211(O) of the Clean Air Act, EPA: • $5M, testing and protocol development, including lifecycle GHG emission analyses • $10M, investments in advanced biofuels

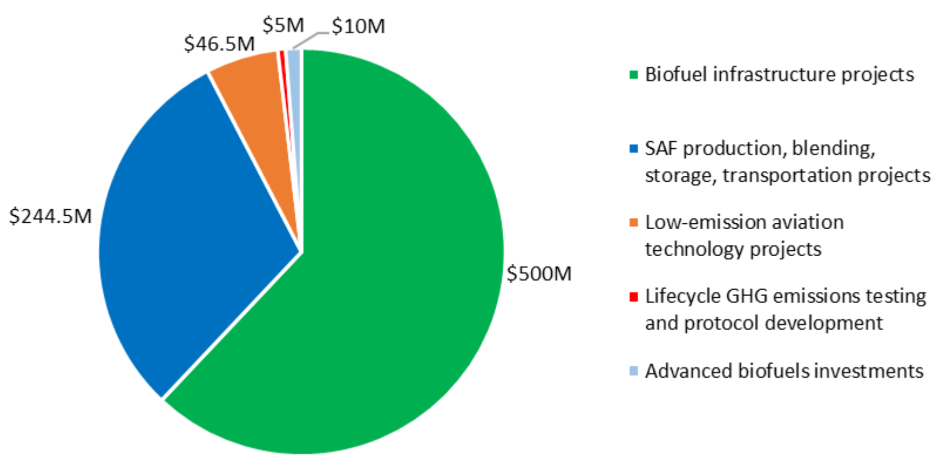

Figure 11.5. Federal funding provisions in the 2022 IRA supportive of biofuels (HR5376 Inflation Reduction Act, 2022).

11.4.7. Offtake Agreements for Advanced Biofuels

Offtake agreements aligning fuel producers and purchasers stabilize the markets for biofuels, including SAF, and encourage investments throughout biofuel and SAF-specific supply chains. Contributing to the total of 94 offtake agreements for SAF globally, U.S.-based producers account for the top three SAF producers, and U.S.-based airlines and a U.S.-based international airline alliance account for the top three SAF purchasers (Table 11.7) (International Civil Aviation Organization, 2023). Recognizing the international nature of aviation, a number of regional collaboratives across industry and governments work towards aligning SAF certification and sustainability, and to improve market certainty, including the Commercial Aviation Alternative Fuels Initiative in which U.S. government agencies and industries participate (Commerical Aviation Alternative Fuels Initiative, n.d.).

Table 11.7. Leading U.S.-based SAF producers and purchasers by offtake volume and number of agreements, May 2023 (International Civil Aviation Organization, 2023).

	Total offtake volume (BG)	Number of offtake agreements
U.S.-based SAF Producers		
Gevo (CO)	9.6	14
Fulcrum (CA)	6.7	3
Alder (SC)	5.7	1
U.S.-based SAF Purchasers		
United Airlines	10.5	6
Delta	3.9	8
OneWorld	3.8	1

11.5. Biofuel market development and policy effectiveness

Table 11.8. Transport biofuels production capacity/actual production (ML/yr)

Year	Bioethanol [1]	Cellulosic ethanol[2]	Biodiesel (FAME)[1]	Renewable diesel (feedstock and pathway not specified)[1]
2010	52.28		1.3	
2011	52.10		3.7	
2012	48.53		3.8	0.23
2013	53.38		5.1	0.20
2014	55.51	0.0028	4.8	0.43
2015	57.51	0.0083	4.8	0.60
2016	59.67	0.0144	5.9	0.67
2017	61.26	0.0217	6.0	0.91
2018	59.96	0.0248	7.0	0.98
2019	53.94	0.0210	6.5	1.16
2020	55.49	0.0078	6.9	1.86
2021	59.06	0.0022	6.5	2.02
2022		0.0053	6.1	3.26

1 U.S. Department of Agriculture. (June 7, 2023). U.S. Bioenergy Statistics. https://www.ers.usda.gov/data-products/u-s-bioenergy-statistics/
2 U.S. Environmental Protection Agency. (December 13, 2022). RINs generated transactions: Total net generation report. https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rins-generated-transactions
Note: Conversion of gallons to liters based on: U.S. Energy Information Administration. (June 23, 2023). Energy conversion calculators. https://www.eia.gov/energyexplained/units-and-calculators/energy-conversion-calculators.php

Table 11.9. Summary of transport fuel consumption (ML)

Year	Gasoline[1]	Aviation fuel (Estimated consumption of based on RFS RIN data, ML/yr)[2]	Bioethanol[3]	Biodiesel[3]	Renewable diesel (feedstock and pathway not specified)[3]
2010	451,784		49.18	0.98	
2011	438,417		49.04	3.35	
2012	435,815		49.01	3.40	0.28
2013	442,172		50.67	5.41	1.12
2014	445,698		52.56	5.36	1.11
2015	458,147		53.83	5.66	1.40
2016	465,792	7.19	54.63	7.89	1.65
2017	464,400	6.43	54.99	7.52	1.78
2018	464,642	6.81	54.59	7.21	1.66
2019	463,123	9.08	49.67	6.86	2.88
2020	401,392	17.41	51.09	7.10	3.11
2021	438,022	19.31	53.43	6.47	4.58
2022	435,705	59.81		6.03	6.44
2023	106,098				

1 U.S. Energy Information Administration. (July 31, 2023). U.S. product supplied of finished motor gasoline (Thousand barrels per day). https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MGFUPUS2&f=A
2 U.S. Department of Energy, Alternative Fuels Data Center. (n.d.) Maps and data – sustainable aviation fuel estimated consumption. https://afdc.energy.gov/data
3 U.S. Department of Agriculture. (June 7, 2023). U.S. Bioenergy Statistics. https://www.ers.usda.gov/data-products/u-s-bioenergy-statistics/
Note: Conversion of gallons to liters based on: U.S. Energy Information Administration. (June 23, 2023). Energy conversion calculators. https://www.eia.gov/energyexplained/units-and-calculators/energy-conversion-calculators.php

11.5.1. Biofuels facilities and main companies

Total number of ethanol production facilities in the U.S., as of January 1, 2023: 187, with a production capacity of 17,663 MMgal/year or 1,152 Mb/d.

- U.S. Energy Information Administration. (August 7, 2023). U.S. Ethanol Plant Production Capacity. https://www.eia.gov/petroleum/ethanolcapacity/index.php

Total number of biodiesel production facilities in the U.S., as of January 1, 2023: 59, with a production capacity of 2,068 MMgal/year or 136 Mb/d.

- U.S. Energy Information Administration. (August 7, 2023). U.S. biodiesel plant production capacity. https://www.eia.gov/biofuels/biodiesel/capacity/

Total number of renewable diesel fuel production plants (and other biofuels plants, excluding fuel ethanol and biodiesel), as of January 1, 2023: 17, with a production capacity of 3,000 MMgal/year or 196 Mb/d.

- U.S. Energy Information Administration. (August 7, 2023). U.S. renewable diesel fuel and other biofuels plant production capacity. https://www.eia.gov/biofuels/renewable/capacity/

11.5.2. Biofuels imports and exports

Table 11.10. Biofuels imports and exports in U.S.

Year	Bioethanol[1]		Transport Biofuel : Biodiesel[1]		Transport biofuel: Renewable Diesel[1]	
	Import (ML/yr)	Export (ML/yr)	Import (ML/yr)	Export (ML/yr)	Import (ML/yr)	Export (ML/yr)
2010	0.16	3.13	0.09	0.41		
2011	1.26	4.14	0.14	0.29		
2012	2.25	2.12	0.14	0.49	0.10	
2013	0.52	3.02	1.30	0.74	0.78	
2014	0.17	3.24	0.73	0.31	0.46	
2015	0.36	3.76	1.34	0.33	0.77	
2016	0.16	5.21	2.68	0.33	0.84	
2017	0.18	6.18	1.49	0.35	0.72	
2018	0.52	5.90	0.63	0.39	0.66	
2019	0.70	5.09	0.65	0.43	0.98	
2020	0.41	4.66	0.74	0.55	1.06	
2021	0.23	5.50	0.80	0.71	1.48	
2022			0.95	1.14	0.99	
2023						

1 U.S. Department of Agriculture. (June 7, 2023). U.S. Bioenergy Statistics. https://www.ers.usda.gov/data-products/u-s-bioenergy-statistics/
Note: Conversion of gallons to liters based on: U.S. Energy Information Administration. (June 23, 2023). Energy conversion calculators. https://www.eia.gov/energyexplained/units-and-calculators/energy-conversion-calculators.php

11.6. Future for Biofuels in the U.S.

Recent policy developments in the U.S. have provided significant advancements in support for biofuels. The updated RFS provides continued support for all categories of biofuels, while expanding support through the inclusion of renewable energy from biomass (U.S. Environmental Protection Agency, 2023a; U.S. Environmental Protection Agency, 2023b). The 2022 IRA extends existing and adopts new federal incentives through a phased approach. This includes SAF-specific credits and clean fuel production credits which take into consideration GHG lifecycle emissions values (HR5376 Inflation Reduction Act, 2022). The 2022 IRA provides substantial funding to develop feedstocks and pathway research which will be necessary to develop innovative fuels. These investments will also support the scaling up of new fuels and the overall production, storage, and transports of biofuels.

A growing number of state policies support biofuels through state-level fuel standards based on lifecycle GHG emission reductions. They also increasingly include SAF as eligible for tax credits. This growing number of state policies reflects the commitment to decarbonizing transportation fuels and the recognition of biofuels, and SAF, as an economic opportunity. Particularly driven by support of the 2022 IRA, domestic biofuel capacity and consumption is expected to increase over the next five years (International Energy Agency, 2022b).

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Conclusions

As described throughout the report, "enabling" policies have, and will continue to play a key role in the growth of biofuel markets. Although market "pull" and technology "push" type policies will continue to be important, several of the Task 39 countries have developed policies that highlight the carbon intensity (CI) of the fuel, including the nature of the feedstock used through to how the biofuel is used (e.g., "well-to-wheel" assessment). Many countries, particularly those involved with IEA Bioenergy Task 39, have committed to the carbon neutrality of their transport sector by 2050, with most countries also targeting short-term GHG reduction goal. For example, Brazil plans to reduce is GHG emissions by 50%, by 2030 (compared to 2005), Germany by 65%, by 2030 (compared to 1990 levels) and the EU by 55%, by 2030 (also compared to 1990 levels). However, to reach these GHG reduction targets and the increased use of renewables in transportation, market pull policies such as volumetric blending and CI reduction mandates will be needed. By using policies, such as those described in the RED programs, regions such as the EU will increase the share of renewables by 2030, giving the member states a choice in how each country will meet its transport related GHG reductions, (e.g., by either achieving a 14.5% reduction in GHG intensity via renewables or renewables representing 29% of the fuels that are used).

Technology push policies have included R,D&D funding and incentives to support biofuel production growth via different technologies and feedstocks. However, the suite of "enabling" policies that have been implemented in the US to help drive biofuels development has made it an attractive destination for investors and feedstock exporters. Federal policies such as the RFS, which sets annual biofuel blending targets, and regional ones such as the CA-LCFS, have been instrumental in creating a favorable market environment for biofuels. The US has also introduced investment and the production tax credits, which provide financial incentives for biofuel production and clean fuel technologies. While the US has played a prominent role in biofuel policy development and implementation, other countries and regions have also implemented effective biofuel policies. For example, the EU's RED and Fit-for-55 programs, Canada's CFR and various regional LCFS programs have all helped increase the amount of biofuels that are produced.

Although this report indicates that there is increasing attention paid to reducing the carbon intensity (CI) of biofuels used by the transportation sector, determining the CI of a fuel is not easy. Consequently, related IEA Bioenergy Task 39 work is focussed on enhancing the international use and acceptance of how the CI of a fuel is determined by the various life cycle analysis (LCA) models that are used. Previous work has shown that different LCA models (e.g., GREET, GHGenius, VSR, BioGrace, etc.) can result in varying results due to differences in assumptions, boundaries, default values and methodologies. This ongoing IEA Bioenergy Task 39 work has highlighted various complexities such as the feedstock that is used, land use changes (direct and indirect), source of electricity, etc.

As it is anticipated that there will be increased (green) electrification of the road transport sector, the hard to electrify transport sectors (e.g., aviation, marine, long-distance trucking) has been receiving increasing attention. These sectors will likely be dependant on using low-CI biofuels if they are to meet the carbon reduction targets set by organisations such as ICAO, IMO, etc.

As well as the technology-push policies that are being used to catalyse the production of low-CI fuels such as SAF, market-pull policies are also being used to ensure that fuels such as SAF will be rapidly adopted. The increased focus on the Carbon Intensity (CI) of biofuels and the international nature of transportation sectors such as marine, aviation, rail and trucking, all indicate why a global perspective, as carried out by IEA Bioenergy Task 39 and as described in this report, should be of value.

Appendix A- Questionnaire

Implementation agendas: 2021-2023 Update

(Compare and contrast transport Biofuels Policies)

Request for information for completion of Country sections

Country Name:

Names and affiliation of authors contributing to the report:

- Please provide links/references to websites and documents referred to in the relevant sections.
- Please add full reference citations at the end of the questionnaire.
- Please provide any appropriate figures, diagrams, maps and graphs as visual aids for specific section(s) rather than only text. All sections don't require figures; however, it will be really helpful if some figures can be provided for some sections to supplement the tables and text.
- Please use the consistent units (metric) for energy, volume and GHG emissions.

1. Introduction and main drivers for transport biofuels in this country

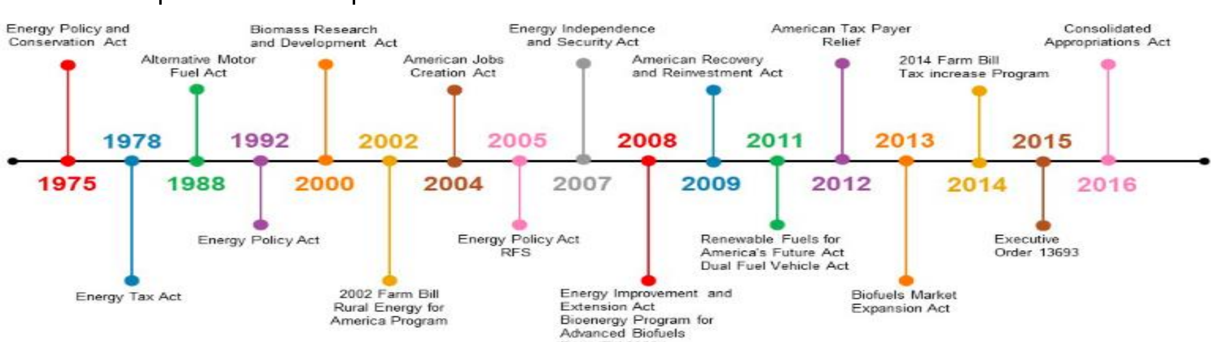
- Please provide a brief summary of your country's total primary energy supply (TPES) and the specific contribution the transport sector within the TPES.
- Please provide a brief summary of your country's historical GHG emissions inventory data and the contribution of the transport sector to national GHG emissions, preferably with the breakdown of different transport sectors (e.g., passenger/light duty vehicles, trucks/lorries, rail, marine and aviation).

1.1. Describe the main drivers for biofuels production and use in your country (e.g., energy security, climate change mitigation/GHG emissions reductions, rural development, job creation).

- Please provide specific targets (if any) for each driver, e.g., 30% GHG emissions reduction by 2030.

1.2. Briefly describe the historical development of biofuels policy in your country and If POSSIBLE, PLEASE include a timeline diagram.

Below is a template of biofuel policies timeline.



A template of timeline of biofuel policies

2. Transport Biofuels policies

2.1. List the main legislation that impacts biofuels production and/or use in your country.

e.g., Renewable Fuel Standard, Low Carbon Fuel Standard (LCFS), GHG Emissions Reduction Goals

2.2. Identify which of the following policies are used in your country to encourage the production and use of transport biofuels- Please include both the established policies and ones that are under-development.

Type of policy	Yes/No (Provide Details / Comments)
Indicate if your country has any market pull policies for transportation fuels such as: - Biofuels blending mandates (e.g., E5, B2) - Low Carbon Fuel Standard (LCFS) - Clean Fuel Standard or specific emission reduction targets - Carbon tax - Emissions Trading (cap-and-trade) Other?	
Indicate whether these market-pull policies target the entire transport sector or specific transport sectors (e.g., passenger/light duty, trucking, rail, marine and aviation).	
Indicate whether life cycle analysis (LCA) model is used in (to measure the carbon intensity of biofuels). Please provide some details on the model (e.g., name, system boundary, co-product allocation, land use change, etc.).	
Are there any sustainability requirements/criteria within your country's biofuel policies that are used to assess environmental performance (e.g., GHG emissions reduction, air pollution reduction, land use change, sustainable forest management etc.)? Are there any socio-economic sustainability requirements?	
Are there any approved sustainability certification and/or verification schemes for transport biofuels and their feedstocks? (To prove compliance under the policy frameworks)	
Indicate if your country has any technology-push policies for transportation fuels such as: Financial incentives:(e.g., subsidies, credits, incentives): - For the biofuels producer (producer credit based on volume of production) - For the biofuels blender (blender's credit based on volume blended) - For the biofuels consumer (e.g., reduced license fees, tax credits for purchasing flex-fuel or natural gas vehicles, etc.)	

Type of policy	Yes/No (Provide Details / Comments)
- Financial incentives for feedstock development (e.g., grants for new feedstock development or new supply chain development) - Tax credits - Eliminating excise tariffs / Putting tariffs on imported biofuels Financial assistance (e.g., loan guarantees, grants) - Research and Development - For construction of pilot, demo or pioneer biofuels production facilities - For development of distribution infrastructure, e.g., fuel stations for E85 - For improvement or upgrading of existing biofuels production to further reduce the CI of biofuels	
Are there specific technology push policies to promote the use of biofuels for long-distance transport sector (trucking, rail, aviation and marine)?	
Are there specific technology push and/or market pull policies that are used to promote the production and use of drop-in or advanced (e.g., cellulosic ethanol) fuels?	
How easy is it for new biofuels to enter the market and/or earn incentives? What are the primary challenges (e.g., uncertain policies, lack of cost-efficient infrastructure, no access to feedstock, etc.)?	
Are there any other policies that promote biofuels production and consumption?	
What is the non-compliance cost (e.g., $/tCO2, $/GJ) of not meeting transport biofuel policies requirements for the obligated parties?	

Please expand on the details of any key policies with a short paragraph and a link to further documents or websites.

2.3. Complete the table below indicating the mandates for bioethanol, biodiesel, and any other transport biofuels. Include federal and provincial/State mandates.

Table - Biofuel's obligations/mandates. Please specify if mandates are specified based on volume or energy content or CO_2 / GHG emissions reduction potential.

Year	Ethanol	Biodiesel	HVO/Renewable Diesel	Others (specify e.g., Biojet / SAF, RNG)
2010				
2011				
…				
2023				

3. Market development and policy effectiveness

Indicate the size of the biofuels market by completing the following tables.
Please specify whether this production data represent biofuels production capacities or actual production levels.

Table - Transport biofuels production capacity/actual production (ML/yr)

Year	Bioethanol (conventional)	Cellulosic ethanol	Biodiesel (FAME)	Renewable diesel / HVO (from lipids)	RNG as transportation fuel	Other advanced biofuels (specify, e.g., biojet / SAF)
2010						
2011						
…						
2023						

Table - Summary of transport fuel consumption (ML)

Year	Gasoline	Diesel fuels	Aviation fuel	Bioethanol	Cellulosic ethanol	Biodiesel	Renewable diesel (From lipids)	RNG as transport fuel	Other advanced biofuels (specify)
2010									
2011									
…									
2023									

4. Biofuels facilities and main companies

1. How many conventional Bioethanol PRODUCTION facilities ARE THERE in your country? (Number of facilities and IF POSSIBLE, list names and capacities and Their locations on A Map (IF THERE ARE too many companies, then provide totals)
2. How many FAME Biodiesel PRODUCTION facilities ARE THERE in your country? (Number of facilities and IF POSSIBLE, list names and capacities and Their locations on A Map (IF THERE ARE too many companies, then provide totals)
3. How many Renewable diesel (HVO OR HEFA) PRODUCTION facilities ARE THERE in your country and IF POSSIBLE, LIST Their locations on A Map. (Number of facilities and IF POSSIBLE, list names and capacities)
4. Please provide the following information on other advanced biofuels producers (e.g., cellulosic ethanol, Biogas, BIOJET, ETC.).

Name of company	Status (planned; operational; closed)	Technology	Production capacity (ML/yr)

5. Biofuels and feedstocks: imports and exports

Please describe the type of biofuels/feedstocks and the volumes/MASSES that are imported/exported.

Year	Transport Biofuel (please specify type, e.g., renewable diesel)		Feedstocks (please specify types, e.g., UCO, animal fats. etc.)	
	Import (ML/yr)	Export (ML/yr)	Import (M tonnes/yr	Export (M tonnes/yr)
2010				
2011				
…				
2023				

6. Co-processing at oil refineries/Repurposing Oil refineries

1. Please describe the number and production capacity of any oil refineries in your country (barrels/day). Please also indicate their location on a map.
2. Please provide any recent/on-going co-processing trials at oil refineries (co-processing rate, type and volume of biogenic feedstocks, insertion points (FCC unit or hydrotreater)), etc.
3. Please provide any recent/on-going repurposing of existing oil refineries into standalone biofuel facilities.
4. Please describe any policies supporting co-processing at oil refineries (e.g., LCFS).

7. Research and Development and Additional information

1. List funding agencies and Major programs.
2. List any major recent/ongoing research projects focusing on biofuels technology development and deployment.
3. Provide any additional information that may be relevant.

(e.g., on new or revised biojet/SAF/biomarine initiatives) Sources of information.

Please list any documents and websites that were used as sources for the above information.

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