Assessment of successes and lessons learned for biofuels deployment

Report Work package 1 | Status of biofuels policies and market deployment in Brazil, Canada, Germany, Sweden and the United States

IEA Bioenergy TCP

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Status of biofuels policies and market deployment in Brazil, Canada, Germany, Sweden and the United States

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EXECUTIVE SUMMARY

Growth in the biofuel industry is far from the levels recommended by energy experts. The transport sector is responsible for one quarter of total GHGs, oil products still provide 91% of its final energy needs. There is a stark contrast between the world's announced objectives on decarbonization and energy diversity and the current status. Renewable fuels have a significant potential to improve the situation. However, the annual growth rate in biofuels (<5%) is well below the 10% output growth needed to be on track with the SDGs. Stronger policy support and greater innovation are required to scale up sustainable biofuel production.

This report provides useful information to spur the development of the biofuel sector. A historical analysis of the biofuel sector across 5 different countries sheds light on the different possibilities for policies, technologies and commercial outcomes. Learnings and take-aways from these cases can be used as a reference for building the right biofuel environment for any given country.

The chosen countries for this study illustrate very different biofuel environments. This diversity provides a rich mix of different perspectives, showing there is no single right answer when it comes to biofuel development. The motivation for adopting biofuels, the approach taken and the outcome; heavily depend on the characteristics of the country and its policy makers. The resulting differences in the biofuel industries vary widely.

Brazil shows the most notable success case for the implementation of biofuels. Its focus on biofuels goes back to the 70s, as a response to the global oil crisis. Brazil's main driver for biofuels has always been energy security. The share of ethanol and biodiesel in transport fuels has increased over time and are currently at a mandatory 27% ethanol blend in gasoline and 12% blend for biodiesel in diesel; the highest levels among the analysed countries. There are additional options for hydrous ethanol, with ethanol-flex fuel vehicles receiving tax incentives. Brazil's long history of implementing biofuels in transportation has shown no issues in terms of vehicle performance. Apart from mandatory blending requirements and tax incentives, Brazil has stimulated the biofuel industry through funding agencies and specific credit lines for bioenergy. There have also been import tariffs on ethanol to protect local production. There are also programs looking at advanced biofuels, notably on green diesel and biokerosene for aviation.

In Canada, the main drivers for biofuels are GHG reduction and rural diversification. Having the world's third largest oil reserves, energy security is not a driver for renewable fuels. Mandates require a 5% ethanol blend in gasoline and a 2-4% biodiesel blend, depending on the province. Biofuels are further incentivized through carbon pricing schemes. Ethanol is mainly produced with corn and biodiesel with cooking oil and animal fats. While federal subsidies were phased out in 2017; there are some provincial initiatives supporting production and consumption. There are also different programs to support R&D in bioenergy. When it comes to advanced biofuels, Canada has developed significant expertise in technologies to convert non-food based feedstocks to ethanol, (CO2 air capture and gasification to produce FT liquids, pyrolysis, and hydrolysis from agricultural residues… etc.).

In Germany, the main driver influencing the development of biofuels is GHG savings. This has been directly reflected in their policy, where Germany has shifted from an energy-related directive (RED) to a GHG one (FQD). Germany sets the mandate for fossil fuel suppliers on GHG reduction targets. The emissions must be calculated on a life cycle basis; this considers both the share of biofuel blended and the emission reduction of the chosen biofuel. Also, carbon taxes provide general incentives for renewable transport. There are no other financial incentives or tax reliefs for biofuels in Germany, making it quite difficult for new biofuels to penetrate the market. The country's policy seems more favourable to vehicle electrification, with subsidies for BEVs and PHEVs. There are also R&D projects on advanced biofuels (biooil from pyrolysis, bioethanol); but there is a stronger focus on electro-fuels.

The main driver for Sweden is also related to climate change mitigation and reduction of GHG emissions. The country does not have specific targets for biofuels other than the ones set by EU RED II. This policy sets targets on carbon emissions for gasoline and diesel, with penalties on any emissions above this level. As in Germany, the policy focuses more on the emissions than in volumetric or energy related shares. Biofuels in Sweden receive strong incentives through full tax exemptions on biofuels, bonuses for fuel-efficient vehicles, and the "pump law", which mandates large fuel retailers to offer at least one pump for biofuels. There is also strong investment support for any climate action programs. Bioenergy covers a 63% of TPES from renewables and is high on Sweden's priorities. Biofuels accounted for 20.6% of transport fuels in 2017. There are many research projects focused on biofuels; with the largest one on biomass gasification and biomethane synthesis.

Drivers for biofuels in the US include energy security, job creation, and rural development. Climate change mitigation has intermittently been a significant driver. At a country level, the RFS program sets volumetric mandates for renewable fuels with minimum GHG reduction requirements. There is also regional legislation, like the LCFS program in California which provides incentives to produce low carbon fuels. Excise duty reduction and blender's credits have also played a role in expanding biodiesel production. Liquid biofuels have seen substantial growth, increasing tenfold from 2000 to 2016. Advanced biofuels production remains relatively small but is gradually increasing.

The five countries present very different drivers, policies, resources and outcomes. An assessment from a sustainability perspective requires a complex analysis, individual in focus to each country. Each country has its own sustainability criteria, reflecting the different choices on biofuels, production processes, blends and other resources. The impact that biofuels show on sustainability will depend on these criteria. Nevertheless, biofuels do show a strong potential for reaching the commitments made in the SDGs and the Paris Agreement. The cases analysed provide a solid reference point to exploit the benefits of biofuels in many different areas.

FOREWORD

Unexpected pandemics, natural climate threats, new trends and needs in the markets, unprecedented political events, including the emergency of modern dictators and populists are all aspects impacting issues of geopolitical power and energy security in the world. As a consequence, this scenario of strong energy interdependence is influencing development, trade, international relations and diplomacy as well as global cooperation on climate. In this scenario, international agreements must be translated into goals and strategies, in which key global actors together must carry out collaborative activities for financing and follow-up agreed measures.

Besides that, there are often different societal priorities and several actors involved with different interests, conditions and power resources, making international, national and local issues even more complex and difficult to separate from each other. At this point, it is important to remember that the Paris Agreement was signed in December 2005, being a global commitment in which 182 countries engaged collectively to keep the global temperature raise well below 2ºC above pre-industrial level was signed. The global community also pledged to make efforts to restrict warming to 1.5ºC. However, the global greenhouse gas (GHG) emissions caused by anthropogenic activities are still increasing, being a stark contrast to the ambitious targets settled through the Paris Agreement.

In face of this worrying picture, far-reaching adaptations to drive transitions in all the society are fundamental in order to decrease emissions. In addition to that, modifications in behaviour and attitudes towards consumption are required alongside a new urban design of our societies. In this context, a new demand for products with low fossil-fuel intensity in replacement of ones with high fossil-fuel intensity are demanded. In all sectors, energy efficiency should be enhanced and fossil sources should be phased out. Changes in industry and transport in which the electrified system will play an important role as well as the use of sustainable produced biofuels are crucial. Finally, wind and solar power are also important energy alternatives.

Based on the above considerations, challenges are undoubtedly extensive. However, on the one hand the transition to a fossil-free economy involves high costs, and on the other, financial opportunities and welfare gains for citizens and business in developed and underdeveloped countries. Regarding biofuel production, the approaching of its potential advantages is fundamental to encourage better feedback, greater pluralism and inclusiveness. In the related debate, the availability of resources in several regions of the world, as well as the level of technology development are two great examples of these potential advantages.

Besides the Paris Agreement, mentioned in the initial paragraphs, the Sustainable Development Goals (SDGs), adopted by all United Nations (UN) Member States in 2015 as part of the 2030 Agenda for Sustainable Development, also should be tackled as a matter of priority to have a CO_2 neutral society. For that, we take back the opening paragraph, exploring the fact that we need common visions and strategies being implemented by key global actors through international agreements.

However, at this point is also important to consider that transport is proving to be an extremely difficult sector to decarbonize. The IEA analysis shows that the rate of progress is well below what is needed to reach SDGs, from fossil carbon to renewable carbon-based fuels. And transport biofuel production is expected to continue growing. However, at annual rates below 5% according to IEA in the near future, whereas sustained levels of 10% output growth per year are needed until 2030 to get on track with SDGs.

The bottom line is that despite billions of dollars of investments, ramped up production of low carbon advanced biofuels remains well below the levels needed to achieve the SDGs. Stronger policy support and a greater rate of innovation are required to reduce the costs of development and scale up of sustainable advanced biofuel production, particularly for sectors like heavy duty transport, aviation and marine which are especially hard to decarbonize. Thus, in this report we analyse international progress, identifying which approaches are proving to be the most effective so they can be expeditiously and more broadly deployed to get transport decarbonization back on track with SDS goals.

To sum up, we answer the following questions:

- What are key-factors for the success of sustainable advanced biofuel projects?
- What is required to re-stimulate vigorous biofuels development and commercialization?

For that, we evaluate the reasons underlying the past and ongoing booms and busts cycles of biofuel technologies development, demonstration, deployment and replication. We do that to identify technology successes and the best policy framework conditions and measures for stimulating increased future markets for production and consumption of sustainable transport biofuels. We focus on transport biofuels in Sweden, Germany, Canada, United States and Brazil.

Our chosen structure reflects our wishes to make an impact on decision-making and policy implementation processes, influencing key actors within this fields. Therefore, our key messages - overall recommendations for policymakers, decision-makers and stakeholders open up this report. After that, we present a brief overview for each country, including the role of governance for biofuels. We continue with a synthesis of existing studies and a description of the state of the biofuel industry.

Following we have case studies technologies in each country, focusing on the role of policy in technical and commercial successes. Then, we focus on the complexity of the biofuel value chain. In this part, we strongly address environmental and socio-economic benefits associated with the approached chains. Finally, closing this report, our efforts are on the strengths and weaknesses of different biofuels.

The report was compiled during start of 2020 and onwards but mostly have collected information on countries which at the time of year 2020 was prevalent and since this may have changed as policy are always evolving and therefore the report cannot be used as exact guide on the terms of policies for the publication date of this report.

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1 BRAZIL: PROMOTING BIOFUELS FROM PROALCOOL TO RENOVABIO

1.1. INTRODUCTION

In 2019, the energy supply (total energy available) in Brazil reached 294 Mtoe, representing an increase of 2% compared to the previous year.[1] The country has a significant portion of its internal energy supply from renewable sources, which corresponded to 46% in 2019.

Public policies adopted by the 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 matrix.

Such a variety comprises liquid biofuels (predominantly ethanol and biodiesel) and solid biofuels - the most relevant being sugarcane bagasse and gaseous, with a still incipient participation of biogas.

Although the latest experienced a growth of over 100% in the last 3 years. It can also be observed that sugarcane by-products (18%) are the second main source within the internal energy supply, behind oil and its derivatives (34.4%).[1]

In 2020, the final energy consumption was 259.4 Mtoe. Sugarcane by-products had a substantial share in several sectors of the economic activity, e.g., transport and industrial sectors.[1] Ethanol (pure and blended with gasoline - E27) is used in otto cycle engines and bagasse is an energy source for steam production in the manufacture of ethanol and sugar.

In addition, sugarcane biomass is used to generate electricity, part of which is consumed in the plants and part is injected into the National Interconnected System (SIN). Figure 1 shows the contribution of different energy sources to the final energy consumption.

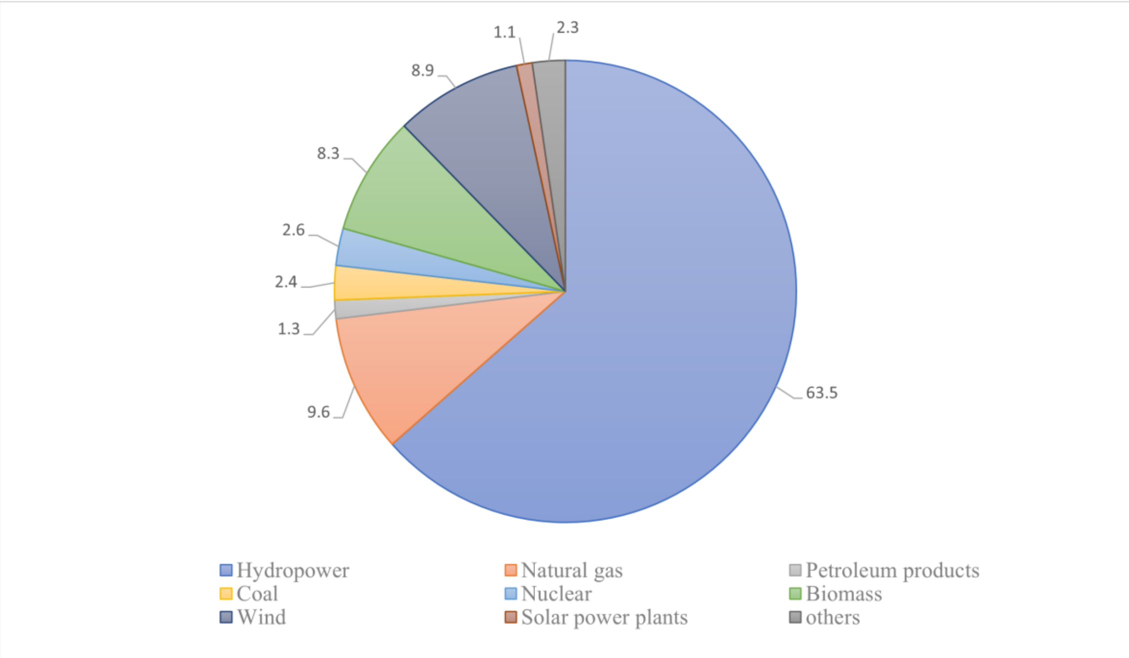

Figure1. Contribution of different energy sources consumption in Brazil.

[1] EPE, 2020a

In 2019 the final energy consumption in the transport sector was 84.8 Mtoe. This figure represents 32.7% of the total energy consumption in Brazil.[2] For road transport, the amount consumed was 78.9 Mtoe, 30.4% of the total. Brazil presents itself as a case of success in regards to the demand for biofuels in the transport sector. Its participation increased from 20.3% in 2009 to 25.1% in 2019. The share of biodiesel increased from 1.7% to 4.7% of the final energy consumption of the vehicle matrix in the period [3]

In 2005 the GHGs emissions were 2,352 Mt CO_{2eq}, with the forest and land use sector as the main emitter with 64.7% of the total (considering net emissions from forests and land use). At the time, the energy and transport sector registered 313 $MtCO_{2eq}$ (13.3%). In a recent survey, GHG emissions fell to 1,305 $MtCO_{2eq}$ in 2016, with the forest and land use sector (22.3%) being the main responsible for this fall. In the same year, the energy and transport sector emitted 422.5 $MtCO_{2eq}$ (32.4% of total).[4] Figure 2 shows the historical GHG emissions in Brazil since 1990.

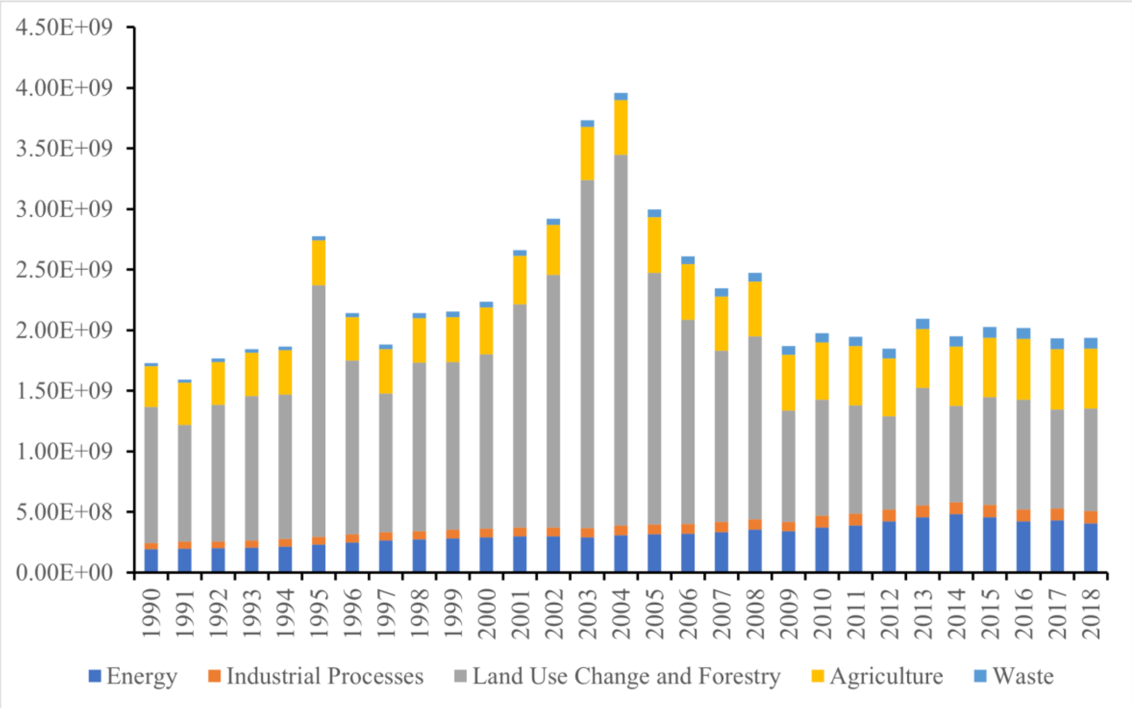

Figure 2. Historical GHG emissions in Brazil

In 2018, total anthropogenic emissions associated with Brazilian energy matrix reached 416.1 $MtCO_{2eq}$. The main contributor to the GHG emissions in energy production and consumption are the transport and industrial sectors, which accounted for 46.3% and 18.8% of total emissions, respectively.[5]

[2] EPE, 2020
[3] EPE, 2020a
[4] MCTI, 2018
[5] EPE, 2019b

1.2. DRIVERS FOR BIOFUEL POLICIES

There are several benefits from the use of biofuels in the Brazilian energy matrix, which can be observed in the economic, social and environmental spheres. Considering liquid biofuels, since Brazilian production of gasoline and diesel is not sufficient to meet domestic demand, the consumption of ethanol and biodiesel acts favourably in order to reduce the risks related to the instability of the world market and to increase security of energy supply. The absence of these biofuels could result in an increase in imports of fossil analogues, 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 phase of their production, or in the industrial stage, including the countryside.

In the case of biodiesel, a stand out initiative is the Social Fuel Seal[6], which benefits small farmers with family farming insertion to the biofuel production process. Indirectly, jobs are also generated in the industry of cultivation implements, agricultural machinery business and services with much trading occurring in rural areas of the country. Besides, it is possible to identify positive impacts on infrastructure, improvements in motorways and railways, in the food production and in the life quality of people living in the neighbouring areas. The environmental benefits of biofuels are due to the lower generation of air pollutants, liquid effluents and solid waste compared to fossil fuels.

The official document driving Brazil's national policy framework for renewable energy today is its Nationally Determined Contribution (NDC) towards achieving the objective of the UN framework convention on climate change. This document, announced in December 2015 during the 21th Conference of Parts of the United Nations (COP 21), forecasts the Brazilian energy trends expected in future years and provides background for the main energy planning document. The Ten Year's Energy Plan (PDE), is elaborated by the Energy Research Agency (EPE) in Brazil 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[7], the Law on the Protection of Native Forests[8], the Law on the National System of Conservation Units[9] 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 committed to reduce its domestic GHG emissions to 37% by 2025 and 43% by 2030, both based on 2005 levels. With regard to energy production and use, the country also intends to adopt further measures that are consistent with the 2°C maximum temperature rise goal, 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 mix and more biodiesel in the diesel mix

- Achieve an estimated 45% share of renewables in the energy matrix by 2030

- Obtain at least a 66% share of hydropower in electricity generation by 2030, not considering self-produced electricity

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[6] *Selo Combustível Social,* in Portuguese
[7] Law 12,187/2009
[8] Law 12,651/2012, hereinafter referred to as the Forest Code
[9] Law 9,985/2000

- 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, 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

On the biofuels use side, in 2017 Brazil launched the National Biofuels Policy (RenovaBio)[10], a state policy recognizing the strategic role of all types of biofuels in Brazil's energy matrix, both for energy security and for mitigation of GHG emissions. This new law is effective from 2020 and have a global target of carbon intensity reduction, established in 95.5 million CBIOs[11] in 2029 (1 CBIO is equivalent to 1 tonne CO_{2eq}).

Due to COVID-19 Pandemic impacts, among other governmental issues, a proposal to revise the goals for 2020, as well as its extension until 2030 have been through a public consultation process.[12]

According to the proposal, the total CBIO to be marketed in 2020 totals 14.53 million and, for 2030, totals 90.67 million. RenovaBio provides a market-based incentive by issuing GHG emissions reduction certificates, named CBIO. The program does not include the creation of carbon taxes or any kind of subsidy to biofuels. The policy includes the creation of CBIO issued by biofuel producers, traded on the stock exchange and the fuel distributors are obliged to acquire a quantity of this credit, established in a resolution. However, RenovaBio's legal and regulatory framework need to be re-evaluated by the official bodies, in order to address a higher transparency in its mechanisms.

In addition, the framework of the Rota 2030 Program[13] was approved by the Brazilian Federal Government in December 2018 (BRASIL, 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 stringent vehicle emissions regulations. Even thought, RenovaBio's methodology and eligibility are still under debate.

1.3. BIOFUELS POLICIES AND OBLIGATIONS

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 (PROALCOOL), increasing the ethanol blending level up to 25% in gasoline (E25) and also introducing hydrous ethanol (E100, approximately 95% ethanol and 5% water) for use in 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 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.[14]

The second phase of expansion took place due to a new market opportunity. In 2003, flex-fuel cars were launched, offering to drivers the option of using both gasoline (containing 20–27% anhydrous ethanol) and hydrous ethanol, at any blend.

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[10] Law 13,576/2017
[11] CBIO is an acronym for *Crédito de Descarbonização* - Decarbonization Credit
[12] MME, 2020
[13] Law 13,755/2018
[14] BNDES, 2008

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 fuel demand. During 2003–2008, the Brazilian sugarcane industry expanded rapidly, with many new and more efficient sugar-ethanol mills commissioned and several of them exporting energy to the grid.[15]

As of 2008, the sector has experienced great difficulties due to the petroleum crisis and the rise in the dollar, which has considerably increased their debts that were tied to this currency, and leaded to a consolidation phase within the industry. Thus, the production increase of 1,8% between 2008 and 2017. In 2019, ethanol production was 36 billion liters and the share of ethanol in the fuel mix used by light vehicles (Otto Cycle - in gasoline equivalent) reached 54.8%, the highest in history.

Brazil's biodiesel program started in 1980 with the PRO-OLEO (Plan for the Production of Vegetable Oils for Energy Purposes) initiative. 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 for the production of 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 centres, 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 fostering feedstock production by small farmers. This program evolved gradually, with soybean oil and tallow proving to be the most relevant feedstocks for production, adopting transesterification process with methanol. There was also the objective of reducing dependence on mineral diesel. This program mandated a substitution of B5 by 2005 and has a schedule to reach B15 in 2023. In 2020, the mandated blending level for biodiesel is B12.

Under the RENOVABIO Program biofuels production will be certified through LCA with issuance of GHG emissions reduction certificates, named, to producers that can be traded in the stock market and purchased by fuel distributers. One CBIO corresponds to a reduction of one tonne of CO_{2eq} in comparison to fossil fuel emissions. With RenovaBio, the government plans to increase ethanol and biodiesel production (MME, 2020).

In 2019, MME called for studies to support the formulation of measures aimed at promoting free competition in the supply of fuels, other petroleum products and biofuels.

In 2020, the National Agency of Petroleum, Natural Gas and Biofuels (ANP) in Brazil approved the start of a public hearing on the specification of green diesel, a renewable fuel for diesel cycle combustion engines, produced by hydrogenation of renewable raw materials, such as vegetable and animal fats, sugarcane, alcohol and biomass. The new fuel will be added to diesel of fossil origin, which currently has mandatory 12% biodiesel.

[15] SCOPE, 2015a

The new biofuel consists predominantly of paraffinic 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[16], since the production of biofuels in the context of biorefinery generates different bioproducts in the same process.

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.

Table 1 summarizes the development of biofuels policies and the industry in Brazil since 1920s.

Year	**Landmark**
1931	Mandatory addition of 5% ethanol to imported gasoline
1938	Mandatory addition of 5% ethanol to national gasoline
1969	Creation of the Centre for Sugarcane Technology (CTC)
1971	Launch of the National Sugarcane Improvement Plan (Planalsucar)
1975	Launch of PROALCOOL establishing the addition of 10% of ethanol to gasoline, progressively increased up to 20% in 1980
1979	Introduction of light vehicles to pure hydrated ethanol (96% ethanol)
1986	Creation of the Motor Vehicle Air Pollution Control Program (PROCONVE), which progressively set limits for vehicle emissions and reinforced interest in ethanol
2002	Creation of the Network of Research and Technological Development in Biodiesel (Probiodiesel)
2003	Introduction of flex-fuel vehicles
2006	Creation of the Brazilian Agency for Agricultural Research (EMBRAPA) Agroenergy
2009	Inauguration of the Brazilian Bioethanol Science and Technology Laboratory (CTBE)*
2015	Beginning of corn ethanol production
2015	Introduction of sugarcane varieties with improved energy-efficiency
2017	RenovaBio is launched[17]

* From 2019, CTBE is called Brazilian Bio-renewables National Laboratory (LNBR).

Following, biofuels obligations are explored.

- RENOVABIO

It was signed into law in 2017[18], objecting to expand the production of biofuels in Brazil. It is based on (i) predictability, (ii) sustainability, and (iii) compatibility with the market growth.

- Anhydrous Mandatory Blend in Gasoline

It was created by Federal Decree 19,717/1931, making the addition of anhydrous ethanol to gasoline consumed in Brazil mandatory.

The Law 13,033/2014 increased the anhydrous ethanol mandatory blend limit in gasoline from 18% (by volume) up to 27.5%

[16] Regulated by ANP Resolution No. 778, of 2019
[17] RenovaBio's eligibility is still under debate within several bodies within the Brazilian Government. The Program methodology is still being assessed and discussed.
[18] Federal Law Nº13.576

The current mandatory blending level is 27% (E27). Besides that, 100% ethanol (hydrous ethanol) is also commercialized in gas stations in Brazil. Following, Figure 3 presents the historical blending mandate in Brazil, since the year of 1931.

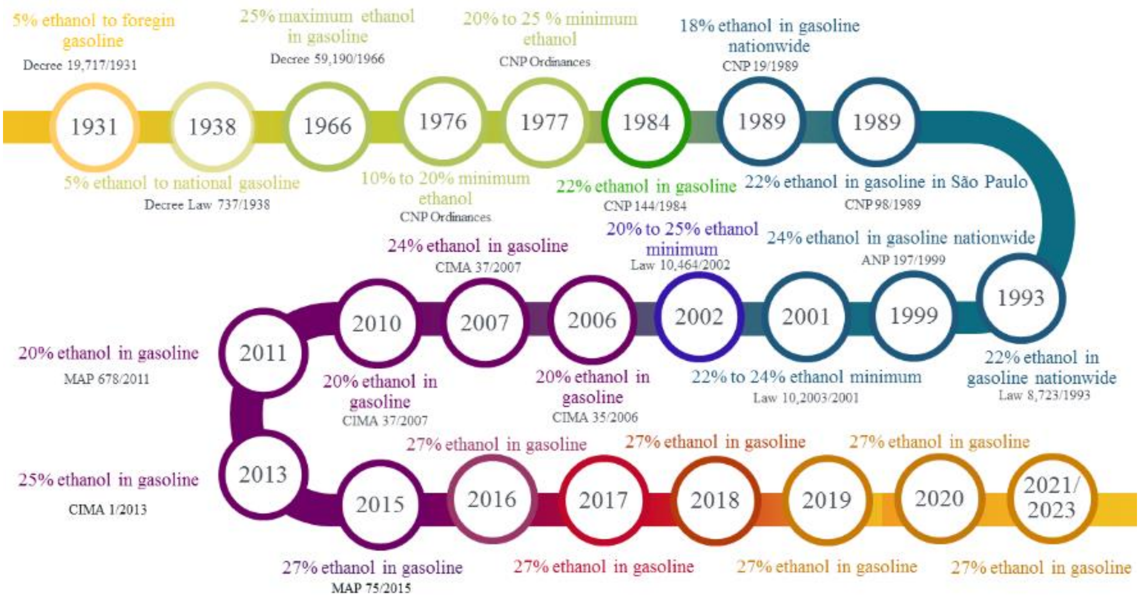

Figure 3. Historical ethanol blending mandate in Brazil[19]

- PNPB

It was created by Law 11,097/2005 to stimulate energy, economic and social objectives as well as more feedstock production by small farmers. The current mandatory blending level is 12%. Figure 4 shows the historical biodiesel blending mandate in Brazil, since 2005.

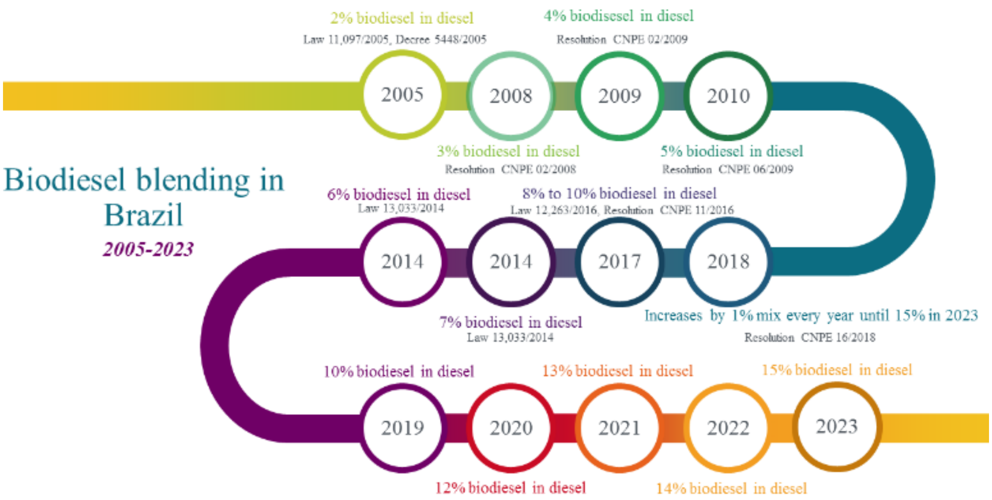

Figure 4. Historical biodiesel blending mandate in Brazil[20]

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[19] EPE, 2016
[20] EPE, 2020; MAPA, 2020

- NDC

The Brazilian NDC targets to increase the share of sustainable bioenergy within the national energy matrix to approximately 18% by 2030, by expanding biofuel consumption and increasing ethanol supply.

- Federal Decree 9,888/2019

It provides annual targets for the reduction of GHG emissions in the transport sector. This reduction targets are the basis for decarbonization goals of RENOVABIO.

- National Energy Policy Council (CNPE) through Resolution No. 15/2019

It establishes national mandatory targets to reduce GHG emissions in fuel sales.

1.4. EXCISE DUTY REDUCTIONS

There are tax incentives for biofuel producers, blenders and users including:

- Tax incentives for ethanol-flex fuel vehicles - tax incentives have played an important role in supporting ethanol consumption since the introduction of flex-fuel cars. Regardless of the engine power, the tax burden as a share of the suggested retail price is usually lower for flex-fuel vehicles than for gasoline only powered vehicles.

- Tax incentives for ethanol fuel - Brazil has a complex tax system including several taxes at the federal, state, and municipal level. Depending on the economic and financial strategies pursued by policymakers, the federal government can provide incentives for gasoline and/or ethanol at the pump.

Currently, the federal government provides preferential treatment for ethanol compared to gasoline under both its Contribution for Intervention in Economic Domain (CIDE)21 and Contribution to Social Integration/Contribution for Financing Social Security (PIS/COFINS) programs. In addition, several states provide differential treatment for ethanol by using a different Tax on Circulation of Goods and Services (ICMS) for ethanol and gasoline.

- The federal government sets federal tax exemptions and incentives for biodiesel, according to the nature of the raw material, size of the producer and region of production, in order to encourage the production of biodiesel and to promote social inclusion.

There are no carbon tax or emission trading emissions trading (cap-and-trade) schemes in Brazil.

1.5. FISCAL INCENTIVES AND INVESTMENT SUBSIDIES

The Regional Producer Subsidy is the only direct subsidy paid by the Brazilian Government. It was created decades ago, providing support for sugarcane producers, to have a higher balance of production costs among producers from the north/northeast states and centre-south.

[21] Law Nº10.336/2001

Throughout the years, the federal government has tailored this program to the evolving reality of the sugarcane industry. In addition to being located in states covered by the program, there are other eligibility conditions for granting this subsidy such as being an independent sugarcane producer (not integrated to sugar-ethanol mills), not producing more than the annual limit of 10 thousand tonnes by crop, and that the amount of the subsidy cannot be higher than the average price of sugarcane in the region.

In August 2017, the Brazilian Government put a tariff in place for ethanol imports, allowing 600 million liters to enter duty-free, with any volume above this being subject to a 20% tariff. This followed a request by ethanol producers, in March 2017, to place a tariff on imported ethanol. Producers claimed the pace of imports jeopardizes domestic ethanol production, especially in northeast region where import volumes have risen significantly due to competitively priced imported corn ethanol. The United States remains the top supplier of ethanol to Brazil.

According to the Foreign Trade Secretariat (SECEX), the import tariff applied to biodiesel (NCM 3826.00.00) is fixed at 14% and the import tariff for petroleum oils containing biodiesel up to and including B30 (NCM 2710.20) is zero.[22]

Exemption of import duties over ethanol, based on RES125/2016, is restricted to a limited annual volume of 1.2 billion litres.

On August 31, 2019, Ordinance No. 547 was published, extending the validity of the import quota exemption for an additional period of 12 months, as of its publication, and changes the total annual volumes covered by the exemption to 750 million liters.

1.6. OTHER MEASUREMENTS STIMULATING THE IMPLEMENTATION OF BIOFUELS

There are several science and technology funds (e.g., National Bank of Economic and Social Development (BNDES), Brazilian Innovation Agency (FINEP), Research Support Foundation of the State of São Paulo (FAPESP), and National Council for Scientific and Technological Development (CNPq), supporting production and development of biofuels in Brazil.

BNDES provides specific credit lines for bioenergy industry, funding investments in sugarcane production, expansion of industrial production capacity for sugar and ethanol, cogeneration, logistics, and multimodal transportation.

In June 2017, the Ministry of Agriculture, Livestock and Supply (MAPA) announced the Brazilian Agricultural Crop and Livestock Plan for 2017-2018. A total of US$ 50 billion will be released to fund agricultural and livestock programs. This represents a 3% reduction over the previous crop plan.

In addition to conventional biofuels, these programs promote the production of advanced and drop-in biofuels for long-distance transport sectors such as aviation. Producers of these biofuels can enter the market once they have been authorized as a biofuel producer by ANP.

Tables 2 and 3 summarize the funding agencies and major programs that support the development of biofuels in Brazil, respectively.

[22] Resolution CAMEX Nº72/2017

Table 2. Funding agencies that support the development of biofuels in Brazil

Agency	Program
BNDES	BNDES is a development bank structured as a federal public company associated with the Ministry of Development, Industry, and Foreign Trade (MDIC). The stated goal is to provide long-term financing for endeavors that contribute to the country's development
CNPq	CNPq is an organization under the Ministry of Science and Technology (MCT) in Brazil, dedicated to the promotion of scientific and technological research and to the formation of human resources for research in the country
CTC	CTC is a research institute that focuses on development for the Brazilian ethanol industry. The Company is engaged in the development of new varieties and technologies in the production of sugar cane and ethanol including: genetic improvement (new varieties), biotechnology and second-generation biofuels.
EMBRAPA	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
BIOEN-FAPESP	FAPESP is a public foundation located in the city of São Paulo, Brazil, with the aim of providing grants, funds and programs to support research, education and innovation of private and public institutions and companies. The Bioenergy Research Program (BIOEN) of FAPESP aims to integrate comprehensive research on sugarcane and other plants that can be used as biofuel sources, assuring Brazil's position among the leaders in the area of Bioenergy. Research includes biomass improvement, production and processing, biofuels production, biorefineries, engines, sustainability and impacts
FINEP	FINEP is linked to the MCT, promoting science, technology and innovation in companies, universities, technological institutes and public/private institutions. FINEP IS headquartered in the city of Rio de Janeiro

Table 3. Major programs that support the development of biofuels in Brazil

Program	Description
BNDES-PAISS	The Joint Plan for Supporting Industrial Technological Innovation in the Sugar-based Energy and Chemical Sectors (PAISS) is a joint initiative of BNDES and FINEP intended for sugarcane rural producers and their cooperatives to select business plans and promote projects that contemplate the development, production and commercialization of new industrial technologies for sugarcane biomass (e.g., E2G, gasification) 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 pretreatment 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 for the production of new products directly obtained from sugarcane biomass
BNDES-ProRenova	The Support Program for Renovation and Implementation of New Sugarcane Crops (ProRenova) is a financing program to renew and implant new sugarcane fields and promote sugarcane production in the country
BNDES-ABC Program	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, and stimulating the recovery of degraded areas, increasing agricultural production on a sustainable basis and adapting rural properties to environmental legislation

1.7. PROMOTION OF ADVANCED BIOFUELS

Table 4 shows operational advanced biofuels production facilities in Brazil. Brazil has two commercial cellulosic ethanol plants including GranBio's Bioflex-I facility in the city of São Miguel dos Campos that has a nominal annual production capacity of 60 million liters, and Raízen plant in Piracicaba that has an annual capacity of 42 million liters.

In addition, there is an experimental plant in CTC in the city of Piracicaba that has an annual capacity of 3 million liters. The commercial plants are debugging technical problems mainly in the pre-treatment and lignin filtration stages and these two plants still operate below their nominal design capacities. By 2024, Raízen plans to build seven more cellulosic ethanol plants.[23]

Recently, Raízen inaugurated one of the largest biogas plants in the world, based in the city of Guariba, having 21 MW of installed capacity. This plant will be used to produce 138 MWh/year from vinasse (during the harvest) and filter cake (off season).

Table 4. Advanced biofuel production facilities in Brazil

Company	Status (planned, operational, closed)	Technology	Production Capacity (ML/year)
GranBio Bioflex-I	Operational	E2G - BioFlex® (AVAP® e GreenPower+®)	60 million litres/year
Raízen - Costa Pinto	Operational	E2G - Iogen Corporation	42 million litres/year
CTC	Operational	E2G	3 million litres/year

Brazil is also engaged in the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) initiative to develop green jet fuel. CORSIA is an emissions reduction agreement, established by the International Civil Aviation Organization (ICAO) and major airlines.

In addition to emission compensation instruments and energy efficiency promotion (spanning technical/aircraft, systemic/operational management and airport infrastructure), CORSIA promotes the use of drop-in aviation biofuels, which should be produced by processes certified by the American Society for Testing and Materials International (ASTM International). The Brazilian market regulation has been updated to allow the use of such biofuels in aviation.

It is worth emphasizing that there are still industrial and economic challenges for bio-jet fuel production to be cost competitive in Brazil and worldwide with aviation kerosene of fossil origin.

ProQR, a program of the Brazilian Federal Government, through the Ministry of Science, Technology, Innovations and Communications (MCTIC), articulated with the German government, aims to develop alternative fuel projects without climatic impacts for aviation. The expectation is that, in up to three years from 2020, the first pilot plant for the production of sustainable kerosene for aviation, should be implemented in the city of Ceará[24]

Another initiative is the trials carried out on co-processing vegetable oils with petroleum feedstocks in refinery hydro-processors at a level 10% by volume in two Petrobras petroleum refineries (Gabriel Passos-REGAP in the State of Minas Gerais and REPAR in the State of Parana). Plans were made for processing of vegetable oil in other Petrobras units including Henrique Lage Refinery – Revap in the State of Sao Paulo and Presidente Bernardes Refinery (RPBC) in the State of Sao Paulo and the Duque de Caxias refinery – Reduc in the State of Rio de Janeiro. However, this approach for hydro-processing has never been effectively implemented due to limited economic competitiveness.

1.8. MARKET DEVELOPMENT AND POLICY EFFECTIVENESS

According to MAPA, 654 million tonnes of sugarcane were produced in 2019. The national sugar production was 30 million tonnes, and ethanol production was higher than 36 billion liters. About 70% of this total refers to hydrous ethanol (25 billion liters) and the remaining for anhydrous ethanol, which is blended with gasoline, with a production of 10.7 billion liters.

[23] GranBio, 2017; Raízen, 2018
[24] GOVERNO DO CEARÁ, 2020

Total ethanol production from corn grain in 2019 reached 1,330 million liters or 3.6% of total ethanol production and tripled the level of corn ethanol production since 2017 (413 million liters).

Currently there are 12 plants producing ethanol from corn in Brazil. Located mainly in the states of Mato Grosso and Goias, 8 are flex-plants, producing ethanol from both sugarcane and corn, and 4 are dedicated only to corn. Corn ethanol plants are feasible in the corn producing areas of Brazil, especially if they can be located close to livestock operations because distiller dried grains and solubles (DDGs), a co-product of corn ethanol production, can be marketed as animal feed, thus increasing business profitability.

However, Brazil's centre-west and northern corn producing areas are located in larger states with lower population densities and limited ethanol demand.

At the end of December 2019, 366 conventional ethanol units, distributed by 65 companies, were able to sell anhydrous and hydrated ethanol, with production capacities of 130 million liters/day and 237 million liters/day, respectively. The crushing capacity was around 740 million tonnes/year. At the same date, there were 51 plants of FAME biodiesel, with a production capacity of 9.3 billion litres. The main raw materials were soybean oil (68%) followed by tallow (11%).[25] Following, Table 5 presents the current production in Brazil, from 2010 to 2019.

Table 5. Current production of biofuels in Brazil between 2010 and 2019[26]

	Production ML/year			**Production Capacity (ML/day)**		
Year	Biodiesel (FAME)	Anhydrous ethanol (conventional)	Hydrous ethanol (conventional)	Biodiesel (FAME)	Anhydrous ethanol (conventional)	Hydrous ethanol (conventional)
2010	2,386.4	8,356.7	19,567.2	16.21		
2011	2,672.8	9,049.6	13,865.9	18.81		
2012	2,717.5	9,563.6	13,913.1	20.57		
2013	2,917.5	12,004.7	15,602.9	21.96	104	205
2014	3,419.8	12,229.8	16,295.8	21.16	106	206
2015	3,937.3	11,564.6	18,684.6	20.37	116	213
2016	3,801.3	11,727.3	16,549.1	20.48	120	219
2017	4,291.3	11,695.2	15,998.5	21.21	128	237
2018	5,350.0	9,505.2	23,692.8	23.72	126	233
2019	5,923.9	10,608.0	24,548.1	25.92	130	237

Table 6 presents historical fuel consumption in Brazil from 2010 to 2019.

Table 6. Summary of transport fuel consumption (ML)[27]

Year	**Automotive Gasoline***	**Diesel fuels**	**Aviation gasoline (Avgas)**	**Aviation kerosene**	**Fuel oil**	**Natural gas**	**Biodiesel**	**Anhydrous ethanol**	**Hydrous ethanol**
2010	22,759.6	38,259.3	69.6	3,878.3	1,006.8	2,007.6	1,889.2	7,097.0	16,163.0
2011	27,062.1	40,323.8	70.4	4,341.7	1,027.6	1,972.0	2,045.5	8,435.4	12,216.3
2012	31,758.2	42,655.0	76.3	4,576.2	980.3	1,941.8	2,201.7	7,759.4	11,299.3
2013	31,679.2	45,359.5	76.3	4,389.8	1,000.0	1,872.0	2,326.2	9,686.0	13,170.0
2014	33,353.0	45,677.5	76.2	4,441.1	1,040.3	1,811.5	2,694.1	11,015.7	13,972.4
2015	30,203.7	43,246.7	63.7	4,390.9	1,007.0	1,764.5	3,153.7	10,940.1	18,788.7
2016	31,403.9	41,833.6	57.2	4,018.8	905.7	1,810.4	3,119.7	11,100.3	15,594.0
2017	32,229.2	41,627.3	51.4	4,009.3	966.5	1,971.0	3,476.9	12,071.6	14,514.3
2018	27,996.8	41,184.0	48.5	4,121.0	1,019.7	2,211.7	4,386.0	10,214.3	20,123.8
2019	27,860.5	41,969.5	43.1	4,032.8	1,023.0	2,284.6	4,796.1	10,553.6	23,246.9

[25] ANP, 2020c

[26] EPE, 2020a; ANP, 2020c

[27] EPE, 2020a

2 CANADA

2.1. INTRODUCTION

Similar to the rest of the world, transport in Canada is fuelled almost exclusively by refined petroleum products derived from crude oil, including (i) gasoline, (ii) diesel, (iii) aviation fuel and (iv) heavy fuel oil mainly used in marine vessels. Currently, over 96% of the transportation sector in Canada is fuelled by petroleum products, making this sector the second largest emitter of GHGs after the oil and gas sector.

Figure 6 presents GHGs emissions from the transport sector account for almost 23% of all GHG emissions in the country, with road transportation responsible for 80% of these emissions. Total GHG emission was 731 million tonnes of CO_{2eq} (Senate of Canada, 2017).

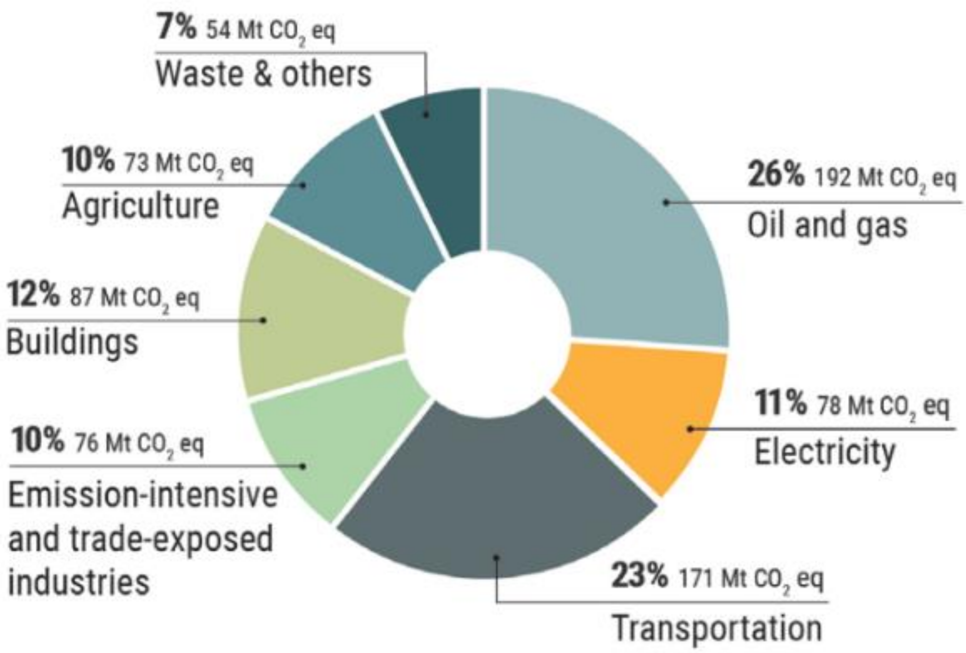

Figure 6. Canada's GHG emission breakdown in 2014[28]

There are several alternatives to reduce the carbon intensity of the transportation sector including improving vehicle fuel efficiency through regulated fuel efficiency standards, increasing the number of alternatively fuelled vehicles such as electric and CNG/LNG vehicles, improving transportation infrastructure and optimizing transport modes, and shifting away from petroleum-based to less carbon-intensive fuels such as biofuels.

[28] Senate of Canada, 2017

Conventional biofuels including ethanol and biodiesel (conventional fatty acid methyl ester- FAME) and, to a small extent, natural gas, have been produced and used in Canada to decarbonize the road transportation sector. Both federal and provincial regulations are in place, known as renewable fuel mandates, which require minimum renewable fuel blending in all gasoline and diesel consumed in the country. In addition to renewable fuel mandates, other regulations are contributing to the decarbonization of the road transportation sector in Canada such as British Columbia's Low Carbon Fuel Requirements Regulation which requires the average lifecycle carbon intensity (CI) of fuel sold within the province to decline over time.

2.2. DRIVERS FOR BIOFUEL POLICIES

Canada has the world's third largest proven oil reserves, after Venezuela and Saudi Arabia, and is one of the top ten oil exporters in the world. Energy security is therefore not the driver for Canada's renewable fuel industry. The primary drivers for renewable mandates are rural diversification and GHG emission reductions to fight climate change. GHG emission reduction now is the primary driver. The Canadian Federal Government plans to introduce carbon intensity benchmarks and require all provinces and territories to have a carbon pricing plan that will expand consumption of renewable energy and biofuels.

2.3. BIOFUELS POLICIES AND OBLIGATIONS

Federal and provincial-level renewable fuels programs have continued to support conventional biofuels production and use across Canada. From 2006 through 2010, the provinces of British Columbia, Alberta, Saskatchewan, Manitoba and Ontario established a blending requirement of 5 to 8.5% for ethanol in gasoline and 2 to 4% for renewable content in diesel. Federal use mandates followed thereafter, and, since December 2010, federal regulations have required fuel producers and importers to have an average ethanol content of at least 5% based on the volume of gasoline produced or imported. Since July 2011, federal regulations have required fuel producers and importers to have at least 2%, on average, renewable content based on the volume of diesel fuel and heating distillate oil that they produce or import. The current federal Renewable Fuels Regulations include a trading system and administrative, compliance, and enforcement provisions such as recordkeeping and reporting.[29]

Table 7 summarizes the percentage of ethanol and biodiesel to be blended with gasoline and diesel as mandated by provincial regulations in 2017. The details of these provincial regulations can be found at Navius (2016 and 2018) and at the Foreign Agricultural Service (USDA) (2018).

In addition to Renewable Fuel Regulations, other federal and provincial initiatives are underway to decarbonize the transport sector. The federal government has released a Pan-Canadian Framework on Clean Growth and Climate Change, which includes a federal carbon pricing framework. The Pan-Canadian Approach to Pricing Carbon Pollution was announced October 2016. This pricing strategy would require all provinces and territories to have some form of carbon pricing plan in place by 2018. In January 2019, the federal government will introduce its own carbon pricing system (the backstop) in provinces that do not design their own system or elements of the backstop in provinces where the system does not fully meet its criteria.

[29] ECCC, 2017

In December 2017, the federal government released its Regulatory Framework on the Clean Fuel Standard (CFS), which describes how Canada will transition from volumetric-based requirements towards a carbon intensity-based approach. Volumetric requirements under the current Renewable Fuels Regulations will remain in force until Environment and Climate Change Canada (ECCC) clarifies how Canada will transition to carbon intensity benchmarks. ECCC is the department within the Canadian government responsible for coordinating environmental policies and programs as well as for preserving and enhancing the natural environment and renewable resources.

Table 7. Provincial biofuels blend mandates in 2017 (%)

Province	Ethanol	Biodiesel	Regulations
British Columbia	5.0	4.0	The Renewable and Low Carbon Fuel Requirements Regulation
Alberta	5.0	2.0	Renewable Fuels Standard Regulation under the Climate Change and Emissions Management Act
Saskatchewan	7.5	2.0	The Ethanol Fuel Act and Ethanol Fuel (General) Regulations The Renewable Diesel Act
Manitoba	8.5	2.0	The Ethanol General Regulation Biodiesel Mandate for Diesel Fuel Regulation
Ontario	5.0	4.0	Ethanol General Regulation[30] Greener Diesel Regulation

In a recent announcement, the federal government issued a nationwide challenge to Canadians to develop the cleanest, most affordable and sustainable aviation fuel to further reduce the carbon footprint of the aviation sector.

In addition to federal initiatives, current and underway provincial initiatives support the production and consumption of biofuels in Canada including the British Columbia's Low Carbon Fuel Standard (BC-LCFS), Quebec's cap-and-trade carbon exchange program (excluding transport biofuels), British Columbia's carbon tax, Ontario's auction for carbon allowances, Alberta's levy of $20 CAD per ton on fossil fuel consumption in 2017, which has increased to $30 CAD per ton in 2018.

2.4. EXCISE DUTY REDUCTIONS

While the Canadian biofuels industry had received support from production and consumption subsidies, provincial subsidies have sunset and federal production subsidies ended March 2017. However, Canadian biofuels continue to benefit from provincial-level volumetric requirements stretching from British Columbia to Ontario, which range from 5% to 8.5% for ethanol and from 2 to 4% for renewable content in diesel. Quebec's Sustainable Development Action Plan would enact the province's first-ever volumetric requirements on renewables, starting at 5% for gasoline and 2% for diesel, by 2020.

2.5. FISCAL INCENTIVES AND INVESTMENT SUBSIDIES

Canada ranked 5th amongst the Organisation for Economic Co-operation and Development (OECD) countries for public expenditures on energy RD&D as a percentage of Gross Domestic Production (GDP) in 2012.

[30] This policy was approved to increase to 10% starting January 2020

Expenditures by the federal government, provincial governments and industry on renewable and clean energy through research, development and demonstration (RD&D) totalled approximately $ CAD 630 million in 2013/14. Bioenergy related research is being conducted across Canada in universities and colleges, federal and provincial laboratories, and industry.

RD&D has been supported at both the federal and provincial/territorial levels.

There are various types of government support provided in Canada for biofuels, spanning across all stages of the biorefining process. The type of support available includes:

- RD&D - Grants and low-interest loans
- Business planning - Grants for feasibility studies and market development
- Plant construction - Grants and low-interest loans, accelerated depreciation
- Production - Fuel tax exemptions, producer payments
- Price support - Mandated biofuel blending requirements and tariffs
- Distribution - Grants for storage and distribution infrastructure
- Consumption -Tax-breaks for the purchase of biofuel-consuming vehicles,

There are variety of investment subsidies that support or have supported the production and consumption of bioenergy and biofuels. Some of the largest incentive programs include:

- EcoEnergy for Biofuels had a $1.5 billion CAD budget over 9 years to boost Canada's production of biofuels. Administered by Natural Resources Canada, the ecoENERGY for Biofuels program ran from April 2008 to March 2017. This program provided incentive rates of up to $0.10 CAD/liter for renewable alternatives to gasoline and $0.26 CAD/L for renewable alternatives to diesel for the first three years, declining in the 6 years thereafter.
- The ecoAgriculture Biofuels Capital Initiative encouraged producer equity/ownership in biofuel facilities and was administered by Agriculture and Agri-Food Canada. The program helped fund projects that used agricultural feedstock to produce bio-fuels and required agricultural producer equity investments of 5% to meet eligibility requirements. This program was extended to March 2013, but is now expired.
- The Program of Energy Research and Development (PERD) is a federal, interdepartmental program operated by Natural Resources Canada (NRCan). PERD funds research and development designed to ensure a sustainable energy future for Canada in the best interests of both its economy and environment.
- NRCan’s Clean growth program is a federal program to advance emerging clean technologies toward commercial readiness so that natural resource operations can better reduce their impacts on air, land, and water, while enhancing competitiveness and creating jobs.
- Sustainable Development Technology Canada (SDTC) is a foundation created by the Government of Canada to support Canadian companies with the potential to become world leaders in their efforts to develop and demonstrate new environmental technologies that address climate change, clean air, clean water and clean soil. Since 2001, the Government of Canada has committed $1.364 billion CAD to SDTC.

There are also a number of new initiatives that support the development of clean technology, including bioproducts. In June 2017, the federal government announced a Low Carbon Economy Fund of $2 CAD billion to support projects that will generate clean growth and reduce GHG emissions towards meeting or exceeding commitments under the Paris Agreement. In addition, Canada is working with international partners through Mission Innovation. Mission Innovation aims to develop ways to produce, at scale, widely affordable, advanced biofuels for transportation and industrial applications.

Canada is playing a leadership role in the implementation of Mission Innovation, as a member of the Steering Committee, as co-lead of the Joint Research & Capacity Building and Business and Investor Engagement subgroups, and through its participation in the Information Sharing and Communications sub-group. Canada is also co-leading the Sustainable Biofuels Innovation Challenge - 16 countries looking to make progress towards implementing affordable, advanced biofuels for transportation and industrial applications. Finally, 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.

Innovation and Energy Technology Sector (IETS) is Canada's leading funding organization for clean energy RD&D. IETS supports energy innovation through its responsibility to: Fund energy RD&D in Canada (incl. private sector, academia, and government) via a suite of programs (OERD); Manage Canada's national energy laboratories (CanmetENERGY) and energy RD&D experts; Work with key stakeholders to strengthen Canada's energy innovation system; and House the Clean Innovation Task Team responsible for delivering a government-wide Clean Innovation Strategy. The vision is to position Canada for leadership in a sustainable, low carbon economy by promoting clean technology and innovation to capture clean jobs, market opportunities and strengthen our competitiveness

2.6. OTHER MEASURES STIMULATING THE IMPLEMENTATIONS OF BIOFUELS

Prior to the announcement of the federal carbon pricing framework, Canada's four largest provinces (BC, Alberta, Quebec and Ontario) already had carbon pricing in place that would meet the federal benchmark. As of February 2018, Manitoba and Nova Scotia are developing their own carbon pricing mechanisms to meet the federal benchmark. The remaining provinces, with the exception of Saskatchewan, have suggested joining the federal pricing system.

In 2008, BC introduced a carbon tax on the purchase and use of fuels. The tax covers approximately 70% of total GHG emissions in BC. Carbon tax rates started at $10 CAD per ton of carbon dioxide equivalent (CO_{2eq}) emissions in 2008, increasing by $5 CAD per ton each year until reaching the current rate of $30 CAD per ton of CO_{2eq} emissions in 2012.

Alberta began applying a levy of $ CAD 20 per ton on fossil fuel consumption in January 2017, and will raise the levy to $ CAD 30 per ton in 2018. This levy, implemented under the Climate Leadership Act, acts as a carbon tax on fossil fuels and exempts biofuels. All biofuels sold in Alberta must demonstrate at least 25% fewer greenhouse gas emissions than the equivalent petroleum fuel.

In November 2015, Alberta announced its Climate Leadership Plan, which intends to:

- Phase out pollution from coal-generated electricity by 2030 by introducing transition payments to owners of six coal units
- Triple renewable energy to supply 30% of generation by 2030, in part through an extension of the Bioenergy Producer Program (discussed below)
- Reduce emissions from the oil and gas sector

- Create Energy Efficiency Alberta to deliver cost saving programs
- Implement a province wide price on carbon

The plan is expected to be funded over the next three years by $ CAD 5.4 billion in gross carbon pricing revenue.

Alberta facilities that emit more than 100,000 tons of carbon dioxide equivalent (CO_{2eq}) per year, including electricity producers, were subject to the Specified Gas Emitters Regulation (SGER) from 2007 through 2017, and were required to reduce their baseline emissions intensity from July 2007 by up to 20% in each compliance period. From January 2018, facility-specific SGER targets have been replaced by an output-based allocation approach using product-level standards under the Carbon Competitiveness Incentive (CCI) Regulation. This approach aims to incentivize deployment of best-in-class technology in each sector, support investment, drive emissions reductions and maintain industry competitiveness.

Alberta's existing Bioenergy Producer Program was extended, with a revised, limited scope through March 2020. The $ CAD 63 million program will provide grants to dedicated biofuel-producing facilities, including:

- Liquid biofuels, such as biodiesel, ethanol and pyrolysis oil
- Biogas electricity production from farm-based anaerobic digesters
- Electricity produced from woody biomass

Some R&D funds are also available for biofuels under the $ CAD 225 million innovation stream in two program areas: Emissions Reductions Alberta ($ CAD 80 million) and Climate Change Innovation and Technology Framework ($ CAD 145 million).

Ontario passed legislation introducing a cap-and-trade system in May 2016 and held its first carbon allowance auction in March 2017. The province intended to link its system with carbon markets in California and Quebec in 2018.

In August 2017, Ontario opened a Low Carbon Innovation Fund (LCIF) of $ CAD 25.8 million to finance projects that would help reduce GHG emissions. The Low Carbon Innovation Fund is part of Ontario's Climate Change Action Plan and is funded by proceeds from the province's carbon market. Companies, entrepreneurs and eligible universities and colleges may apply for funding to create and commercialize new, globally competitive, low-carbon technologies that would help Ontario meet its GHG emissions reductions targets. The fund aims to support technologies in areas such as: alternative energy generation and conservation, new biofuels or bioproducts, next-generation transportation and novel carbon capture and usage technologies.

Quebec passed legislation introducing a cap-and-trade system (excluding transport biofuels) in 2012 and held its first carbon allowance auction in December 2013. The first joint California-Quebec carbon allowance auction was held in November 2014. Emission units not allocated free of charge are auctioned off by the government four times a year. A minimum price of $ CAD10.75 was set for 2013, which is scheduled to increase at a rate of 5% plus inflation every year until 2020. For joint auctions with California, the minimum price is set by retaining the higher of the two system's minimum prices at the exchange rate prevailing at the time of the auction.

In October 2016, Quebec became the first province in Canada to introduce a "zero emission vehicle standard," by adopting a bill to encourage automakers to improve their zero-emission vehicle (ZEV) offer. The ZEV mandate is an approach developed in the United States that imposes penalties on automakers that do not sell enough electric vehicles. While Ontario and British Columbia encourage

ZEV ownership by offering financial incentives, Quebec will place the onus on vehicle manufacturers by requiring them to meet ZEV sales targets. Now that the bill has been adopted, the process of adopting the legislation has begun. Mandatory sales reporting by manufacturers is expected to begin when the legislation is adopted, likely in 2018.

In February 2017, Environment and Climate Change Canada (ECCC), issued a discussion paper explaining its intention to consult with provinces, territories, stakeholders as well as Indigenous Peoples on a national regulation to reduce Canada’s GHG emissions through increased use of lower carbon fuels and alternative technologies.

At the federal level, there are a number of programs that support R&D of bioenergy. For example, the AgriInnovation program of Agriculture and Agri-Food Canada is designed to accelerate the pace of innovation by supporting R&D activities and facilitating the demonstration, commercialization and/or adoption of innovative products, technologies, processes, practices and services.

The Canadian Forest Service (CFS) of Natural Resources Canada has identified the emerging bioeconomy as an important driver for transformation and change in the Canadian forest industry. CFS scientists are conducting research to determine biomass availability and sustainable harvesting guidelines. Through programs such as the Transformative Technologies Program, CFS supports the innovation of renewable energy and novel pre-commercial products and processes. Importantly, CFS conducts economic and market research on bioenergy, bioproducts, and biochemicals to estimate the size and potential of the Canadian industry.

The Office of Energy Research and Development of Natural Resources Canada manages a suite of programs to support the advancement of bioenergy such as the Program of Energy Research and Development, the ecoENERGY Technology Initiative, the Clean Energy Fund and the ecoENERGY Innovation Initiative. These programs fund bioenergy research and development both within and outside the federal government, along with demonstration projects across Canada, in order to support energy technology innovation that produces and uses energy in a cleaner and more efficient way.

The Agricultural Bioproducts Innovation Program is a $ CAD 145 million grant that mobilizes research networks that conduct scientific research projects with a specific focus on developing effective and efficient technologies for an agricultural biomass conversion; evolve beyond bio-fuels production to a sustainable, bio-based economy. The program runs on a multi-year basis.

The Natural Sciences and Engineering Research Council of Canada (NSERC) supports research and innovation undertaken by universities and companies. NSERC funds scholarships, fellowships, research chairs, strategic projects and networks. Relevant networks include The BiofuelNet Network of Centres of Excellence (2012 - 2017), the recently completed NSERC Bioconversion Network, the NSERC Biomaterials and Chemicals Strategic Network (2010 - 2015) and the NSERC Industrial Biocatalysis Network (2014 - 2019). In 2015, NSERC undertook a review of the research priorities for its Strategic Partnership Grants, the goal of which is to increase research and training in targeted areas that could strongly enhance Canada’s economy, society and/or environment within the next 10 years. Bioenergy and Bioproducts are one of four research areas under the Natural Resources and Energy Target Area.

2.7. PROMOTION OF ADVANCED BIOFUELS

Though Canada's production of biofuels using advanced technology platforms is limited, federal and provincial policy incentives favouring lower carbon intensity biofuels would provide additional support to advanced biofuels production in Canada. Canada has developed significant expertise in the development of technologies to convert non-food based feedstocks to ethanol. Examples of key players and current foci:

- Carbon Engineering – direct air capture of CO_2 and subsequent gasification to produce Fischer–Tropsch (FT) liquids
- Enerkem – gasification (municipal residues) and catalysis
- Ensyn – pyrolysis-based technology for renewable heating fuel and refining coprocessing to transport fuels
- Greenfield Global – integration of grain-based and cellulosic-based ethanol production
- Iogen – enzymatic hydrolysis (agricultural residues) and biogas-based fuels
- Forest Products Biotechnology and Bioenergy Research Group from the University of British Columbia (UBC) - pre-treatment of softwoods

Although Canada's production of biofuels using advanced technology platforms is limited, federal and provincial policy incentives favouring lower carbon intensity biofuels provide additional support to advanced biofuels production in Canada. Two Canadian firms have achieved, or will soon achieve, commercial-scale production. Enerkem makes cellulosic methanol and ethanol (which can be used as fuel or other industrial chemicals) from syngas by recycling carbon in non-recyclable municipal solid waste (MSW).

In 2014, Enerkem launched the world's first full-scale MSW-to-biofuels and chemicals facility in Edmonton, Alberta. Enerkem's Edmonton plant started producing only methanol, but with the addition of a methanol-to-ethanol converter unit, the plant also began producing ethanol in 2017, with a current annual methanol-ethanol production capacity of 38 million liters. The Edmonton plant became the first ever MSW-to-cellulosic ethanol plant certified to meet renewable fuel obligations under the U.S. Renewable Protection Standard (RFS) and to generate Renewable Identification Number (RIN), having received U.S. Environmental Protection Agency (EPA) pathway approval in 2017. Also, in 2017 its ethanol scored the lowest carbon intensity value ever issued by the British Columbia Ministry of Energy and Mines under BC's Renewable and Low Carbon Fuel Requirements Regulation.[31]

Ensyn Technologies Inc., established in 1991, began its focus on renewable fuels in 2005 with the commissioning of its 70 dry tons/day plant in Renfrew, Ontario, which was initially designed to produce renewable fuels and chemicals and then retooled in 2014 to focus on heating oil and fuel. Ensyn transforms woody biomass into pyrolysis oil that can be used as a biocrude feedstock and co-processed at refineries to produce lower carbon fuels and chemical feedstocks, used as a renewable fuel oil for heating and cooling, or to produce specialty chemicals. In 2014, Ensyn Corporation converted its production plant in Renfrew, Ontario to a dedicated fuels facility with a 12 million litre/year production capacity. Using Ensyn's patented RTP® pyrolysis technology, this plant has been supplying renewable heating fuel to clients in the Northeast US since 2014.

[31] Enerkem Website

Production capacity is also being used to develop and demonstrate refinery co-processing, and the use of Ensyn's pyrolysis oil as a renewable biocrude feedstock for petroleum refineries. In 2016, construction began on the Cote Nord Project at Port Cartier, Quebe, a 50/50 joint venture between Ensyn and Arbec Forest Products. This plant will have a capacity to transform forest residues using rapid thermochemical liquefaction into 40 million liters/year of biocrude. Project commissioning was scheduled to begin at the end of 2017, with product offtake focusing initially on heating markets in the northeast U.S. and eastern Canada as well as a renewable feedstock for petroleum refinery coprocessing to produce lower carbon transport fuels[32].

In its recent joint project, Ensyn, Arbec Forest Products and Groupe Rémabec started the development of 40 million litres/year biocrude production facility, located in Port-Cartier, Quebec. The project will convert approximately 65,000 dry metric tons per year of slash and other forest residues from local sources to biocrude. The biocrude will be sold to customers in the U.S. Northeast and in Eastern Canada for heating purposes and as a renewable feedstock. Project start-up is scheduled for mid-2018.

In 2016, Canfor Pulp Products Inc. (CPPI), a global producer of premium pulp and paper, and Licella Fibre Fuels Pty Ltd. (Licella), an Australian biofuels production start-up, formed a joint venture to use Licella's technology to economically convert biomass into biocrude. Using Licella's first-of-kind Catalytic Hydrothermal Reactor (Cat-HTR) technology that converts lower-value biomass from wood waste and pulp mill waste to lower carbon sustainable biofuel, the companies intend to convert residual wood and by-product streams from the CPPI Kraft pulp mills in Prince George, BC, Canada, into biocrude oil which can be co-processed by existing refineries into next-generation biofuels and biochemicals.

The joint venture follows preliminary trials conducted in Australia where Licella successfully converted residual sawmill wood and pulp mill by-product streams originating from CPPI Kraft processes into a stable biocrude oil. In 2019, the joint venture project team plans to continue to advance this technical development and the engineering phases of the project have commenced. The goal is to commission a commercial demonstration scale plant in 2022 that would produce between 100,000 and 400,000 barrels/year of biocrude.

2.8. MARKET DEVELOPMENT AND POLICY EFFECTIVENESS

Figure 15 shows the consumption of transportation fuels in Canada from 2010 to 2016. As this figure shows, there was a steady increase in the consumption of ethanol over this period. The volume of ethanol consumed annually increased from about 1,700 million liters in 2010 to 2,800 million liters in 2015. The volume of biodiesel consumed annually also increased over the same period from about 110 million liters in 2010 to 470 million liters in 2015. Hydrogenation derived renewable diesel (HDRD) is also blended into diesel though in smaller volumes. The amount of HDRD being blended is estimated to have increased from 37 million liters in 2010 to 300 million liters in 2016.[33]

Since 2012, the United States (FAME biodiesel and, in recent years, HDRD) and Singapore (HDRD) have supplied between 85% and 100% of Canada's total imports of renewable fuels for diesel blending, with the EU making up the difference. Figure 7 and Figure 8 present Canada's consumption of ethanol and biodiesel and HDRD, respectively, indicating the feedstocks used and their associated avoided GHG emissions. Biofuels consumption has avoided 24.9 Mt of CO_{2eq} between 2010 and 2016.

[32] Ensyn Website
[33] Navius Research, 2018

Annual avoided GHG emissions have grown from 1.8 Mt in 2010 to 4.1 Mt in 2016. Trends in biofuel carbon intensities in BC indicate that biofuel production is becoming less emissions intensive[5]. Following, Figure 9 shows the Consumption of biodiesel and HDRD in Canada by fuel type and feedstock, from 2010 to 2016.

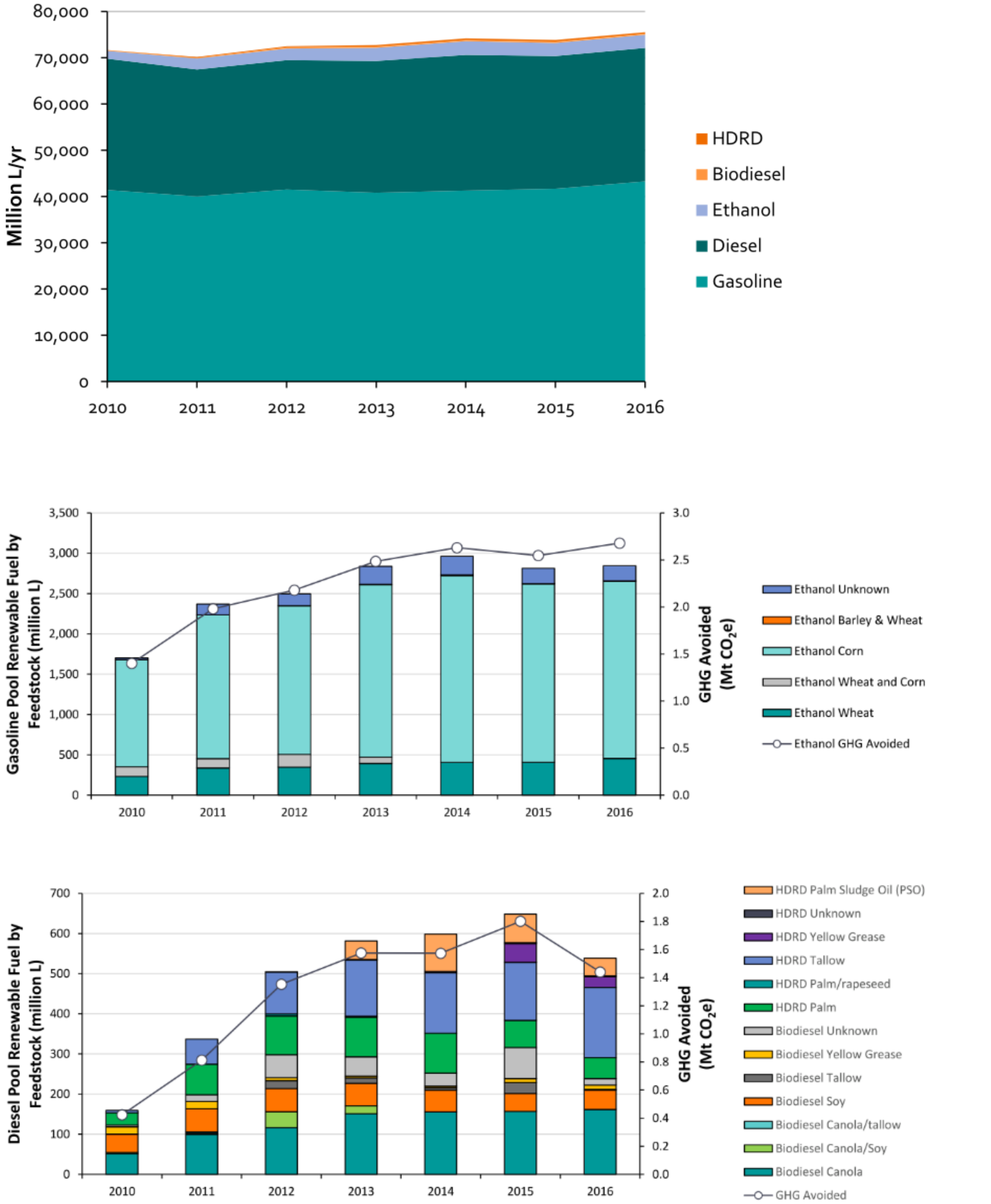

Figure 9. Consumption of biodiesel and HDRD in Canada by fuel type and feedstock, 2010-2016[32]

In 2016, Canadian fuel ethanol utilization exceeded the federal use mandate (2,346 million liters of ethanol), at 2,843 million liters (6% ethanol in gasoline pool). However, for the purposes of the mandate, compliance units can be carried forward into a future compliance period, carried back for use in a previous compliance period, or cancelled if required to do so. Given the availability of suitable agricultural feedstocks and an interest to support rural development, a large portion of Canada's ethanol demand is met through domestic production.

There are currently 11 operating ethanol plants in Canada with an estimated 1.7 billion liters of annual production capacity, which represents about 60% of total ethanol demand.[34] On average, the United States supplies 98% of Canada's ethanol imports. As Canada imports ethanol to meet the federal blend mandate, there are generally no ethanol exports.[35] Ethanol production has been nearly constant since 2011, with plants operating at or near full capacity. It is expected that fuel ethanol production will grow to 1,880 million liters in 2018 on limited capacity expansion projects and facilities continuing to operate at or near capacity. Feedstock choice for ethanol plants has largely been driven by differences in geography and agronomy.[8]

Grain corn is the dominant feedstock, grown predominantly in Ontario, Quebec and Manitoba. Low protein, high starch wheat varieties are used in Alberta and Saskatchewan, and Manitoba uses both wheat and corn. There has been an increasing interest in developing corn varieties that can be grown in Western Canada. As more corn varieties are developed with lower heat unit requirements, it is expected that corn use for ethanol production will increase in Saskatchewan and perhaps Alberta.[8]

In 2016, 4.225 million metric tonnes of feedstocks were purchased by the ethanol industry. Between 2014 to 2016, two facilities switched feedstocks from wheat to corn in order to increase throughputs (the higher starch content in corn provides a greater ethanol yield) and improve production economics. It is estimated that in 2014, 78% of Canadian ethanol production was derived from corn and 22% from wheat. By 2016, corn contributed 81% of ethanol production, with wheat falling to 19%. It is anticipated that this corn/wheat split was similar in 2017 and will remain so in 2018 due to the location of plants in/around major corn producing regions.[8]

Canadian biodiesel production capacity has remained well below domestic demand since 2011, and in 2017 there was no commercial production of renewable diesel in Canada. In 2017, there were nine commercial FAME biodiesel production facilities in operation with total national biodiesel production capacity of 591 million liters per year. Most of Canada's biodiesel is produced from used cooking oil and animal fats, with the remainder being derived mainly from canola oil. The national market for biodiesel/renewable diesel will evolve further as provincial markets develop and implement clean fuel standards, a process already underway in some provinces. Based on the current federal mandate of 2% blending in diesel, about 600 million litres is required annually.[8]

[34] Renewable Industries Canada and NRCan, 2018
[35] USDA, 2018

In recent years, much of Canada's biodiesel production has been exported to the United States in response to U.S. biomass-based diesel tax support, RIN support, and U.S. EPA rule-making for obligated volumes under the U.S. RFS, which continues to grow U.S. demand for biodiesel. Canada imports sufficient volumes of FAME biodiesel and renewable diesel to meet Canadian blending requirements. In 2016, Canadian biodiesel exports increased 74%, reaching 464 million liters. In 2017, biodiesel exports fell from the record high 464 million liters to 350 million liters in response to reduced U.S. consumption.

New U.S. legislation excluding foreign-sourced biomass-based diesel from the tax credit would severely reduce, if not completely halt, Canadian exports of biodiesel to the U.S. Such a policy shift would be expected to push more Canadian biodiesel into Canadian distribution channels and reduce Canadian imports of biodiesel.[36]

The economic impact of the construction phase of renewable fuels plants, at 2013 replacement cost prices, was assessed to include a total direct investment of $ 2.69 billion CAD and total net economic activity of $ 4.38 billion CAD. The employment impact is the creation of 22,874 direct and indirect jobs during the respective construction periods.[37]

[36] USDA, 2018
[37] CRFA, 2013

3 GERMANY

3.1. INTRODUCTION

In Germany, about 30% of total energy demand (approximately 8.996 PJ in 2018) relates to the transport sector, of which just approximately 4% are renewable fuels.[38] This share has decreased in the past few years, but is still mainly covered by biofuels that are used for road transport. However, the share of GHG emissions from transport has slightly decreased from 165 Mt in 1990 to about 164 in 2018 (163,6 Mt). The transport sector contributes about 19,7% to the total GHG inventory in in Germany.

For comparison, the transport share in the country GHG emissions inventory was 13,5% in 1990.[39] In the light of the Paris agreement, CO_{2eq} emission reduction of the transport sector is now a high priority in Germany. According to the German climate protection plan, the GHG reduction target for transport is 40 to 42% until 2030 (compared to 1990).[40] Over the same time period, an increase in freight transport of about 38% and in personal transport of about 13% is forecasted by 2030 (compared to 2010).[41] This has to be accompanied by the given challenges in fulfilling emissions standards in the context of energy and transport mode.

In this light and pushed by debates (e.g., on bans for combustion engines as result of the “diesel scandal”) in Germany, there are ongoing serious discussions about making a paradigm change to establish renewable based electro mobility and renewable fuels like hydrogen and power based synfuels (so-called power-to-X (PtX) fuels, e.g., power-to-gaseous fuels (PtG) or power-to-liquid fuels (PtL)) in addition to or instead of biofuels. Especially for transport sectors like aviation, heavy duty road transport and cargo shipping, there are enormous challenges to implement powertrains driven by electrical energy; electrical power is not an option or only to a minor extent for these transport sectors.[42]

3.2. DRIVERS FOR BIOFUEL POLICIES

Taking into consideration 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, Germany will be subject to Article 17 of the RED 2009/28/EC “Promotion of the Use of Energy from Renewable Sources” that states that GHG savings from biofuels, compared to fossil fuels, must exceed 35% as of 2009, 50% as of 2017, and 60% as of 2018 (if the production line started in or after 2017).[43]

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[38] BMU, 2016; UBA, 2020
[39] BMWi 2019, 2015
[40] BMU, 2016
[41] BMVI, 2020
[42] Müller-Langer et al., 2016
[43] European Parliament, 2009a

3.3. BIOFUELS POLICIES AND OBLIGATIONS

The most important instruments for decarbonizing the transport sector in the EU along the whole value chain or well-to-wheel (WTW) or well-to-tank (WTT) are (i) related to the fuel side, a target of 10% sustainable renewables in transportation according to the RED 2009/28/EC and 6% GHG emission reduction from road fuel suppliers by 2020 according to the FQD Directive 2009/30/EC[44] and (ii) related to the vehicle side or tank-to-wheel (TTW), CO_2 emission standards for cars and vans and legislation for a broad market introduction of clean and energy-efficient vehicles (Regulation (EC) No 443/2009; Regulation (EU) No 333/2014; Regulation (EU) No 510/2011; Regulation (EU) No 253/2014)[45] or (iii) related to, e.g., the aviation side or tank-to-wake (TTW), with targets for biofuels and low carbon fuels.

However, in the current policies there is no direct link or harmonization between WTT and TTW emissions; the first considers GHG emissions (e.g., including all CO_2 equivalents such as methane and nitrous oxide), whereas the latter considers just CO_2 emissions related to fuel combustion for driving vehicles. Figure 10 shows the Climate protection plan of German Federal Government between 2020 and 2030, taking into account (i) energy, (ii) industry, (iii) transport, (iv) buildings and (v) agriculture.

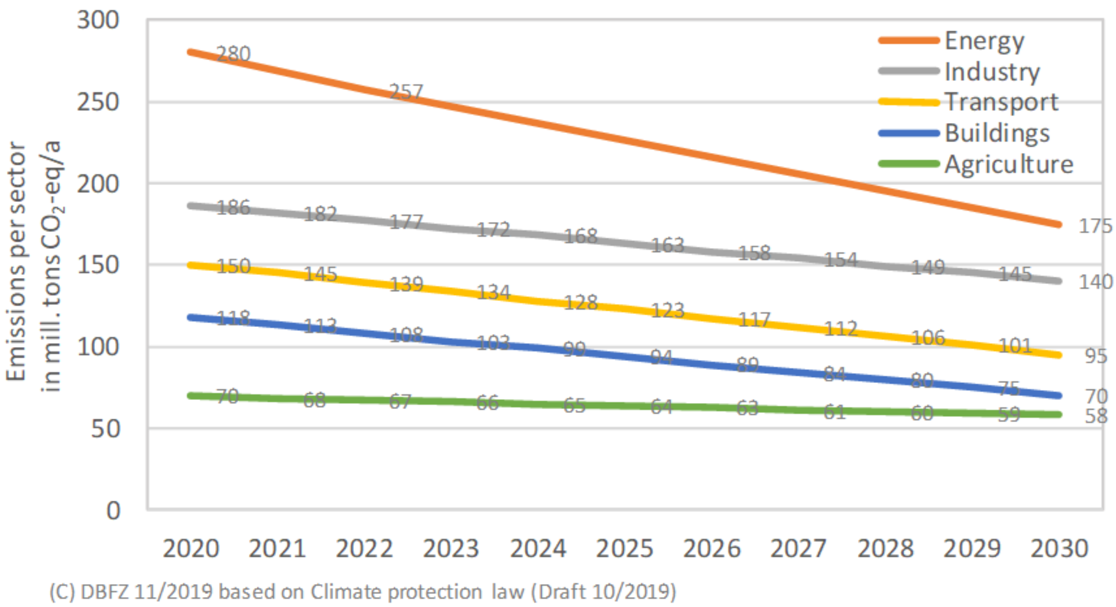

Figure 10. Climate protection plan of German Federal Government[46]

Moreover, with the Directive on the deployment of alternative fuels infrastructure[47], member states are required to develop national policy frameworks for market development of alternative fuels (mainly electricity, CNG, LNG and hydrogen) with regard to infrastructure requirements. In addition, the Energy Taxation Directive (ETD) is binding and sets minimal taxation rates for energy carriers.

For the WTT-related part, RED and FQD have been implemented at the EU Member State (MS) level. Up to now, member states differ significantly in setting policy instruments and measures. Most of them have shifted away from financial instruments towards quota systems for fuel suppliers.

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[44] European Parliament 2009b
[45] European Parliament 2014c; 2014d; 2011; 2009c
[46] DBFZ, 2019
[47] European Parliament, 2014b

For the time frame post-2020, only general, not sectoral related, binding targets until 2030 are set which are: (i) about 40% GHG emission reduction compared to 1990, (ii) 27% share of renewable energies related to energy consumption at EU level and (iii) 27% improvement in energy efficiency (COM(2014) 15).[48]

In 2016, the EU set an overall frame with its European strategy for low-emission mobility (COM(2016) 501).[49] More recently, the EU approved a revised RED – (RED II) which includes a biomass and biofuel sustainability policy that addresses also quotas for advanced biofuels and criteria for electricity-based heating and cooling. RED II includes for instance targets such as 14% renewable energies in transport by 2030, limits for conventional biofuels, and minimum shares for advanced biofuels.

Starting in 2015 and until 2020, the GHG quota is the binding regulation for promotion of biofuels in Germany, making the EU FQD leading instead of the original RED.

In Germany, the European directives and regulations are implemented adequately by §37 BImSchG (Federal Immission Protection Act) including BiokraftNachV (related to original RED) and 36. BImSchV (related to FQD) and the EnergieStG (related to ETD). In 2014, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety published the draft of the twelfth law amending the BImSchG, which includes a change in GHG reduction targets (3,5% from 2015/4% from 2017/ 6% from 2020). In addition, it contains numerous enabling provisions which will simplify the implementation of future European law into national law.

As the first and probably only European member state to do so, Germany shifted from an energy-related quota to a GHG-related quota starting in January 2015, making the FQD the leading policy instead of the original RED. This means that fossil fuel supplier companies will be obligated to sell their respective biofuel or renewable fuel with its fossil counterpart gasoline or diesel (which is usually done through blending), in order to produce a fuel mixture which achieves a 3,5%/4%/6% GHG mitigation (compared to fossil gasoline and diesel mix) for the entire fuel sector from 2015/2017/2020 onwards.

The target continues after 2020 at a fixed level of 6%. Biofuels are currently the only way to fulfil the target, however other policy instruments are anticipated to follow. Because only actual emission savings count towards the quota (e.g., double counting is not allowed; GHG emissions of biofuels must be calculated on a life cycle basis according to the GHG methodology described in RED/FQD), the exact increase in biofuels depends on its specific GHG intensity: the higher the specific GHG mitigation potential, the lower the renewable fuel consumption required to fulfil the quota.

The quota target has to be achieved by companies placing fossil fuels on the market over the calendar year (e.g., with possible variations throughout the year and in different regions). Additional GHG quota shares above the annual target may be used to meet the following year's target. Moreover, obligated entities can delegate their quota requirements to a third party through bilateral contracts. In the case of non-fulfilment of obligations, penalties of about 47 EUR ct/kg CO_{2eq} as well as 19 EUR/GJ are binding.

Taking into account biofuels obligations, from 2010 until the end of 2014, Germany had an overall biofuel target which mandated the use of at least 6,25% biofuel (in energy content) in all transport fuel. During this period, differentiated biofuel targets were also in place including at least 2,8% biofuel in gasoline and 4,4% biofuel in diesel.

[48] European Parliament, 2014a

[49] European Parliament, 2016

Mandates or biofuel volume obligations have been shifted from an energy related quota to a GHG-based quota in 2015. Germany is the first EU member state to implement a GHG related quota: from 2015, 3,5% GHG mitigation; from 2017, 4%; and from 2020 onwards, 6% (GHG mitigation compared to fossil gasoline and diesel mix) for the entire fuel sector.

The 38. BImSchV legislation regulates limits on the maximum energetic share of conventional biofuels such as FAME biodiesel, ethanol, and HVO/HEFA fuels produced from food-competing feedstocks as well as establishes mandates for advanced fuels according to EU RED.

The carbon intensities of biofuels are considered indirectly via the national application of the binding methodology of EU RED within the BioKraftNachV, with minimum GHG reduction potentials of 35% and 50% for all facilities from 2018, and for new facilities from 10/2015, and 60% for new facilities from 2017 (the average GHG mitigation potential in 2016 was about 73%). In addition, a carbon tax is indirectly applied via CO_2 tax for passenger cars (KraftStG).

Germany is evaluating specific policies to promote advanced biofuels. There are no specific policies promoting aviation biofuels (however they can qualify for incentives). There are no financial incentives for advanced/new biofuels, making it quite difficult for new biofuels to penetrate into the fuel market, even with the GHG quota; an appropriate advanced fuel quota will be probably established that will help contribute to the commercial implementation of such fuels.

The Federal government has authorized the “Bundesanstalt für Landwirtschaft und Ernährung” - Federal Institute of Agriculture and Nutrition (BLE) to guide and supervise biofuels certification. The BLE is responsible for controlling the sustainability certification systems to be used, in accordance with RED certification bodies and the web-based documentation system called “Nabisy”. Figure 11 summarizes the targets and policy measures for the transport sector in Germany.

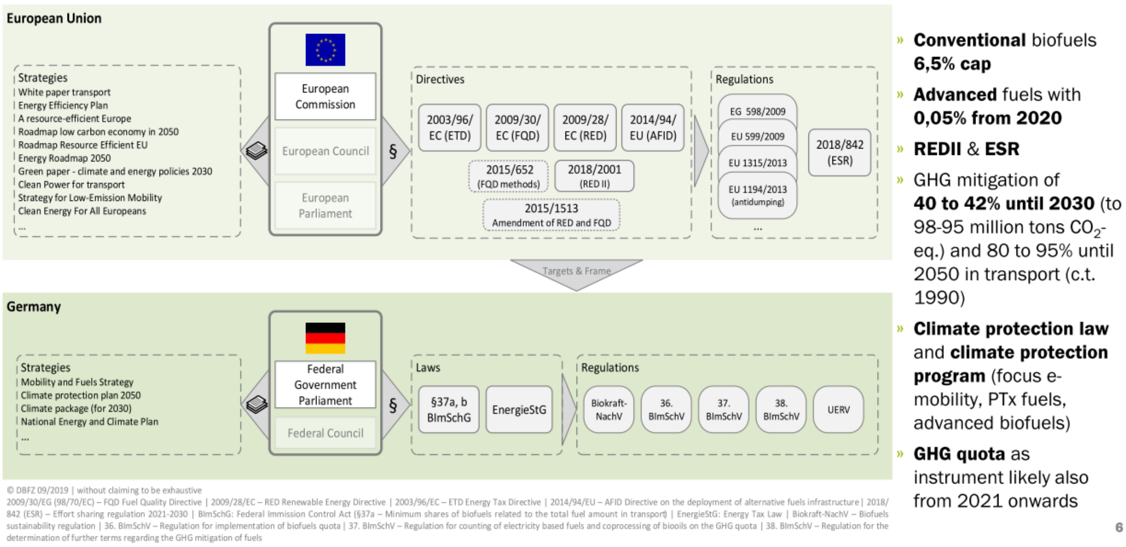

Figure 11. Targets and policy measures (GHG quote) for the transport sector in Germany[50]

50 DBFZ, 2020

3.4. EXCISE DUTY REDUCTIONS

According to the German Energy Tax Law, since 2018 there is no tax relief for FAME biodiesel, HVO/HEFA fuels, vegetable oils or ethanol. FAME biodiesel, HVO/HEFA fuels and vegetable oils have the same fuel tax as diesel fuel (€ 0,4104/liter). Ethanol has the same fuel tax as gasoline fuel (€ 0,6545/liter). The fuel tax for CNG and biomethane is € 0,0139/kWh until 2023, increasing progressively until € 0,0318/kWh in 2027. Only biofuels used for agriculture or forestry remain fully tax exempted.

In addition, carbon taxes are indirectly applied via a CO_2 tax on passenger cars. In Germany, a toll is payable for the use of federal highways for motor vehicles whose total weight is at least 7,5 tons. This toll is not payable when using vehicles powered by natural gas in the period from 1.1.2019 to 12.31.2020. After this period, the vehicles will pay toll composed of infrastructure costs (0,08 to 0,174 EUR/km), air pollution (0,011 to 0,085 EUR/km) and noise pollution (0,002 EUR/km).[51]

3.5. FISCAL INCENTIVES

Currently, there is no fiscal incentives for biofuels in Germany.

3.6. INVESTMENT SUBSIDIES

Not relevant for biofuels but for electro mobility, there is a financial support, which in June 2020 was increased to up to 9.000 EUR for plug-in battery electric vehicles (BEVs), up to 6.750 EUR to plug-in-hybrid vehicles (PHEVs), and for loading stations up to 4.500 EUR (and for some municipalities up to 6.000 EUR).[52] The list of cars supported can be found in the list of the Federal Office of Economics and Export Control (Bundesamt für Witschaft und Ausfuhrkontrolle), and the municipalities benefits in the list of the General German Automobile Club (Allgemeiner Deutscher Automobil-Club e.V.).

3.7. PROMOTION OF ADVANCED BIOFUELS

In Germany, there are recognizable projects on advanced transport biofuels at different TRLs 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 EU RED. Capacities for lignocellulosic fuels remain quite low, however. This is also true for electricity-based fuels such as PtX fuels (e.g., hydrogen, synthetic natural gas or liquid hydrocarbon fuels).

There were and are different funding programs for RD&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).

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[51] BMJV, 2019; Naumann et al., 2019
[52] BAFA 2020a; 2020b

Table 8. Overview on ongoing process developments and infrastructure on biofuels for transportation being carried out at pilot and demo levels in Germany

Type of biofuel/ conversion route	Process characteristics,	TRL/FRL, Capacities	Stakeholder in research and industry in Germany
Biooil from pyrolysis as fuel intermediate	Flash pyrolysis of different biomasses, catalytic upgrading to fuel components and slurry production for gasification	Bioliq® demo plant, 2 MW pyrolysis, TRL 5	Karlsruhe Institute of Technology (KIT)
Biocrude from hydrothermal processes as fuel intermediates	Bioethanol & Chem. | wood; lignocellulose pre-treatment (organosolv method), fermentation, enzyme production, organosolv lignin, sugars (for ethanol and various platform chemicals)	Fraunhofer CBP pilot plant in Leuna, operational since 2013, TRL 4-5 lignocellulose pre-treatment: 1 t wood/week, expanded in the period 03/2016-09/2019	Fraunhofer CBP, Deutsches Biomasseforschungszentrum (DBFZ), Thyssen, Linde Engineering
	Hydrothermal liquefaction	Lab / technical plants, TRL 3	DBFZ, KIT, Uni Hohenheim, TI
	Hydrothermal liquefaction & gasification	Pilot plant Verena, TRL 5-6	KIT
BTG | Syngas for Methanol, chemical products	Pre-treatment and gasification	TRL 6-7 - Pilot Plant - 25.000 tons from coal, waste or residues processed per year (planned for 2021)	CARBOTRANS project, TU Bergakademie Freiberg, Merseburg University of Applied Sciences, Fraunhofer IMWS and others
BTL | H_2-rich synthesis gas, bio-coal and bio-oil	Thermo-Catalytic Reforming (TCR©), Pressure Swing Adsorption and Hydro Deoxygenation	TRL 6-7 - Demonstration Plant (1/5/2017 - 30/4/2021) in Sulzbach-Rosenberg	Fraunhofer CBP (Coord.), Zweckverband Müllverwertung Schwandorf and others
Bioethanol (fermentation)	Cellulosic ethanol from agricultural residues like wheat and maize straw	Demo plant sunliquid® in Straubing, operational since 2014, TRL 7, FRL 6 1.000 t/a (from 4.500 t/a straw). Building a 50.000 t/aplant in Romania and signed license agreement in Slovakia and China	Clariant
	Bioethanol from corn-stover, grass and other agriculture waste	TRL 4-5 - Pilot Plant (30 t/y) - focus on development of a commercial yeast for cellulosic ethanol*	Lesaffre (aquired Butalco plant in Stuttgart)
Isobutene (fermentation)	Fermentation	Demonstration plant (TRL 6)	Fraunhofer CBP / Global Bioenergies
HVO/HEFA	Hydrotreating processes, different feedstocks	Technical units, TRL 2-3	TU Bergakademie Freiberg (TUBAF), VT Schwedt
HCVO (Hydrotreated Cracked Vegetable Oil)	2-step process for different feedstocks: 1st step = SRD (Solvolytic Reactive Distillation) for cracking and deoxygenation: intermediate product = CVO (Cracked Vegetable Oil) 2nd step = hydrotreating: product = HCVO	TRL 6 pilot project (X-Energy/READi™-PtL project) 2019-21: capacity of SRD READi™ process pilot plant = 2 tons per week UCO; plant under construction (planned commissioning 2021)	HAW Hamburg, Nexxoil, KBS Krebs Brüggen Sekundärrohstoffe
BTL | Methanol / DME /gasoline and other fuels	Bioliq process, fast pyrolysis, entrained flow gasification, hot gas cleaning, synthesis	5 MW gasification 40-80 bar (TRL 6-7), 2 MW gasoline synthesis (TRL 7)	Bioliq-project, KIT, Chemieanlagenbau Chemnitz, Air Liquide
BTL | Fischer-Tropsch	Micro-structured reactor module	2-50 bpd container plant, TRL 5, syngas transfer from bioliq plant	EnergyLab2.0 at KIT, INERATEC

BTL | Kerosene	Thermo-Catalytic Reforming (TCR©), Pressure Swing Adsorption, Hydro Deoxygenation and Hydro cracking/ isomerization	TRL 6-7 – Demonstration Plant – Scale and Location to be determined (probably near TCR© Susteen plant)	University Birmingham (Coord.), Fraunhofer Umsicht, Susteen Technologies, BIGA Energie GmbH, and others
BTG | FT Liquids	Pre-treatment, gasification, syngas formation and FT Synthesis	TRL 4-5 – Pilot plant. Utilization of infrastructure from TUDA pilot plant in Darmstadt with other modules. Planning construction	TU Darmstadt, Aichernig Engineering GmbH, and others
XTL | Methanol, gasoline	HP-POX gasifier (Since 2003), FlexiSlag gasifier (since 2013) and GSP gasifier (since 2018). STF synthesis pilot plant	TRL 6-7 - 5 MW (gasifier) and 10 MW (synthesis) and 120 L/h gasoline output by the STF gasoline pilot plant, which can also synthetize methanol	TUBA Freiberg, Air Liquide, Chemieanlagenbau Chemnitz
	2-stage hydrothermal liquefaction, refining	Technical plant, TRL 4	DBFZ and partners
Biomethane via biogas (fermentation)	Straw fermentation, fertilizer production; (additional: Bioethanol plants (grain, sugar beet) and biogas	Commercial plant, 16,5 MW (136 GWh/a) from 40 kt/a straw, TRL 8, FRL 8 (260 kt/a bioethanol + 480 GWh biomethane)	VERBIO AG
Biomethane via gasification	Gasification, gas conditioning, methanation	Plant units at technical labs	KIT/EBI, Uni Erlangen, DBFZ, ZSW, CUTEC
	Gasification, catalytic honeycomb methanation (mobile container), compression	TRL 5, 60 kW (CH_4)	DVGW/EBI, KIT/EBI
Bio-LNG	Gasification or renewable CO_2 + H_2O-electrolysis, catalytic three phase methanation	TRL 5, 100 kW (CH_4)	KIT/EBI
	High pressure fermentation + electrolysis + biological methanation + liquefaction	TRL 5, 15 kW (CH_4)	Uni Hohenheim, DVGW-EBI
Biomethane (Bio-CNG/LNG)	Anaerobic fermentation in combination with hydrothermal processes and methanation	Technical pilot plant by end of 2021 including components with TRL 4 – 9	DBFZ, UIT
Different fuels	Fuel science center (formely Tailor-made fuels from biomass) Biomass pretreatment; enzymatic + catalytic biomass processing; synthesis and conversion to platform molecules and fuels	Lab units	RWTH Aachen, Fraunhofer IME, Max-Planck-Institute

* Bacovsky, 2020

In addition, the topic of so-called PtX (ie., PtG or PtL fuels or chemicals, also called electrofuels) is gaining an increasing interest, especially in context of the German energy transition and increasing shares of renewable electricity. PtL is viewed as carbon neutral and clean fuel by different OEMs. There are different projects on PtL ongoing in Germany, with examples including:

- PtL demo plant (160 l/day) of Sunfire in Dresden, co-financed by the Federal Ministry of Education and Research (BMBF)
- Planned PtL demo plant in Lünen using CO_2 exhaust gases from the lignite power plant of Steag Lünen, together with Mitsubishi Hitachi Power Systems Europe (MHPSE), Carbon Recycling International (CRI), co-financed by EC Horizon 2020

- PtX integrated into the Helmholtz EnergyLab2.0, a platform combining different energy conversion and storage technologies with overall process control and simulation, on site at KIT with KIT, DLR and FZJ as partners. Innovative technologies are considered such as micro-reaction FT synthesis for PtL, reverse water gas shift reaction, co-electrolysis and others for syngas generation, PtG by different reactor systems, and development of catalysts and catalytic processes from lab to pilot.
- Hydrogen cluster HYPOS pushing the production of electrolytical hydrogen and methanation to synthetic natural gas

Currently, there are important funding programs for RD&D that are addressing advanced fuels and – to a minor extent - also biofuels. In general, there has been a decrease in funded projects related to biofuels. Funding programs include for instance:

- 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.
- 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 PtX)
- Federal Ministry of Transport and Digital Infrastructure (BMVI), within the frame of mobility and fuel strategy projects like, e.g., research and demonstration project on the use of renewable jet fuel at Airport Leipzig/Halle (DEMO-SPK) which deals with the supply and use of multi-blend 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 project on the production and demonstration of drop-in hydrocarbon fuels for soon implementation and use in the existing vehicle fleet.

3.8. MARKET DEVELOPMENT AND POLICY EFFECTIVENESS

Currently the market is mainly based on conventional renewable fuels which are expected to remain dominant at least until 2020. For advanced biofuels, there are many RD&D activities. However, there are only a few production plants. The development of production and use of conventional biofuels such as FAME biodiesel, ethanol, HVO/HEFA fuels and biomethane is shown in 4. There is no production capacity for HVO/HEFA fuels in Germany. Biomethane is produced in significant capacities but for different markets; just a share of roughly 4% is used for transport applications. Pure vegetable oils as fuels (PVO) (annual volume in the range of 5,4 million t/a (6,2 billion liters/year) in 2018[53] are not presented separately due to these also being used as feedstocks for FAME biodiesel and several other uses. Following, Figure 12 shows the production of conventional biofuels in Germany.

[53] OVID 2018b, 2018a

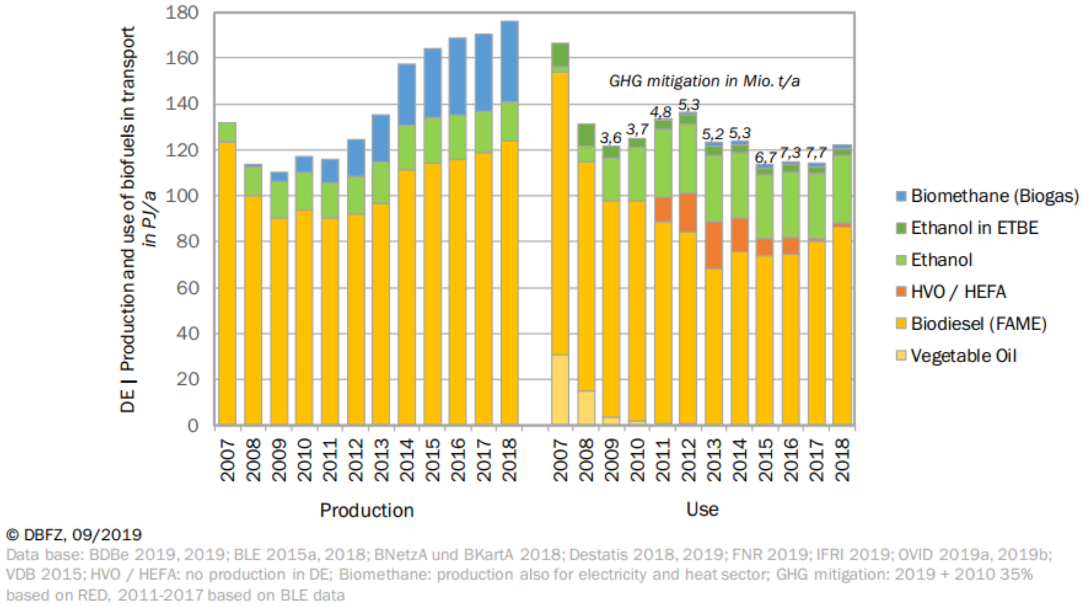

Figure 12. Production of conventional biofuels in Germany[54]

In 2018, biofuels avoided 9,5 million tons CO_{2eq} in Germany, being the fuel specific GHG mitigation (main fuel options): 83% Biodiesel (FAME), 86% Bioethanol, 77% HVO/HEFA and 90% Biomethane. The raw materials used to produce biofuels consisted 36% of residues and 64% of cultivated biomass (mostly rapeseed, palm oil, corn and wheat).[55] Table 16 presents biofuel production capacity in Germany.

Table 9. Biofuel production capacity[56,57]

Year	Biodiesel/FAME (ML/year)	Ethanol + ETBE (ML/year)	Biomethane/Biogas (PJ/year)
2007	3.783	398	-
2008	3.067	581	1
2009	2.772	750	4
2010	2.880	762	6
2011	2.760	721	10
2012	2.817	774	15
2013	2.965	848	19
2014	3.408	917	23
2015	3.504	934	25
2016	3.544	932	31
2017	3.646	850	33
2018	3.465	785	33

In 2018, about 4,12% or 113 PJ/a of the transport fuels used were biofuels, of which about 81 PJ/a were biodiesel (FAME, the main raw material is Palm Oil, Rapeseed and Waste and Residues), 6 PJ/a of HVO/HEFA fuels (mainly based on palm oil and used cooking oil), about 31 PJ/a of ethanol (mainly based on wheat and sugar beet) and about 1 PJ/a biomethane from biogas (mainly based on residues).

[54] DBFZ, 2019; Naumann et al., 2019
[55] BLE, 2019
[56] Naumann et al. 2019; Lenz et al. 2017; VDB 2020; BDBE 2020b; UDOP 2019
[57] No production capacities for HVO/HEFA fuels; cellulosic ethanol capacity 1.262.000 liters/a

Following, Figure 13 shows the biofuel use in Germany in the year of 2018. Subsequently, Table 10 presents the biofuel consumption and market share.

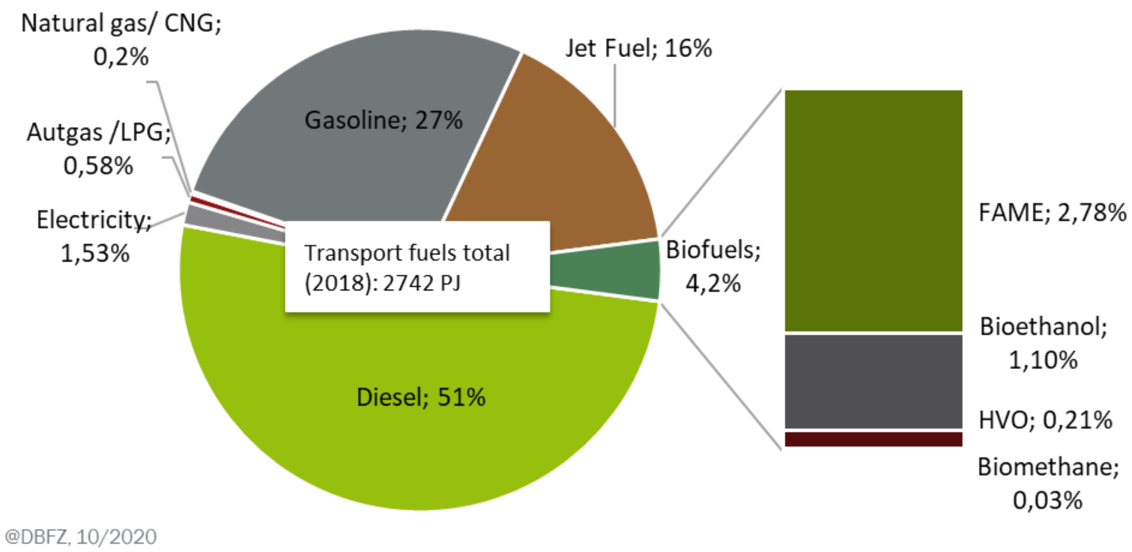

Figure 13. Biofuel use in Germany in 2018

Table 10. Biofuel consumption and market share[58]

Year	FAME Biodiesel (ML/year)	Pure Plant Oil (PPO)/ Vegetable oils (ML/year)	HVO/HEFA (ML/year)	Ethanol + ETBE (ML/year)	Biomethane / Biogas (PJ/year)	Total energy demand transport (PJ/a)	Market share of biofuels (%, energy related)
2007	3.318	911	-	581	-	2.601	6,38
2008	3.062	436	-	790	-	2.571	5,10
2009	2.883	108	-	1.134	-	2.541	4,80
2010	2.928	66	-	1.291	-	2.559	4,89
2011	2.506	21	320	1.563	-	2.568	4,95
2012	2.117	27	502	1.583	1,21	2.559	4,77
2013	1.972	1	599	1.519	1,75	2.612	4,56
2014	2.226	6	427	1.479	1,63	2.616	4,63
2015	2.243	2	214	1.445	1,25	2.621	4,31
2016	2.257	-	210	1.483	1,37	2.696	4,23
2017	2.480	3	42	1.460	1,62	2.743	4,19
2018	2.586	-	175	1.502	1,00	2.742	4,12

Unit conversion: 1 metric ton of biodiesel is equivalent to 1,136 liters; 1 metric ton of ethanol is equivalent to 1,262 liters; 1 metric ton of PPO is equivalent to 1,087 liters and 1 metric ton of HVO/HEFA fuel=1,282 liters

The import and export data of Bioethanol and Biodiesel (FAME) in Germany from 2010 to 2019 is indicated in Table 11. During this period, the domestic production of bioethanol was never higher than the demand, receiving almost three quarters of the imports from European countries including Netherlands, Belgium, France and Hungary. For Biodiesel, the country has over years of overproduction and has a positive balance of exports for the biofuel, being the two major importers the Netherlands and Poland.

[58] Naumann et al., 2016; VDB, 2017; BDBE, 2017; Lenz et al., 2017; OVID, 2017; BAFA, 2017; BLE, 2016; BLE, 2014; BLE, 2014; BMVI, 2016; Arbeitsgemeinschaft Energiebilanzen e.V., 2017. cf. also country report in IEA AMF, 2017a incl. electricity, cellulosic ethanol not relevant

Table 11. Import and export of bioethanol and biodiesel (FAME) in Germany from 2010 to 2019[59]

Year	Bioethanol		Biodiesel (FAME)	
	Import (ML/year)	Export (ML/year)	Import (ML/year)	Export (ML/year)
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

Unit conversion: 1 metric ton of biodiesel is equivalent to 1.136 liters; 1 metric ton of ethanol is equivalent to 1.262 liters

To meet the GHG emissions quota, from 3,5% GHG reduction from 2015 to 4% from 2017 and 6% from 2020, direct or indirect effects are expected with regard to the biofuels amount or renewable fuels used. The major driver for competitiveness between fuels within the quota remains the fuel specific GHG emissions reduction potential. Despite the target for advanced biofuels and the ongoing debate about EU RED II, for Germany at least until 2020, it is likely that due to the higher GHG reduction quota of 70% fuel specific GHG mitigation potential on average, the biofuels amount could slightly increase but will be limited by blending levels with fossil fuels (e.g., B7, E10 etc.). The framework for increasing use of biomethane as transport fuel remains uncertain. This is also true for PtG fuels.[60]

The 6% reduction target for the German GHG emissions quota continues after 2020. Despite this, the EU regulation is binding until 2030 (e.g., to achieve 40% GHG emissions reduction and to incorporate 27% renewable energies into the energy mix). However, this regulation is not sector-related. Especially with regard to increasing capacities or building up markets for advanced biofuels, it is very difficult to create scenarios that could be likely as the biofuel and renewable energy market sectors are constantly undergoing changes depending on global and regional policies (e.g., targets post-2020, market interventions such as subsidies and support schemes, etc,) as well as fluctuating market conditions (e.g., prices for raw materials, auxiliaries and mineral oil).

In Germany, there are two approved certification schemes recognized by the EU for transport biofuels. The International Sustainability & Carbon Certification (ISSC) is recognized since August of 2016 and acts in a global range. The Certification of Sustainably Produced Biomass (REDcert) is recognized since August of 2017 and acts in the EU. Both voluntary schemas cover diverse basis of biomass as raw material and covers the entire supply chain of the biofuel industry.

Moreover, there is also the challenge of societal acceptance, which leads invariably to further market variability. However, there is ever increasing attention being given to biorefinery concepts, to maximize biomass-to-products ratios and realize biorefineries are multiproduct facilities (e.g., producing an array of biofuels, bulk chemicals, feeds and foods, and energy products). The diversification of biomass-based products will make such plants less susceptible to market shifts.

According to the 37. BImSchV which regulates the co-processed biogenic oils, the co-processing of biogenic oil in fossil refineries are credible for the greenhouse gas emission quota established in the country until 2020, but there isn´t any important initiative of co-processing oils or further refining currently in Germany.

[59] Naumann et al. 2019; F.O. Licht 2018, 2019, 2020
[60] Lenz et al., 2017

About 27 facilities with an overall combined capacity of about 4 million t/a (5,54 billion liters per year) are still producing biodiesel, in a production capacity ranging from 2.000 to 300.000 t/a; this reflects some consolidation, as in 2012 there were about 51 production facilities) (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).[61]

The first modern era plants producing ethanol in Germany started operation in 2005. Ethanol is now produced in seven 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 709.000 t/a (805 million liters per year), mainly provided by producers including VERBIO AG, CropEnergies AG, Suiker Unie GmbH & Co. KG and Nordzucker AG (BDBE 2020a). Biomethane from upgraded biogas was produced by about 216 plants in 2018. The main companies producing biomethane for transport are VERBIO AG (biomethane from ethanol stillage and straw), E.ON Bioerdgas GmbH, and Berliner Stadtreinigungsbetriebe.[62]

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[61] Naumann et al., 2019

[62] The list of the bioethanol and biodiesel production facilities can be found at: https://datenbank.fnr.de/index.php?id=7696. The location of these facilities can be found at: https://datenbank.fnr.de/karten/biokraftstoffe/index.php.

4 SWEDEN

4.1. INTRODUCTION

The EU has set a goal to reach a 20% share of gross final energy consumption from renewables by 2020. Each Member State designed its own national action plans to reach this goal. Figure 14 shows the overall share of energy from renewable sources, taking into account the EU Member States in the gross final energy consumption in 2019.

Sweden had a higher share of energy from renewable sources (56.4%) in its gross final consumption. This positive outcome has been enacted by Directive 200928/EC on the encouragement of the utilization of energy from renewable sources.

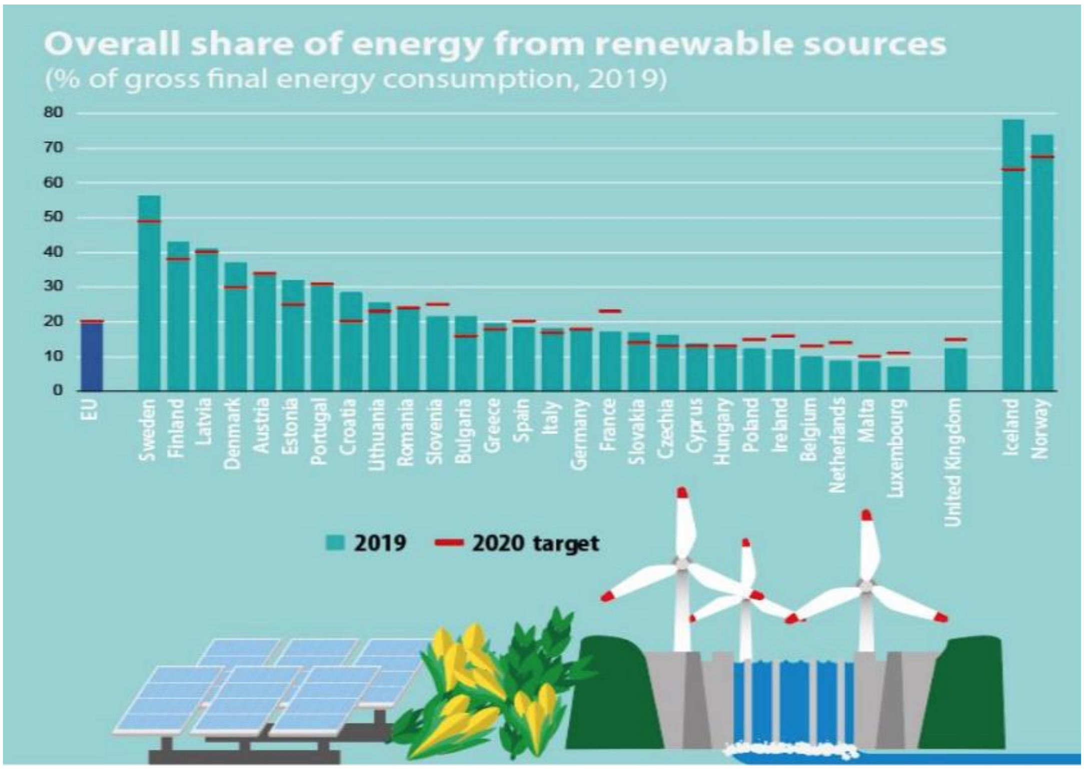

Figure 14. Share of energy from renewable sources in the EU Member States (% of gross final energy consumption) in 2019[63]

To reduce the carbon intensity of the transportation sector, the EU agreed to establish a common goal of 10% for the share of renewables (e.g., liquid biofuels, hydrogen, biomethane, etc.) by 2020. In 2019, the share of renewable energy in transportation was 8.9%.

Figure 15 shows the share of renewable energy in transport fuels, including multiple-counting and not real percentage points. Based on this calculation, the share of renewable energy in transport fuels for Sweden was 30.3% (29.7 – 2018), whereas real percentage was around 19%. The country has opted not to divide its renewable energy target into sub-targets by sector. Thus, Sweden has no specific targets for bioenergy, apart from the targets set by the EU RED.

[63] EUROSTAT, 2020

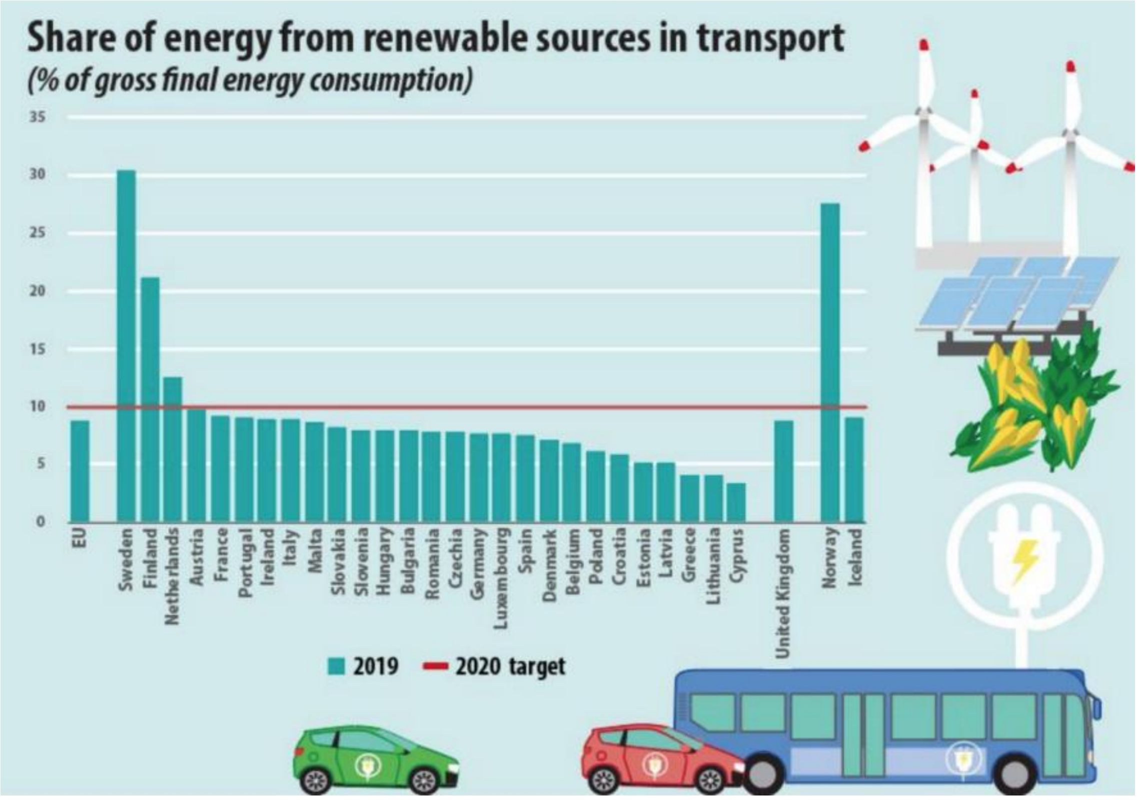

Figure 15. Share of energy from renewable sources in transport (% of gross final energy consumption) in 2019[64]

In addition to the targets set by the EU, the Swedish Parliament decided in 2009 that Sweden's vehicle fleet shall be fossil fuel independent by 2030. In 2014, the government declared the country should become a "fossil free welfare state" by 2050. In 2017, the Parliament decided upon a climate-political framework, with climate emissions reduction of 70% by 2030 compared with 2010 and "at the latest in the year 2045, Sweden shall have no net emissions of GHG to the atmosphere, and will thereafter achieve negative emissions". In January 2018, a new climate law came into effect.

High shares of bioenergy, hydropower and nuclear power characterizes the energy supply in Sweden, accounting for 95% of domestic energy production and 73% of TPES in 2017. The country counts with a substantial and growing supply of bioenergy, mostly originated from domestic forest sources. The supply of biomass-based fuels and waste increased by 24%, between 2007 and 2017 across transport and heat generation, among other sectors. Oil supply decreased by 20% at the same period, due to increasing use of biofuels in the transport sector and biomass in the heating sector. The increasing trend in biofuels in the transport sector is shown in Figure 16.

[64] EUROSTAT, 2020

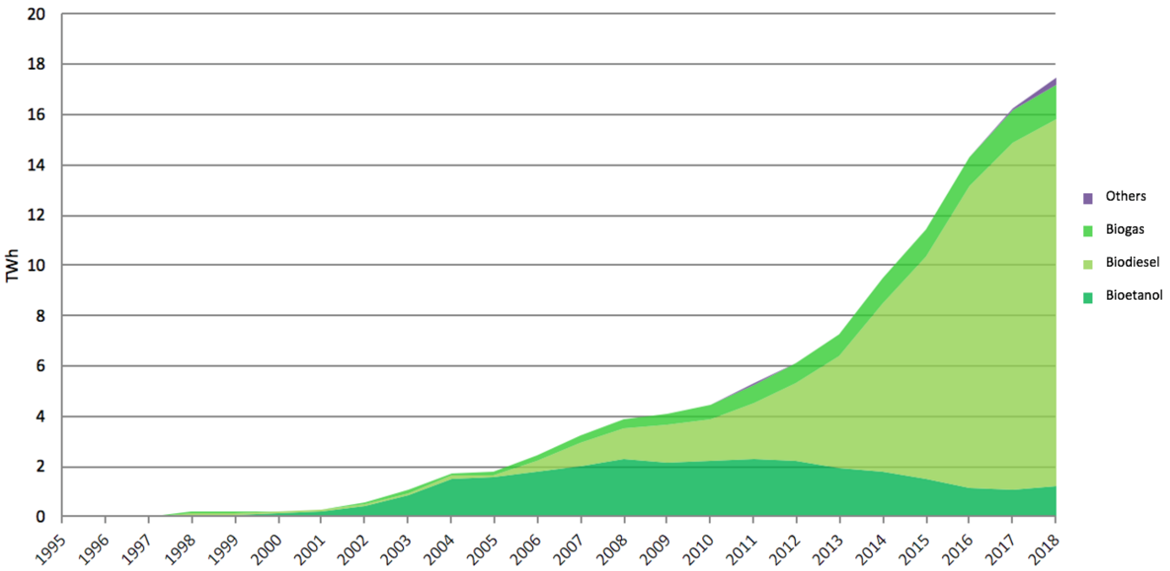

Figure 16. Biofuels in the transport sector (domestic) by fuel, from 1995 to 2018[65]

According to preliminary statistics from the Swedish Energy Agency (SEA), bioenergy represents 63% of TPES from renewable energy sources with 229.5 TWh, followed by hydropower (64.6 TWh) and wind energy (19.9 TWh), in 2019. Bioenergy comprise (i) biomass, (ii) combined heat and power (CHP) plants, (iii) biomass heating plants, (iv) biogas, (v) biofuels, (vi) biooils and (vii) other biobased energy in industry. The role of solar energy is marginal in Sweden, as Figure 17 presents.

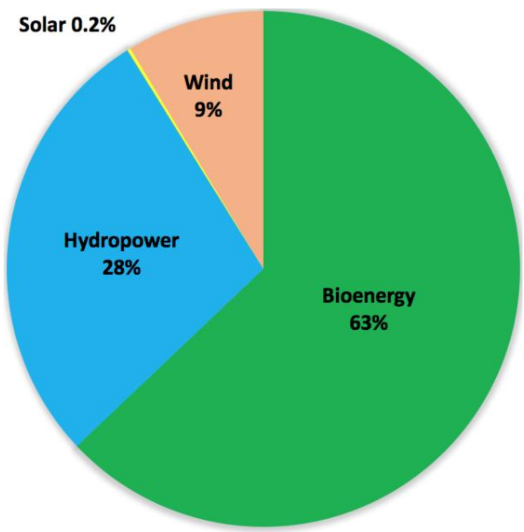

Figure 17. Renewable energy in Sweden, in 2019[66]

Following, Figure 18 shows Sweden's historical GHG emission and the contribution of the different segments from 1990 to 2016.

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[65] Sweden, 2020
[66] Sweden, 2020a

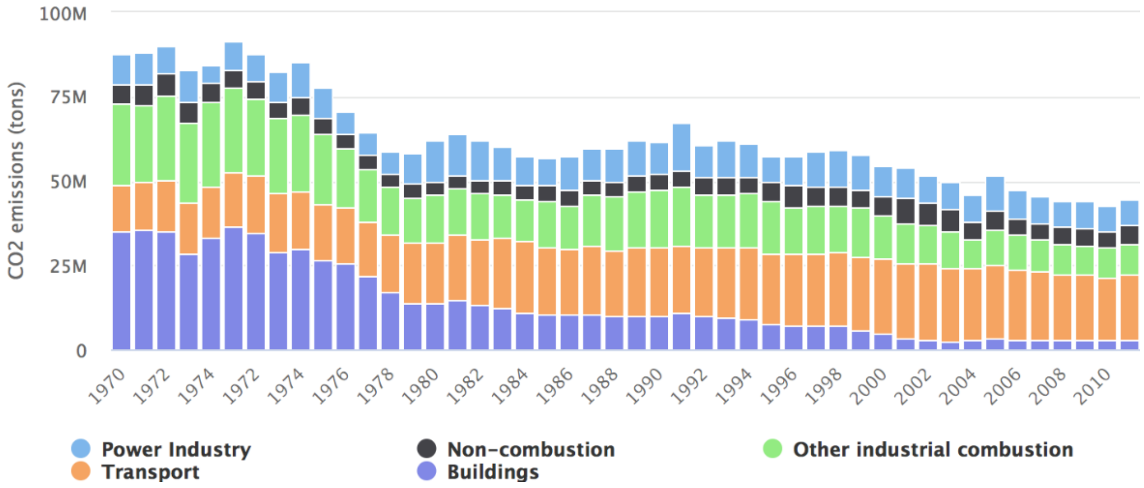

Figure 18. Sweden CO_2 emissions by years from 1990 to 2016[67]

Throughout this period, the emissions from transport were dominated by road transportation. A decreasing trend could be considered due to more energy efficient vehicles and increase use of biofuels in this sector, although the effects of these measures on emission reduction have been suppressed by an increased tendency in the quantity of traffic.

The total emissions for 2019 were 50.9 million tonnes, exclusive of LULUCF and of international transports. Of these (i) work machines constituted 3.3, (ii) waste 1.1, (iii) heat and power 4.6, (iv) industry 16.3, (v) domestic transport 16.4, (vi) agriculture 6.9, (v) solvents and other chemical product uses 1.5, (vi) seating of houses and offices 0.8 million tonnes respectively. In 2016 the total emissions were 53.6 million tonnes and since then the reduction has been made almost all of it in the transport sector.

4.2. DRIVERS FOR BIOFUELS POLICY

The main drivers for biofuels in Sweden are (i) climate change mitigation and (ii) reduction of GHG emissions. Other important drivers are (iii) energy security, (iv) technology development towards a circular bioeconomy and (v) job creation. In addition to that, sustainability is the key element in policies for energy, climate and the environment.[68]

[67] Worldmeters, 2019
[68] http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/

4.3. BIOFUELS POLICIES AND OBLIGATIONS

The energy policies have been rather stable since a long period of time in Sweden. The main incentives and tax measures are shown in Figure 19. The most relevant policies to the transportation sector are discussed below.

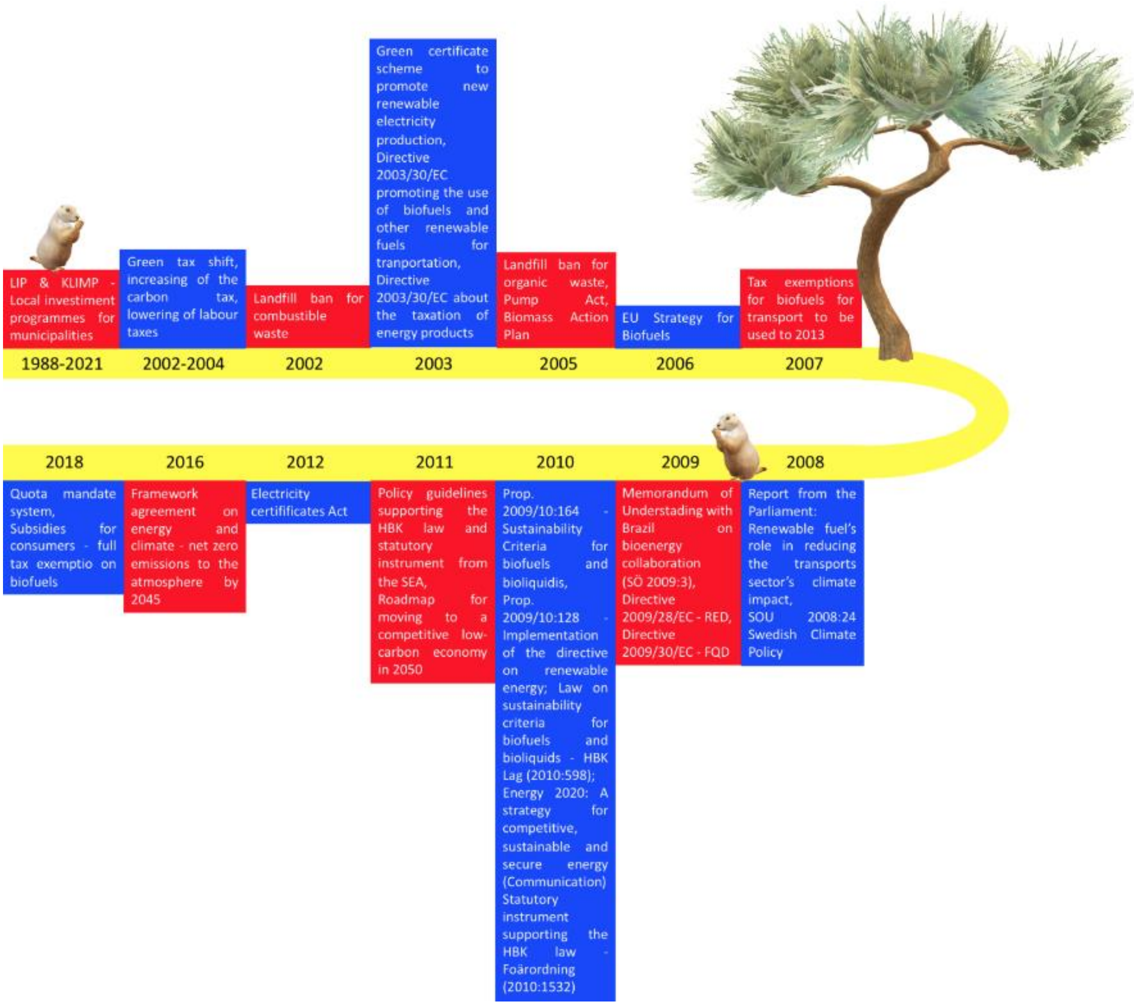

Figure 19. Sweden's bioenergy policies timeline from 1988 to 2018

Taking into consideration biofuel obligations, transport fuels are subjected to an energy tax and a carbon tax as well as a value-added tax (VAT), where all are based on volume instead of energy unit. The VAT (25%) is added to the total sum which means that the energy and carbon taxes are also subject to VAT. The energy tax has been revised every year with change in taxation and biofuel policy.

This tax always remains above the minimum tax on fuels set by the EU in its Energy Tax Directive. Under certain circumstances, tax exemptions can be made, and Sweden has historically applied for state-aid approval for tax exemption of biofuels. Biofuels were initially fully tax exempt; however, the tax exemption was reduced in 2015 because of EU concern that this approach risked overcompensating some fuels, e.g., ethanol E85 and Rapeseed Methyl Esters (RME).

Later there has been reduced tax exemption when price changes have occurred but always as reaction to dated changes and not current prices. Since January 2018, all biofuels are once again fully tax exempt. The current energy tax for Petrol Environmental Class 1 (EC1) is 4.13 SEK/liter, and 4.74 SEK/liter for Diesel Environmental Class 1 (EC1). Regarding the carbon tax, the values are 2.61 for petrol and 2.26 for diesel, respectively.[69]

Since July 2018, a reduction quota mandate system has been in place with emissions reduction targets for petrol (gasoline) and diesel. Sweden follows the given emission values for petrol and diesel according to the RED II. This policy mandates a reduction in carbon dioxide emissions of 4.2% for petrol and 21.0% for diesel by January 2021 compared with neat fossil fuels. Highly concentrated biofuels such as E85, HVO100, B100 and others outside the petrol and diesel standard are not included and are fully tax exempted until end of 2021 and for bio-CNG until 2030. The penalty cost for not meeting the mandate is by law maximum 7 SEK per kg of carbon dioxide equivalent units but the current regulation stipulates 5 SEK for petrol and 4 SEK for diesel.

In addition, there are longstanding policies on vehicles to incentivize efficiency, e.g., classifying cars based on their environmental performance for eligibility to receive bonuses or other benefits, that have impacted biofuel consumption. There are other initiatives that have isolated impacts but these are the most important and relevant.[70]

The reduction quota obligation for petrol, diesel and full tax exemption on high-blend, highly concentrated biofuels came into effect as of July 2018. The 2030 goal is to achieve a 70% reduction in carbon emissions and an approximate biofuel share of 50% on an energy basis assuming continuing efficiency improvements and electrification in transport. Emission reduction quotas for 2018 to 2020 are shown in Table 12. The proposal from the SEA for reduction levels from 2021 to 2030 is presented in Table 13.

Table 12. Reduction quota system with mandated reduced carbon emissions for each fuel type[71]

Reduction	July 2018	January 2019	January 2020
Petrol	2.6%	2.6%	4.2%
Diesel	19.3%	20.0%	21.0%

Table 13. Reduction level proposed by the Swedish Energy Agency from 2021 to 2030[72]

Reduction	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Petrol	6.0%	7.8%	10.1%	12.5%	15.5%	19.0%	22.0%	24.0%	26.0%	28.0%
Diesel	26.0%	30.5%	35.0%	40.0%	45.0%	50.0%	54.0%	58.0%	62.0%	66.0%

[69] https://drivkraftsverige.se/statistik/skatter/skatter-fossila-drivmedel-och-branslen/
[70] http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/
[71] SEA, 2019
[72] Swedish Government, 2020

It is noted that a state investigation about proposing policy for increased production and use of bio-jet fuels in Sweden was delivered in 2019 which proposed a reduction quota mandate from 2020. The government has yet to propose to the parliament for such a law to be decided upon.

The system would start with a quota of 0.5% by volume and increase to about 30% by 2030 and increased to 100% by 2045. Noteworthy is that the mandate would include both domestic and international air traffic which is fuelled in Sweden.

4.4. EXCISE DUTY REDUCTIONS

The main legislation impacting biofuels are the tax exemption on biofuels distributed as transport fuels and the “pump law” on distribution of biofuels. As discussed before, the tax exemption has varied from full to reduced tax exemption but from January 2018 all biofuels are fully exempted from the tax (note that this tax is divided into energy tax and carbon dioxide tax components).[73]

The petrol/diesel usage ratio in Sweden is closer to the North American average than the European average, largely due to tax differences. However, diesel is increasing its share rapidly due to fiscal incentives for new cars and an increasing demand for transportation of goods.

4.5. FISCAL INCENTIVES

The “pump law” mandates fuel retailers that have a fuel turnover above 1,500 m^3 per month to offer at least one fuel with a greater than 50% biofuel blend, meaning at least one pump dedicated to biofuels. A number of government institutions, foundations and authorities provide funding for biofuels R&D. There are investment subsidies (fiscal incentives) for biofuel pumps available from the Swedish EPA.

4.6. INVESTMENT SUBSIDIES

Subsidies for investments are available for pilot and demo plants, and for climate action programs that reduce carbon emissions (also for commercial technologies). The SEA provides 25% investment support and the Swedish EPA provides up to 45% investment support. Support is also provided for investments in electric charging stations and biogas infrastructure.

There are subsidies for consumers, most notably the full tax exemption on biofuels (low blends until June 2018 and then taxed under reduction quota system, with highly concentrated biofuels fully exempt until 2021).

As of April 2021, car buyers can receive a maximum SEK 70,000 bonus for certain more fuel-efficient vehicles, or conversely be penalized for vehicles emitting more than 95 gCO^2/km. The penalty (malus) for each gram of CO_2 above 95 gCO_2/km is an additional cost of SEK 77 per each additional gram, which is charged during the first three years of vehicle use. If the emissions are above 140 gram per km, the owner pays an additional SEK 100 per gram.

[73] http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/

4.7. OTHER MEASURES STIMULATING THE IMPLEMENTATION OF BIOFUELS

Diverse funding agencies and programmes are dedicated to supporting research on (i) hydropower, (ii) wind power, (iii) solar cells, (iv) sustainable biomass production and (v) conversion into district heating (DH) as well as CHP plants. Major funding agencies and sources in Sweden include the following:

- SEA
- Swedish EPA
- Swedish Knowledge Centre for Renewable Transportation Fuels (F3)
- Swedish Research Council for Sustainable Development (FORMAS)
- Swedish Research Council (Vetenskapsrådet)
- Mistra Foundation
- Knowledge Foundation (KK-stiftelsen)
- Swedish Government Agency for Innovation Systems (Vinnova)

Bioenergy has a high priority within Sweden's R&D portfolio. Over the years, Swedish energy R&D has investigated most of the major economically and environmentally relevant bioenergy topics.

The three most ambitious projects up to 2017 in Sweden's overall energy R&D portfolio all focus on development of new bioenergy technologies and processes (e.g., (i) gasification of black liquor, (ii) saccharification and fermentation of woody cellulose and (iii) synthesis of liquid fuels via gasification).

These technologies are all considered central to advancing Sweden's current use of bioenergy. In 2018, the SEA announced a contribution of EUR 50 million to establish and operate a pilot plant to test hydrogen-based steel production, although the biomass component within this project is relatively small.

In addition, there are more than 10 research projects focused on biofuels within the SEA's thermochemical biofuels program (Termokemiska biodrivmedelsprogrammet) up to 2020.

In terms of production and budget, the largest research, development and demonstration (RD&D) project is the biomass gasification and biomethane synthesis pilot demonstration plant Gobigas, in Gothenburg. This project was funded by the SEA as a first demonstration phase. The second phase of the project - Gobigas 2 for a four-time scale-up was cancelled despite EU funding in the NER300 program, due to reasons of uncertain financial returns on investment and high capital costs.

Other important projects are the RenFuel pilot plant for organic catalysis of lignin to biocrude with a capacity of 3,000 tonnes per year, in which the biocrude is intended to be used for HVO (renewable diesel) production externally and the Bio-DME plant in Piteå producing DME via black liquor gasification.

The Swedish EPA also has a $800 million climate investment subsidies program (KlimatKlivet) where projects are developed to reduce fossil fuels use and associated carbon emissions. In this program, there are a few projects involving biofuel production (e.g., pyrolysis of biomass and biogas plants) which are intended to commence plant construction in the next two years. One such project is Pyrocell with 25 000 tonnes of "biooil" where the start of construction was made in March 2020.[74,75]

4.8. PROMOTION OF ADVANCED BIOFUELS

Following the EU policy, there is no special system other than the reduction quota system favouring biofuels that enable high emission reductions. The same tax exemption incentives as other biofuels are applied to advanced biofuels, and all biofuels must also comply with sustainability measurement/verification requirements (e.g., EU sustainability criteria) and fuel quality standards. Following, Table 14 lists operational and planned advanced biofuels projects in Sweden.

Table 14. Operational and planned advanced biofuels projects in Sweden[76]

Company	Status	Technology	Production Capacity
Gothenburg Energy	Closed	Biomass gasification for biomethane	20 MWth biomethane
Domsjö Fabriker	Operational	Cooking digester, ethanol	21 ML
SunPine	Operational	Tall oil separation to raw tall diesel for HVO	100 ML
Preem	Operational	Hydrogenation to HVO	200 ML
SunPine	Operational	Tall oil separation to raw tall diesel for HVO	50 ML
Preem	Operational	Hydrogenation HVO	500 ML
Södra	Operational	Separation to methanol	5 ML
Setra	Construction	Wood pyrolysis to biooil for HVO	26,000 tonnes
SCA	Planned	Tall oil separation to raw tall diesel for HVO	100 ML
St1	Construction	Hydrogenation to HVO	200 ML
St1	Planned	Hydrogenation to HVO	200 ML
RenFuel	Planned	Organic catalysis to biocrude for HVO	200 ML
Domsjö Fabriker	Planned	Biofuels	400 ML
Energifabriken	Planned	RME	25 ML

The first bio-SNG plant at industrial scale in the world, GoBiGas in Gothenburg, started operating in 2014. This plant provided 20 MW (160 GWh) of bio-methane to the gas grid. The outcome from the demonstration is that the technology is ready for large scale deployment, applying commercially mature components, for which the production cost would be in the range of EUR 0.55 per litre petrol equivalent (whereas feedstock is 35% of the cost) at the current feedstock price for woody biomass in the region. The demonstration was finalized in March 2018 and the plant was decided to be closed because the right market conditions were not available for the continuation.

Forest biomass by-products such as tall oil and lignin are co-processed, or piloted to be co-processed, respectively, in a fossil refinery. Sunpine uses Crude Tall Oil (CTO) to produce Crude Tall Diesel (CTD) on a commercial scale (150,000 cubic metres/year) at its plant in Piteå. The CTD is refined at Preem refinery in Gothenburg to HVO. Preem and Vattenfall recently published plans to use electrolysis to produce the hydrogen gas used for HVO production.

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[74] http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/
[75] www.naturvardsverket.se

[76] SEA, 2019b

Preem and RenFuel are assessing the construction of the world's first lignin plant for biofuels, at a pulp mill. This plant is expected to produce an annual volume of 100,000-200,000 tonnes of crude lignol (biooil) for further refining to HVO products. At this point no location has been publicly released.

In addition, a joint-venture by Setra and Preem called Pyrocell has been set up. Pyrocell will process sawdust with pyrolysis into liquids and Preem will refine these to HVO biofuels at their refinery. Pyrocell announced in 2019 the selection of the Dutch companies TechnipFMC and BTG BioLiquids (BTG-BTL) to design and build the plant. The start-up for some 26,000 tonnes per year is planned for September 2021.

A collaboration between Fortum, Preem and Valmet aim to develop and commercialize a pyrolysis technology for upgraded pyrolysis liquid suitable e.g., as refinery co-feed (based on a technology platform similar to Fortum's Joensuu bio-oil plant, supplied by Valmet). Preem will process the upgraded pyrolysis liquid into transportation fuels at their refineries.

4.9. MARKET DEVELOPMENT AND POLICY EFFECTIVENESS

Biofuels for transport has expanded quickly in recent years as shown in Table 15. In 2017, biofuels accounted for 20.6% of all transport fuels sold in Sweden, compared to 6.9% in 2011. The largest share was HVO fuel, which accounted for two thirds of all biofuels sold an amount equivalent to about 25% of all diesel sold. HVO fuel is based on oleaginous (lipid/fatty acid) feedstocks like tall oil, animal fats, and recovered vegetable oils. HVO can be fully blended with diesel. In current standard for diesel FAME fuels are constricted but there is a standard for neat RME fuel.

Table 15. Biofuels used for transport in Sweden, from 2010 to 2017[77]

Year	Petrol	Diesel fuels*	Aviation fuel	RME	HVO	Ethanol	Biofuels market share (%)
2010	4 322	4 055	191	225	0	393	5.8
2011	3 997	4 146	211	250	45	410	6.9
2012	3 661	4 025	211	294	131	393	8.4
2013	3 460	3 965	211	293	289	359	10.3
2014	3 325	3 865	211	368	439	324	13.4
2015	3 191	3 945	201	451	655	256	15.7
2016	3 236	4 577	221	341	1204	222	18.6
2017	3 101	4 608	-	326	1446	205	20.8

*Diesel fuels exclude heating oils

Following, Table 16 shows Sweden's biofuel mandates. There is an ethanol mandate for E5. While E10 is also technically possible, it is not pursued by petrol companies. There is also a biodiesel B5. While B7 is allowed, because of problems using biodiesel in certain cars, B5 is mostly pursued by refineries. Historically and until June 2018, only volumes factored into the use of biofuels in Sweden not energy content or carbon intensity.

[77] SEA, 2019c

From July 2019, however, carbon emission reductions have become the dominant factor. There are both EU standards (EN228 and EN590) and Swedish standards (MK1 Petrol and MK1 Diesel). With now improved EU standards, the current differences between the EU and Swedish standards are small. There are also other market mechanisms such as a carbon tax, imposed since January 1991, that apply for households and industry.

Until 2010, bioethanol was the most important liquid biofuel in Sweden. Since then, it has lost market share because of taxation changes both on fuels and on vehicles for ethanol fuel.

Use of diesel type biofuels overtook use of ethanol biofuels in 2011 and diesel biofuels use has continued to grow (from 7.4 PJ in 2010 to 42.7 PJ in 2016). Despite growing biofuels use, Swedish consumption of liquid biofuels is primarily based on imports, with only 10-15% supplied by domestic production. Biogas use in transport has also seen continuous growth in recent years, with interesting development in Liquified Biogas (LBG) (from 1.2 PJ in 2005 to 7.3 PJ in 2016). In recent years, there has been some development with HVO green petrol blended in petrol from some distributors, but volumes smaller than 20 000 cubic metres per year.

Table 16. Biofuel obligations/mandates (% by volume)[78]

Year	Ethanol	Biodiesel	Other (specify e.g., advanced fuels)
2010	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated B7* is allowed but obligated as B5
2011	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated B7 is allowed but obligated as B5
2012	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated B7 is allowed but obligated as B5
2013	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated B7 is allowed but obligated as B5
2014	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated B7 is allowed but obligated as B5
2015	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated B7 is allowed but obligated as B5
2016	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated B7 is allowed but obligated as B5
2017	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated B7 is allowed but obligated as B5
2018	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated B7 is allowed but obligated as B5
2019	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated B7 is allowed but obligated as B5

*B7 has been mostly 7% but depending on price and various problems with RME 5-7% and the distributor

There are two ethanol plants in Sweden, the St1 Refinery in Gothenburg with a 5 ML/year capacity. The feedstock for this facility is bakery waste. The second facility is Agroetanol plant in Norrköping with a capacity of 230 ML/year. In some years, one production line was closed and the capacity was only 160 ML/year (initial start-up production capacity).

There are two large FAME biodiesel facilities in Sweden. Adesso Bioproducts in Stenungsund have capacity today to produce 155 ML RME (FAME biodiesel) per year. Energifabriken in Karlshamn have capacity to produce 55 ML RME/year. There are also a number of small plants where farmers produce FAME for their own or local consumption and also biogas to bio-CNG plants.

78 SEA, 2019d

Sunpine in Piteå produces 100 ML Raw Tall Diesel (RTD) per year. In December May 2020, one more plant with an additional 50 ML RTD per year capacity came online. RTD is the raw material used to make HVO fuels at Preem. The Preem refinery in Gothenburg has the capacity to produce >200 ML HVO fuels per year including HVO petrol. Table 17 summarizes biofuels production capacities.

Table 17. Biofuel production – installed production capacity (ML/year) from 2006 to 2017

Year	Biodiesel (FAME)	Ethanol (conventional)	Cellulosic ethanol	Biogas as transportation fuel (consumption)	Renewable diesel (from lipids)	Other advanced biofuels
2010	203	230	19.5	0.6 TWh	100	1)
2011	203	230	19.5	0.7 TWh	100	1) 2)
2012	203	230	19.5	0.8 TWh	100	1) 2)
2013	203	230	19.5	0.9 TWh	100	1) 2)
2014	203	230	19.5	1.0 TWh	100	1) 2) 3)
2015	203	230	19.5	1.1 TWh	100	1) 2) 3)
2016	203	230	19.5	1.3 TWh	200	1) 2) 3)
2017	203	230	19.5	1.5 TWh	200	1) 2) 3)

1. Since 2004, the Biorefinery Demo Plant, a cellulosic ethanol pilot plant with a capacity of 300-400 litres per day, has been operated under the auspices of Research Institutes of Sweden (RISE); if operated at capacity for 300 days per year, it has an annual ethanol production capacity of 120,000 liters.

2. Since 2011, a pilot plant for bio-DME production from black liquor has been operating with a capacity of 4 ton per day; if operated 300 days year, its annual capacity is 1200 tonnes.

3. Since 2014, a pilot plant for biomethane production via biomass gasification has been operating with a methane synthesis capacity of 20 MWth biomethane; if operated 300 days per year, its annual capacity is 11,200 tonnes.

There are also approximately 300 biogas plants in Sweden, nearly all of them small in comparison with other Swedish biofuels plants. It is difficult to estimate total production capacity as a varying share is further upgraded to biomethane for transport. The other plants produce biogas used for power and heat production.[79]

[79] http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/

5 UNITED STATES

5.1. INTRODUCTION

The United States (US) economy remains highly dependent on liquid transportation fuels, still primarily derived from petroleum but increasingly including renewable content, to power various transportation fleets. In 2016, the US had about 21% of the world's registered vehicles (268.8 million including passenger cars, motorcycles, trucks, buses, and other vehicles) and accounted for about 20% of the world's oil consumption. The transportation sector represents a primary user of energy in the US, comprising 29% of total US energy use, with 95% of this energy provided by fossil fuels.

As shown in Figure 20, the majority of total primary energy supplied by renewable energy sources is provided by bioenergy (4,079 PJ), followed by hydropower (971 PJ), wind energy (826 PJ), geothermal energy (384 PJ) and solar energy (282 PJ).

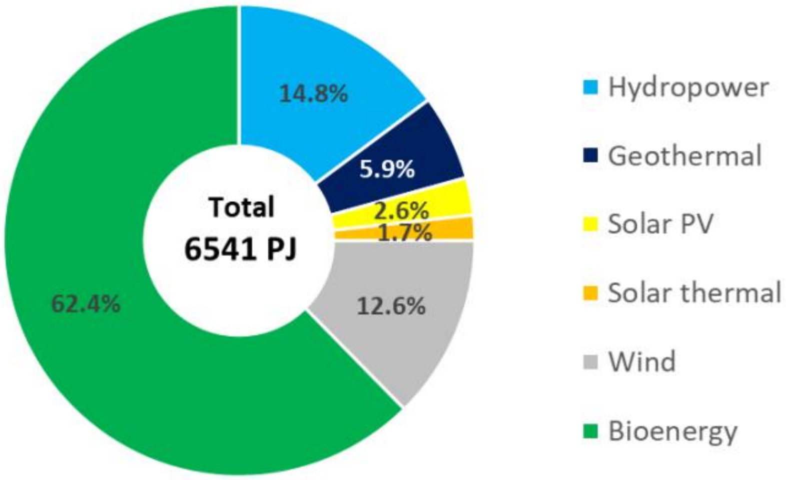

Figure 20. TPES from renewable energy in the US in 2016[80]

Figure 21 shows total primary energy supply from bioenergy in the US in 2016. Solid biomass represents about half of bioenergy supply (51.2% or 2,090 PJ), of which 374 PJ was used in the residential sector. There is also a major role for ethanol in gasoline (33% or 1,348 PJ), followed by biodiesel (7.8% or 319 PJ). Biogas (3.8% or 155 PJ) and renewable MSW (3.8% or 155 PJ) reach somewhat lower shares. Liquid biofuels saw a more than 10-fold increase from 124 PJ in 2000 to 1,362 PJ in 2012; the average growth rate was then about 4-5% per year up, reaching 1,679 PJ in 2016.

[80] World Energy Balances © OECS/IEA 2018

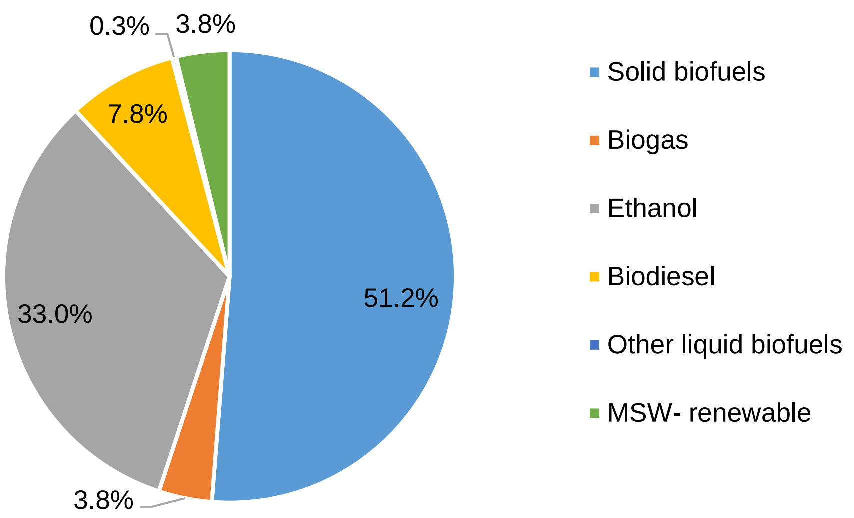

Figure 21. Distribution of TPES from bioenergy in the US in 2016. Total bioenergy supply in the US in 2016 was 4079 PJ[81]

5.2. DRIVERS FOR BIOFUELS POLICIES

The main drivers currently are (i) job creation, (ii) rural development and (iii) energy security, together bundled as - advancing a thriving bioeconomy. [82,83]

Climate change mitigation was previously a large driver but is no longer a major driver under the current administration. However, it is likely to become a key driver again in the near future as already mounting climate disruption worsens and the ability to dispute or disregard the growing peril of global warming wanes.

5.3. BIOFUEL POLICIES AND OBLIGATIONS

Historically, in past administrations, especially before the tight oil fracking revolution over the past decade, the main drivers for developing biofuels in the US have been energy security first and foremost and then also and increasingly climate change mitigation. Before US domestic petroleum production increased due to fracking, petroleum imports into the US accounted for over 60% of total consumption and the level of imports was continuing to grow.

In recent years, due to the fracking revolution, this trend has impressively been reversed. In 2017, US net imports of petroleum accounted for only 19% of US petroleum consumption, the lowest level since 1967.[84] As shown in Figure 22, in 2017 total net energy imports into the US fell to 7.3 quadrillion British thermal units (quads), a 35% decrease from 2016 and the lowest level since 1982. In 2017, the US also substantially increased its fossil fuel exports over 2016 levels, with larger exports of crude oil (89% higher), petroleum products (11%), natural gas (36%), and coal (61%). Petroleum products including gasoline, distillate fuel, propane, and other fuels currently comprise the majority (54%) of

[81] World Energy Balances © OECS/IEA 2018
[82] https://energy.gov/eere/bioenergy
[83] The strategic plan for the Bioenergy Technologies Office (BETO), the office within the United States Department of Energy (DOE) leading biofuels development, is available at: https://www.energy.gov/sites/prod/files/2017/09/f36/beto_strategic_plan_december_2016.pdf

[84] EIA, 2018

US energy exports.

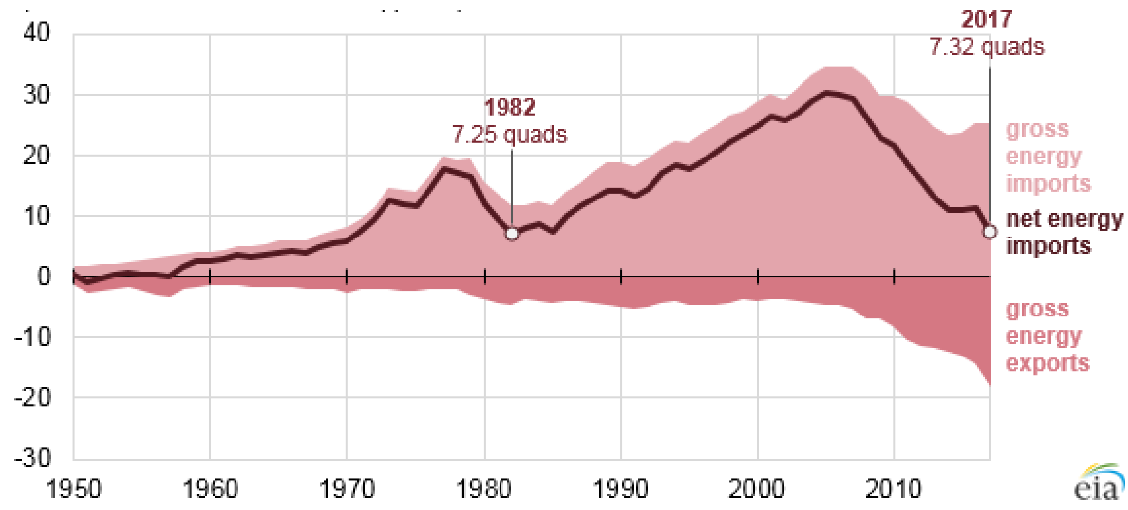

Figure 22. US gross and net energy trade from 1950 to 2017

In addition to the significant increase in the domestic production of fossil fuels, continuing relatively low petroleum prices and an unclear carbon policy landscape are hindering further investment in conventional and especially advanced liquid biofuels. This situation will not likely change until the future of both the federal renewable fuel standard (RFS2) and the Corporate Average Fuel Economy (CAFE) vehicle efficiency standards are better understood. These policies remain under discussion for revision, and policy changes are anticipated, however it remains unclear what they will be.

Taking into account biofuel obligations, the Energy Independence and Security Act (EISA) was enacted in 2007 to enhance domestic production of fuels and spur economic development while reducing reliance on imports and improving the environment (through reducing both the absolute level of fossil fuel use (lowering GHG emissions), and fuel combustion-related pollution such as ground-level ozone and smog).

This EISA contains a number of provisions to increase the energy efficiency and the availability and use of renewable energy. One of these provisions amended the original RFS created under the Energy Policy Act of 2005. The 2007 amended RFS (RFS2) targets the ramping up of domestic biofuel production to 36 billion gallons per year (BGY) by 2022 (over 136 billion liters). As depicted in Figure 23, this comprises 15 BGY of conventional corn starch-based ethanol (approximately 57 billion liters) and 21 BGY of advanced, cellulosic and biodiesel biofuels (approximately 80 billion liters) (e.g., 16 BGY of cellulosic biofuels, 4 BGY of advanced biofuels, and 1 BGY of biomass-based biodiesel).

The Clean Air Act provides EPA authority to adjust cellulosic, advanced and total volumes set by Congress as part of the annual rule process, and volume obligation targets for advanced biofuels have been lowered in recent years owing to commercial production levels lagging initial expectations, e.g., the de facto stalling of commercial deployment of cellulosic ethanol following the crash in oil prices in mid 2014.

The EISA legislation also contains a general waiver authority that allows the Administrator (EPA) to waive the RFS volumes, in whole or in part, based on a determination that implementation of the program is causing severe economic or environmental harm, or based on inadequate domestic supply. Table 18 presents the four categories of renewable fuels mandated under the RFS program.

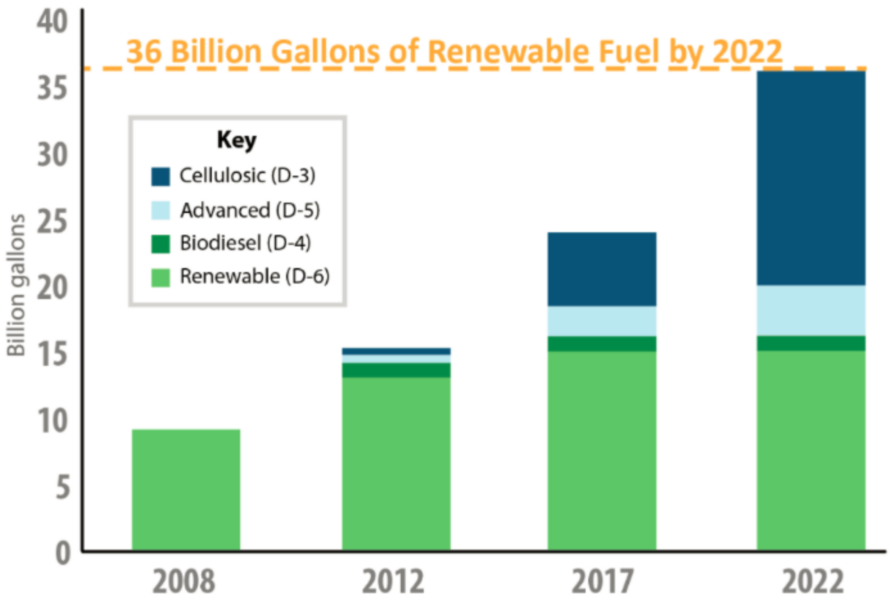

Figure 23. Volume targets for renewable fuels under revised RFS2 as originally enacted in 2007

Table 18. Renewable fuels categories under the RFS program

Category	Code	Minimum GHG reduction requirement[85]	Description
Cellulosic Biofuel	D3	60%	Renewable fuels made from cellulose, including ethanol, renewable gasoline, biogas-derived CNG and LNG
Cellulosic Diesel	D7	60%	Cellulosic diesel, jet fuel and heating oil
Advanced Biofuel	D5	50%	Renewable fuels other than ethanol derived from corn starch (sugar cane ethanol), biogas from other waste digesters, etc.
Biomass-derived Diesel	D4	50%	Renewable fuels that meet the definition of either biodiesel or non-ester renewable diesel
Renewable Fuel	D6	20%	Renewable fuels produced from corn starch or any other qualifying renewable biomass

In November 2018, EPA finalized volume requirements under the RFS program for 2019. Table 19 lists these volumes for four categories of biofuels. The volume requirements have increased for all biofuel categories. The highest change is seen in cellulosic biofuels with over 100 million gallons increase in 2019 compared to 2018.

Table 19. Biofuels volume requirement under EPA RFS program[86]

Year	2018	2019	Change in 2019 compared to 2018
Cellulosic biofuels (billion gallons)	0.311	0.418	+35%
Biomass-based diesel (billion gallons)	2.00	2.10	+5%
Advanced biofuels (billion gallons)	4.28	4.92	+15%
Renewable biofuels (billion gallons)	19.28	19.92	+3%
Total biofuels	25.87	27.36	+5.8%

[85] Compared to the petroleum baseline
[86] Biofuels Digest, 2019

The federal RFS is the primary policy encouraging biofuels use in the United States. The RFS is implemented by the US EPA. EPA implements the revised program (RFS2) in consultation with the USDA and US Department of Energy (USDOE).[87]

Obligated parties under the RFS program are refiners or importers of gasoline or diesel fuel. Compliance is achieved by blending renewable fuels into transportation fuel, or by obtaining credits, called RIN to meet an EPA-specified Renewable Volume Obligation (RVO). RVO percentages are calculated by dividing the mandated quantity of each renewable fuel type by the total estimated supply of non-renewable gasoline and diesel fuel in each year. The RVOs are applied to each obligated party's actual supply of fuels to determine its specific renewable fuel obligation for that year.

To qualify as a renewable fuel under the RFS program, a fuel should be produced from an approved feedstock through an approved pathway. For a given approved feedstock, there can be several approved conversion pathways. A RIN is generated when a producer makes a gallon of renewable fuel by an approved pathway and this RIN is then attached to it. Obligated parties should blend the renewable fuel into fuel derived from petroleum, or purchase RINs credits to meet their specified annual volume obligation.

RINs are traded in two forms: (i) “assigned RINs” are directly associated with a batch of fuel and purchasers obtain both the renewable fuel and the RINs together and (ii) “separated RINs” are separated from a specific batch of renewable fuel and are traded separately. The renewable fuel producer generates these separated RINs and market participants can then trade these RINs with obligated parties that can obtain and retire them for compliance with annual RVOs. Figure 24 presents a schematic of a RIN’s lifecycle under the RFS program.

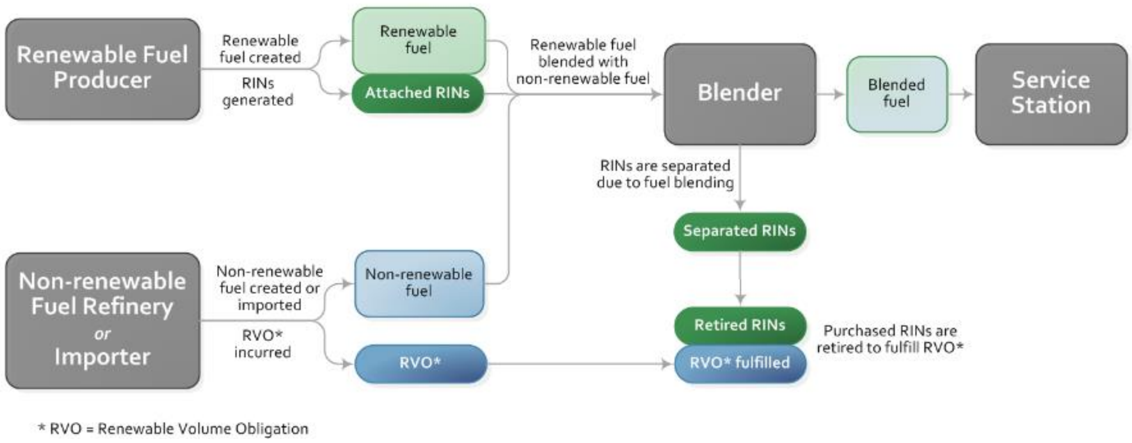

Figure 24. Lifecycle of a RIN under RFS program[88]

Besides the RFS, another strong policy driving increased biofuels production and use in the US is Low-Carbon Fuel Standard (LCFS). The main goal of this legislation is to decarbonize the transportation sector by at least 10% by 2020 (from a 2010 baseline) by using low-carbon alternative fuels such as ethanol, bio-jet and biodiesel as well as cleaner burning fossil fuels such as CNG and LNG. Enacted in 2007, with specific eligibility criteria defined by the California Air Resources Board (CARB) in April 2009, and first taking effect in January 2011, this legislation was readopted in 2015. CARB is the responsible organization in California to implement and monitor LCFS.

[87] An overview of the program and its history of development is provided at: https://www.epa.gov/renewable-fuel-standard-program/overview-renewable-fuel-standard

[88] US EPA, 2017

Compared to the RFS program in which there are volumetric mandates for renewable fuels, California's LCFS incentivizes production of low carbon fuels. The LCFS program is fuels agnostic, with credits or deficits generated based on a fuel's\CI. All fuels and energy systems compete against each other including natural gas, electricity\, biofuels, etc. Figure 15 6 shows the volumes of alternative fuels (low carbon fuels) consumed in California from 2011 to 2017. The total volume of alternative fuels increased 60% in 2017, from 1,152 million gasoline gallon equivalent (GGE) in 2011 to 1,930 GGE.

California's LCFS works with three other programs to reduce transportation GHG emissions (e.g.., its Cap-and-Trade Program, Advanced Clean Car Program, and SB 375 legislation). Other jurisdictions following California include Oregon and Washington in the US and British Columbia in Canada. Together, they have formed a regional initiative called the Pacific Coast Collaborative. Each jurisdiction has its own LCFS in place and a regional low-carbon fuels market is being considered for the future.[89] Beyond California and structured to more broadly support bio-based production, Iowa has also developed a bio-based chemicals production credit program.[90]

A variety of fuels are being sold into California, but the main product is ethanol, as presented in Figure 25. Ethanol is coming mostly from US mid-west states such as Minnesota, Iowa, Kansas, Nebraska, Illinois, and Indiana. The lowest CI ethanol is the most likely product to be sold into the California market, as it has more credit value for the producer. The most efficient plants from a production standpoint, and ones using alternative feedstocks or who have very good energy profiles, are the producers servicing the California market.

Geography matters as well, and how and how far fuels have to travel to market can also be an important factor. Credits are available for qualifying production under both the US federal RFS and state of California LCFS. Standard measurements and/or verification processes are not yet in force. Many sustainability metrics and measurement schemes are being examined (e.g., Global Bioenergy Partnership (GBEP) indicators) however more work is needed to develop consensus reporting requirements and certification procedures.

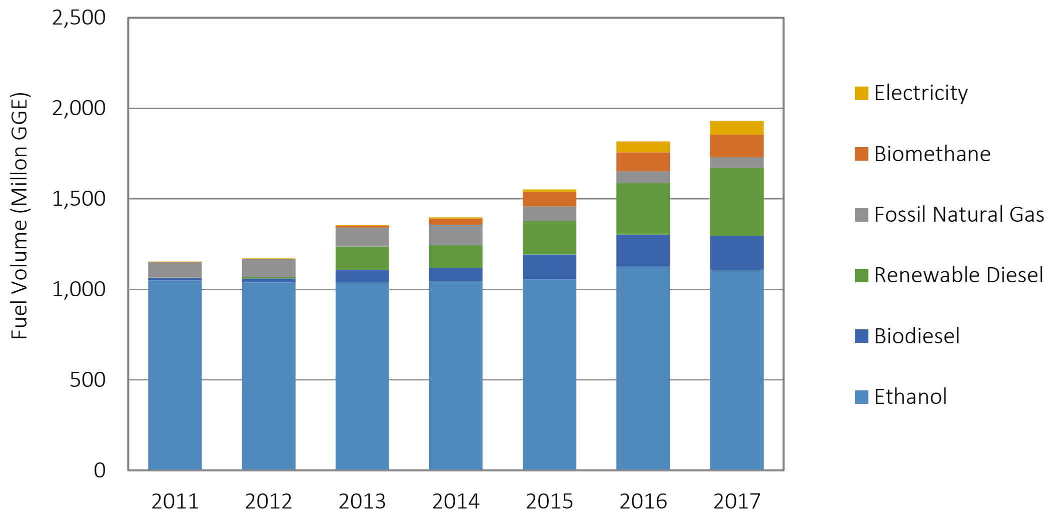

Figure 25. Alternative low-carbon fuel volumes used in California[91]

[89] An overview of California's LCFS program and its history of development is provided at: https://www.arb.ca.gov/fuels/lcfs/lcfs.htm.

[90] https://tax.iowa.gov/legislative-summaries/renewable-chemical-production-tax-credit-program

[91] California Air Resources Board, 2019

California is pushing its GHG reduction goals beyond its original 2020 goal. The original provision in California's Global Warming Solutions Act of 2006 required California to reduce its GHG emissions to 1990 levels by 2020. Updated legislation increases this goal to reduce emissions 80% below 1990 levels by 2050. The LCFS is a key element of the strategy to decarbonize the transportation sector, requiring a 10% reduction in the CI of transportation fuels between 2011 and 2020. CARB is poised to extend its LCFS program to 2030 and require a 20% reduction to be achieved.

CARB continues to work on refining and updating its LCFS program to make it an ever more effective tool for reducing emissions. Most recently, California's GHG, Regulated Emissions and Energy Use in Transportation (CA GREET) model for fuel ethanol was updated to reflect industry's production efficiency improvements, which is expected to create more credit generation by the program.

CARB has also added additional crediting mechanisms, e.g., new ways to generate credits, one of these being by using alternative (lower CI) jet fuel. Another new pathway that could be very beneficial for the ethanol industry is to recognize and reward carbon capture and sequestration (CCS). If this moves forward, CCS could provide a new source of revenue, a lot of GHG reduction and a significant new area for credit generation.

One of the other big changes being implemented in California's LCFS is third-party verification. CARB will require facilities to contract an independent third party to verify their pathway (application data) is indeed valid. Verification is one of the most important amendments being proposed by CARB, as it will provide a way for CARB to better understand how the fuels production plants are operating.

Traditionally, custom pathways were outlined for plants based on a facility's CI score. Many factors go into determining the CI of a plant, such as how much energy it is using, what kind of energy it is using, what production yield it is achieving, what coproducts it is producing, and more. The challenge for CARB is keeping track of all of the salient information. The large amount of data that needs to be tracked stretches CARB's capabilities, so it has requested third parties to become CARB-certified verifiers (after having satisfactorily completed requisite training programs) to assist this effort. Third-party verification will become mandatory for any LCFS participants in 2019. The goal is for most of the amendments to take effect January 2019, but some will be phased in over time.

Similar to the California LCFS, Oregon's Clean Fuels Program was initiated in 2009. In some respects, it does not have as many regulations as California's program does however it also requires a minimum of 10% CI reduction over 10 years. In 2015, the Oregon legislature passed S.B. 324 which allowed for the full implementation of the Clean Fuels Program within the calendar year 2016. Currently there is a single biodiesel producer pathway approved for the program. Oregon also has an existing renewable fuel standard which requires blending of 5% biodiesel into the transportation diesel supply.

Other regions in the US are considering similar legislation. The US mid-west has shown interest several times in creating its own LCFS program, as it would be a lot easier to transport and sell fuel within the mid-west where the majority of US biofuels are produced. In Minnesota, B20 will be in effect during the state's summer months of April through September; the biodiesel minimum blend level will remain at 5% October through March.

5.4. EXCISE DUTY REDUCTIONS

There are also blenders credits that are in force at times/in specific time periods for various biofuels; the blenders credit has been particularly important for expansion of biodiesel production in recent years. Various incentives that vary by city or state also exist. At the end of 2015, the biodiesel blender's tax credit of $1.0 per gallon was extended through 2016 (and to retroactively cover 2015). There have been tax credits for the purchase of alternative fuelled vehicles, e.g., flex-fuel, in the past, but none at present except for electric or fuel cell vehicles.

5.5. FISCAL INCENTIVES AND INVESTMENT

Both USDA and US DOE administer loan guarantee programs intended to buy down the risk of constructing first of a kind scaled up commercial facilities. The USDA's 9003 Biorefinery Assistance Program assists companies in the development, construction, and retrofitting of new and emerging technologies for advanced biofuels, renewable chemicals and bio-based products by providing loan guarantees of up to $250 million for commercial facilities.

Information on US DOE's Loan Guarantee Program can be found here. Other agencies such as the US EPA and the National Science Foundation (NSF) also provide funding, mostly for research, some directed at biofuels.

There are many other laws and incentives depending upon the fuel type and jurisdiction.[92]

In addition to federal and state legislations supporting the production and use of biofuels to help decarbonize the US's transportation sector, increasing CAFE standards have been contributing to the decarbonization of the transportation sector by reducing energy consumption through increasing the fuel economy of light duty vehicles (cars and trucks). Increasing CAFE standards have been highly effective in reducing demand for transport fuels.[93]

Carbon taxes continue to be lobbied for by various stakeholder groups, however no legislation is yet under serious consideration. Emission trading schemes and state compacts are being used for acid rain-precursors but not yet for GHGs.

5.6. OTHER MEASURES STIMULATING THE IMPLEMENTATION OF BIOFUELS

The USDA and US Department of Energy (DOE) and some states also administer a wide variety of programs aimed at encouraging greater production and use of bioproducts and biofuels. USDA's National Institute of Food and Agriculture (NIFA) through its Division of Bioenergy supports research on sustainable production of biomass, genomic improvement of bioenergy feedstocks, as well as other areas of biomass conversion.

NIFA has provided financial incentives for feedstock development such as in the Advanced Hardwood Biofuels Northwest and Northeast Woody/Warm-season Biomass Consortium initiatives. A listing of projects facilitating the development of regional bio-based industries producing advanced biofuels, industrial chemicals, and other bio-based products can be found here. In addition, USDA's Agricultural Research Service (ARS) focuses on feedstock development, feedstock production and biorefining.

The Food, Conservation, and Energy Act of 2008 (2008 Farm Bill) established new energy programs, including the Biorefinery Assistance Program, the Biobased Marketing Program and the Biomass Crop Assistance Program (BCAP). The Agricultural Act of 2014 (2014 Farm Bill) reauthorized and provided $880 million for energy programs established in the 2008 Farm Bill; expanded the Biorefinery Assistance Program to include biobased products and renewable chemical manufacturing; and expanded the Biopreferred program to include forestry products.

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[92] The USDOE's Alternative Fuels Data Centre provides a good single site for finding/searching

[93] More information on the US's CAFE standards can be found at: https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy

The USDA Biomass Crop Assistance Program (BCAP) was created to support the establishment and production of eligible crops for conversion to bioenergy in selected BCAP project areas; and to assist agricultural and forest land owners and operators with collection, harvest, storage, and transportation of eligible material for use in a biomass conversion facility. The 2014 Farm Bill authorized $3 million support for biomass research and development grants.

US DOE has supported related feedstock supply chain development such as Sun Grant/DOE Regional Biomass Feedstock Partnership and Feedstock-Conversion Interface Consortium. Information about US DOE's feedstock development and conversion programs can be found here. The US DOE provides research funding through both its Office of Energy Efficiency and Renewable Energy's (EERE) (primarily via EERE's Bioenergy Technologies Office (BETO)) and its Office of Science (SC) (primarily via SC's Biological and Environmental Research Office (BER)). Funding is directed at advancing biochemical, thermochemical and hybrid biofuels production technologies.

The primary focus is on non-food/feed feedstocks such as lignocellulosic biomass, photosynthetic algae and carbonaceous waste streams such as MSW and CO/CO_2 rich gases. Over the past 10 years (2007–2017), three Bioenergy Research Centres (BRCs) supported by the Genomic Science program within DOE's SC BER Office have made significant advances toward the bio-based economy. These centres are the Great Lakes Bioenergy Research Centre, the Joint BioEnergy Institute, and the BioEnergy Science Centre (now becoming the Centre for Bioenergy Innovation).

In February, a fourth DOE-funded centre also began operating, the Centre for Advanced Bioenergy and Bioproducts Innovation. These BRCs are producing multiple breakthroughs in the form of deepened understanding of sustainable biomass production practices, targeted re-engineering of biomass feedstocks, development of new methods for deconstructing feedstocks, and engineering of enzymes, microbes and inorganic catalysts for more effective production of a diverse range of biofuels and bio-based products.

Another supporting initiative by DOE is the State Energy Program (SEP) to help advance the clean energy economy while contributing to national energy goals.

5.7. PROMOTION OF ADVANCED BIOFUELS

Despite the substantial presence of conventional biofuels (e.g., biodiesels and starch-based ethanol) in the US transportation fuel market, the production of advanced cellulosic feedstock-based biofuels remains relatively small. Advanced biofuels production volumes remain far below original targets due to slower than expected progress in scale up and deployment of commercial production of cellulosic ethanol and other advanced biofuels. In 2017, total production of renewable diesel, cellulosic biofuels, and bio-jet was 453, 10, and 1.7 million gallons (1,715, 38, 6.5 million liters) respectively (based on EPA RIN data). Future production level increases depend on the ability to export as well as on how fast cellulosic biofuels production can be ramped up.

It is anticipated that biofuels production for the aviation sector will continue to increase, in part due to the anticipated global expansion of commercial aviation and limited alternative options beyond low carbon biofuels to decarbonize this sector. Additionally, the US military previously committed to increase its use of domestically manufactured aviation fuel and biodiesel fuels as part of a national security imperative. However, while the US Secretaries of Agriculture, Energy, and the Navy in 2011 signed a Memorandum of Understanding to commit $ USD 510 million ($170 million from each agency) to produce hydrocarbon jet and diesel biofuels, the future of this initiative is currently unclear and under discussion. Table 20 lists operational, under construction and planned bio-jet and renewable diesel production facilities in the US.

Table 20. Operational and planned jet fuel and renewable diesel production facilities in the U.S.

Project Name	Location	Feedstock	Technology	Capacity (ML/year)	Operational - year started or anticipated
Fulcrum Sierra Biofuels	Storey County, NV	MSW	Gasification	38	2019
Emerald Biofuels	Gulf Coast	Fats, oils, and greases	HEFA	333	2017
Red Rock Biofuels	Lakeview, OR	Woody biomass	Gasification, micro-channel FT	61	2017
AltAir Fuels	Los Angeles, CA	Fats, oils, and greases	HEFA	152	2016
REG Synthetic Fuels	Geismar, LA	Fats, oils, and greases	HEFA	284	2014
Diamond Green Diesel	Norco, LA	Fats, oils, and greases	HEFA	568	2013
SG Preston	South Point, OH	Fats, oils, and greases	HEFA	455	2020
SG Preston	Logansport, IN	Fats, oils, and greases	HEFA	455	2020

With the support from US federal and state agencies and many collaborations among universities, national labs and companies, the science and technology for producing lower carbon renewable biofuels keep marching forward with the efficiencies and technology readiness levels of many routes to biofuels continuing to improve. Recent examples of such advances include:

- Demonstration of commercial-scale cellulosic ethanol production improving: In 2017, POET-DSM's pioneer cellulosic ethanol production facility in Emmetsburg, Iowa, reported beginning to routinely achieve corn stover conversion yields of 70 gallons ethanol per bone-dry ton of biomass, near this plant's design target, albeit this facility remains in a ramp-up phase for plant throughput. More recently, POET-DSM announced it is going to add on-site enzyme manufacturing to this facility.

- Ethanol production from corn fibre being implemented in existing corn dry mills: Ethanol production from corn fibre has become an area of active R&D and commercialization since 2014, when the EPA classified corn kernel fibre as a crop residue, with multiple routes now being commercialized to convert some or most of the corn kernel fibre by-product present in dry mill ethanol facilities to ethanol. These technologies enable conventional corn ethanol dry mill plants to generate 2%-10% additional ethanol (cellulosic ethanol) from their captive fibrous residue stream(s). Technology development companies with patented corn fibre to cellulosic ethanol pathways include D3MAX, Edeniq, ICM and Quad County Corn Processors. EPA has so far approved seven corn ethanol plants to produce cellulosic ethanol from corn kernel fibre (Table 21).

Table 21. List of ethanol plants approved to generate RINs from corn kernel fibre

Corn Ethanol Plant	Location	Data approved by EPA to generate cellulosic ethanol
Quad County Corn Processors	Galva, IA	October 2014
Pacific Ethanol	Stockton, CA	September 2016
Flint Hills Resources	Shell Rock, IA	December 2016
Little Sioux Corn Processor	Marcus, IA	January 2017
Siouxland Energy & Livestock Cooperative	Sioux Center, IA	June 2017
Flint Hills Resources	Iowa Falls, IA	October 2017
Mid America Agri Products/Wheatland LLC	Madrid, NE	December 2017

The increase in cellulosic ethanol production owing to increasing implementation of corn fiber conversion technology as well as increasing production from the POET-DSM plant discussed above is measurable. Cellulosic ethanol production was more than doubled from 3.8 million gallons (14.3 million liters) in 2016 to 10 million gallons (38 million liters) in 2017, as more corn stover- and corn kernel-based ethanol production came online. EPA RIN data indicate production volumes are continuing to increase during 2018 year to date.

- Drop-in fuels by co-processing in petroleum refineries advancing: co-processing refers to the simultaneous processing of biogenic and fossil (petroleum) feedstocks, especially combined processing in existing petroleum refineries of biomass-derived biocrudes or bio-oils with intermediate petroleum distillates such as vacuum gas oil (VGO). This co-processing approach is of interest because of its potential to use existing fuel refining, distribution and storage infrastructure to produce lower carbon drop-in fuels. Several national labs and universities are active in co-processing R&D, and a few commercial refiners are exploring production at pilot and larger scales. Current research is mostly examining the potential to do such co-processing using fluid catalytic cracking (FCC) or hydrocracking/hydrotreating units in existing refineries. Research to date suggests that co-processing of up to 20% (by wt.) biogenic oils (e.g., vegetable oils, animal fats) with VGO may be possible in FCC units. The US DOE estimates that more than 8 billion gallons of renewable hydrocarbon fuels (over 30 billion liters) could potentially be produced via co-processing using the 110 FCC units that already exist in the US.

Following, Figure 26 presents the production of cellulosic ethanol, from 2012 to 2017.

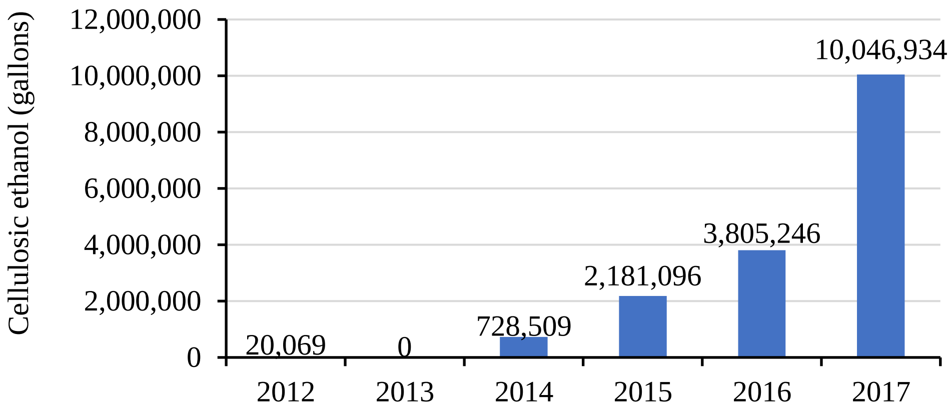

Figure 26. Production of cellulosic ethanol, 2012-2017[94]

- Commercialization of ethanol from CO/syngas progressing: LanzaTech's gas fermentation platform enables regional production from local wastes and residues, including gases as varied as industrial flue gas, gasified biomass wastes and residues, biogas, and high-CO_2 stranded natural gas. Originally founded in 2005 in New Zealand, the company relocated its headquarters to the US in 2014.

[94] Based on EPA RIN data

- Co-optimization of fuels and engines: The US DOE's crosscutting "Co-Optima" initiative tackles fuel and engine innovation from a systems perspective, with the goal of optimizing overall performance and efficiency. This initiative seeks to improve transportation fuel economy 15%–20% beyond BAU (business as usual) targets for separate R&D on engines and fuels. This is a large collaboration drawing on the expertise of two DOE research offices, nine national laboratories, and numerous industry and academic partners. Results to date indicate that increasing the efficiency of internal combustion engines through the use of renewable blending components has great potential to increase the efficiency of both conventional and hybrid vehicles. Higher octane gasoline allows for greater fuel efficiencies, but engines must be tuned to optimally works on higher-octane blends. By matching high octane fuels to high compression ratio engines, the auto industry can gain an additional 3-4.5% in vehicle efficiency.[95]

- Algae-based biofuels: Algae have significant potential to support advanced biofuels and biorefining industry in the US, and the goal of US DOE BETO's Advanced Algal Systems Program is to develop cost-effective algal biofuels production and logistics systems. Since reviving its algal biofuels program in 2009, BETO has invested in a variety of research, development, and demonstration projects tackling the barriers to economic scale-up of commercial algal biofuels. A recent report, "National Algal Biofuels Technology Review" discusses the current status and remaining challenges to commercialize production of algal-based biofuels and bioproducts in the US.

- Feedstock development: Research is also underway to develop improved biomass/bioenergy crops that exhibit more favourable chemical compositions and are easier to convert to targeted biofuels. One example of alternative feedstock development is an effort to transform sugarcane and Miscanthus into better feedstocks for producing biodiesel and bio-jet fuels by engineering these plants to produce higher levels of oil (lipids) rather than sugar (carbohydrates). In February 2018, the US DOE awarded $10.6 million grant to the so-called Renewable Oil Generated with Ultra-productive Energycane (ROGUE) project, a collaboration by researchers from the University of Illinois, Brookhaven National Laboratory, University of Florida, and Mississippi State University. USDA and US DOE also support a variety of projects to develop cost-efficient and reliable feedstock logistics and supply chains. For example, DOE's High-Tonnage Biomass Logistics Demonstration Projects were focused on developing five improved harvesting technologies to reduce biomass logistics costs while maintaining or improving harvested biomass quality.

5.8. MARKET DEVELOPMENT AND POLICY EFFECTIVENESS

Over the past decade, the RFS2 has effectively propelled increased production and use of biofuels in the US, primarily more conventional ethanol production from corn kernel starch but also conventional fatty acid methyl ester (FAME) biodiesel from oleaginous feedstocks. In recent years, volumes of cellulosic ethanol and renewable diesel (also known as hydrotreated vegetable oil (HVO) or hydroprocessed esters and fatty acids (HEFA)) have also increased. Figure 15 8 shows how ethanol production has increased under RFS2. In 2017, a total of 15.8 billion gallons (59.8 billion liters) of fuel ethanol was produced in the US. This production came from 199 plants located across 29 states.

[95] More information on Co-Optima can be found at: https://www.energy.gov/eere/bioenergy/co-optimization-fuels-engines

Considering supply and distribution chains, this production alone accounts for over 270,000 jobs. In 2015, about 0.1 billion gallons of ethanol was imported into the US and the total exported volume was about 0.8 billion gallons. US motor gasoline consumption has grown in the past four years, increasing from 8.7 million barrels per day (b/d) in 2012 to 9.3 million b/d in 2016, resulting in an increase of 7% in additional ethanol demand for E10 blending in gasoline that has helped to support the consistent growth in ethanol production over this period. The US remains the largest producer of ethanol in the world (58%), followed by Brazil (26%) and EU (5%).

Following, Figure 27 shows the historical production of ethanol in the US, from 2000 to 2017.

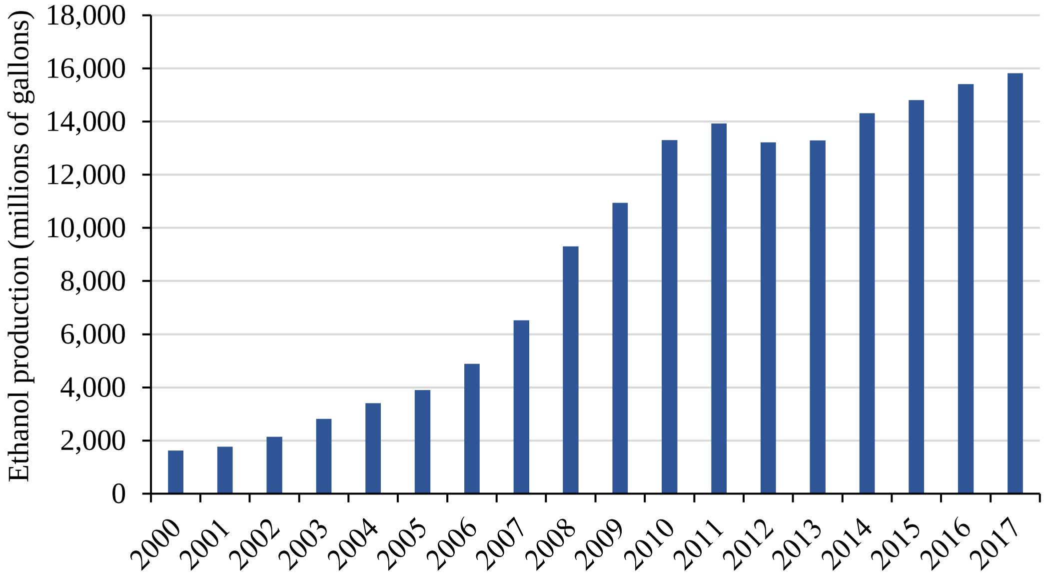

Figure 27. Historical production of ethanol in the US, from 2000 to 2017

Corn is the primary feedstock for ethanol production in the US, and large corn harvests in recent years have contributed to increased production. The USDA estimates that the US produced a record 15.1 billion bushels of corn in the 2016-17 harvest year, 11% more than the 2015–16 harvest. Increased corn yields and relatively stable corn prices help make increased conventional ethanol production from corn kernel starch more profitable. In 2017, about 30% of the total US corn crop – over 4.2 billion bushels of corn – was used to produce fuel ethanol.

Similar to ethanol, the RFS has driven increased production and use of diesel biofuels in the last 10 years, both FAME biodiesel and renewable diesel type. As presented in Figure 29, diesel biofuels production reached about 2.5 billion gallons (9.5 billion liters) in 2017 as compared to 215 million gallons (814 million liters) in 2010. This production level was achieved by 97 plants operating across 37 states. FAME biodiesel and renewable diesel compete for the same oleaginous feedstocks and the recent trend has been renewable diesel starting to outcompete for the limited feedstock, meaning more renewable diesel (HVO/HEFA fuels) production and less FAME biodiesel production.

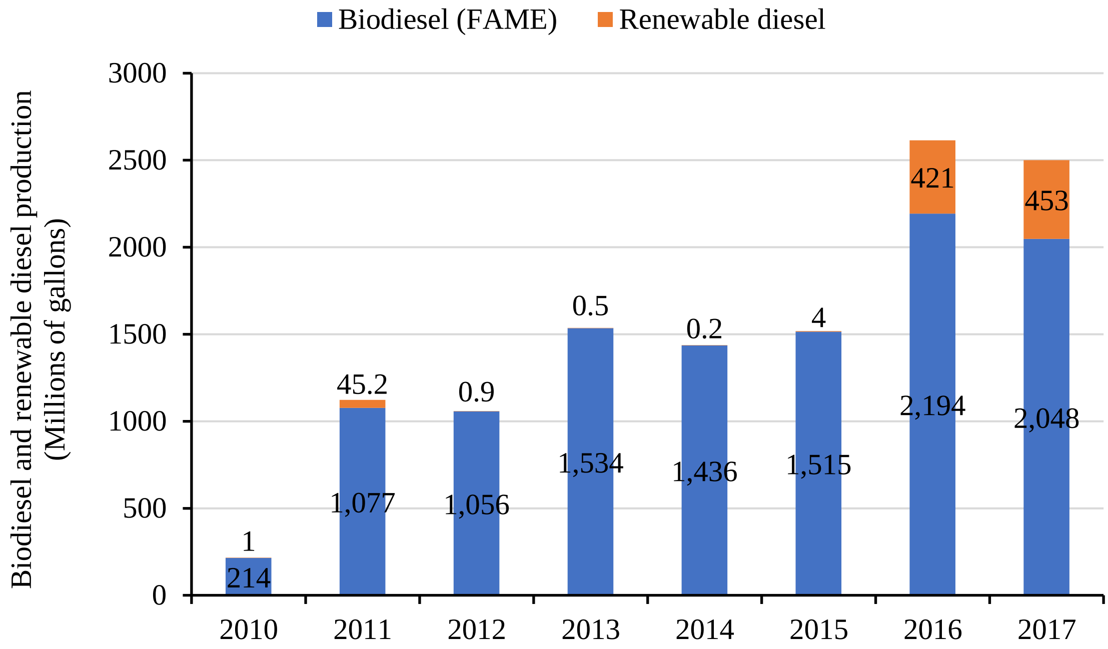

Figure 28. Diesel biofuel production in the US from 2010 to 2017[96]

Production volumes of diesel-substituting biofuels are limited by the availability of oleaginous feedstocks. In 2016, 11.05 billion pounds (over 5 million metric tons) of such feedstocks were used to produce diesel biofuels, 77% vegetable oils and 23% recycled/used vegetable oils and animal fats. Soybean oil was the largest single feedstock for US production, using 6.1 billion pounds of soybean oil in 2016, compared to 4.9 billion pounds in 2015, an increase of 24%, and representing approximately 28% of total 2016 US soybean oil production (22.1 billion pounds (over 10 million metric tons).

Table 22. Summary of transport fuel consumption (ML/year)

Year	Gasoline*	Diesel fuels	Aviation fuel (jet only)*	Biodiesel	Ethanol	Market share of biofuels (%)
2006	523,976	175,075	94,749	988	20,749	2.67
2007	527,648	176,249	94,143	1,339	26,065	3.32
2008	512,658	158,874	89,298	1,149	36,656	4.73
2009	513,037	152,401	80,856	1,218	41,778	5.45
2010	512,090	160,388	83,090	985	48,675	6.17
2011	498,538	165,309	82,711	3,355	48,806	6.53
2012	494,715	157,776	81,121	3,403	48,763	6.64
2013	503,649	162,735	83,241	5,409	50,026	6.89
2014	509,403	169,889	85,285	5,364	50,891	6.85
2015	512,696	172,577	89,828	5,656	52,794	7.01
2016	520,721	170,798	93,689	7,894	54,344	7.34
2017	514,059	157,322	95,771	7,478	54,415	7.47

* Aviation gasoline consumption also reported

Based on projecting 10 month "through October 2017" results to full calendar year 2017 and on the project 11 month "through November 2017" results to full calendar year 2017

https://www.eia.gov/energyexplained/?page=us_energy_transportation

[96] Based on EPA RIN data

6 SUSTAINABILITY CRITERIA FOR ASSESSED COUNTRIES

6.1. THE EU DIRECTIVES

Within the EU, the EU Renewable Energy Directive (RED II) settles a minimum amount of 14% biofuels and other renewable fuels for transportation that must be used in every Member State by 2030. In addition to that, the Fuel Quality Directive (FQD) is intended to fuel suppliers, compliant them to mitigate GHG emission with 6% by 2020. Therefore, only biofuels meeting the sustainability criteria related to (i) net GHG savings, (ii) biodiversity and (iii) land use can be relied towards the goals. Taking into account the indirect Land Use Change (ILUC) in RED II, one of the main points is the endeavor to lower indirect GHG from biofuel production.

In 2009, the EU adopted the Renewable Energy Directive (RED I), by which all Member States should have 10% (on energy basis) biofuels within the transportation sector by 2020. RED II is an amended version that come into effect in December 2018. This updated edition shifted the legal framework from 2020 to 2030. There is a union goal asserting that the whole proportion of energy coming from energy sources must be 32% of the final energy use in the EU, by 2030.

In addition to that, there is a national target defined in RED II, by which all Member States must determine a commitment for fuel suppliers, guaranteeing that the minimum proportion of renewable energy within the transportation sector is 14% of the entire energy used in the EU by 2030. After the year of 2023, this target shall become more rigorous, in order to be aligned with the 55% emission reduction goal by 2030. Also, RED II outlines diverse sustainability and GHG emission standards related to biofuels that the Member States are required to comply with in order to follow the targets. Finally, for the purpose of receiving financial support (e.g., tax exemptions) biofuels shall fulfil the sustainability criteria.

Following, the Fuel Quality Directive (FQD) was established in 2009 setting demands on fuel specifications and compelling fuel suppliers to decrease GHG emissions. Thus, by 2020 every sold part of energy shall decrease life cycle of GHG emission as a minimum of 6% in contradiction with the EU-standard fossil fuel in 2010. Consequently, there are several options by which this reduction can be obtained according to the FQD (e.g., using of biofuels and alternative fuels). Moreover, biofuels should follow similar sustainability criteria settled in RED II.

Dialogues considering an increased lower rate and an assertive movement of the sustainability criteria from FQD to RED were held in 2021. Prior to that, adjustments to RED I and FQD were adopted by ILUC, in 2015, inserting values for biofuels and toughen sustainability criteria in comparison with RED and FQD. Since then, the ILUC rules were incorporated in RED II together with the criteria for specifying high ILUC-risk feedstocks for biofuels.

6.2. TRANSPORTATION SECTOR CONTRIBUTING TO RENEWABLE ENERGY

As aforementioned, the Member States may determine an obligation for the fuel suppliers, guaranteeing 14% as the minimum amount of the final energy use in the transportation sector, in 2030. RED II presented calculation rules for the 14% goal with the purpose of decreasing the incentives to endorse less sustainable biofuels. Following, the amount represented by biofuels based on food or feed crops can only be 7% of the 14% goal. Also, there is a constraint for the quantity that can be high-ILUC risk fuels (e.g., palm oil) which is not permitted to expand and shall decline to 0% in 2030. In this section, is important to punctuate that RED II encourages advanced biofuels (e.g., biofuels based on lignocellulosic and non-food cellulosic material as well as algae, waste, manure and sewage sludge.

As a consequence, the Member States shall establish a binding sub-target for advanced biofuels at a minimum rate of 0.2%, 1% and 3.5% in 2022, 2025 and 2030, respectively. The remaining fuels, originated from used cooking oil and animal fats, can be estimated to the 14% goal. In this group, renewable electricity and recycled carbon fuels are also included.

Following, taken into account the sustainability criteria used for different biofuels, RED II enables the advanced biofuels to be counting twice towards the 14% goal. Considering fuels generated from used cooking oil animal fats, 1.7% can be calculated twice towards the 14% goal (or the 3.5% goal for advanced biofuels). The acceptance of only 1.7% to be double-counted is to adjust with the limited supply of the feedstocks. Furthermore, the renewable electricity for road transportation should be calculated four times. In addition to that, for rail-bound transportation, it can be mattered 1.5 times towards the goal.

6.3. THE SUSTAINABILITY CRITERIA WITHIN THE EU

RED II affirms that raw material for biofuel production cannot be captured from highly biodiverse grassland, land with elevated carbon stocks (e.g., wetland, peatland), nature protection regions and primary forest, in order to be considered sustainable. RED II delineates different criteria to be performed in order to diminish the risk of using raw material originated from an unsustainable production, whether the raw material production is forest biomass.

Taking into account RED I, a demand of 35% GHG emission saving from the utilization of biofuels was considered. According to ILUC Directive, GHG emission savings originated from the utilization of biofuels manufactured in old production sections shall be at least 50%, from 1 January 2018. Considering production sections that started after 5 October 2015, the reasoned edge is 60%. Finally, for sections in which the biofuels production began from 1 January 2021, the limit taken is 65%.

6.4. THE CONFORMITY OF SUSTAINABLE CRITERIA IN THE EU

The sustainability criteria in RED I is employed for biofuels and bioliquids, whereas the same criteria are employed for solid biomass fuel utilized for gaseous biomass fuels used for electricity and transportation, as well as electricity and heating. Within the Member States, companies paying fuel tax are taken as economic operators being responsible for presenting the fulfillment of the sustainability criteria. They are required to have a control scheme in order to maintain the route of the diverse biofuel groups, considering from where the raw material is originated from as well as the sustainability attributions of each group. Therefore, independent auditors examine and endorse the quality of the control schemes.

6.5. RED II IN SWEDEN

The combination of renewable fuels into the transportation sector is ordered by the reduction mandate. It entered into force on 1 July 2018, in Sweden. Updates (e.g., regulations for which fuels can be utilized in order to encounter the reduction mandate) entered into force on 1 August 2021. In addition, the execution of the sustainability criteria is performed by a review of the legislation 2010:598 (sustainability criteria for biofuels and liquid biofuels) coming into force on 1 July 2021.

RED II comprises several defaults GHG values for partitions of the biofuel production chain, between cultivation, processing, transporting and distribution. Following, the economic operators can decide to utilize (i) these default values (whether the biofuel chain is in conformity with those ones that are registered in the directive), (ii) their own calculated real values, or (iii) a combination of (iv) default and (v) real values. Taken into account the third option – calculation of real values is made in appliance with LCA methodology and regulations delineated in the Directives annexes.

Whether there are by-products originated from the manufacture process related to the fuel, they can divide the GHG emissions in relation to their energy matter. Still, there are numerous negative emissions that can decrease the total GHG emission rate (e.g., enhanced agricultural management procedures enabling more carbon to be bound in soil, surplus electricity generated within the biofuels plant, CO_2 that is isolated and geologically stored as well as CO2 which is separated and displaced. Finally, there is a GHG bonus whether raw material is cultivated on seriously degraded land.

6.6. RED II IN GERMANY

Taken into account Germany, in 2009 the country settled legislative acts for the sustainable production of biofuels, bioliquids and biomass based on RED. The most important are: (i) the energy tax, (ii) the renewable energy source act law for priority of renewable energy (EEG), (iii) the sustainable-biofuels ordinance and (iv) the biomass-electricity-sustainability ordinance.

The official bureau is called Bundesanstalt für Landwirtschaft und Ernährung (BLE), being in charge of assessing the implementation of RED sustainability criteria. BLE also redact an annual progress report in support of the Federal Government. Besides, this bureau recognizes and monitor all certification schemes and bodies within Germany. Particularly, the BLE handles with essential biofuels data for the allocation of biofuels to the biofuel quota. In addition, BLE also takes care of this data for tax relief disposable to the biofuel quota body and to central customs agencies.

Bering in mind the bioenergy context, the BLE is liable for data necessary for compensation. Still, BLE is responsible for renewable source bonus to installation operators that are disposable to the system operators. In this context it should be noted that the data asked for BLE in order to conform to an effective achievement of the German legislation is equal to the level of data requested by RED.

Taking into consideration the conversion of liquid biomass into electricity, the BLE is also responsible for keeping a register of all existing installations. For that, the BLE controls the plausibility of the final agent verifications of sustainability. In addition to that, the BLE also checks issues partial verifications of sustainability connected to the supplier demands. In order to avoid bureaucratic approaches, there is an electronic scheme used by the BLE called WEB-application Nabisy. It is capable to control at each level the plausibility of verifications of sustainability is working. This system also issues partial verifications of sustainability on supplier demands.

Whether the economic agent deliver the data needed for verification of sustainability and provision of compliance with the RED, as well as complementing the legislation in Germany, they are considered entitled to request a national tax relief or a credit in opposition to the biofuel quota in Germany. In the same way, the agents can also claim a payment of compensation by network operators within the electricity division.

Finally, recapturing the sustainable-biofuels ordinance and the biomass-electricity-sustainability ordinance and bearing in mind the sustainable biomass production regulations, the BLE acknowledges certification schemes with the aim of accepting at all levels of the sustainability taking into account production, transport and distribution of biomass that should be achieved.

Finally, Germany has other three certification schemes, besides the latest EU certification systems. The country has 29 certification bodies which are recognized. They are in charge of the accomplishment of the conditions of the ordinance/s. In addition, they are considered to deal with standards of the certification schemes connected to industries and operational sites, as well as providers operating under a determined certification system.

6.7. THE SUSTAINABILITY CRITERIA IN CANADA

In Canada, the Low Carbon Fuel Standard (LCFS) constitutes a compliant legislation that determines an obligatory decreasing within the GHG intensity of fuels that are sold in a province. The LCFS have been utilized entirely to transport fuels, in Canada. In addition, LCFS determines the emissions performance needed, also enabling providers flexibility in accomplishing the standard, comprising the option of using credit trading. Suppliers of unconventional low-carbon fuels (e.g., biofuels, hydrogen) can obtain credits.

Until 2017, BC was the only province with a prevailing LCFS. Even though the federal government intended to have LCFS, in order to enlarge the policy exceeding transport fuel, and embracing fuels utilized by construction and industry. However, this movement brings several issues on policy design and implementation. The country opted to use this tool, mainly because it has an elevated GHG decreasing potential. Besides, LCFS has an immediate impact by enhancing the emissions intensity of current fuels utilized. Finally, it can also stimulate clean innovation, speeding the moving towards cleaner fuels within the society.

Taking into account some key principles on LCFS designing, it is important to consider the existence of an extensive scope, rigorous and predictable goals, and suitable compliance instruments. Nevertheless, issues related to regional effects, cost effectiveness and innovation effects are also crucial. In addition, LCFS can supplement other GHG mitigation policies, on the national and sub-national levels (e.g., carbon pricing and renewable fuel standards). However, policy interactions and boundaries are complicated do assess, and they need to be taken into account since the beginning of the policy design.

In addition to the LCFS, the Clean Fuel Standard (CFS) is also an essential part of the climate plan in Canada in order to decrease emissions, as well as speeding up the utilization of clean technologies and fuels, and generating jobs in a mixed economy. Many sectors (e.g., biofuels, agriculture and low-carbon energy sectors) can be impacted by this tool. This tool provides fuel suppliers versatility to encounter the stipulations in a cost-effective way. It also provides encouragement for industries to modernize and embrace clearer technologies in order to lower compliance costs.

It was designed to promote innovation and acquire clean technologies as well as enlarging the utilization of low carbon fuels within the Canadian economy. Throughout this initiative, fossil fuels will gradually become cleaner, in due course. In addition to that, reasonable price alternatives for consumers will become progressively available. The compliance credits can be formed in three different ways. The first one is addressing schemes that decrease the carbon intensity of fossil fuels (e.g., carbon capture and storage). The second is throughout the supply of low carbon fuels (e.g., ethanol in gasoline). Finally, the third one focus on the replacement of fossil fuels by lower carbon fuels or energy (e.g., hydrogen in vehicles). Finally, the CFS will supplement other climate policies and investments in Canada, along with carbon pollution pricing.

Following, the demand for credits will promote a market signal towards investment in low-carbon-intensity fuels and technologies. Therefore, the LCS will drive the Canadian society towards innovation and economic growth. Summing up, the main goal of the CFS is the 10-12% decreasing of fuel carbon intensity in the average of fuel carbon intensity by 2030, taking 2016 as base year. The predictable outcome will be a decreasing on emissions of approximately 17.5 $MtCO_2e$ by 2030.

Taking into account implementation procedures, the process initiated in 2016, targeting liquid, gaseous and solid fossil fuels in Canada. After that, the publication of proposed regulations for the CFS in the Canada Gazette occurred on December, 2020. At that time, the focal point was concentrated only on liquid fossil fuels, keeping restricted options for gaseous and solid fossil fuel displacement. Since then, several developments and improvements were done. The goal to publish its final regulations is the spring of 2022, when specific constituents will come into effect at this time, comprising registration, applications and activities for the credit establishment. Finally, it will come into effect by December, 2022.

6.8. THE SUSTAINABILITY CRITERIA IN THE U.S.

Retaking some topics that were previously explored in the U.S. analysis, the Renewable Fuel Standard (RFS) is a program developed under the Energy Policy Act, in 2005 (EPAct), that also rectified the Clean Air Act (CAA). In addition to that, the Energy Independence Security Act of 2007 (EISA) further modified the CAA, broadening the RFS. The EPA developed the program together with the U.S. Department of Agriculture and Department of Energy.

The RFS demands a specific volume of renewable fuel to substitute or decrease the amount of petroleum-based transport fuel, heating oil or jet fuel. The renewable fuel categories stablished are: (i) biomass-based diesel, (ii) cellulosic biofuel, (iii) advanced biofuel and (iv) total renewable fuel.

The EISA's promulgation occurred in 2007 and it substantially enhanced the proportion of the program. Besides, the key changes targeted were (i) the increasing of longstanding targets to 36 billion gallons of renewable fuels, (ii) the enlargement of the amount requirements (by year) over 2022, (iii) the inclusion of determined forms of waiver authorities and (iv) the addition of specific description for renewable fuel related to quality (e.g., GHG emissions).

Throughout the Clean Air Act, EPA's authority can modify cellulosic, as well as advanced and total amounts established by the Congress. This is part of the annual rule procedures. Taking into account fuel requirements to be qualified as renewable under the RFS, EPA should specify fuel qualifications according to determined regulations and statute. In this context, it is fundamental that fuels accomplish a decreasing in GHG emissions in correlation with the oil baseline, in 2005.

The RFS was the chosen EPA's instrument to endorse fuel pathways, taking into account four main groups of renewable fuels. Ethanol from sugarcane, jet fuel from camelina, cellulosic ethanol from corn stover and CNG waste compose a group of advanced pathways already supported. Taking into account biomass-based diesel, a 50% lifecycle GHG emissions decreasing should be fulfilled. Following, cellulosic biofuel should be originated from cellulose, hemicellulose, or lignin, meeting a reduction of 60% lifecycle GHG decreasing. Advanced biofuel should be originated from qualifying sustainable biomass (except corn starch). Its requirement is 50% of GHG lowering. Finally, ethanol produced from corn starch should meet a 20% lifecycle GHG reduction decreasing.

The EPA remains reviewing and endorsement plans, incorporating fuels produced with advanced technologies and new raw materials. Specific biofuels analogous to gasoline and diesel do not need to be blended. Instead, they can simply be added in oil-based fuels, being a forthcoming promise.

6.9. THE SUSTAINABILITY CRITERIA IN BRAZIL

Brazil has been a pioneer within the biofuel agenda, globally. The country produces and utilizes substantial amounts of ethanol, having developed initiatives to support this fuel since 1975, when the National Alcohol Program (PROALCOOL) was adopted. At that time, it was an outcome of the consequences of oil shock prices within the Brazilian economy. Since then, other initiatives were taken, such as the National Biodiesel Production and Use Program (PNPB) to enhance the consumption of biodiesel.

In Brazil, ethanol is originated from sugarcane and it has been assessed to decrease GHG emissions by 71% taking into account the calculations of EU RED. In addition to that, biodiesel is originated from soybean. It has been assessed to decrease GHG by 31%, also considering the RED.

In Brazil there are ethanol and biodiesel mandates for road fuels. The existent standard demands a 27% blend of ethanol within gasoline. Progressively there was a growing demand on biodiesel blends – in 2017 the required amount was 8%. Afterwards this amount was replaced by 9% and 10% in 2018 and 2019. The Regulatory Official Body in charge of these issues are the Ministry of Mines and Energy (MME) and the National Agency of Petroleum, Natural Gas and Biofuels (ANP).

Following the Brazilian trend to enlarge its domestic sustainable biofuels market, the National Biofuels Policy, officially named as RenovaBio was launched in 2017. [97] The Brazilian Government aims at continuing to enhance the share of biofuels in the total final energy consumption of the transport sector, within the energy matrix in the country. In addition to that, the country also aims at fulfilling its commitments under the Paris Agreement throughout this program that went into effect in December, 2019.

It is an essential instrument towards the decreasing of GHG, being based on predictability and sustainability of biofuels, taking into account the three fundamental and constitutional pillars – social, economical and environmental.

RenovaBio was also born to address some of the demands of the powerful biofuel sector in Brazil towards an effective policy that settles clear and predictable regulations on the ethanol production within the energy matrix.

According to the sector, the main objectives of this program are (i) enhance biofuels, (ii) promote energy security, (iii) ensure predictability of investments, (iv) reduce emissions within the transportation sector, (v) improve air quality in large cities, (vi) promote technological innovation in the sector and (vii) generate more jobs and income. [98]

The Program is driven towards yearly goals, and the expected outcome is to restrain the release of more than 600 million tons of CO_2 in the course of the following 10 years throughout the utilization of renewable fuels within the energy transport matrix.

In addition to that, the factories may have their manufacture units inspected. This is important for a zero-deforestation movement. Then, based on the inspection and LCA analysis, an environmental index will be produced. This index will be certified by the ANP and the producing units can generate decarbonization credits entitled - CBIOS.

[97] Law 13.576/2017

[98] https://unica.com.br/iniciativas/renovabio/

Considering ethanol, less carbon intensity industries would demand approximately 650 liters of biofuels in order to generate one CBIO. Also, these decarbonization credits constitute an exchange-tradable guarantee. And any individual agent or legal part is allowed as buyer them in the stock market. Throughout the program fuel distributors will be constrained to acquire these guarantees, in order to encounter individual emission decreasing goals. These targets are anchored on the amount of fossil fuels traded by the distributor.

Renovabio is fundamental because it establishes a progressive transition towards a cleaner energy matrix. It is also important to punctuate the assigned value for energy production originated from biomass (e.g., corn, soy) that the program strengthen. The program also enables the incorporation of diverse biofuels (e.g., ethanol, biodiesel and biomethane) within the transport matrix in Brazil. These biofuels rely on an already stablished infrastructure, as well as technology (e.g., flex-fuel engines) in order to encourage this transition.

Through this instrument, the expected outcome is a substantial incentive for competition as well as motivation for producers, generating a higher efficiency when using tools to measure and decrease their emissions. Finally, as mentioned above, R&D towards the development of technologies within the whole supply chain of biofuels (e.g., chemicals, fuels and fertilizers, machineries in general) are also awaited as important outgrowths.

In the light of the foregoing, RenovaBio seems to be an efficient policy for the purpose of promoting biofuels and decreasing GHG emissions in Brazil. However, it is important to punctuate that some of the endeavours to consolidate the program are still being carried out by the government.

The political structure and its influences are complicated to understand, in this country, as well as lobbying issues. Since the democratic period, the changes occurred within the current presidential term have never been observed in Brazil - ministers, diplomats and members of the official bodies were replaced overnight due to several motifs, including numerous damaging corruption scandals.

In addition to that, RenovaBio’s regulatory framework requires a re-evaluation as well as the mechanisms used by this program. Transparency issues are also fundamental and should be addressed if the country is expecting an international recognition of the program.

7 List of figures

8 List of tables

9 List of abbreviations

GHG - Greenhouse Gas
SDGs - Sustainable Development Goals
UN - United Nations
RenovaBio - National Biofuels Policy
PROALCOOL - National Alcohol Program
SIN - National Interconnected System
NDC - Nationally Determined Contribution
PDE - Ten Year's Energy Plan
COP21 - 21th Conference of Parts of the United Nations
EPE - Energy Research Agency
MME - Ministry of Mines and Energy
PRO-OLEO - Plan for the Production of Vegetable Oils for Energy Purposes
PNPB - National Program for Production and Use of Biodiesel
ANP - National Agency of Petroleum, Natural Gas and Biofuels
CTC - Centre for Sugarcane Technology
Planalsucar - National Sugarcane Improvement Plan
PROCONVE - Motor Vehicle Air Pollution Control Program
Probiodiesel - Network of Research and Technological Development in Biodiesel
EMBRAPA - Brazilian Agency for Agricultural Research
CTBE - Brazilian Bioethanol Science and Technology Laboratory
LNBR - Brazilian Bio-renewables National Laboratory
CNPE - National Energy Policy Council
CIDE - Contribution for Intervention in Economic Domain
PIS/COFINS - Contribution to Social Integration/Contribution for Financing Social Security
ICMS - Tax on Circulation of Goods and Services
SECEX - Foreign Trade Secretariat
BNDES - National Bank of Economic and Social Development
FINEP - Brazilian Innovation Agency
FAPESP - Research Support Foundation of the State of São Paulo
CNPq - National Council for Scientific and Technological Development
MAPA - Ministry of Agriculture, Livestock and Supply
MDIC - Ministry of Development, Industry, and Foreign Trade
MCT - Ministry of Science and Technology
BIOEN - Bioenergy Research Program
PAISS - Joint Plan for Supporting Industrial Technological Innovation in the Sugar-based Energy and Chemical Sectors
ProRenova - Support Program for Renovation and Implementation of New Sugarcane Crops
CORSIA - Carbon Offsetting and Reduction Scheme for International Aviation
ICAO - International Civil Aviation Organization
ASTM International - American Society for Testing and Materials International
MCTIC - Ministry of Science, Technology, Innovations and Communications
RPBC - Presidente Bernardes Refinery
DDG - Dried Grains and Solubles
Repar - Presidente Getúlio Vargas Refinery

FAME - fatty acid methyl ester
CI – Carbon Intensity
CFS - Clean Fuel Standard
USDA - Foreign Agricultural Service
ECCC - Environment and Climate Change Canada
BC-LCFS - British Columbia's Low Carbon Fuel Standard
OECD - Organisation for Economic Co-operation and Development
GDP - Gross Domestic Production
RD&D - Research, development and demonstration
PERD - Program of Energy Research and Development
NRCan - Natural Resources Canada
SDTC - Sustainable Development Technology Canada
IETS - Innovation and Energy Technology Sector
BC - British Columbia
SGER - Specified Gas Emitters Regulation
CCI - Carbon Competitiveness Incentive
LCIF - Low Carbon Innovation Fund
ZEV - Zero-emission vehicle
ECCC - Environment and Climate Change Canada
CFS - Canadian Forest Service
NSERC - Natural Sciences and Engineering Research Council of Canada
FT – Fischer-Tropsch
UBC - University of British Columbia
MSW - Municipal solid waste
RIN - Renewable Identification Number
RFS - Renewable Fuels Standard
EPA - Environmental Protection Agency
CPPI - Canfor Pulp Products Inc.
Licella - Licella Fibre Fuels Pty Ltd.
Cat-HTR - Catalytic Hydrothermal Reactor
HDRD - Hydrogenation derived renewable diesel
PtX - Power-to-X
PtG - Power-to-gaseous fuels
PtL - Power-to-liquid fuels
WTW - Well-to-wheel
WTT - Well-to-tank
TTW - Tank-to-wheel
TTW - Tank-to-wake
ETD - Energy Taxation Directive
MS - Member State
BLE - Federal Institute of Agriculture and Nutrition
BEVs - Battery electric vehicles
PHEVs - Plug-in-hybrid vehicles
FRL - Fuel readiness levels
KIT - Karlsruhe Institute of Technology
DBFZ - Deutsches Biomasseforschungszentrum

TUBAF - Technical University Bergakademie Freiberg
SRD - Solvolytic Reactive Distillation
CVO - Cracked Vegetable Oil
TCR - Thermo-Catalytic Reforming
BMBF - Federal Ministry of Education and Research
MHPSE - Mitsubishi Hitachi Power Systems Europe
CRI - Carbon Recycling International
BMEL - Federal Ministry of Food and Agriculture
BMWi - Federal Ministry for Economic Affairs and Energy
BMVI - Federal Ministry of Transport and Digital Infrastructure
ISSC - International Sustainability & Carbon Certification
REDcert - Certification of Sustainably Produced Biomass
SEA - Swedish Energy Agency
CHP - Combined heat and power
VAT - Value-added tax
RME - Rapeseed Methyl Esters
EC1 - Environmental Class
DH - District heating
FORMAS - Swedish Research Council for Sustainable Development
KK-stiftelsen - Knowledge Foundation
Vinnova - Swedish Government Agency for Innovation Systems
CTO - Crude Tall Oil
CTD - Crude Tall Diesel
LBG - Liquified Biogas
RISE - Research Institutes of Sweden
LPG - Liquid propane gas
FRS - federal renewable fuel standard
CAFE - Corporate Average Fuel Economy
EISA - Energy Independence and Security Act
BYG - Billion gallons per year
USDOE - US Department of Energy
RVO - Renewable Volume Obligation
CARB - California Air Resources Board
LCFS - Low-Carbon Fuel Standard
GGE - Gasoline gallon equivalent
GBEP - Global Bioenergy Partnership
GREET - Regulated Emissions and Energy Use in Transportation
CCS - Carbon capture and sequestration
NSF - National Science Foundation
DOE - Department of Energy
NIFA - National Institute of Food and Agriculture
ARS - Agricultural Research Service
BCAP - Biomass Crop Assistance Program
EERE - Office of Energy Efficiency and Renewable Energy's
BETO - Bioenergy Technologies Office
SC - Office of Science

BER - Environmental Research Office
BRCs - Bioenergy Research Centres
SEP - State Energy Program
VGO - Vacuum gas oil
FCC - Fluid catalytic cracking
BAU - Business as usual
ROGUE - Renewable Oil Generated with Ultra-productive Energycane
FAME - Fatty acid methyl ester
HVO - Hydrotreated vegetable oil
HEFA – Hydro-processed esters and fatty acids

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A good breakdown of estimated shares of total US transportation energy use by mode of transport is provided at: https://www.eia.gov/Energyexplained/?page=us_energy_transportation#tab2

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