Implementation Agendas: 2018-2019 Update
Compare and Contrast Transport Biofuels Policies

IEA Bioenergy

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The Task's periodically issued Implementation Agendas report has been updated to summarise current policies being used within Task 39 member countries to encourage the production and use of biofuels. This report also describes the market penetration of biofuels in Task 39 member countries as well as China and India which are two of the world's major countries also aspiring to increase their production and use of biofuels. The policy environment has changed substantially since the last report update in 2014, and the report's format has been revised to try to better compare and contrast the relative success of the various policies being used to promote biofuels development and use around the world. A questionnaire was sent to Task 39 representatives (and ExCo members) in 2017, and collected responses were compiled and used to update the country specific chapters of this report. A copy of this questionnaire is provided in Appendix I. The Task 39 country representative contributors to this report are listed below by their country and institutional affiliations.

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Executive Summary

Global production and use of transport biofuels

Global biofuels production has continued to increase over the last decade, from over 37 million tonnes oil equivalent (Mtoe) in 2007 (~64 billion liters) to over 84 Mtoe in 2017 (~145 billion liters). It increased 3.5% from 2016 to 2017, which is well below its annual growth rate of 11.4% over the past decade however the most growth in three years. The highest growth was observed in the Asia Pacific region, which realized an annual growth rate of 20.1% over the period 2006-2016 and a 6% increase from 2016 to 2017. The Americas and Europe still continue to have the highest shares of biofuels production. In 2017, North America, South and Central America and Europe had world shares of 45.5%, 26.9% and 16.8%, respectively.

The main biofuels being produced are ethanol, biodiesel (fatty acid methyl ester or FAME), and renewable diesel fuels produced by hydrogenating (hydrotreating) animal and vegetable oils and fats (also known as hydrotreated vegetable oil (HVO) or hydrotreated esters and fatty acids (HEFA) fuels), as well as a growing amount of biomethane in some countries such as the United States (US), Sweden, and Germany. In energy terms, in 2017, an estimated 65% of biofuel production was ethanol, 29% was FAME biodiesel and 6% was HVO/HEFA fuels; while growing rapidly as a transport fuel, biomethane contributed less than 1% of total biofuel use.

Global biofuels production is forecast to grow at a modest annual growth rate of 3% over the next five years, with most growth expected to come from Latin America and non-OECD countries in Asia[1]. In Brazil, the drivers for biofuel demand remain strong and it is anticipated that the new RenovaBio policy will accelerate new investment to increase biofuel production capacity. China intends to roll out 10% ethanol blends in gasoline nationwide, which will require a six-fold increase in national output, and this is simulating new investment in ethanol production capacity. The growth prospects for conventional biofuel production in Europe and North America are more limited. The recent announcement in the European Union (EU) of a specific target for advanced biofuels and biogas of at least 0.2% in 2022, 1% in 2025 and at least 3.5% in 2030, however, is stimulating interest from large oil companies as they develop their strategies to achieve these targets. The cellulosic and advanced biofuels targets under the Renewable Fuel Standard (RFS) program in the US also continues to stimulate interest in establishing and increasing advanced biofuel production in North America.

Although conventional biofuels (i.e., sugar/starch-based ethanol and FAME biodiesel) comprised more than 93% of global biofuels market share in 2017, worldwide efforts continued to demonstrate production and use of drop-in and other advanced biofuels. This is largely in response to the growth in policies requiring or promoting biofuels that demonstrate improved sustainability attributes, especially lower life cycle net carbon emissions (lower carbon intensity) and less potential to exacerbate undesirable land use change; for example, fuels produced from agricultural, forestry, industrial or municipal wastes and residues. In 2017, the growth of advanced biofuels was led by HVO/HEFA fuels, followed by ethanol from cellulosic materials such as corn fibre, and by fuels from thermochemical gasification- or pyrolysis-based processes. Demand for HVO/HEFA biofuels is expected to continue to grow because of their “drop-in” properties and low carbon intensities,

[1] This region groups together all Asian countries apart from China, India, Japan and South Korea. The region ranges from Afghanistan through Mongolia, to Southeast Asia and the islands of the Pacific.

especially when produced from waste and residue oleochemical feedstocks such as tallow and used cooking oil, which account for an increasing share of HVO/HEFA feedstocks. These fuels are now primarily produced in Europe, Singapore and the US, and production is expected to continue to grow as new facilities come on line and new investments are made to increase existing plant capacities.

Production of advanced biofuels from cellulosic feedstocks, including cellulosic ethanol, has so far only been demonstrated at relatively small scales globally due to slower than forecast progress in scale up and commercial deployment. Most cellulosic ethanol is now being produced in the US and EU. In 2017, total production in the US was 38 million liters, mainly from corn kernel fibre and corn stover. A number of pilot, demonstration and pre-commercial advanced biofuels plants in other countries such as Canada, Brazil, Austria, China, India and Italy are also producing or have produced advanced biofuels from lignocellulosic biomass feedstocks ranging from agricultural and forest residues and the cellulosic portion of municipal waste streams, however large volume commercial production remains to be proven. Policy interest in advanced biofuels remains strong. The Biofuture Platform, a 20-member country collaboration initiated by Brazil, has advocated an increase in low-carbon biofuel consumption. India aims to deliver twelve advanced biofuel plants, several of which are in development, and China intends to vigorously develop cellulosic ethanol. EU policy support for advanced biofuels after 2020 is also expected to strengthen, building on an increasing number of quota policies announced by member states.

Global biofuels trade

In recent years, the international trade of biofuels has increased to meet the global demand for renewable fuels. Ethanol and biodiesel constitute much of this trade because they are the most established and largest volume biofuels, but there is potential for more trade of drop-in biofuels such as HVO/HEFA fuels. Ethanol has been traded for decades and has developed into a large-volume global market. In contrast, biodiesel trade is less established and has been encouraged by policies and incentives that promote biofuels, particularly in the EU. The current major participants in liquid biofuels trade are the US, the EU, Brazil, and Argentina. The volume and direction of biofuel trade depends on many factors, including policies, tariffs, crop yields, feedstock availability and biofuels supply and demand within individual countries. Some of the most significant policies influencing where biofuels are imported and produced are the EU's Renewable Energy Directive (RED and REDII), the US's Renewable Fuels Standard (RFS) and California's Low Carbon Fuel Standard (LCFS). International import/export tariffs also play an important role.

Transport biofuels policies

Policies and fossil fuel prices are the main factors driving the rate of biofuels growth in specific countries and world regions. Many forms of policy instruments are being used, including blending mandates, fuel and carbon taxes and renewable or low carbon fuel standards, as well as a variety of fiscal incentives and public financing mechanisms. Table 1 summarizes the types of biofuel policies being implemented to propel further biofuel production and use in IEA Bioenergy Task 39 member countries as well as in China and India.

Table 1. Policies for production and use of biofuels in Task 39 member countries plus China and India

Country	**Biofuels mandates**	**Fuel excise tax reduction/exemption**	**Other policy mechanisms**
Australia	- No national renewable fuels target - New South Wales: 5% biodiesel and 6% ethanol (volume) - Queensland: 0.5% biodiesel and 4% ethanol (volume)	- Producer grant scheme (fuel excise reduction)	-
Austria	- 6.3% biodiesel, 3.4% ethanol and 5.75% biofuels (energy content) - 0.2% advanced biofuels target by 2022 (energy content)	- Tax concessions for fuels with a biofuel share of at least 4.4% - Pure biofuels exempted from mineral oil tax	-
Brazil	- 27% ethanol and 10% biodiesel (volume) - 100% hydrous ethanol is also marketed in all gas stations in Brazil.	- There are tax incentives for biofuel producers, blenders and users including tax incentives for ethanol-flex fuel vehicles, tax incentives for ethanol fuel and federal tax exemptions and incentives for biodiesel production	-
Canada	- Federal use mandates: 5% ethanol and 2% biodiesel (volume) - Five provinces of British Columbia, Alberta, Saskatchewan, Manitoba and Ontario established a blending requirement of 5% to 8.5% for ethanol and 2% to 4% for biodiesel (volume)	-	- British Columbia's Carbon Tax and Low Carbon Fuel Standard - Ontario's auction for carbon allowances - Alberta's carbon levy
Denmark	- 5.75% biofuels (both ethanol and biodiesel) (volume) - 0.9% for advanced biofuels by 2020	- CO_2 excise exemptions for biofuels	-
European Union (EU)	- Cap on food and feed crops of max 1% above 2020 consumption with a maximum of 7% (energy content) - Sub-target for advanced biofuels of 0.2% for 2023, 1.0% for 2025 and 3.5 for 2030 (energy content) - Use of high iLUC crops should gradually decrease to 0% in 2030 unless they are certified to be low-iLUC	-	-
Germany	- GHG reduction of 3.5%/4%/6% in the fuel mix for the entire fuel sector from 2015/2017/2020 onwards	There is no tax relief for FAME biodiesel, HVO/HEFA fuels, vegetable oils and 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	- A carbon tax is indirectly applied via CO_2 tax for passenger cars
Japan	- 500 million liter ethanol mandate (volume) - Introducing 10 million liters (crude oil equivalent) of second generation biofuels (volume)	- No diesel oil delivery tax for B100 - A special tax incentive for the consumption of ethanol - Import of bio-ETBE encouraged through a zero tariff	-

Table 1. Policies for production and use of biofuels in Task 39 member countries plus China and India (continued)

Country	Biofuels mandates	Fuel excise reduction/exemption	Other policy mechanisms
Netherlands	- 16.4% biofuels (both ethanol and biodiesel, double counting advanced biofuels) (energy content) - 1.0% for advanced biofuels in 2020	-	-
New Zealand	- No mandate on biofuel use or any biofuel volume obligations	- Fuel excise exemption for ethanol (including imported ethanol) - No excise exemption for biodiesel	- Emissions trading scheme
South Africa	- No mandate on biofuel use or any biofuel volume obligations	- Fuel excise exemption for ethanol - Biodiesel manufacturers receive a rebate of 50% on the general fuel levy	-
South Korea	- 2.5% mandate for biodiesel (volume)	-	-
Sweden	- GHG emissions reduction of 2.6% for gasoline and 19.3% for diesel	- The tax exemption has varied from full to reduced tax exemption but from January 2018 all biofuels are fully exempted from tax	-
The United States (US)	- Volume targets for biofuels including conventional corn-based ethanol and advanced, cellulosic and diesel biofuels	-	- California's Low-Carbon Fuel Standard (LCFS) - Biodiesel producer's credit
China	- No official national mandate for ethanol and biodiesel use in the transportation sector - 11 provinces and cities (known as pilot provinces and cities) selected as fuel ethanol pilot zones for mandatory E10 blending (volume) - Small trial program using 2% and 5% biodiesel blends carried out in a few provinces (volume)	- An excise tax exemption for waste oil-based biodiesel production - No excise tax exemption for ethanol	- Fuel ethanol subsidies: halted since 2016 for conventional grain ethanol (1 G); subsidies for 1.5 generation ethanol (from cassava or sweet sorghum) since 2013-2017 but phased out in 2018; cellulosic ethanol production subsidy of $0.07 per liter (600 RMB per ton) - Import tariffs on US-origin ethanol
India	- No official national mandate for ethanol and biodiesel use in the transportation sector - The 20% and 5% blending targets are proposed (volume)	- No excise tax exemption/reductions for ethanol and biodiesel	- Deregulated diesel prices - Allow 100% foreign direct investment in biofuel technologies - Over $30 million USD investment in biofuel R&D and second generation ethanol technology - Biofuel imports are banned but the import of feedstock for production of biodiesel is permitted to the extent necessary

As Table 1 illustrates, blending mandates remain the most widely adopted mechanism for increasing production and use of renewable fuels in the road transport sector. Mandates of various forms are prevalent in all geographic regions and for countries spanning different levels of economic development. Worldwide, 64 countries currently have biofuels mandates and targets. The bulk of mandates continue to come from the EU's 27 member states, where the recently revised Renewable Energy Directive (REDII) specifies a 10% renewable content by 2020. Fourteen countries in the Americas (North, Central and South America) have mandates or targets in place or under consideration, 12 in the Asia-Pacific region, 11 in Africa and the Indian Ocean region, and 2 in non-EU countries in Europe.

As in past years, in 2017 national and sub-national governments continued to require specific shares of FAME biodiesel or ethanol to be blended into transport fuels. As shown in Table 1, all Task 39 member countries except South Africa and New Zealand have biofuels mandates in place. In addition to blending mandates for conventional biofuels, the US and some EU member states, including Austria, Denmark, Netherlands and Italy, also have developed or are developing blending mandates for advanced biofuels, which are becoming mandatory as of 2021 across the EU based on the new provisions of the RED II. In China, while there are not yet official national mandates for ethanol or biodiesel use in the transport sector, 11 provinces and cities (known as pilot provinces and cities) have been selected as pilot zones for mandatory fuel ethanol (E10) blending. Similarly, small trial programs to use 2% and 5% biodiesel blends have been carried out in a few provinces. Similar to China, India does not yet have official national mandates for ethanol or biodiesel, however blending targets for biodiesel and sugar/starch ethanol of 5% and 20%, respectively, are being considered. Implementation of national biofuels mandates are anticipated in both China and India in the near future. The United Kingdom (UK) has recently implemented its Renewable Transport Fuel Obligations Order (RTFO II) and created a specific target for certain types of advanced biofuels including aviation and high blends.

Biofuel blending mandates have proven to be effective for establishing biofuels markets and shielding biofuels from low oil prices. However, mandates alone have not proven as successful for expanding or maintaining strong biofuels markets without proper enforcement and accompanying measures. An example is the collapse of biodiesel production in Australia's state of New South Wales, where biofuels mandates in place since 2007 have been ineffective. The mandates are not also helpful in increasing the markets beyond the mandated levels, for example the blend wall issue in the US.

The main reasons biofuels mandates have not worked well in some jurisdictions are varied and include lack of secure supply of feedstock, high costs for feedstocks due to competing uses, low crude oil prices, shortage of infrastructure such as fuel pumps to sell biofuels, food security concerns and sustainability issues such as the potential to exacerbate detrimental impacts of indirect land use change (ILUC). While biofuel mandates have helped to reduce transport sector greenhouse gas (GHG) emissions, they have not always been successful in meeting GHG reduction targets since biofuel obligations are either based on biofuels' volume or energy content rather than decarbonisation potential. In other words, biofuel mandates alone often have not provided sufficiently strong incentives to spur producers to continue to innovate to reduce the carbon intensity of their biofuels.

Fuel excise tax reduction/exemption-based policies and import/export tariffs have been used mainly to make the production and use of biofuels economical at early stages of market development. As biofuels production becomes more cost competitive, e.g., as production costs decrease or the price of petroleum rises, fuel excise reduction/exemption incentives are often either modified or lifted. These types of policies have been employed in 10 of Task 39's member countries (Australia, Austria, Brazil, Denmark, Germany, Japan, New Zealand, South Africa, Sweden and the US). Similar to mandates, the implementation of fuel excise tax reduction/exemption-based policies alone in a jurisdiction has not been a strong enough driver to foster biofuels market expansion when deployed in isolation. New Zealand and South Africa provide examples of this, where even though some excise tax exemptions exist, there is no or only very small levels of biofuels production and use.

Low carbon fuel standards (LCFS) are a newer policy approach that is proving to be more successful for driving increased production and use of biofuels, particularly lower carbon intensity advanced biofuels. Rather than obligating defined production volumes or blending levels, this approach incentivizes reductions in the carbon intensity of fuels production, including for renewable biofuels. In addition to encouraging more efficient production of conventional biofuels, LCFS-based policies spur the development and expanded production of more life cycle efficient advanced biofuels. Under LCFS policies, fuels that can be produced at a lower carbon intensity compared to the petroleum-based gasoline and diesel fuels they displace generate higher carbon credits, which results in higher market values for these fuels. The state of California in the US and the province of British Columbia in Canada are two jurisdictions at the forefront of implementing this type of policy. Across the EU as a result of the RED, but specifically Germany and Sweden have also implemented GHG reduction quota obligations for biofuel use in their transportation sectors.

LCFS policies are helping to spur investors, entrepreneurs, scientists, and engineers to develop innovative low-carbon transportation technologies and strategies, and are also driving on-going innovations in the conventional biofuels market to reduce carbon intensities. One prime example is the development of bolt-on and integrated conversion technologies enabling existing corn-ethanol dry mills in the US to convert corn kernel fibre coproduct into cellulosic ethanol. Another is reusing or selling the carbon dioxide (CO_2) produced by ethanol fermentation instead of considering the CO_2 coproduct stream to be a waste. Beyond these innovations, existing conventional ethanol plants can also lower their carbon footprint by transitioning away from fossil fuel-based energy to obtain their heat and/or electricity supply from renewable sources such as biogas/renewable natural gas, municipal solid wastes (MSW) or agricultural- or forest-based biomass.

In addition to conventional biofuels, LCFS policies are spurring production and use of low-carbon advanced biofuels and HVO/HEFA biofuels. The higher credits generated by lower carbon intensity advanced biofuels can make their production more economical. Due to the higher production cost of HVO/HEFA biofuels compared to conventional FAME biodiesel, these fuels are mainly being sold in markets such as California and British Columbia where LCFS policies are in force that incentivize biofuels based on their carbon intensity, or where there are other supporting policies based on GHG emission reductions such as in Germany and Sweden.

A hybrid of successful policy mechanisms that have been stimulating increased production and use of biofuels within EU member states are the EU's Energy Directive (RED, 2009/28/EC) and Fuel Quality Directive (2009/30/EC). These directives are binding on all EU member states and need to be implemented into member states' respective national laws.RED requires countries achieve at least a 10% share of renewable energy in transport fuels in 2020 and simultaneously specifies that only sustainable biofuels count towards this 10% target. The principle sustainability criterion for biofuels under the RED are minimum GHG emission reduction thresholds compared to regular fossil gasoline and road diesel; and these GHG reductions become progressively stricter in the lead-up to 2020. Other sustainability criteria – defining the eligibility of biofuels to count towards the mandatory target – include the origin of feedstocks, namely the environmental, biodiversity and soil characteristics they stem from. In parallel, the FQD requires EU countries achieve at least a 6% carbon intensity reduction over their lifecycle of all fuels traded in the Union, including fossil fuels.

In 2018, the EU further revised their renewable energy directive, now referred to as REDII, to also include solid biomass sustainability criteria and stricter biofuel sustainability criteria than before, as well as quotas for the use of advanced biofuels made from certain feedstocks. The revised agreement states that at least 14% of transportation fuel must come from renewable sources by 2030. Conventional or first-generation, crop-based biofuels are capped at 2020 levels plus an extra 1% but cannot exceed 7% of final consumption of road and rail transport. In addition, the share of advanced biofuels and biogas must be at least 1% in 2025 and at least 3.5% in 2030. Food crops, such as palm oil, that can result in high indirect land use change (ILUC) (when not cultivated in a sustainable manner) are to be phased out unless third-party certified as low-ILUC biofuels.

Market-pull instruments including biofuels blending mandates and fuel/CO_2 excise reduction/exemptions are broadly effective to support technologies that are relatively mature, as they create a demand for biofuels that is typically met with commercial conversion technologies such as conventional ethanol or biodiesel. However, such instruments can be limited in their capacity to pull early-stage technologies into the market, since these biofuels are often not yet commercially viable, or are typically more expensive to be produced commercially, thus struggling to compete against fossil fuels and conventional biofuels. In contrast, regulatory frameworks such as California's LCFS, the EU's REDII, Brazil's RenovaBio and Canada's Clean Fuel Standard (CFS) are examples of policies that aim to pull advanced biofuels into the market by providing fuel agnostic financial incentives to produce biofuels products at the lowest carbon intensities.

Despite the dominance of market-pull instruments (i.e., biofuels blending mandates, fuel/CO_2 excise tax reductions/exemptions and LCFS), significant resources also have been dedicated to supporting technology research, development and demonstration (RD&D), in particular through grant instruments dedicated to advanced biofuels. Such measures are technology-push instruments which are typically effective to drive early stage technology development (such as advanced biofuels) towards demonstration and commercialization. Technology-push instruments help reduce the cost of research and development to drive new ideas and reduce cost, taking early stage technologies through the valley of death that exists between initial development and demonstration.

Financial measures used to encourage expanded biofuels production and use take a number of forms, including:

- Grants for conversion technology development to increase technology readiness levels to de-risk the technology and supply chain development. Various grants and financial programs are developed mainly to de-risk early market development and initial commercial projects for technologies with long-term market potential but high investment risk
- Loan guarantees to buy down the risk of financing larger first-of-a-kind commercial facilities
- Corporate tax breaks to newly built biofuels production facilities
- Guaranteed return on renewable energy assets
- Compensation for depreciation of acquired renewable energy assets
- Rebates and bonuses to car buyers for the purchase of certain vehicles such as flex-fuel vehicles (FFVs) and other rebates such as reduced license fees and tax credits. For example, Brazil has successfully introduced policies expanding their fleet of FFVs. This has facilitated the widespread deployment of higher-level biofuels blends (e.g., high blend of 27% ethanol in Brazil), and the use of unblended biofuels like hydrous ethanol in FFVs
- Funding available from municipalities and companies for buying alternative fuel vehicles

New engines that allow to harmonize biofuels and electric power trains (biofuel hybrid vehicles), with gains in efficiency and environmental performance are already in commercial stages that may influence how fast biofuels can accomplish, competitively, targets of GHG emissions mitigation considered in transport and energy policies for several countries.

Despite all these financial measures, progress on production of advanced biofuels has been hampered by the slow rate of commercialisation and the fact that advanced biofuels, at this stage of development and in the current market and policy environment, are not cost-competitive with conventional starch or sugar-based biofuels. Due to the immaturity of advanced biofuels feedstock supply chains in terms of feedstock production and supply logistics, feedstock sustainability, and also conversion technology efficiency, the vast majority of existing pilot, demonstration and pre-commercial advanced biofuels projects in Task 39 member countries as well as in China and India are supported by various types of financial incentives provided by federal, state and municipal government agencies.

Compare and contrast transport biofuels policies

Table 2 summarises strengths and limitations of existing biofuels policies.

More biofuel policies are beginning to introduce sustainability criteria for conventional biofuels. Since 2009, the EU's RED stipulates minimum reductions in GHG emissions compared with fossil fuels and prohibit growing biofuels feedstocks in areas converted from land with previously high carbon stocks (e.g., wetlands or forests) or producing them from raw materials obtained from land with high biodiversity (e.g., primary forests or grasslands) - up to 2020 biofuels must save at least 50% or 60% depending on when the biofuel facility came into operation, increasing to at least 65% post-2020. Only biofuels that comply with all sustainability criteria can contribute to national renewable energy targets and are eligible to receive support. Canada has released a set of guiding principles for sustainable biofuels, and the state of California has established an LCFS policy framework requiring a reduction in life-cycle carbon intensity for transport fuels. In some cases, sustainability concerns can lead to revisions in supporting policies, such as the new package of clean energy and emissions reduction goals passed by the European Commission under RED II, which include a scaling down of conventional biofuels and an increasing role for advanced biofuels and other low-carbon alternatives, such as renewable electricity, for powering transport. In Brazil, the forthcoming adoption of the Renovabio program, introducing a LCFS (low-carbon fuel standard) in vehicular fuels, has reinforced sustainability in biofuels production.

Biofuels policies for aviation and marine sectors

Policies to promote renewable energy in the transport sector continue to focus primarily on road transport, especially at the national level. Other important sub-sectors of transport such as rail, aviation and shipping have until recently drawn comparably less policy attention despite also being large energy consumers and GHG emitters. Transport policies and industry efforts are increasingly focusing on deploying biofuels for all long-haul transport sectors (i.e., road, rail, aviation and shipping), where electrification is much more challenging. The aviation industry recognises the need to address climate change by decarbonizing and has adopted a number of targets, including a 50% reduction in net aviation CO_2 emissions by 2050 (compared to 2005 levels). Few direct support policies now target the use of renewable fuels in the aviation sector. Indonesia introduced a 2% renewable jet fuel mandate in 2017, which is set to increase to 5% by 2025. EU's new REDII allows aviation biofuels as an opt-in to count more highly (using a multiplier of 1.2) in the contributions towards the region's renewable transport target. In 2018, in addition to new policy developments, the Netherlands, Norway, UK and US re-committed to promoting alternative jet fuel production. As of year-end 2017, five renewable jet fuels, plus 5% co-processing of bio-crude, were certified for blending with fossil-based jet fuels (at levels ranging from 10% to 50%).

Shipping is another long-distance transport sector that is under increasing pressure to reduce its carbon and sulfur emissions. It now mainly uses heavy fossil-based fuels that contain sulphur and heavy metals. Along with aviation, shipping is one of the hardest transport sectors to decarbonise. Apart from technological challenges, the deployment of renewables in shipping faces numerous barriers, such as the large price gap between renewable and conventional fuels and very limited regulations, particularly regarding the GHG emissions attributes of maritime fuels. International shipping is regulated by the International Maritime Organisation (IMO). Since the Paris agreement (which did not include international shipping), the IMO has developed reduction strategies for GHG emissions and other air pollutants. In 2016, the IMO agreed to a 0.5% cap on sulphur in its fuels by 2020. In 2018, the IMO reached an agreement on an "initial strategy" to reduce CO_2 emissions from shipping. The initial Strategy identifies measures that could indirectly support the GHG reduction efforts. One of these measures concerns the use of zero-carbon or fossil-free fuels for the shipping sector and the development of robust lifecycle GHG / carbon intensity guidelines for alternative fuels.

Table 2. Strengths and limitations of existing biofuels policies

Policy instrument	Strengths	Limitations
Biofuel blending mandates	- Effective for developing a biofuel market at early stages - Effective in establishing biofuels markets and in shielding biofuels from low oil prices - Greater certainty of increased development - broadly effective to support technologies that are relatively mature, as they create a demand for biofuels, which is typically met with commercial conversion technologies such as conventional ethanol or biodiesel	- Need to balance costs of infrastructure while demand is low in early stages - Need suitable governance to ensure compliance - Not necessarily so useful in expanding /maintaining markets - Not necessarily successful for meeting GHG reduction targets - Limited in their capacity to pull early-stage technologies into the market, since these are often not commercially viable, or are typically more expensive to be produced commercially - struggling to compete against first generation biofuels
Excise duty reductions/exemptions	- Increases the competitiveness of biofuels with fossil fuels, especially at early stages of development, if fossil vs renewable fuels are taxed differently - Can be also considered for the production of biomass such as dedicated biomass crops (e.g. switchgrass, carinata, willow) in order to ensure sufficient feedstocks for production of conventional and advanced biofuels and ultimately achievement of mandates for use - Broadly effective to support technologies that are relatively mature, as they create a demand for biofuels, which is typically met with commercial conversion technologies such as conventional ethanol or biodiesel	- As fuel excise rates vary, this may not be a strong enough driver to foster the biofuels market as an stand-alone policy - Limited in their capacity to pull early-stage technologies into the market, since these are often not commercially viable, or are typically more expensive to be produced commercially - struggling to compete against first generation biofuels
Low carbon fuel standards (LCFS)	- Technology neutral - Favours technologies able to offer the most significant decarbonisation relative to cost - Spurs the development and production of more life cycle efficient advanced biofuels	- Unlikely to simulate demand for higher cost, less-developed technologies with long-term potential - Determining life cycle emissions is complex and time consuming and requiring big data collection

Table 2. Strengths and limitations of existing biofuels policies (continued)

Policy instrument	**Strengths**	**Limitations**
Low carbon fuel standards (LCFS)	- Encourages conventional biofuel producers to lower their carbon footprint by transitioning away from fossil fuel-based energy and making better use of their by-products such as CO_2	- Results of life cycle analysis depend on system boundaries, allocation methods and other assumptions and are subject to debate - Need suitable governance to ensure compliance - Need suitable verification process to measure the carbon intensity of biofuels produced from different feedstock-conversion technology pathways
Research and development, demonstration funding and financial de-risking measures, mainly for advanced biofuels and power-to-X technologies	- Necessary to support early market technology development and initial commercial projects with longer-term market potential but high investment risk - Successful in de-risking technology and catalysing private investment for subsequent stages, somewhat sparing public budgets as technologies advance into commercial stages	- Financial risks associated with potential project failures
Sustainability policy	- Propel the production and use of advanced biofuels using non-food crop feedstocks such as municipal solid waste (MSW), used cooking oil, and agricultural and forest residues	- Could constrain further production of conventional biofuels from food crops, even for cases where there is little potential for detrimental indirect land use changes - Could make waste production profitable, which is not in line with overall waste reduction initiatives and polices

Challenges for the further growth of transport biofuels industry

Despite many active R&D projects and continuing advances being made in conventional and advanced biofuels technologies – and a large potential to further increase biofuels production and use globally – the biofuels industry faces significant challenges. Petroleum prices remain modest and future policies to promote renewable fuels and improve vehicle fuel efficiency standards remain highly uncertain. On-going high uncertainty about future policy and funding programs to support conventional and advanced biofuels continues to be a major obstacle to accelerating biofuels development, especially in some major biofuels producing jurisdictions like the US. Worldwide, the food versus fuel debate has driven increased development focus towards advanced biofuels over the last 7-8 years, with countries putting in place specific targets for advanced biofuels and caps on conventional biofuels. However, commercialization of these advanced biofuels technologies has been much slower than earlier forecast, with only limited volumes being produced so far, with the result that most targets for expansion of advanced biofuels production and use have not been met. Extensive research and development into production of advanced fuels is on-going, however, with the research focus increasingly shifting towards drop-in biofuels for heavy-duty transport as well as enabling a faster route to large scale lower carbon biofuel production by co-processing of bio- and fossil-based feedstocks at oil refineries.

Conclusions

Policies have proven to be a key component in the development, deployment and use of biofuels such as bioethanol, biodiesel and "drop-in" biofuels. The IEA Bioenergy's Task 39 is fortunate to have several "biofuel countries" as members, representing a diverse range of biofuels producers and consumers. One of the Task's activities has been to collect information on existing/emerging biofuels policies and production and use levels over the period 2006-2017. In all cases, biofuels policies have played an important role in developing regional and national biofuels markets. Most policies have primarily promoted the production and use of road transport biofuels with the rail, aviation and shipping sectors drawing less policy attention despite being significant fuel consumers, carbon emitters and potentially large markets for biofuels. A mixture of market-pull and technology-push policy instruments has been most successful at encouraging biofuel production and use. While many of the original policies were developed to promote energy security, more recent policies, such as the California and British Columbia low carbon fuels standards (LCFS), have GHG reduction as a primary goal. Although various jurisdictions have combined policies in different ways, blending mandates continue to be one of the most successful mechanisms used to increase biofuel markets.

Table of Contents

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1. Global production and use of biofuels

1.1 Introduction

The transport sector accounted for 29% of total global energy consumption in 2015, as shown on the left side of Figure 1-1. Of the total energy used for transport, approximately 75% (21.9% of 29%) is for road transport, two-thirds for passenger mobility and one-third for freight. International and domestic aviation and shipping each account for another roughly 10.5% (3.1% of 29%), with the balance used for pipeline and rail transport (IEA, 2017a; IRENA, IEA and REN21, 2018).

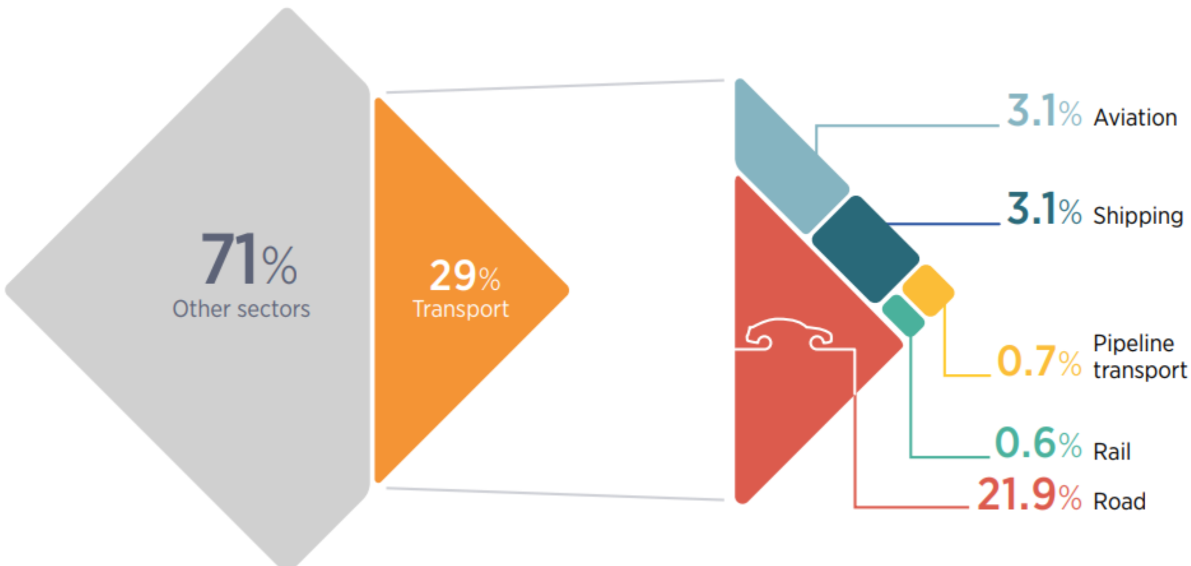

Figure 1-1. The role of transport in total energy consumption in 2015 (IEA, 2017a; IRENA, IEA and REN21, 2018)

Because of the importance of energy density in the sector, transport remains heavily reliant on energy dense fossil fuels, especially petroleum-based liquid fuels. As of 2015, 96% of the sector's energy use came from petroleum-derived products, representing 64.7% of world oil consumption (IEA, 2017b). Renewable energies accounted for only 3.1% of final energy demand for transport, significantly lower than that being achieved for electricity and heat; this 3.1% contribution of renewable energy to transport breaks down to 1.6% from ethanol, 0.8% from biodiesel, 0.4% from other liquid biofuels, 0.01% from biomethane, and 0.3% from renewable electricity (see Figure 1-2) (IEA, 2017a).

The transport sector is a significant contributor to global carbon dioxide (CO_2) emissions, representing 23% of all such global energy-related emissions – and over 75% of this is from road transport (Figure 1-3). Between 2010 and 2015, transport sector emissions increased by 2.5% annually (IEA, 2017c). To date, strategies to decarbonise the transport sector are clustered into measures to "avoid, shift and improve." Of these measures, increasing energy efficiency (part of he "avoid" cluster) and the use of renewable energy (part of the "improve" cluster), are central to completely decarbonising the transport sector.

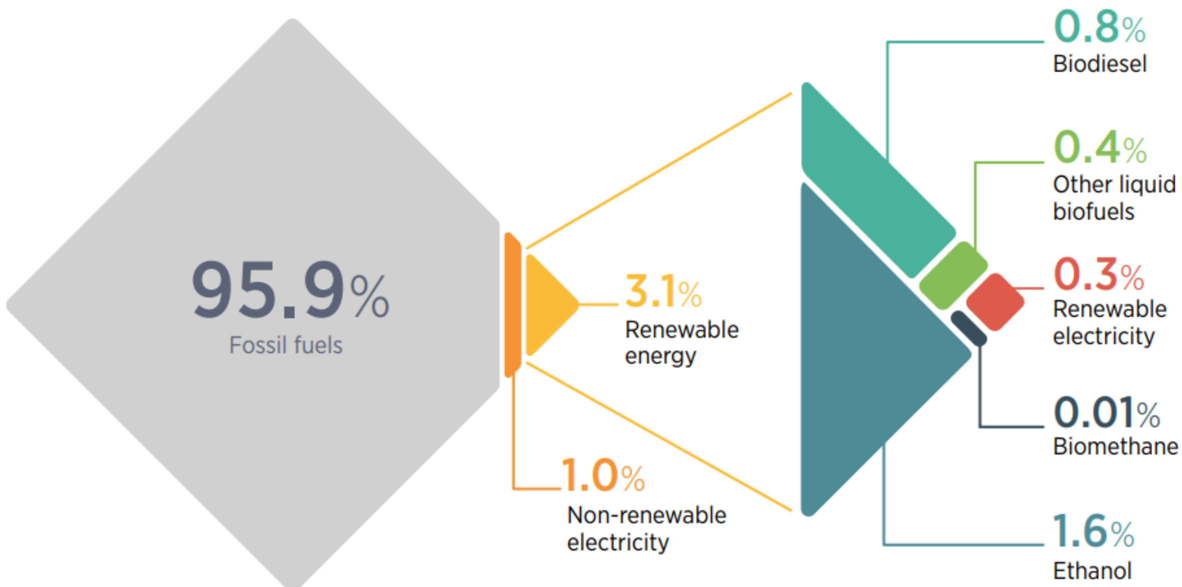

Figure 1-2. Transport energy use by fuel type in 2015 (IEA, 2017a; IRENA, IEA and REN21, 2018)

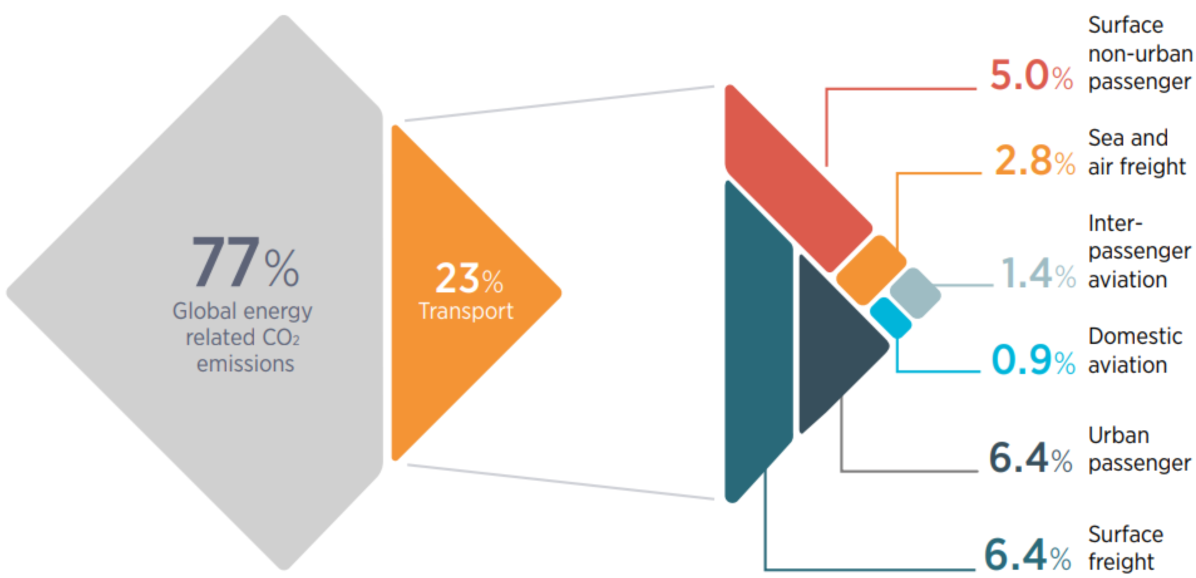

Figure 1-3. Global CO_2 emissions by transport mode in 2015 (ITF, 2017; IRENA, IEA and REN21, 2018)

As shown in Figure 1-2, biofuels are currently the main contributor to transport sector decarbonisation. The production and use of biofuels have been increasing over the last decade mainly because of supporting policies, fiscal incentives and various financial assistance programs. In addition to greenhouse gas (GHG) reduction benefits, energy security and increased economic activities especially in rural communities have driven biofuel industry growth. The next section discusses the production, use and international trade of biofuels.

1.2 Biofuels production and use

Globally, biofuels production has continued to increase over the last decade, from over 37 million tonnes oil equivalent (Mtoe) produced in 2007 (~64 billion liters) to over 84 Mtoe in 2017 (~145 billion liters). It increased 3.5% from 2016 to 2017, which while well below its annual growth rate of 11.4% achieved over the past decade, is the most growth in three years (see Figure 1-4). The highest annual growth rate was observed in the Asia-Pacific region, which grew at an annual rate of 20.1% over the period 2006-2016 and saw a further 6% increase from 2016 to 2017.

The Americas and Europe continued to have the highest shares of biofuels production. In 2017, North America, South and Central America and Europe had world shares of 45.5%, 26.9% and 16.8%, respectively. Table 1-1 lists the world's top ten biofuel producing countries in 2017. The United States (US) remained the largest producer (43.9%), followed by Brazil (22%) and Germany (3.9%) (BP, 2018).

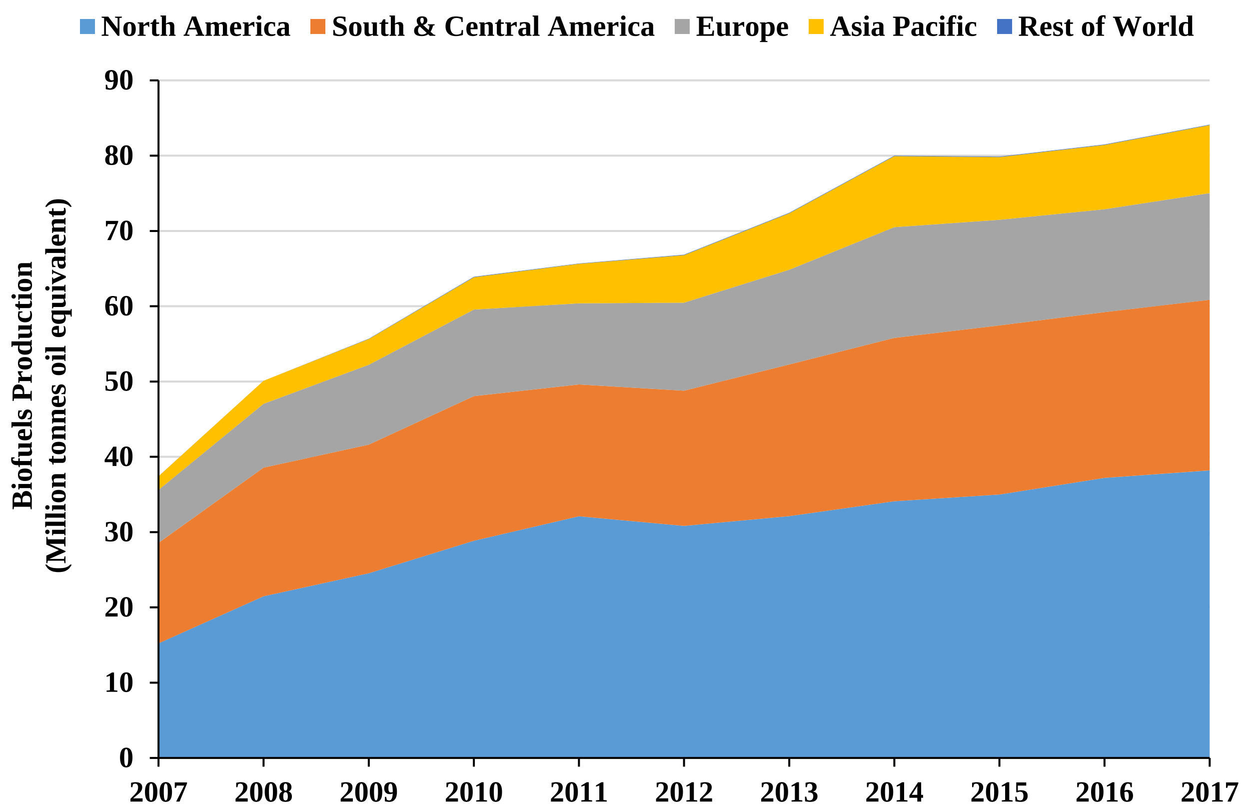

Figure 1-4. World biofuels production, 2007-2017. Biofuels production increased at an annual growth rate of 11.4%, from over 37 Mtoe produced in 2007 to over 84 Mtoe in 2017 (Adapted from BP, 2018)

Table 1-1. Top ten biofuels producing countries in 2017

Country	Biofuels production (million tonnes oil equivalent)	Share in 2017
US	36,936	43.9%
Brazil	18,465	22.0%
Germany	3,293	3.9%
Argentina	3,131	3.7%
Indonesia	2,326	2.8%
France	2,224	2.6%
China	2,147	2.6%
Thailand	1,846	2.2%
Netherlands	1,658	2.0%
Spain	1,541	1.8%

The main biofuels produced were ethanol, biodiesel (fatty acid methyl ester or FAME fuels), and biofuels produced by treating animal and vegetable oils and fats with hydrogen (known as hydrotreated vegetable oil (HVO) or hydrotreated esters and fatty acids (HEFA) biofuels), as well as a growing contribution from biomethane in some countries such as the US, Sweden and Germany. As estimated, 65% of biofuel production (in energy terms) was ethanol, 29% was FAME biodiesel and 6% was HVO/HEFA. The use of biomethane as a transport fuel, while growing rapidly, contributed less than 1% of the biofuel total (REN21, 2018).

The total worldwide production of ethanol increased from 29 Mtoe (~60 billion liters) in 2007 to 54 Mtoe (~110 billion liters in 2017) (see Figure 1-5). The US and Brazil maintained their leads in ethanol production in 2017, together accounting for 84% of global production. The next largest producers were China, Canada (not shown) and Thailand. Production of FAME biodiesel grew from over 9 Mtoe (~11 billion liters in 2007) to over 27 Mtoe (~35 billion liters) in 2017. Over the 2007-2017 period, global ethanol production grew at an annual rate of 3.3% and biodiesel production by 4%, driven mainly by growth in Argentina, Brazil and Spain.

Most future biofuels growth is expected to occur in Latin America and non-OECD Asian countries[2]. In Brazil, the drivers for biofuel demand remain strong and the new RenovaBio policy is anticipated to facilitate new investment to increase biofuel production capacity. China intends to roll out 10% ethanol blends in gasoline nationwide, which will require a six-fold increase in output and is leading to new investments to expand ethanol production capacity. The growth prospects for increased production of conventional biofuels in the EU and the US are more limited. Production of conventional biofuels may fall in the EU after 2020 because of a less favourable policy landscape. Ethanol production in the US is forecast to level off over the next five years as increasing fuel efficiency in the vehicle fleet lowers demand for ethanol blended with gasoline and the corn ethanol limit (E10 "blendwall") is reached with respect to the US's RFS2 policy. For these reasons, investment in new production capacity has declined (IEA, 2018). However, the October 2018 announcement by the US government that regulations preventing selling of E15 during

[2] This region groups together all Asian countries apart from China, India, Japan and South Korea. The region ranges from Afghanistan through Mongolia, to Southeast Asia and the islands of the Pacific

summer months will be ended may result in increased production and use of grain (and cellulosic) ethanol in the US.

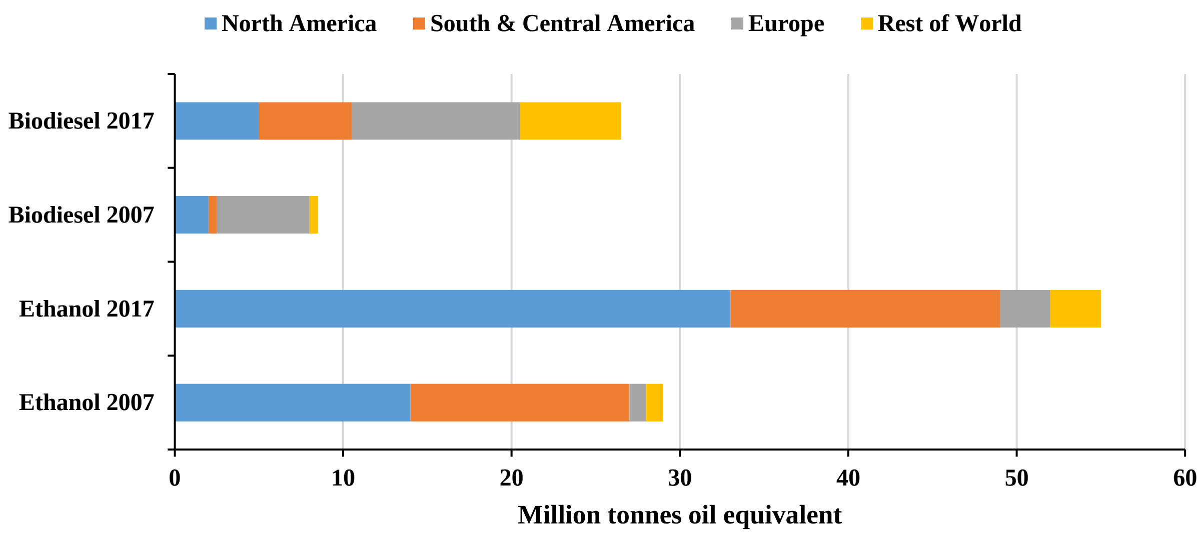

Figure 1-5. Ethanol and biodiesel production growth from 2007 to 2017 by world region. Globally, ethanol and FAME biodiesel production grew at annual rate of 3.3% and 4%, respectively (Adapted from BP, 2018).

Key feedstocks for conventional ethanol production globally are sugarcane, sugarbeet, corn and wheat. Key feedstocks for biodiesel production are seed oils (i.e., rapeseed, sunflower, soybean and palm), animal fats, used cooking oils (UCO) and waste greases (BioFuture Platform, 2018).

Although the vast majority of biofuels production and use is still based on conventional biofuels, drop-in biofuels such as HVO/HEFA have increased their market penetration, especially in regions with LCFS policies in force such as California and British Columbia where biofuels are valued based on their carbon intensity not only their energy content. Over 3.1 Mtoe (4.4 billion liters) per year of HVO/HEFA biofuels are now being produced worldwide. Table 1-2 summarises known drop-in biofuels production facilities worldwide. As shown in this Table, waste and residue feedstocks now account for a significant share of HVO/HEFA biofuels production, supporting deeper decarbonisation from these fuels. Consequently, production of HVO/HEFA biofuels – now primarily based in Europe, Singapore and the US – is expected to continue to grow as new facilities come on line and new investments are made to increase existing plants' capacities (REN21, 2018).

A majority of HVO/HEFA biofuels are renewable diesel (RD), with a small portion of aviation biofuels ("biojet") produced at AltAir's facility in California. Due to the higher production cost of RD compared to FAME biodiesel, these fuels are mainly sold in markets such as California and British Columbia where LCFS policies are in force to incentivize biofuels based on their carbon intensity, or where there are other supporting policies based on GHG emission reductions such as in Germany and Sweden. Another factor playing a major role in the continuous growth of RD and biojet production and use is that these biofuels are functionally identical to the petroleum fuels they are intended to supplement or displace. These biofuels are also fully compatible with the existing fuel distribution and use infrastructure and thus they fully qualify as drop-in biofuels.

While not yet commercialized, other routes to drop-in biofuels that can leverage a portion of the substantial existing petrochemical/refining infrastructure are also under development, seeking to develop a non-renewable + renewable feedstock co-processing approach to produce lower carbon drop-in fuels that can be used in existing vehicle engines.

Table 1-2. Commercial production of drop-in biofuels from oleochemical feedstocks (IRENA, 2017; California Air Resource Board, 2018)

Company	**Location**	**Production capacity (billion liters)**	**Feedstock**
Neste	Two facilities in Finland, one in Netherlands and one in Singapore	2.57	Mixed oleochemical feedstocks and used cooking oil
Diamond Green Diesel	US	0.605	Soybean oil UCO Tallow Corn oil
REG Geismar	US	0.283	Rendered UCO Non-rendered UCO Corn oil Tallow Soy oil
ENI S.p.A.	Italy	0.473	Soybean oil & other oils
AltAir Fuels	US	0.17	Mixed oleochemical feedstocks
UPM biofuels	Finland	0.12	Tall oil
Cepsa (2 demo facilities)	Spain	0.12	Unknown
Preem Petroleum	Sweden	0.02	Tall oil
East Kansas Agri-Energy	The US	0.011	Unknown
World Total		4.37	

Global production capacity for advanced biofuels at the end of 2015 was estimated to be 850 million liters per year (Araújo et al., 2017; IRENA, 2016). Planned capacity expansions add about 1.5 million liters of new capacity per year, with initiatives underway in Brazil, China, Canada, France, the Netherlands, Sweden, the United Kingdom, and the US (Araújo et al., 2017; IRENA, 2016). While the majority of existing capacity is for cellulosic ethanol, this advanced biofuel has so far only been produced in relatively small volumes. Most of the cellulosic ethanol is being produced in the US and EU. The US RFS2 targets by 2022 an annual production of 80 billion liters of advanced cellulosic biofuels and biomass-based biodiesel. Some EU member states including Austria, Denmark, Italy and the Netherlands have developed blending mandates for advanced biofuels. However, advanced biofuels production volumes remain far below US and EU targets due to slower than expected progress in scale up of commercial production. The volume of cellulosic ethanol production qualifying under the US RFS2 reached only 38 million litres in 2018. Production of ethanol from cellulosic residues such as corn kernel fiber in conventional corn ethanol plants in the United States is expanding. In 2017, five corn ethanol plants, with a combined capacity of nearly 2 billion litres (500 million gallons), were approved by the US Environmental

Protection Agency (EPA) to generate Renewable Identification Numbers (RINs) credits under RFS2 program (REN21, 2018).

A number of pilot, demonstration and pre-commercial advanced biofuels plants in other countries such as Austria, Brazil, Canada, China, India and Italy are also producing or have produced advanced biofuels from lignocellulosic biomass feedstocks ranging from agricultural and forest residues and the cellulosic portion of municipal waste streams but large volume commercial production remains to be proven. A list of current facilities that produce advanced biofuels at pilot and demonstration scales can be found at the IEA Bioenergy Task 39's large-scale demonstration plants website: http://demoplants.bioenergy2020.eu/.

Commercialisation of thermally-based processes for producing biofuels – including hydrothermal liquefaction, pyrolysis and gasification – also advanced in 2017. Enerkem in Canada adapted its commercial-scale gasification plant in Edmonton, Alberta, which processes 300 tonnes per day of sorted municipal wastes, to produce ethanol instead of methanol, and this fuel qualifies as cellulosic ethanol under the US RFS2. Additional plants based on this technology are under development in the Netherlands and China (Biofuels International, 2017; ChemEurope.Com, 2018; REN21, 2018). In addition, Ensyn in Canada has been providing pyrolysis oils from its Ontario-based production plant to US customers for space heating and cooling applications, with this fuel also qualifying as a cellulosic biofuel under the US RFS2 program (Ensyn, 2018). In Norway, a first-of-its-kind demonstration plant is being developed based on hydrothermal liquefaction technology. The company Steeper Energy (Denmark and Canada) is licensing its proprietary Hydrofaction technology to Silva Green Fuel, a Norwegian-Swedish joint venture (Biofuels International, 2017). Licella (Australia) is in a joint venture with the forestry company, Canfor (Canada), to produce and upgrade bio-crude produced by a hydrothermal liquefaction process in the Canadian province of British Columbia, and previously announced plans to build a plant in Australia (Canfor, 2016).

Biomethane has been mainly produced in the US and the EU. The largest market for biomethane is the US and its production has been stimulated since 2015 when biomethane began to be included in the cellulosic biofuels category of the RFS2 program. US biomethane consumption grew nearly six-fold between 2014 and 2016, then increased another 15% in 2017 to 17.4 PJ (EPA, 2017; REN21, 2018). The other globally significant market for biomethane is Europe where consumption increased 12% between 2015 and 2016, to 6.1 PJ. Production and use in the EU were concentrated in Sweden (4.7 PJ), where producing biomethane from food wastes is encouraged as part of a comprehensive waste reduction policy, and where use of biomethane as a transport fuel is prioritised over its use for electricity production or for injection into gas grids. In 2016, Germany (1.3 PJ) was Europe's second largest user of biomethane for transport (IEA Bioenergy Task 37, 2017; REN21, 2018).

Biofuels are essential to limit climate change. Interest in strengthening policies and reducing uncertainty about future policies for advanced biofuels remains strong. The Biofuture Platform, a 20 member country collaboration initiated by Brazil, is advocating for an increase in the production and consumption of low-carbon biofuels. India aspires to deliver twelve advanced biofuel production plants, several of which are now in development, and China intends to vigorously develop cellulosic ethanol. EU policy support for advanced biofuels after 2020 is also expected to strengthen, building on an increasing number of quota policies announced by member states (IEA, 2018).

Although the use of biofuels in aviation is seen as a long-term priority, the quantity of biofuels used in aviation is still a very small fraction of total fuel use in the transport sector. In 2017, a number of airlines and airports made progress in using biofuels for long-haul flights, securing appropriate fuels and making biofuels available at key airports. Interest in the use of biofuels in marine applications also increased in 2017, pushed by the soon to be in force requirement in coastal regions to reduce sulphur emissions from ships, as well as by the shipping industry's longer-term decarbonisation targets (IEA Bioenergy Task 39, 2017). Biofuels are also increasingly being used as a fuel for rail transport. In the Netherlands, 18 new trains are being brought into service that will be fuelled with biodiesel (Biofuels International, 2017). Indian Railways is experimenting with the use of biodiesel, compressed biogas and ethanol on its networks (Srivastava, 2018).

1.3 Global biofuels trade

In recent years, the trade of biofuels has increased to meet the global demand for renewable fuels. Ethanol and biodiesel contribute much of this trade because they are the most established biofuels, but there is potential for increased trade of drop-in biofuels such as HVO/HEFA fuels. Ethanol has been traded for decades and has developed into a global market involving large volumes. In contrast, biodiesel trade is less established and has been encouraged by differences in policies and incentives promoting biofuels between different countries/regions, such as the US and EU. The current major participants in liquid biofuels trade are Argentina, Brazil, the EU and the US. The volume and direction of biofuels trade depend on many factors, including policies, tariffs, and crop yields. Figure 1-6 shows an influence diagram for the trade of liquid biofuels between the US.

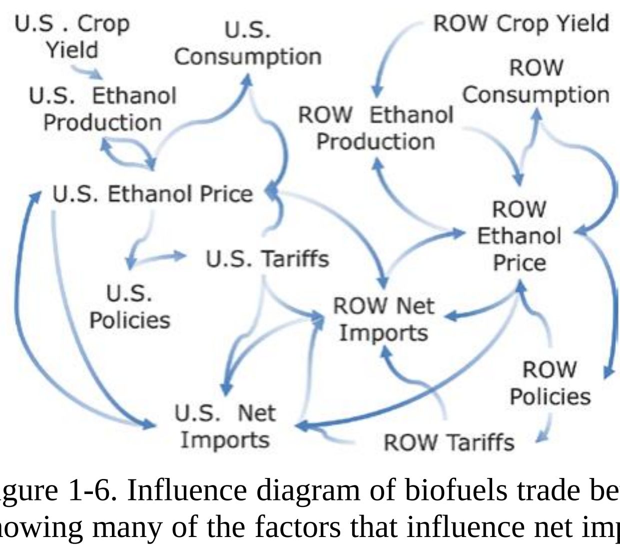

Figure 1-6. Influence diagram of biofuels trade between the US and the rest of the world (ROW) showing many of the factors that influence net imports and point-of-use prices for biofuels in the US (NREL, 2013).

Domestic production and consumption policies and import/export tariffs also affect biofuels trade. Some of the most significant policies influencing where biofuels are imported and produced in effect are the EU's REDII, the US's RFS2, international import/export tariffs and California's LCFS. For example, REDII has caused much more demand for biodiesel imports in the EU while the price for biodiesel in the US has not been competitive with petroleum-based diesel. Another example is the strong demand for low carbon fuels such as biodiesel and renewable diesel in California due to its LCFS policy that rewards a higher market value (higher credit) to fuels with a lower carbon intensity.

Global trade patterns for ethanol have been changing, partly in response to rapidly rising demand in China and also due to the introduction of protective import tariffs in several countries. In 2015, China became a major importer of ethanol, especially from the US; however, as domestic production in China increased, in early 2017 tariff barriers were introduced that greatly reduced imports. Brazil also introduced an import quota in 2017 aimed at discouraging import of US-produced ethanol. International trade in biodiesel is also being affected by changing import tariffs. In February 2018, the US introduced "anti-dumping" tariffs on imports from Indonesia and Argentina. In Europe, however, tariffs on imports of biodiesel were ended in 2017 (REN21, 2018).

1.4 Future growth of biofuels industry

Transport biofuel production and consumption needs to triple by 2030 to ensure that biofuels' share of transport fuel demand, which was 3% in 2017, can reach 10% by 2030 as required by the IEA's Sustainable Development Scenario (SDS)[3]. Production has not been growing fast enough to meet this target, however. Increasing output threefold requires sustained average annual production growth of 10% through to 2030 whereas only 3% annual growth is forecast over the next five years. In the SDS, the biggest acceleration of biofuel demand is anticipated to occur in China, India and Latin America, with biofuel production expected to grow in each of these countries over the next five years. In countries where transport biofuels industries are at an earlier stage, such as Mexico and South Africa, market development is also needed to keep on track with the SDS. In addition, the SDS requires a significant technology shift from conventional biofuels towards lower carbon advanced biofuels. As shown in Figure 1-7, by 2020, with the plants under construction, production of advanced biofuels can reach 1.4 Mtoe (2 billion litres), which represents just 1.3% of forecast conventional biofuels production on a volumetric basis. After 2020, greatly accelerated commercialisation of advanced biofuels will be required to ensure they are able to supply a substantial share of all transport biofuels by 2030 (IEA, 2018).

[3] https://www.iea.org/newsroom/news/2017/november/a-new-approach-to-energy-and-sustainable-development-the-sustainable-development.html

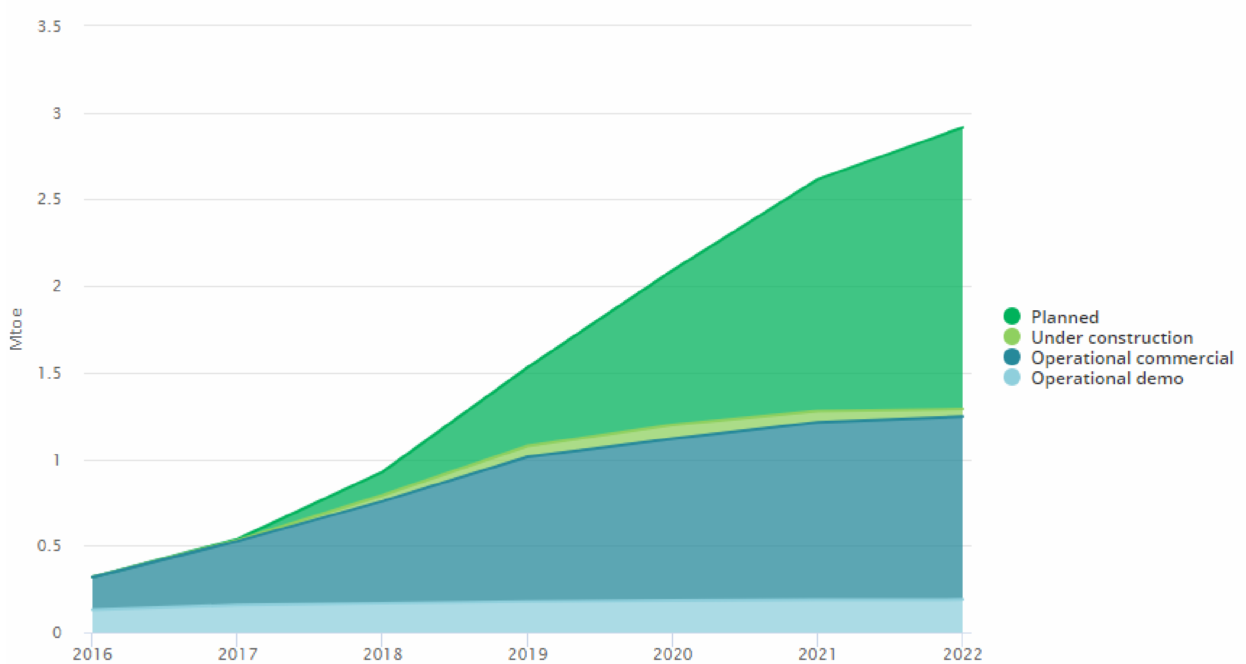

Figure 1-7. Current and projected global production of advanced biofuels, 2016-2022 (IEA, 2018)

Ensuring that a high proportion of announced advanced biofuel projects start producing on schedule will require an improved policy climate that provides a variety of measures to promote increased production and uptake, such as advanced biofuels quotas or LCFS frameworks as well as financial de-risking and financial supports for different stages of R&D and commercialization. Unless production costs can be significantly reduced through technology learning and scale-up, advanced biofuels will continue to be cost disadvantaged compared to conventional biofuels and fossil fuels, thus requiring greater policy support to ensure sufficient economic viability such that substantial commercial expansion will occur.

The promising development of fuel cells for vehicular applications, using ethanol directly or hydrogen from ethanol reforming on board, can be the straightforward path to adopt hydrogen in transport.

The vast majority of biofuel use remains in road transport, with only minimal consumption in the aviation and marine sectors. In the SDS, by 2030 about 11% of the combined demand from aviation and marine transport is met by biofuels. Reaching this level of consumption so quickly will require extremely strong policy frameworks that accommodate the international nature of these distinctive transport sectors as well as technical fuel specification requirements for use in planes or ships.

It is clear that massive policy innovation is needed for transport biofuels to meet SDS goals. Technology-neutral policies that specify reductions in fuel life-cycle carbon intensity, such as California's LCFS and Germany's climate protection quota, create demand for fuels that offer the highest decarbonisation relative to cost. These types of policies are proving effective for reducing greenhouse gas (GHG) emissions from biofuels (IEA, 2018).

The rest of this report focuses on the production and use of biofuels and the role of policies being used to promote development of biofuels markets in 15 countries. These countries include the 13 countries (plus the European Commission) that were members of IEA Bioenergy Task 39 in the 2016-2018 triennium as well as China and India which are two of the world's major countries also aspiring to increase their production and use of biofuels. The individual chapters for each country reported on also summarize other measures being taken by these countries to develop or stimulate their respective biofuels industries, including fiscal incentives and investments in research, development and commercialization. Where appropriate, the report also updates the current status of biofuel sustainability assessments and related factors influencing policy development. The final chapter of the report examines biofuels policies being used in these different countries and the extent to which they have been effective.

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2. Australia

Steve Rogers, Licella

Summary Box

- There is no national renewable fuels target; this is left to the states.
- So far, only two states have biofuels mandates, Queensland and New South Wales (NSW). The biofuels mandates in Queensland are 0.5% biodiesel and 4% ethanol, and in NSW they are 5% biodiesel and 6% ethanol (volume basis).
- The Producer Grant Scheme to reduce fuel excise for ethanol and biodiesel was revised in 2016. For biodiesel, excise increments year on year until the it reaches 50% of the fossil diesel excise. Ethanol excise is capped at a lower price relative to biodiesel due to its lower energy content.
- Production of ethanol is relatively stable. In contrast, production of biodiesel has collapsed due to high costs for feedstock such as tallow coupled with low world oil prices.
- The NSW biofuels mandate, despite being in place since 2007, is ineffective as it is not enforced.
- There are no advanced biofuels mandates and there is no production and only limited use of HVO/HEFA fuels.
- The Australian Government provides grants for R&D programmes in the area of renewable energy technologies, and invests in related R&D and early stage commercialisation.

2.1 Introduction

In Australia, federal energy policy is a political minefield and has been the downfall of numerous party leaders and Prime Ministers over the past ten years[4]. During this time, Australia has changed Prime Ministers six times. The very challenging federal electoral term of only three years, along with strong vested interests in fossil fuels, has made it impossible to get any long term energy policy in place to extend the federal Renewable Energy Target (RET). The RET was originally established in 2001 and subsequently extended in 2011 to deliver 45,000 gigawatt-hours of renewable electricity by 2020 as part of the Labour governments Clean Energy Future Package that also introduced a price on carbon as well as established the Clean Energy Finance Corporation (CEFC) and ARENA – The Australian Renewable Energy Agency. The Liberal opposition led by Tony Abbott had the reform of the carbon tax as a cornerstone policy and following Abbott's election, the Labour government's Clean Energy Future Package was dismantled in 2014; however, the CEFC and ARENA have remained despite Abbott trying to remove them. The latest federal attempt to link to policy Australia's Paris GHG reduction obligations of 26% reduction on 2005 levels through the National Energy Guarantee (NEG) has been dumped following the removal of the latest Prime Minister Malcolm Turnbull. Turnbull has lost his leadership twice now over climate policy and has now resigned from politics.

Australia's RET target of 45,000 gigawatt-hours of renewable electricity by 2020 will be met without any further stimulus as a result of a rapidly increasing uptake of solar by consumers due to falling prices for solar panels, high insolation rates and increasing power prices.

As the RET was a renewable electricity target and not a renewable energy target, it only accounts for ~35% of Australia's GHG emissions which have now started to increase again[5]. (Figure 2-1)

[4] http://www.abc.net.au/news/2018-08-23/climate-change-policy-a-brief-history-of-seven-killings/10152616

[5] http://www.environment.gov.au/system/files/resources/7b9824b8-49cc-4c96-b5d6-f03911e9a01d/files/nggi-quarterly-update-dec-2017-revised.pdf

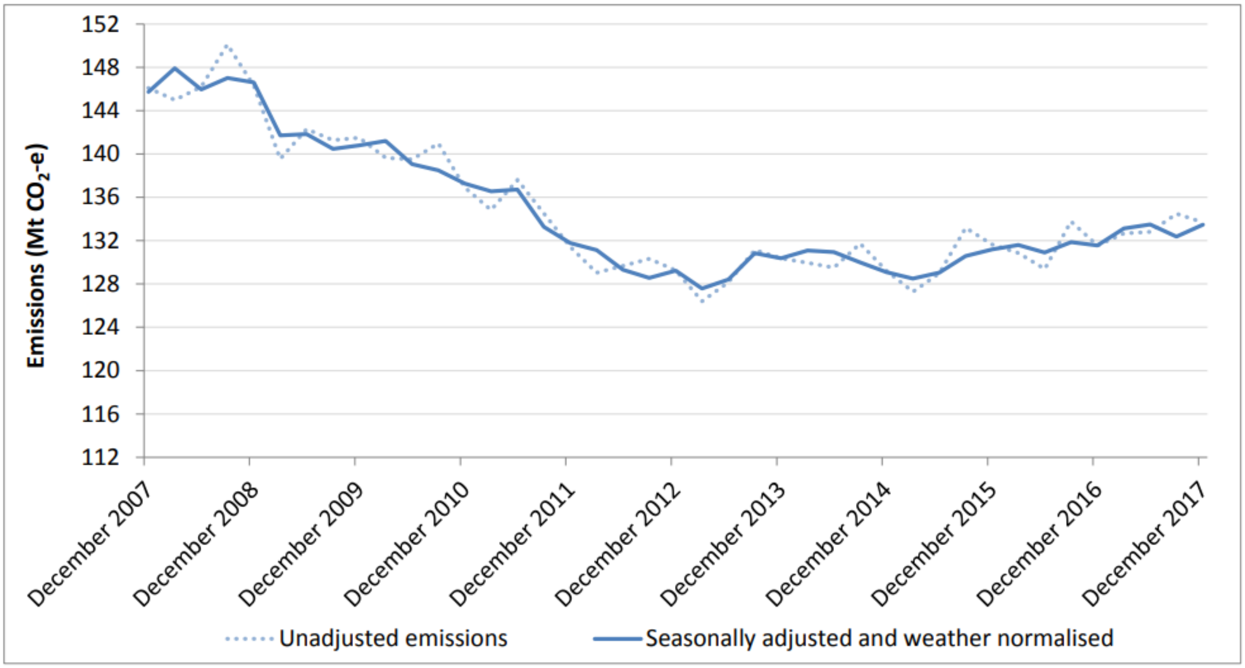


Figure 2-2. Australian national GHG emissions (source: Department of the Environment and Energy, 2018)

Some of the six states and two territory governments have made commitments to renewable energies for electricity, however there are no national renewable fuels targets, with only the staes of New South Wales (NSW) and Queensland having any mandates. (Table 2-1) The NSW mandate is ineffectual though as the Government grants the liable party (fuel distributors) exemptions due to a lack of supply. Investors are scared to invest in new plants due to this which results in the policy being ineffective. As a consequence, GHG emissions from transport have increased by 22% since 2005 and now account for 17% of total emissions, up from 14% in 2005. (Figures 2-2 and 2-3).

Table 2-1. Renewable energy (electricity) and biofuel mandates in Australian states and territories.

State/ Territory	Target	Target Date	Net zero Emission Target	Current % Renewable Energy	Biodiesel Mandate %age	Ethanol Mandate %age
ACT	100%	2020	2050	22		
SA	50%	2050		47		
VIC	40%	2025	2050	12		
Queensland	50%	2030	2050	7	0.5%	4%
NSW	No target		2050	17	5.0% (achieving 0.1%) *	6% (achieving 2.5%) *
Tasmania	100%	2022	2050	92		
WA	No target		No	7		
Northern Territory	50%	2030	No	2		
National	26%	2030				

* https://www.fairtrading.nsw.gov.au/__data/assets/pdf_file/0005/381488/Biofuels_results_4Q_2017.pdf

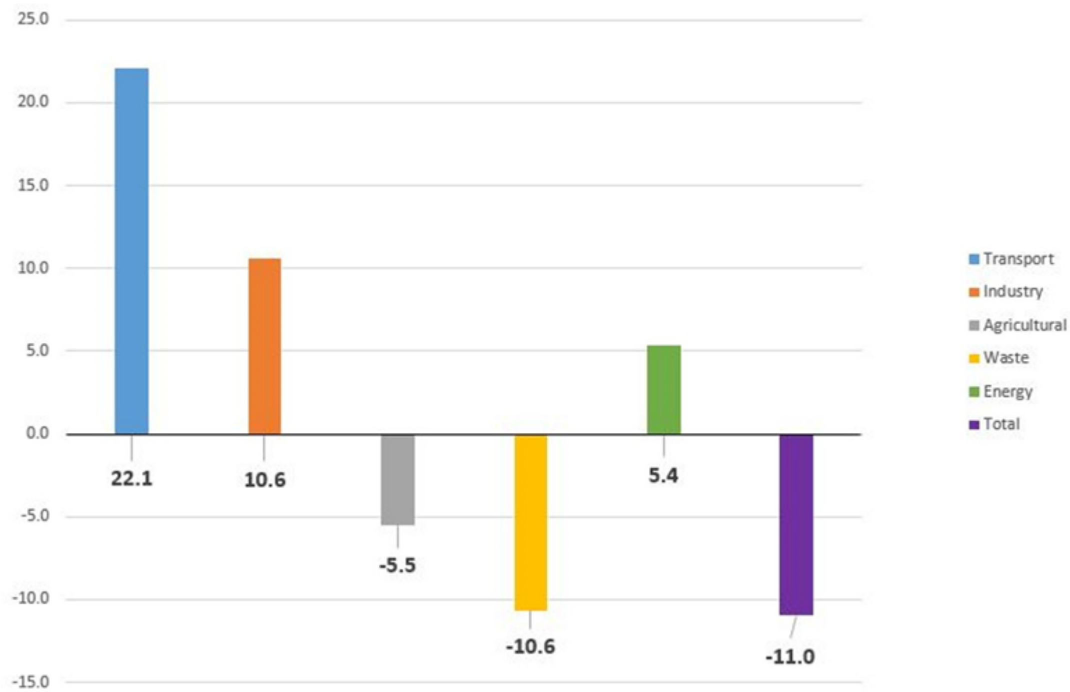


Figure 2-3. Percentage change in emissions per sector from 2005-2017 (excluding land use change)

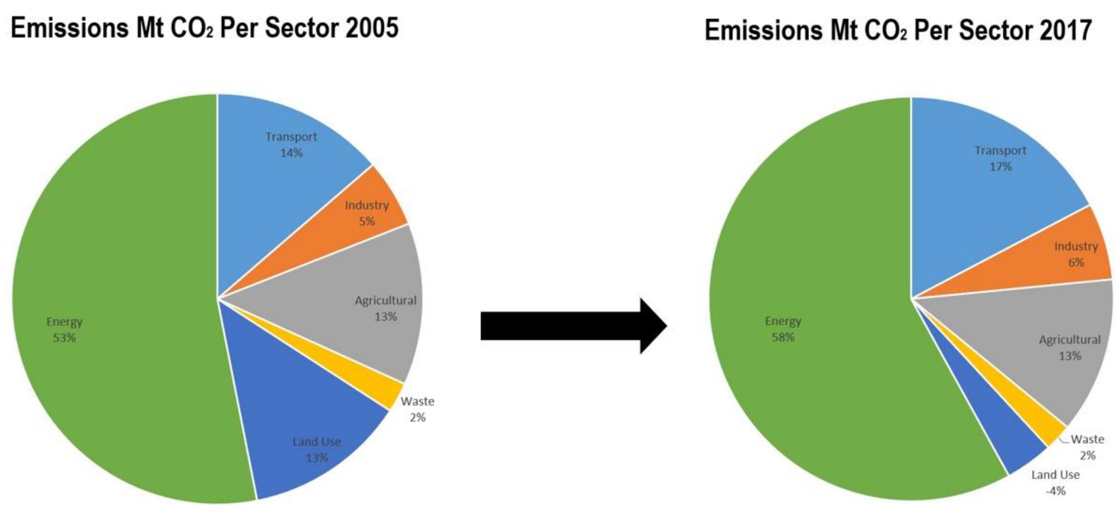
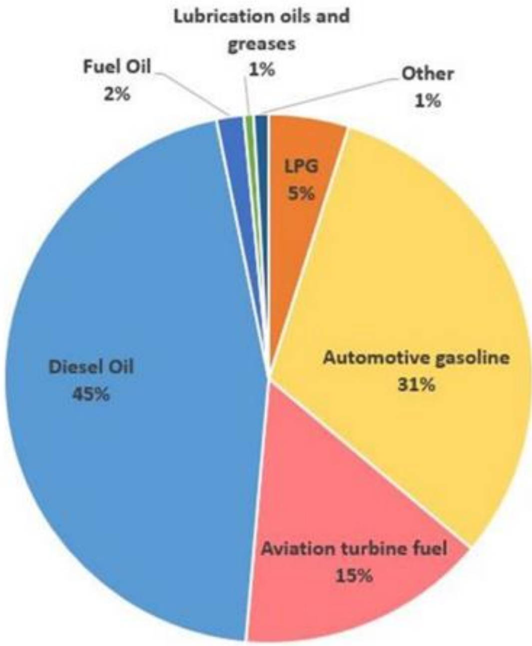


Figure 2-4. Australian GHG emissions by sector (Australian Government, 2017 and 2018)

As shown in Figure 2-5, Australia has a high reliance on diesel, gasoline and aviation fuel due to its geography and high penetration of primary industries, e.g., agriculture, mining and forestry.



Type of Fuel	Sales in Mega Liters
LPG	2862.7
Automotive gasoline	18,208.50
Aviation turbine fuel	8925.4
Diesel Oil	26,517.10
Fuel Oil	978.7
Lubrication oils and greases	340.6
Other	534.60
Total	**58,298.50**

Figure 2-5. Australia fuel sales by type, 2016-2017 (Australian Government, 2017)

2.2 Main drivers for biofuels policy

For the reasons outlined above regarding the challenges in getting a united position, the Liberal/National Coalition parties show no interest in enhancing any biofuels policy. The existing ethanol policy was found in a 2015 report from the Federal Audit Office to be ineffectual and to have benefited one company significantly.

Excerpt of findings from the Auditor General's report into the federal ethanol incentive program:

The Auditor-General
ANAO Report No.18 2014–15
Performance Audit

The Ethanol Production Grants Program

Department of Industry and Science

Source: ANAO.

9. The EPGP has had five participants. When the program commenced, it had two initial participants, increasing to five participants for a single year (2008–09), then declining and remaining at three participants since. Between 2002–03 and 2013–14, one participant (Honan Holdings Pty Ltd) received $543.4 million (70.2 per cent of all program funding).

10. At a number of key program phases, reviews of the EPGP have been commissioned. In February 2014, an assessment by the Bureau of Resources and Energy Economics (BREE)[6], a unit within Industry, found that:

- while the annual cost of the program had been significant, regional employment and greenhouse gas abatement benefits had been modest;
- the health benefits that accrue from reduced air pollution are also modest and declining;
- there would appear to be no net benefit for agricultural producers;
- while the program supported an additional lower priced fuel product, the benefits to motorists were less than they should have been; and
- there was no evidence that provision of support for the Australian ethanol industry provided downward pressure on petrol prices.

2.3 Biofuels policy

2.3.1 Biofuels obligations

As outlined above, biofuels are currently not included in any National Renewables Policy and whilst there is a federal biofuels incentive scheme, there is no federal biofuels policy and this is left to the States. So far, only two states have mandates including Queensland and New South Wales (NSW) but unfortunately the NSW mandate despite being in place since 2007 is ineffective as the mandate is not enforced due to lack of supply. (Figure 2-5)

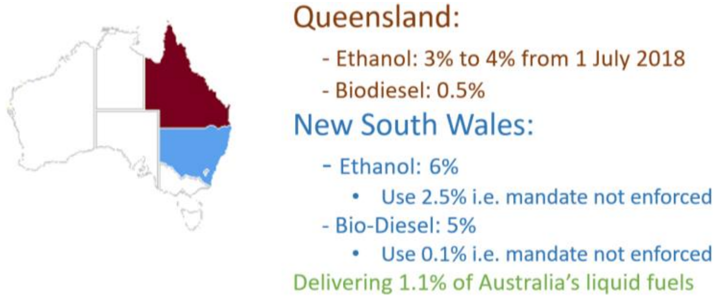


Figure 2-6. State biofuel mandates in Australia

The Queensland mandate was introduced in January 2017 as part of its Bio-Futures Package[6], which is a very positive initiative that has garnered widespread interest from other countries interested in the enormous potential of Queensland's biomass resources. The launch of the mandate was accompanied by a successful advertising campaign explaining the benefits of using ethanol. There was also an App developed to allow drivers to determine if ethanol could safely be used in their cars.

Australia has natural advantages for producing bioenergy, including expertise in agricultural science, an established agricultural economy and an abundance of natural resources. With the right policies, Australia has enormous potential to significantly increase supply and demand of biofuels, even in a scenario with significant electrification of transport and mining demand.

Aviation, marine and heavy vehicles have few or no alternatives to using liquid fuels. The largest increase in liquid fuel demand in Australia over the long term is expected to be in aviation fuel.

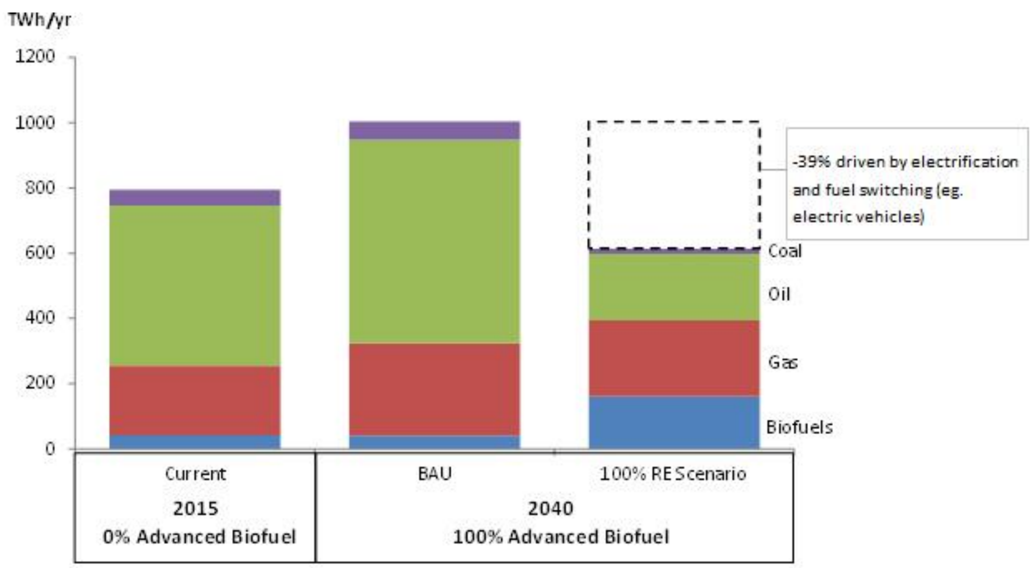


Figure 2-7. Energy supply projections - non-electricity (Source: ClimateWorks Australia, Office of Chief Economist, Biofuels Association of Australia)

In the 2040 scenario by ClimateWorks Australia partially illustrated in Figure 2-6, advanced/drop-in biofuels make up an increasing share of biofuels supply as they become more cost-competitive, since such biofuels face fewer barriers to entry such as the need for engine modifications at high biofuel blend rates. ARENA anticipates that in the longer term advanced/drop-in biofuels will have a substantially larger share of the Australian biofuels market than ethanol and FAME biodiesel.

2.3.2 Excise duty reductions

The Producer Grant Scheme whereby the producer of ethanol or biodiesel was provided with a grant equivalent to the excise amount was stopped in June 2015, with excise being removed on these two commodities. Going forward, excise for these biofuels increments up year on year. For

[6] https://www.statedevelopment.qld.gov.au/industry-development/biofutures.html

biodiesel, this occurs until the biodiesel excise reaches 50% of the fossil diesel excise. Ethanol excise is however capped at a lower price relative to biodiesel due to its lower energy content. (Figure 2-7) Disappointingly, in the excise adjustments, no provision was made for renewable diesel (which was in the earlier scheme) as it was deemed not required as none was being produced at commercial scale. Bioenergy Australia is currently working to try to have renewable diesel again included in excise benefits.

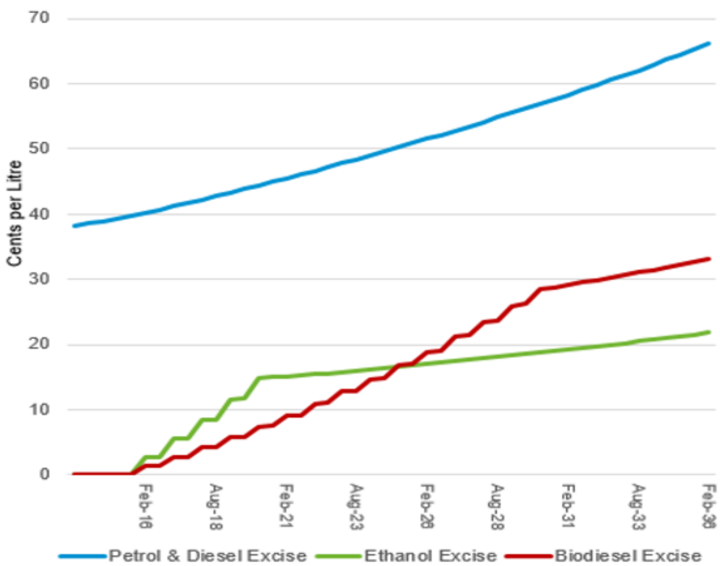


Figure 2-8. Fuel excise changes (assumed 2.5% CPI indexation)

Despite obvious opportunities for the agricultural sector, there is great interest within the farming community to preserve the existing full excise relief received by farmers on fossil diesel. The recent policy change whereby ethanol now pays an excise perversely results in bio-fuels costing more than fossil if prices are at parity.

2.3.3 Fiscal Incentives

Not available.

2.3.4 Investment subsidies

Queensland is by far the most prominent state in terms of promoting the use of biofuels. In 2016, it launched its Bio-futures program that aims to develop a $1 billion bioeconomy. Various Queensland State programs are in place to help support this. (https://www.statedevelopment.qld.gov.au/industry-development/biofutures.html.)

2.3.5 Other measures stimulating biofuels implementation

R&D: Australia has a very positive R&D arrangement were companies with a turnover of less than $20 million per annum are able to get a rebate of 43.5% on R&D expenses https://www.ato.gov.au/Business/Research-and-development-tax-incentive/.

The Australian Renewable Energy Agency (ARENA) was established in 2011 to improve the competitiveness of renewable energy technologies and to increase the supply of renewable energy. It provides grants for R&D programmes in the area of renewable energy technologies, and it invests in related R&D and early stage commercialisation. It has invested in and continues to support the Australian bioenergy sector through co-funding grants; see https://arena.gov.au/about/what-is-renewable-energy/bioenergy/

The Clean Energy Finance Corporation (CEFC) is a $A 10 billion fund designed to facilitate and increase flows of finance into the clean energy sector. It commissioned a report that outlines the status of the industry:
https://www.cefc.com.au/media/107567/the-australian-bioenergy-and-energy-from-waste-market-cefc-market-report.pdf.

The CEFC is also a $ A 100 million cornerstone investor in a $ A 200 million bioenergy fund that is run by the specialist investment organisation Foresight Group, which has invested in multiple bioenergy projects in the UK:
http://www.foresightgroup.eu/institutional/our-business/infrastructure/australian-bioenergy-fund-abf/

Despite all the above incentives and funding opportunities, biofuels development and commercial deployment face a number of significant barriers including:

- Lack of consistent policy causing geo-political risk
- Australia is a high cost economy snd this impacts the cost of feedstocks, including aggregation, and feedstocks also often have alternative, higher value uses
- Lack of fuel distribution infrastructure, and conflict with the business models of existing oil companies
- Inadequate or lack of biorefining capacity (in Australia) to produce refined, drop-in biofuels suitable for end users
- Low levels of consumer/investor knowledge and acceptance of bioenergy/biofuels
- Fragmented biofuels supply chains

ARENA's investment in biofuels demonstration projects, and in some cases in research and development, has the potential to address these barriers and improve the competitiveness and supply of biofuels in the long term, as well as helping Australia capitalise on its natural advantages in producing biofuels.

2.4 Promotion of advanced biofuels

Currently, there are no specific policies promoting the sale of advanced biofuels and there is limited production of advanced biofuels in Australia. However, Australia has been one of the world leaders in development of advanced biofuels technologies due to its significant R&D tax credit outlined above and support from ARENA[7]. As a consequence, Australia is home to the world's largest Hydrothermal Liquefaction (HTL) pilot plant at Licella's Somersby facility in NSW. This is one of three pilot plants at the site and is capable of processing 10,000 tonne per year of feedstock

[7] https://arena.gov.au/projects/?project-value-start=0&project-value-end=500000000&technology=bioenergy

slurry[8]. Work at this site has enabled the development of two commercial projects in Canada and the UK[9].

A domestic waste lube oil refiner, Southern Oil[10], is looking to leverage its refining capability at its 2 facilities in Wagga and Gladstone and has announced[11] plans for a 200 million liters (ML) advanced biofuels plant at its Gladstone facility in Queensland. Work on HTL treatment of algae and biosolids has also been undertaken by Muradel[12] at their Wyalla facility in South Australia.

Cellulosic ethanol development is also being assisted by ARENA through its support of Ethtec who aim to construct a $30 million purpose built pilot-scale facility in the Hunter Valley in NSW. The facility is targeting a range of non-food lignocellulosic biomass waste plant matter including sugarcane bagasse, forestry residues and cotton gin trash known. Curtin University has also received support for their research work on gasification and pyrolysis of mallee feedstocks[13]. Gasification R&D projects also have been conducted on the production of advanced biofuels from algae and lignocellulosic biomass.

2.5 Market development and policy effectiveness

Biofuel production in 2018 is estimated to be unchanged from 2017 but remains significantly below its peak in 2014, when production reached 400 million liters (ML) and consumption including biofuel imports approached 800 ML. Production of ethanol is relatively stable and is supported by a 6% mandate in NSW, while a 3% mandate in Queensland took force in 2017. The ethanol industry in Australia has three established producers in NSW and Queensland, with an installed production capacity of 440 ML. The largest ethanol producer in NSW uses wheat starch and has the capacity to manufacture around 300 ML of ethanol per year. Queensland has two ethanol plants, one operated by United Petroleum at Dalby, and a smaller facility operated by Wilmar at Sarina. The Dalby biorefinery is located in the sorghum growing region in the Darling Downs and normally buys around 200,000 metric tons (MT) of sorghum grain annually from local growers, an amount which can produce 80 million liters of fuel-grade ethanol. At full capacity, the Dalby biorefinery also produces 830,000 MT of wet distillers' grain which is used for animal feed supplements, mainly in the dairy and cattle feedlot industries. In mid-2017, the Dalby ethanol biorefinery announced a US $20 million investment to boost annual production capacity by 24 million litres to 100 ML. The Sarina biorefinery produces fuel ethanol from sugar. It has the capacity to manufacture around 60 ML of ethanol annually. Imports of ethanol from all sources appear to be uncompetitive with standard fuels under the current excise tax regime.

[8] https://www.licella.com.au/facilities/
[9] https://www.licella.com.au/projects/
[10] http://www.sor.com.au/
[11] http://www.sor.com.au/northern-oil-advanced-biofuels-pilot-plant
[12] https://arena.gov.au/projects/advancing-marine-microalgae-biofuel-to-commercialisation/
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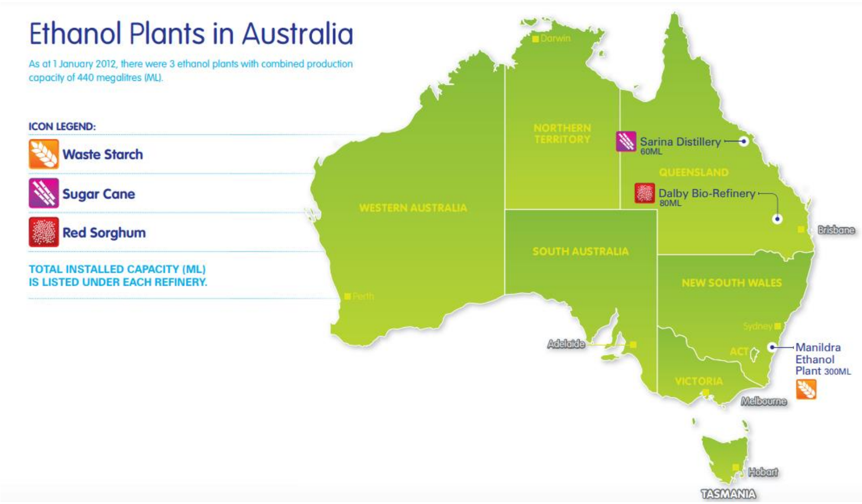

Figure 2-9. Ethanol production plants in Australia (IEA Bioenergy Task 42, 2015)

By contrast, production of biodiesel has collapsed due to high costs for feedstock (such as tallow) and low world oil prices. A surge in biodiesel imports occurred in 2013-15, building up stocks and keeping consumption higher than it would have been otherwise before the excise rebate scheme closed partly due to higher crude oil prices, which have fallen since mid-2014. Imports of biodiesel from all sources are subject to full excise and appear to be uncompetitive with standard diesel imports. These developments have reduced the scale of the biodiesel market, and the B2 mandate in NSW and related tax relief have been insufficient to prevent firms leaving the industry. The largest biodiesel producer, Australian Renewable Fuels (ARF), closed in early 2016 although production capacity remains. Exports of tallow to Singapore for the manufacture of renewable diesel have increased significantly in recent years, reflecting reduced demand from biofuel refineries in Australia. Europe is the main destination for exports of Australian canola for use in the production of biofuels.

The Australian biodiesel industry has seen dramatic reductions in production and capacity since 2015. Demand for biodiesel and hydrogenated vegetable oil (HVO)/renewable diesel in Australia has fallen from 440 ML in 2014-15 to less than 15 ML in 2017, a 96% reduction. Domestic production of biodiesel has fallen from 72 ML in 2014-15 to around 15 ML in 2017 (79% reduction).

Since 2006, despite installed biodiesel/HVO plant capacity reaching 550 ML in 2008 (nine large plants), Australia's production of biodiesel never exceeded 80 ML per year (pa). In 2014, there were nine installed biodiesel plants, with a total capacity of 376 ML pa. Installed capacity is currently ~ 111 ML pa.

Ecotech Biodiesel appears to be the only commercial biodiesel operator in the Australian market, annually producing ~5ML pa against an installed capacity of 30ML pa. They are hopeful that the Queensland mandate will allow them to increase their production to close to their capacity. The only other plant in production, originally operated by Biodiesel Industries Australia, is estimated to be producing ~2ML p.a. FAME biodiesel, mainly from used cooking oils (UCO), for use in trucks operated by its new parent, Scanline. This plant is located in Maitland NSW, has a 20 ML pa capacity, and has been in production since 2003.

Australian Renewable Fuels, formerly the largest biodiesel producer in Australia, went into administration in January 2016, with its Barnawartha plant being sold to Thorney Technologies in early 2017. It is believed that this plant is intended to be restarted with the product being exported to the US. There are two other small biodiesel production facilities producing limited volumes of biodiesel in Echuca in Victoria and Henderson in Western Australia.

In July 2015, federal government policy introduced full diesel excise on imports of biodiesel/HVO, which resulted in imports crashing from 345 ML in 2014-15 to zero in 2016. In 2014-15, about 92 ML of biodiesel was imported and sold into the Australian market. In 2017, imports of biodiesel fell to virtually zero. In 2014-15, about 253 ML of renewable diesel/HVO was imported and sold into Australia; there were no imports in 2017.

Increased overseas demand for Australian biodiesel feedstocks has placed upward price pressure on biodiesel feedstock prices and some producers have been priced out of the market. For example, tallow and UCO were (and still are) in high demand by Neste in Singapore to supply the US biodiesel market.

The main biofuels retailers in Australia are BP, Shell and Caltex. BP has contracts in place for 55 ML pa of ethanol. BP has >100 retail outlets for biofuels blends. Shell has about 10 outlets selling E10 blends in each of the major cities of Melbourne, Sydney and Brisbane. Caltex has E10 outlets in NSW and Queensland but the number is uncertain. Caltex also sells a range of biodiesel blends (B5 to B20) to contract customers.

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3. Austria

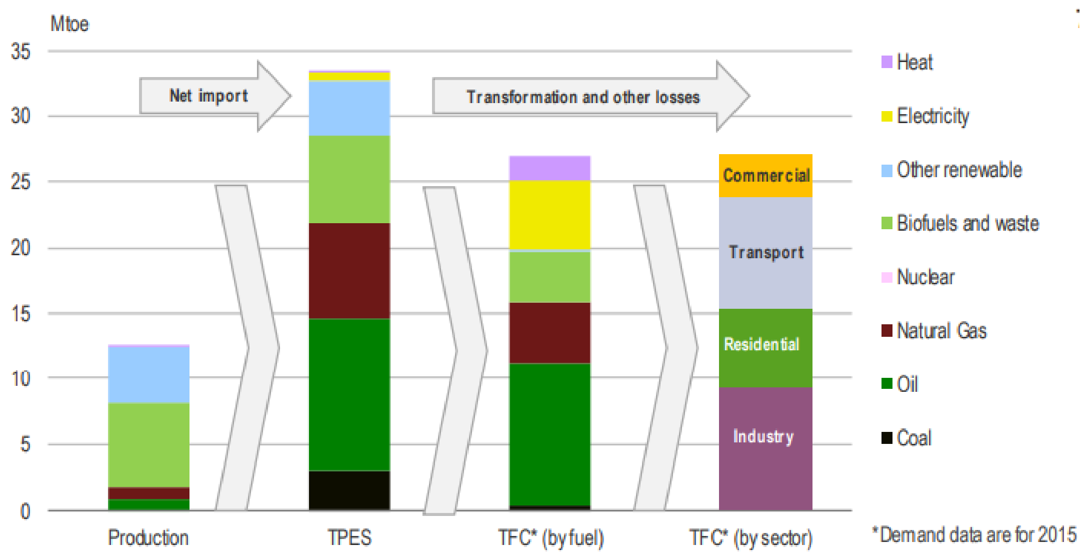
Dina Bacovsky, BIOENERGY 2020+ GmbH

Summary Box

- The biofuel volume obligation includes at least 3.4% ethanol and 6.3% biodiesel on an energy content bases. The carbon intensity or emissions of biofuels are not currently taken into account.
- Aims to achieve a minimum overall biofuel share in transport fuel of 8.45% (by energy content) by October 2020.
- The market share of biofuels consumed in road transport in 2016 was 7.1% by energy content. Of these biofuels, 80% were biodiesel, 9% ethanol, 1% ETBE and 10% HVO (by energy content).
- To promote the production and consumption of advanced biofuels, the revised RED (RED II) targets will be implemented (0.2% target by 2022). There are no specific policies promoting aviation biofuels.
- Tax concessions are granted for fuels with a biofuel share of at least 4.4% (by energy content). However, to be eligible, the fuel must also be sulphur-free (less than 10 mg sulphur per kg of fuel). Since January 2000, the use of neat or pure biofuels as fuels has been exempted from mineral oil tax.
- The government is funding advanced biofuels R&D projects dealing with a wide range of topics and types of advanced biofuels.

3.1 Introduction

Renewable energy accounts for about one-third of Austria's total primary energy supply, most of it in the form of biofuels, combustible waste, and hydropower. As two-thirds of the country's electricity is generated from hydro-electric power, around 37% of Austria's energy needs are produced domestically.



TPES: Total primary energy supply; TFC: Total final consumption.

Figure 3-1. Energy supply and demand in Austria, 2016. Total primary energy supply was 33.3 million tonnes of oil equivalent (Mtoe), 33% renewables (IEA average 10%) (IEA, 2017)

Austria's national Renewable Action Plan hopes to stabilize energy consumption by stipulating that the energy used nationally in 2020 will be the same as in 2005, i.e., 1,100 PJ. This will mean that energy use in various economic sectors will have to be drastically reduced, including:

- -22% in the traffic sector
- -12% heating and cooling
- -6% in electricity

The country plans to increase renewable energy production from 373 PJ in 2011 to 388 PJ in 2020. In other words, 34% of energy consumed in 2020 is to be renewable. The projected renewable energy share in 2020 will be:

- 51% Bioenergy
- 41.2% Hydropower
- 4.5% Wind
- 0.5% Photovoltaic

3.2 Main drivers for biofuels policy

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

The EU has established a legal framework concerning transport fuels. These include the Renewable Energy Directive (RED) 2009/28/EC on the promotion and use of energy from renewable sources and the Fuel Quality Directive (FQD) 2009/30/EC. The RED has set a goal of 20% final energy consumption from renewable sources by 2020, and a specific sub-target of 10% share of renewable energy in the transportation sector by 2020; the FQD requires a minimum 6% reduction in GHGs per energy unit of transport fuel by 2020. The 20% renewable energy consumption has to be met by the EU as a whole and member states agreed to burden sharing such that Austria has to reach 34%.

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

Post 2020 targets for renewable energy are a minimum of 27% of final energy consumption in the EU as a whole by 2030. Recently, the revision of the Renewable Energy Directive has been completed, and new sub-targets for the transport sector have been defined. The overall goal is to reach 14% renewable energy in the transport sector by 2030; advanced biofuels may be double-counted for reaching this target, and renewable electricity used in vehicles may be quadruple-counted. Advanced biofuels should contribute a minimum share of 0.2 % of biofuels by 2022, 1% by 2025, and 3.5 % by 2030. The contribution of conventional biofuels is capped at 7% or lower, depending on the level of current consumption in the respective member state.

3.3 Biofuels policy

The main legislations that impact Austria’s biofuels industry include:

- EU Renewable Energy Directive (RED) 2009/28/EC
- EU Fuel Quality Directive (FQD) 2009/30/EC
- Fuel Ordinance – Änderung der Kraftstoffverordnung 2012 (i.d.F. BGBl. II Nr. 259/2014)
- Sustainability Ordinance – Nachhaltigkeitsverordnung BMF (BGBl. II Nr. 157/2014)
- Ordinance on Agricultural Feedstocks for Biofuels - Landwirtschaftliche Ausgangsstoffe für Biokraftstoffe und flüssige Biobrennstoffe (i.d.F. BGBl. II 250/210)
- Mineral Oil Tax Law - Mineralölsteuergesetz 1995 (BGBl. I Nr. 630/1994, geändert durch das Bundesgesetz BGBl. I Nr. 151/2009) in der Fassung BGBl. I Nr. 118/2015
- Ethanol Blending Order - ethanolgemischverordnung (BGBl. II Nr. 378/2005) and its revision Bioethanolgemischverordnung (BGBl. II Nr. 260/2007)

For the Clean Fuel Standard, EU regulations apply:

- Regulation on Emissions at Type Approval, Reg No. 715/2007
- Regulation on Emission Performance of Cars, Reg. No 443/2009; Reg. No 333/2014

In order to enter the market and/or earn incentives, the fuel specification has to match the existing standards for Diesel or Otto fuels; the company producing or importing the fuel has to register with elNa; in addition, the production chain has to comply with the sustainability criteria, and this has to be certified.

There are no market-based mechanisms such as carbon tax and emissions trading (cap-and-trade). To promote the production and consumption of advanced biofuels, the targets mentioned in the revised RED will be implemented (0.2% target by 2022). There are no specific policies promoting aviation biofuels in the country.

3.3.1 Biofuels obligations

In November 2004, the EU Biofuel Directive 2003/30/EC was transposed into Austrian national law with an amendment to the Fuel Ordinance of 1999. This amendment stipulates that all companies putting fuels on the market (e.g., OMV and the Austrian mineral oil company) must, from October 2005, replace 2.5% of the total energy quantity by biofuels. From 2007, this percentage was increased to 4.3%, and in 2008 it was raised to 5.75%, as stipulated in the Directive.

The EU Renewable Energy Directive (RED) 2009/28/EC and the Fuel Quality Directive (FQD) 2009/30/EC were transposed into Austrian national law by again amending the Fuel Ordinance in 2009, 2012, 2014 and 2018. The Fuel Ordinance stipulates:

- From 2010, 5.75% (by energy content) of all Otto and Diesel fuels should be biofuels or other renewable fuels.
- The greenhouse gas emissions of all fuels supplied to the transport sector have to be reduced by 6% by the end of December 2020.
- Fuels can only be counted towards these targets if they fulfill the sustainability criteria (same thresholds and requirements as in RED and FQD). Any feedstock produced in Austria must comply with EU regulations. Imported feedstocks or biofuels must be certified by another Member State or a voluntary scheme approved by the EC or Austrian control bodies.

Mandates or biofuel volume obligations include:

- At least 3.4% of ethanol to be added to gasoline
- At least 6.3% of biodiesel to be added to diesel

The carbon intensity or emissions of biofuels are not currently taken into account.

Prior to the most recent developments, the “Fuels Ordinance” of 2012 defined technical specifications for motor fuels as well as substitution regulations for biofuels primarily with regard to environmental performance aspects. As of December 2012, biodiesel was specifically defined as FAME (fatty acid methyl ester). FAME can be used as a blending component up to an amount of 7% (by volume) of the total diesel fuel. The biodiesel has to be produced exclusively from vegetable oils.

Austria’s sustainability assessments are based on RED and EU frameworks. The new EU RED and FQD directives are challenging. Ongoing Indirect Land Use Change (ILUC) and overall sustainability concerns are leading to a de-emphasis of conventional and advanced biofuels.

RED and FQD biofuel sustainability criteria are being implemented into Austrian law by two separate ordinances. The cultivation of feedstock is regulated by an ordinance on agricultural feedstocks for biofuels and bioliquids, while the fuel mandate that came into force in 2011 governs the certification of commercialized biofuels. Double counting of GHG savings made by biofuels produced from wastes, residues, non-food cellulosic material and lignocellulosic material will be assessed on a case-by-case basis.

3.3.2 Excise duty reductions

In 1999, an amendment of the Austrian tax law stipulated there would be no tax on biodiesel and ethanol to a certain limit. The "Austrian Decree on Transportation Fuels" allows blending up to 7% biodiesel with fossil diesel. Blends more than 5% in gasoline were taxed at the full amount. Also, if the biodiesel is produced in small-scale plants and it is exclusively used by farms themselves, it is free of mineral oil tax.

Together with the amendment to the Fuels Ordinance in 2004, the Mineral Oil Act has been revised (Mineral Oil Tax Law, BGBl. I Nr 180/2004). Accordingly, tax concessions are now granted for fuels with a biofuel share of at least 4.4% (by energy content). However, to be able to benefit from these tax concessions, the fuel must also be sulphur-free (less than 10 mg sulphur per kg of fuel). The use of pure biofuels as fuel has been exempted from mineral oil tax since January 2000. The Bioethanol Blending Order that entered into force in October 2007 allows refunding of the mineral oil duty for E75 blends.

3.3.3 Fiscal incentives

Not available.

3.3.4 Investment subsidies

- For the biofuel consumer (e.g., reduced license fees, tax credits for purchase of flex-fuel vehicles or natural gas vehicles, etc.): There is funding available (up to € 2,000 per vehicle) for municipalities and companies when buying alternative fuel vehicles.
- There is funding available for the construction of demonstration facilities for the production of renewable energy
- There is funding available for Research and Development: € 16 million under the New Energies 2020 R&D program

3.3.5 Other measures used to stimulate the production and use of biofuels

National funding is provided through the Austrian Research Promotion Agency FFG. Owners and providers of funds for the research programs are the Austrian Ministry for Transport, Innovation and Technology (bmvit) and the Federal Ministry of Science, Research and Economy (bmwfw).

National R&D funding programs include instruments that are open to all fields of research (to fund fundamental research, applied research and build-up of research infrastructure) and thematic calls (such as the New Energies 2020 program and the IEA Research Cooperation).

EU funding is available through the Horizon 2020 program.

The ERA-NET scheme provides a platform to coordinate research funding programs between several EU member states. Transnational projects are created and each partner is funded through national funds.

3.4 Promotion of advanced biofuels

The Austrian government is funding a variety of R&D projects on advanced biofuels and has also developed several advanced biofuels pilot or demonstration plants although only one is currently operational (Table 3-6) . The funded R&D projects are dealing with a wide range of different topics and types of advanced biofuels, for example biomass gasification and synthesis to FT-diesel, mixed alcohols, conversion of algal biomass, lignocellulosic biogas and lignocellulosic ethanol. Major research projects spanning a range of Technology Readiness Levels (TRLs) include:

- **Vienna / Güssing Gasifier**: BIOENERGY 2020+ plans to install a dual-fluidised bed gasifier reactor for performing high-temperature gasification to produce synthesis gas (CO, H_2), followed by downstream processing to produce gaseous, liquid and chemical products (e.g., by methanation, Fischer-Tropsch synthesis, etc). The current TRL is 4-7. See https://www.bioenergy2020.eu/content/en/competence_areas/biomass_gasification/gasapplications for details.
- **bioCRACK + bioBOOST**: BDI is further developing its technologies for pyrolysis of solid biomass and subsequently upgrading this pyrolysis oil in the Fluid Catalytic Cracking (FCC) units within petroleum refineries. The current TRL is 6. See https://www.bdi-bioenergy.com/en-bdi_biolife_science-396.html for details.
- **Winddiesel**: Repotec, Güssing Energy Technologies and Vienna University of Technology are jointly investigating power-to-liquids technology. Hydrogen, derived from electrolysis using renewable electricity, is added to syngas produced by biomass gasification and then converted to FT-liquids. The current TRL is 6-7. See www.winddiesel.at for details.
- **Heat-to-Fuel**: This is an EU-funded project. Three Austrian entities (BIOENERGY 2020+, Güssing Energy Technologies and Vienna University of Technology) and 11 other partners from another six European countries cooperate to upgrade alternative, residual biomass feedstocks and convert excess heat to liquid fuels in a combined gasification, Fischer-Tropsch and Aqueous Phase Reforming plant. The current TRL is 3-6. See http://www.heattofuel.eu for more details.
- **TORERO**: This is an EU-funded project involving 5 partners including the Austrian research organisation and Joanneum Research. Torero will demonstrate a technology concept for producing ethanol from a wood waste feedstock, fully integrated in a large-scale, industrially functional steel mill: 1) Wood waste is converted to "biocoal" by torrefaction; 2) this biocoal replaces fossil powdered coal to fuel a steel mill blast furnace; 3) carbon monoxide in blast furnace exhaust gases is microbially fermented to ethanol. See http://www.torero.eu for details.

- **CO2-free logistics**: Starting in May 2018, DB Schenker, Fronius, HyCentA, and Energieinstitut Linz will jointly work to demonstrate the production of hydrogen through a high pressure PEM electrolyzer and the utilization of this hydrogen in fuel cell-powered fork lift trucks. The current TRL is 8.
- **Reformer Steam Iron Cycle**: OMV, AVL and University of Technology Graz are jointly developing a process for the decentralized production of renewable hydrogen via reforming of biobased feedstocks in combination with chemical looping of iron based oxygen carriers. The underlying process is called the Reformer Steam Iron Cycle (RESC), which has been patented recently by the research group. The current TRL is 3.
- **OSCYME**: AEE Intec is investigating a new reactor concept for carrying out enzymatic hydrolysis of lignocellulosic feedstocks. The goal of this project is to develop a continuous enzymatic hydrolysis process using a novel plug-flow reactor that substantially improves conversion rates and reduces enzyme addition requirements. This newly developed reactor will be the basis for an improved hydrolysis process eventually applicable in the biobased industries to save energy, resources and time. See http://www.aee-intec.at/index.php?seitenName=projekteDetail&projekteId=212&lang=en for more details.

3.5 Market development and policy effectiveness

Austria has targets mandating the blending of biofuels, introduced by BGBl. II Nr. 398/2012. In 2015, the overall biofuels target was a minimum 5.75% biofuel in transport fuel (by energy content); see Table 3-1. In addition, there were separate targets (by energy content) of at least 3.4% biofuel in petrol and at least 6.3% biofuel in diesel. Austria aims to achieve a minimum overall biofuel share of 8.45% in transport fuel based on energy content by October 2020. A fuel supplier that fails to fulfill their quota obligations must pay an administrative penalty as established in the Krarfahrgesetz 1967, Fassung vom 04.05.2015. The growth and stabilization of installed production capacity for ethanol and biodiesel production is summarized in Table 3-2, with consumption trends shown in Table 3-3.

Table 3-1. Biofuel obligations/mandates (% by energy content)

Year	Ethanol	Biodiesel	Overall biofuels target (any biofuel)
2010	3.4	6.3	5.75
2011	3.4	6.3	5.75
2012	3.4	6.3	5.75
2013	3.4	6.3	5.75
2014	3.4	6.3	5.75
2015	3.4	6.3	5.75
2016	3.4	6.3	5.75
2017	3.4	6.3	5.75
2018	New biofuels obligations/mandates will be re-established when REDII will be transposed into national law.		

The Austrian regulation defines values as % by energy content. These values can be fulfilled by adding 5% by volume of ethanol to gasoline and 7% by volume of biodiesel to diesel.

Table 3-2. Biofuel production – installed production capacity (ML/year)

Year	Biodiesel (FAME)	Ethanol (conventional)	Cellulosic ethanol	Biogas as transportation fuel	Renewable diesel (from lipids)
2006	137	0	-	-	-
2007	270	15	-	-	-
2008	280	90	-	-	-
2009	362	177	-	-	-
2010	378	202	-	-	-
2011	348	220	-	-	-
2012	297	220	-	-	-
2013	243	226	-	-	-
2014	327	234	-	-	-
2015	381	226	-	-	-
2016	345	228	-	-	-

Table 3-3. Summary of transport fuel consumption and market share (ML/year)

Year	Gasoline	Diesel fuels	Aviation fuel	Biodiesel*	Ethanol**	Market share of biofuels*** (% by energy content)
2006	2,677	7,353	N.A	381	-	
2007	2,643	7,522		426	26	
2008	2,466	7,276		454	73	
2009	2,476	7,111		572	85	7.00
2010	2,447	7,440		561	105	6.58
2011	2,359	7,246		561	99	6.75
2012	2,305	7,281		561	107	6.77
2013	2,239	7,703		561	87	6.19
2014	2,183	7,581		650	100	7.68
2015	2,204	7,738		673	109	8.87
2016	2,201	8,062		561	109	7.10

* From 2006 onwards (and phasing in since 2005) almost all diesel fuels contain around 7 % by volume of biodiesel
**From 2009 onwards (and phasing in since 2007) all gasoline contains around 5 % by volume of ethanol or bio-ethyl tert-butyl ether (BioETBE)
***Market share of biofuels in the total transport fuel consumption. It also includes the contributions of PPO (Pure Plant Oil), HVO and biomethane, and is calculated as % by energy content of all fuels used for road transport

The market share of biofuels consumed in road transport in Austria in 2016 was 7.1% by energy content (Table 3-3). Of these, 80% were biodiesel, 9% ethanol, 1% ETBE and 10% HVO (all by energy content).

Table 3-4. Ethanol facilities

Company	City	Capacity (ML/year)
AGRANA Bioethanol GmbH	Pischelsdorf	246

Table 3-5. FAME biodiesel facilities

Company	City	Capacity (ML/year)
Biodiesel Süd GmbH	Bleiburg	22
Münzer Bioindustrie GmbH	Wien	157
Eco Fuels Danube GmbH	Krems	56
HPF Biokraft Hirtl GmbH	Fehring	5
Abid Biotreibstoffe GmbH	Hohenau	56
Novaol Austria GmbH	Bruck an der Leitha	107
Biodiesel Kärnten GmbH	Arnoldstein	56
Münzer Paltental	Gaishorn am See	67
Brantner Energy GmbH	Krems	17
Total capacity		543

Note: There is no national HVO producer in Austria.

Table 3-6. Advanced biofuel producers

Company	Status	Technology	Production capacity
Bio SNG Güssing	closed	Gasification of wood chips and subsequent methanation for the production of biomethane	100,000 liters/a
BIOENERGY 2020+	operational	Synthesis of FT-liquids from syngas from the gasification of wood chips	50,000 liters/a
AustroCel Hallein	planned	fermentation of brown liquor at the pulp mill for the production of ethanol	30 million liters (ML)/a

Biodiesel is the main biofuel produced in Austria. Biodiesel production capacity in Austria is ~ 540,000 ML/year from 9 production facilities (Table 3-5). Production reached its peak in 2015 with nearly 381 ML of biodiesel produced, with production falling to 345 ML in 2016. Total biodiesel consumption in 2016 was 561 ML, of which 498 ML was blended with fossil diesel, and 73 ML used directly.

In 2016, 228 ML of ethanol was produced in Austria, lower than the amount of biodiesel production. While Austria's E10 ethanol demand could be met by the production capacity of a single plant, i.e., the AGRANA ethanol plant in Pischelsdorf (Table 3-4), plans for E10 have been discarded and E5 remains the typical ethanol blend. The Pischelsdorf plant has a capacity of 240 ML of ethanol per year, which at this level of production is capable of displacing 1/3 of Austria's soy protein imports through DDGS co-production. This plant's GHG emission reductions of 50% have been certified by Joanneum Research.

In recent years, pure plant oils are increasingly being used directly as fuels, in particular by agricultural vehicles and road freight transport. While national production data is not readily available, in 2016 it was estimated that there were 15,595 tonnes of plant oils used directly as fuel.

Biogas produced in Austria is mainly used on site for heat and power production, with an estimated production of 308 Mm^3 of biogas per year. Efforts are also being made to introduce "Bio-CNG" into the transport fuel market, but the number of CNG fuel capable vehicles must still be increased.

3.6 Sources

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4. Brazil

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Summary Box

- In 2017, Brazil established new legislation for the biofuel sector, named RenovaBio. The RenovaBio program will create a regulatory framework to revitalize the biofuels sector and foster energy efficiency gains in biofuels production and use. This new law will come into force in 2020.
- RenovaBio will provide a market-based incentive for higher production efficiencies and lower carbon biofuels production by issuing GHG emissions reduction certificates, named "CBio". One CBio corresponds to a reduction of one ton of carbon dioxide equivalent (CO_{2eq}) in comparison to fossil fuel emissions.
- With RenovaBio, the government plans to increase annual ethanol production from the current 30 billion liters to around 50 billion liters by 2030, and also to increase biodiesel production from 4 billion liters to 13 billion liters over the same period.
- The mandatory blend levels for ethanol and biodiesel are currently 27% (E27) and 10% (B10), respectively. 100% hydrated ethanol (a.k.a. "hydrous ethanol") is also marketed in all gas stations in Brazil.
- There are tax incentives for biofuel producers, blenders and users, including tax incentives for ethanol-flex fuel vehicles and for ethanol fuel and there are federal tax exemptions and incentives for biodiesel production.
- There are several science and technology funds that support continued innovation in the production and use of low carbon biofuels.

4.1 Introduction

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 1976, in response to the impacts of the oil shocks during the 1970s, the Brazilian government created the Proálcool program, 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 E100 dedicated vehicles was eventually phased out and replaced by mandatory ethanol blending 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. Features of the Proálcool program included (Nogueira, 2008):

a) Mandating minimum levels of anhydrous ethanol in gasoline;
b) Making consumer prices for hydrous ethanol lower than for gasoline;
c) Providing competitive prices for ethanol producers;
d) Developing favorable financing terms for mills to increase their production capacity;
e) Reducing taxes on new cars and annual registration fees for vehicles capable of running on hydrous ethanol;
f) Mandating the sale of hydrous ethanol at gas stations; and
g) Creating ethanol storage reserves to ensure supply throughout the year.

In 1985, due to the decline in oil prices and strengthening of international sugar prices, the government revised its ethanol policies, reducing the average financial returns to the sugarcane industry and stimulating greater allocation of sugarcane to produce sugar for export. This led to a temporary end to the expansion of the Proálcool initiative.

The second phase of expansion took place because of a new market opportunity. In 2003, flex-fuel cars were launched and well accepted by consumers. Flex-fuel cars offer drivers the option of using gasoline (containing 20–27% anhydrous ethanol), hydrous ethanol, or any blend of the two. 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 demand of the international market for using ethanol in gasoline blends. During 2003–2008, the Brazilian sugarcane industry expanded rapidly, with many new and more efficient sugar-ethanol mills commissioned. A consolidation phase within the industry also began as positive indicators for the industry's environmental sustainability were demonstrated alongside increasing support for new technology development and transfer (Leal et al., 2015).

In 2008, the Brazilian ethanol agroindustry started to suffer due to the increasing lack of price competitiveness relative to gasoline coupled with policies that favored the use of petroleum-based products. As the Brazilian fleet was flex-fuel, ethanol demand decreased such that by 2010 ethanol production was 30% less than in 2008 (Youngs et al., 2015). In 2018, the share of ethanol in the fuel mix used by light vehicles (Otto Cycle - in gasoline equivalent) reached 50.2%, the highest in history (www.unica.com.br/noticia/6537316920342041397).

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 centers, and in 2002 ethanolysis of vegetable oils was chosen as the main route to initiate a substitution program for petroleum diesel, the PROBIODIESEL program. As Brazil is a large ethanol producer, ethanolysis was chosen as the production route instead of methanolysis. The National Program for Production and Use of Biodiesel was created in 2005 to further stimulate energy, economic and social objectives as well as more feedstock production by small farmers. This program evolved gradually, with soybean oil and tallow proving to be the most relevant feedstocks for production. This program mandated a substitution of B5 by 2005 and suggested that in 15 years the substitution of B20 would be implemented. In 2018, the mandated blending level for biodiesel was B10.

In 2017, Brazil established a new legislation for the biofuel sector, named RenovaBio. The RenovaBio program creates a regulatory framework to revitalize the biofuels sector, encouraging energy efficiency gains in biofuels production and use. It recognizes that different biofuels have different capacities to contribute to the de-carbonization goals set at the 21st Conference of the Parties (COP21). The policy aims to meet the annual decarbonization targets set by the government for a minimum 10-year period. Biofuels production will be certified through life cycle analysis (LCA) with issuance of GHG emissions reduction certificates, named "CBio" in Portuguese (an acronym for "Crédito de Descarbonização" – Decarbonization Credit), to producers that can be traded in the stock market and purchased by fuel distributers. One CBio corresponds to a reduction of one ton of carbon dioxide equivalent (CO2eq) in comparison to fossil fuel emissions. With RenovaBio, the government plans to increase ethanol production from the current 30 billion liters to around 50 billion liters by 2030 and biodiesel production from 4 billion to 13 billion liters over the same period. Figure 4-1 shows the governance structure for RenovaBio.

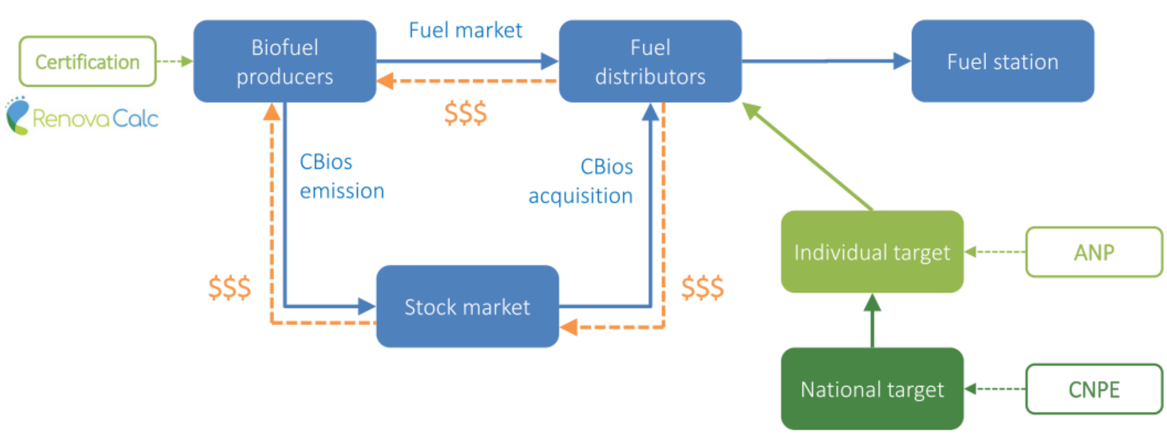

Figure 4-1. RenovaBio's governance structure

4.2 Main drivers for biofuel policy

Energy security was initially the main driver for the implementation of biofuels in Brazil. Both the Proalcool and the Biodiesel Programs started in Brazil for economic reasons. More recently, governmental programs were updated to better consider sustainability concerns and to place a greater emphasis on social and environmental aspects.

4.3 Biofuels policy

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 United Nations framework convention on climate change. This document, announced in December 2015 during the Paris Conference (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), also known as Plan for Energy Expansion, elaborated by Brazil's Energy Research Agency (EPE) and published every year by the Ministry of Mines and Energy. In addition, all policies, measures and actions to implement Brazil's NDC are carried out under the National Policy on Climate Change (Law 12,187/2009), the Law on the Protection of Native Forests (Law 12,651/2012, hereinafter referred to as the Forest Code), the Law on the National System of Conservation Units (Law 9,985/2000) as well as related legislation following established processes. The Brazilian government is committed to implement its NDC with full respect to human rights, in particular the rights of vulnerable communities, including indigenous populations, traditional communities and workers in affected sectors, and to also promote gender-responsive measures.

As described above, in 2017 Brazil launched RenovaBio (Law 13,576/2017), 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 reduction of greenhouse gas emissions. This new law will be enforced beginning in 2020. RenovaBio provides a market-based incentive by issuing GHG emissions reduction certificates, named "CBio". The program is not expected to include the creation of carbon taxes or any kind of subsidy to biofuels. The program should include the creation of CBios issued by biofuel producers, which will be transferred to fuel distributors at the time of purchase. Fuel distributors will likely have mandates to acquire a certain volume of CBios. A secondary market for CBios is likely to be created, since fuel distributors that do not have enough certificates will have to buy them to fulfill their annual mandates.

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;

- 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, the framework of the Rota 2030 program was approved by the Brazilian federal government in December 2018 (Brazil, 2018) to foster greater 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. Studies show that under Brazilian conditions biofuels are able to provide better GHG emissions mitigation than electric vehicles (Souza et al., 2018).

4.3.1 Biofuels obligations

National Biofuel Policy – RenovaBio – Law 13.576/2017.

Executive Order 9.308/2018 - Establishes annual mandatory targets for the reduction of greenhouse gas emissions for commercial biofuels, effective beginning in 2020.

Ethanol mandatory blend level increased from 18% up to 27.5% - Law 13.033/2014. The current mandatory blending level is 27% (E27). 100% ethanol (hydrous ethanol) is also marketed in all gas stations in Brazil.

Biodiesel mandatory blend level increased from 5% up to 15% - Laws 11.097/2005; 13.033/2014 and 13.263/2016. The current mandatory blending level is 10%.

4.3.2 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) and Contribution to Social Integration/Contribution for Financing Social Security (PIS/COFINS) programs. In addition, the governments of several Brazilian states provide differential treatment for ethanol by using different state taxes for 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.

4.3.3 Fiscal incentives

The "Regional Producer Subsidy" is the only direct subsidy paid by the government of Brazil. The program was created decades ago to provide support for sugarcane producers from the north-northeastern states to balance their cost of production with those of the more developed growing areas in center-south Brazil. 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 tons 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 March 2017 request by Brazilian ethanol producers to place a tariff on imported ethanol. Producers claim the pace of imports jeopardizes domestic ethanol production, especially in northeastern Brazil 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 Secretariat of Foreign Trade, 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.

4.3.4 Other measures used to stimulate the production and use of biofuels

There are several science and technology funds such as BNDES, FINEP, FAPESP, and CNPq that support the production and use of biofuels.

The National Bank for Social and Economic Development (BNDES) provides specific credit lines for the sugar, ethanol, and bioenergy industries to fund investments in sugarcane production, expansion of industrial production capacity for sugar and ethanol, cogeneration, logistics, and multimodal transportation. BNDES reports that in 2016 a total of $R 2.02 billion was released to finance the sugarcane/sugar/ethanol/energy cogeneration industry, down $R 743 million compared to 2015, due to financial difficulties faced by the sector.

There are also financial incentives for feedstock development and to renew crop plantings from BNDES:

- Line 1: New varieties, especially those focused on border region production environments; more suitable for agricultural mechanization; and/or producing higher amounts of biomass and/or total recoverable sugar (TRS) with emphasis on transgenic improvement;
- Line 2: Machines and implements for planting and/or harvesting, as well as for the collection of straw and/or waste, with emphasis on expanding the use of precision farming techniques;
- Line 3: Integrated production management, planning and control systems;
- Line 4: Agile and efficient propagation techniques for seedlings and innovative biotechnological devices for planting; and
- Line 5: Adaptation of industrial systems for energy crops compatible and/or complementary with the agro-industrial system for ethanol production from sugarcane.

Line 6: Financial incentives for feedstock development from BNDES PAISS grants.

In June 2017, the Ministry of Agriculture, Livestock and Supply announced the Brazilian Agricultural Crop and Livestock Plan for 2017-2018. A total of $R 190.25 billion (around $US 50 billion) will be released to fund agricultural and livestock programs, including Prorenova for sugar and PAISS for ethanol. This represents a 3% reduction over the previous crop plan. A total of $R 1.5 billion should be available to finance the Prorenova program for 2017-2018. Prorenova is a credit line to finance the renewal and/or expansion of sugarcane fields, which is intended to prioritize the use of new sugarcane varieties. The Prorenova credit line's annual interest rate is comprised of the "long term interest rate" (TJLP) plus 3.7%, with payment due within 96 months of contracting the finance.

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 biofuels producer by the National Agency of Petroleum, Natural Gas and Biofuels (ANP).

The financial instruments offered by PAISS include: a) credit in special financing lines; b) equity participation; c) non-reimbursable funds for cooperative projects between companies and the R&D institution; and d) non-refundable economic support (grants) for companies, defined depending on the case (amount, technological risk, involved institutions, etc). After the call for tenders and a sequence of thorough screening steps to select the projects, Industrial PAISS granted about $US 625 million in financing lines, leveraging investments of $US 1.7 billion, to be deployed between 2011 to 2014 (BNDES, 2011), while Agricultural PAISS made available $US 630 million for projects over the period 2014-2018 (BNDES, 2015; CGEE sobre 2G Sugarcane Bioenergy & Biochemicals, pg 88).

Table 4-1. Government investments in research and development*

Institution	*Biofuels and bioproducts*				
	(Thousand dollars)				
Year	2012	2013	2014	2015	2016
CNPq Grants and scholarships	446,023	1,096,924	397,354	194,283	30,636
FAPESP** Grants and scholarships	49,194	47,090	40,445	29,617	2016: 30,195 2017: 44,507 2018:28,466
FINEP Concessions	0	4,215	1,781	1,447	3,149
Demonstration plants	28,206	36,594	72,090	114,423	31,647
Low interest loans and non-refundable funds for universities and research institutes	30,568	41,434	94,985	18,614	71,916
FINEP Total	58,774	82,243	168,856	134,484	106,712
Petrobras CENPES	32,000	28,000	20,388	10,554	7,706
BNDES Subsidies		288	235	102	73
TOTAL Investment in biofuels	**644,765**	**1,336,788**	**796,134**	**503,524**	**282,034**

* Source: MRE. FAPESP values are US$ dollars

** Source: https://bv.fapesp.br/47292

4.4 Promotion of advanced biofuels

Brazil has two commercial cellulosic ethanol plants including GranBio's Bioflex-I facility in São Miguel dos Campos (AL) that has a nominal annual production capacity of 82 million liters, and the Raízen plant in Piracicaba (SP) that has an annual capacity of 42 million liters. In addition, there is an experimental plant in the Canavieira Technology Center (CTC) in Piracicaba (SP) that hasan 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 (GranBio, 2017; Raízen, 2018).). By 2024, Raízen plans to build seven more cellulosic ethanol plants (https://www.raizen.com.br/pt/energia-do-futuro-tecnologia-em-energia-renovavel/etanol-de-segunda-geracao).

For developing green jet fuel, the International Civil Aviation Organization (ICAO/UN) and major airlines established an emissions reduction agreement known as CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation), which sets out from 2020 a path to carbon neutral growth of the aviation industry (ICAO, 2018).

In addition to emission compensation instruments and energy efficiency promotion (spanning technical/aircraft, systemic/operational management and airport infrastructure), CORSIA also promotes the use of drop-in aviation biofuels, which should be produced by processes certified by ASTM International (American Society for Testing and Materials International) (ASTM, 2016). 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 biojet fuel production to be cost competitive in Brazil and worldwide with aviation kerosene of fossil origin. In order to deepen its knowledge in this subject, Brazil's Energy Research Office collaborated with the German Agency for International Cooperation (GIZ) on a project to create a reference model for using sustainable synthetic aviation fuels in Brazil. One of the main objectives of the research was to examine the status quo of the aviation fuel value chain in Brazil and to determine the actual market cost for distributors. The project sought to analyse the actual costs of aviation fuels, including hidden costs, which could identify local opportunities for producing alternative aviation fuels based on economically viable logistics conditions. This research predicted that synthetic aviation fuels will become economic competitive after 2030.

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 Minas Gerais and REPAR in Paraná). Plans were made for processing of vegetable oil in other Petrobras units including the Henrique Lage Refinery – Revap (SP), the Presidente Bernardes Refinery – RPBC (SP) and the Duque de Caxias refinery – Reduc (RJ). However, this approach for hydro-processing has never been effectively implemented due to limited economic competitiveness.

4.5 Market development and policy effectiveness

At the end of December 2017, 382 ethanol plants were producing anhydrous and hydrous ethanol, according to the Product Movement Information system (ANP Simp). The report does not characterize whether the unit is operating or is idle and does not consider the exclusively sugar-producing mills. Total anhydrous and hydrous ethanol production capacities were 128 million liters/day and 237 million liters/day, respectively.

According to the Ministry of Agriculture, Livestock and Food Supply (MAPA), 635.6 million tons of sugarcane was produced in calendar year 2017. This amount is 5.2% lower than in the previous year, when 670.6 million tons were produced. In 2017, national sugar production totalled 38.1 million tons, 2.0% lower than the previous year, with ethanol production similarly decreased by 2.1% and totaling over 27 billion liters. About 57.8% of this total refers to hydrous ethanol: about 16 billion liters. In comparative terms, the production of this fuel decreased by 3.43% compared to 2016. Regarding the production of anhydrous ethanol, which is blended with gasoline, there was a decrease of 0.3%, with total production of 11.7 billion liters.

The sugarcane processing industry varies the ratio of sugar and ethanol being produced from harvest to harvest according to market factors, with production typically in a range of 40:60 sugar:ethanol production or vice versa. However, once sugar-ethanol mills adjust their facilities to produce a specified ratio of sugar:ethanol for a given year/production season, there is much less flexibility to change this ratio during the production year.

Total ethanol production from corn grain for 2017 is projected to be 480 million liters or 1.8% of total projected ethanol production, and twice the level of corn ethanol production in 2016 (235 million liters). Currently there are four plants producing ethanol from corn in Brazil. Located in the states of Mato Grosso and Goias, two are flex-plants, producing ethanol from both sugarcane and corn, and the other two 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 distillers dried grains and solubles (DDGs), a co-product of corn ethanol production, can be marketed as animal feed, thus increasing the profitability of the business. However, Brazil’s center-west and northern corn producing areas are in larger states with lower population densities and limited ethanol demand. Figure 4-2 shows the location of ethanol production facilities in Brazil (December 2017).

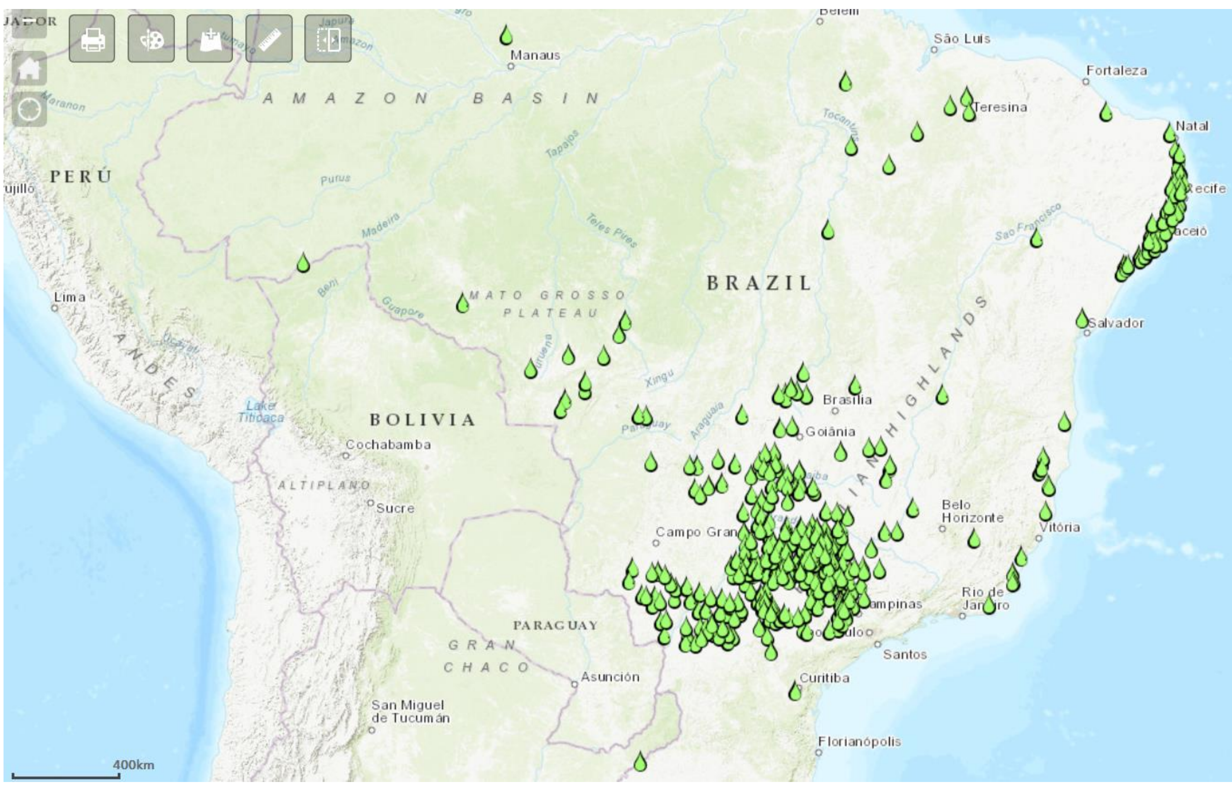

Figure 4-2. Ethanol production facilities in Brazil as of December 2017

As of December 2017, Brazil had 50 biodiesel plants with a combined installed production capacity of 7.6 billion liters per year (see Figure 4-3). In 2017, the amount of B100 produced increased 12.9%, reaching 4.3 billion liters, up from 3.8 billion liters in the previous year. The percentage of B100 compulsorily added to fossil diesel was 7.9% throughout 2017. The main raw materials were soybean oil (65%) followed by tallow (12%).

Brazil imports almost no biodiesel. Under the country's National Biodiesel Production Program (PNPB), created in 2004 and regulated by ANP through an auction system, only domestically produced biodiesel is eligible for the auction. Businesses involving heavy duty vehicle fleets like long haul trucks, buses, rail transportation and agricultural machinery are allowed to use higher blends than those specified by current legislation and could potentially import biodiesel, however in practice they do not do so as the price of the imported product is not competitive with domestically produced biodiesel.

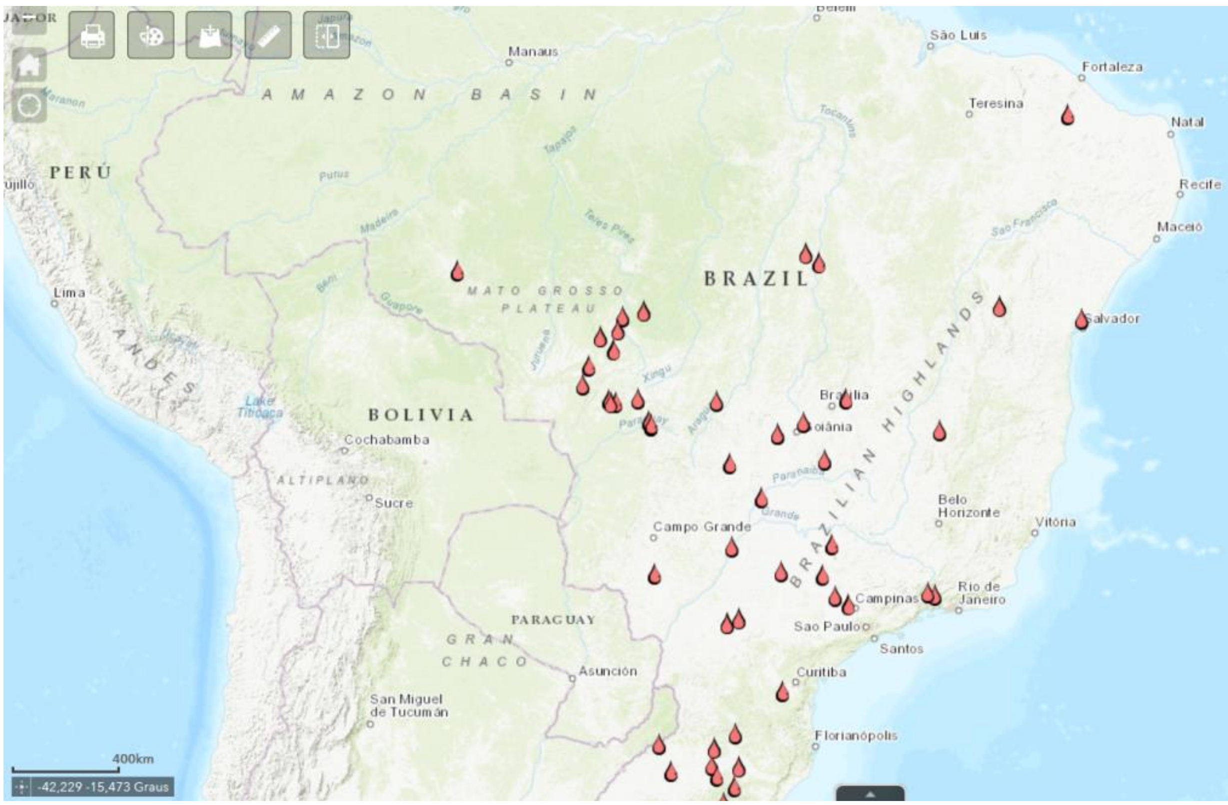

Figure 4-3. Biodiesel production facilities in Brazil as of December 2017

Table 4-2 shows how the level of mandated ethanol and biodiesel blending has varied in Brazil since 2010, and

Table 4-3 shows how the mandate for blending anhydrous ethanol varied from 2006 to 2016. Note that in some years, there are variations in the mandate during the year.

Table 4-2. Biofuel obligations/mandates (% by volume)

Year	Ethanol	Biodiesel
2010	25	5
2011	22	5
2012	22	5
2013	25	5
2014	25	6
2015	25	7
2016	27	7
2017	27	8

Table 4-3. Mandate for anhydrous ethanol in Brazil, 2006-2016 (USDA, 2018)

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

Finally, Table 4-4 show historical fuel consumption in Brazil over the period 2008-2017.

Table 4-4. Historical fuel consumption in Brazil, 2008-2017 (ML/year)

Year	**Gasoline**[1]	**Diesel**[2]	**Kerosene**[3]	**Ethanol (Fuel and Other Industrial Chemicals)**[4]	**Biodiesel**[5]
2008	18,942	45,702	3,444	22,816	1,067
2009	19,118	44,389	3,463	24,283	1,489
2010	22,829	49,142	3,896	24,414	2,226
2011	27,132	51,270	4,372	21,729	2,492
2012	31,834	54,844	4,604	20,258	2,632
2013	31,755	57,783	4,407	24,171	2,780
2014	33,429	59,375	4,453	26,142	3,214
2015	30,267	55,562	4,398	30,705	3,835
2016	31,461	52,158	4,026	27,572	3,719
2017	32,281	52,060	4,015	27,559	4,227

[1] These figures include aviation gasoline.
[2] These figures show total consumption of diesel, including diesel consumption in transformation centers such as electricity generation.
[3] These figures show total consumption of kerosene, including jet fuel, kerosene feedstock, industrial kerosene and lightning kerosene.
[4] These figures show total consumption of ethanol, including fuel and other industrial uses.
[5] These figures show final consumption of biodiesel, excluding biodiesel consumption in transformation centers such as electricity generation.

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5. Canada

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Summary Box

- There are federal and provincial blending mandates for conventional biofuels.
- Federal blending mandates: 5% ethanol and 2% biodiesel (volume basis).
- Five provinces – British Columbia, Alberta, Saskatchewan, Manitoba and Ontario – have established a blending requirement of 5% to 8.5% for ethanol and 2% to 4% for biodiesel (volume basis).
- Several federal and provincial initiatives are underway to decarbonize the transport sector including federal Renewable Fuels Regulations, Pan-Canadian Framework on Clean Growth and Climate Change, Regulatory Framework on the Clean Fuel Standard (CFS), British Columbia's Low Carbon Fuel Standard (BC-LCFS), Alberta's levy of $ CAD 20 per ton on fossil fuel consumption in 2017, and Quebec's cap-and-trade carbon exchange program (excluding transport biofuels).
- Among provincial regulations, British Columbia's (BC) low-carbon fuels program has proven to be a successful program to reduce the carbon intensity of the fuel transportation market in BC.
- In 2016, the Government of Canada announced its intention to develop a Clean Fuel Standard (CFS) to reduce Canada's annual GHG emissions by 30 Megatonnes by 2030 through the increased use of lower carbon fuels, energy sources and technologies.
- Various types of federal and provincial government support are provided in Canada for biofuels, spanning across all stages of the biorefining process such as grants and low-interest loans, grants for feasibility studies and market development and grants for storage and distribution infrastructure.

5.1 Introduction

Similar to the rest of the world, transportation in Canada is fuelled almost exclusively by refined petroleum products derived from crude oil, including gasoline, diesel, aviation fuel and 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 greenhouse gases (GHG) after the oil and gas sector. Figure 5-1 shows GHG 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 (Senate of Canada, 2017).

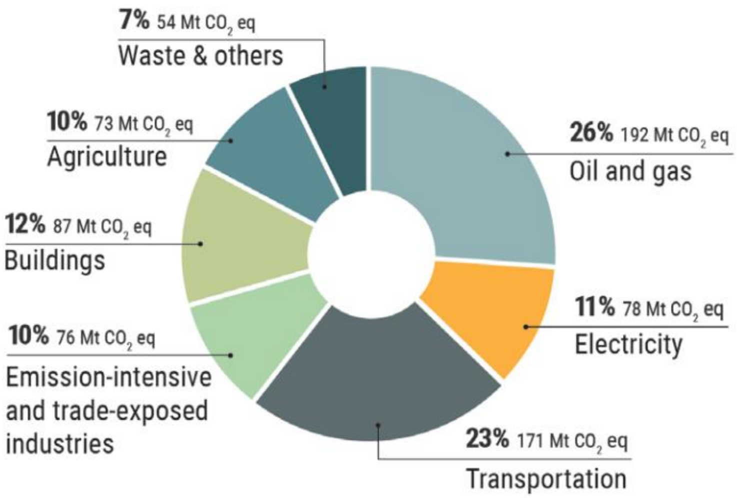

Figure 5-1. Canada's GHG emission breakdown, 2014. Total GHG emission was 731 million tonnes of CO_2eq with 23% contribution from the transportation sector (Source: Senate of Canada, 2017).

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.

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.

5.2 Main drivers for biofuels policy

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.

5.3 Biofuels policy

5.3.1 Biofuels 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 (ECCC, 2017).

Table 5-1 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 USDA Foreign Agricultural Service (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.

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. The most recent update on the CFS's timeline for developing regulations, including when the CFS will come into effect and the phased approach to be implemented for the regulated fuel streams, can be found here.

Table 5-1. 2017 provincial biofuels blend mandates (%)

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* Greener Diesel Regulation

* This policy was approved to increase to 10% starting January 2020

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. The details of this program can be found here.

In addition to federal initiatives, current and underway provincial initiatives support the production and consumption of biofuels in Canada including 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.

5.3.2 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.

5.3.3 Fiscal incentives and Investment subsidies

Canada ranked 5th amongst OECD countries for public expenditures on energy RD&D as a percentage of GDP in 2012.[14] Expenditures by the federal government, provincial governments and industry on renewable and clean energy RD&D totalled approximately $ CAD 630 million in 2013/14. Bioenergy related research is being conducted across Canada in universities and colleges,

[14] http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/files/pdf/2014/14-0173EnergyMarketFacts_e.pdf

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

5.3.4 Other measures stimulating the implementation 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 (CO2e) emissions in 2008, increasing by $5 CAD per ton each year until reaching the current rate of $30 CAD per ton of CO2e 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; and
- 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 research and development funding is 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.

Québec 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 research and development 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 to 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.

5.4 Promotion of advanced biofuels

Though Canada's production of biofuels using advanced technology platforms is limited, federal and provincial policy incentives favoring 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, University of British Columbia (UBC) – pretreatment of softwoods

Although Canada's production of biofuels using advanced technology platforms is limited, federal and provincial policy incentives favoring 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. RFS and to generate RINs, having received U.S. 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 (Source: Enerkem Website).

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. 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 northeastern U.S. and eastern Canada as well as a renewable feedstock for petroleum refinery coprocessing to produce lower carbon transport fuels (Source: Ensyn Website).

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.

5.5 Market development and policy effectiveness

Figure 5-2 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 (Navius Research, 2018).

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 European Union making up the difference. Figure 5-3 and Figure 5-4 show Canada's consumption of ethanol and biodiesel and HDRD, respectively, indicating the feedstocks used and their associated avoided greenhouse gas (GHG) emissions. Biofuels consumption has avoided 24.9 million tonnes (Mt) of CO2e between 2010 and 2016. Annual avoided GHG emissions have grown from 1.8 Mt in 2010 to 4.1 Mt in 2016. Trends in biofuel carbon intensities in British Columbia indicate that biofuel production is becoming less emissions intensive (Navius Research, 2018).

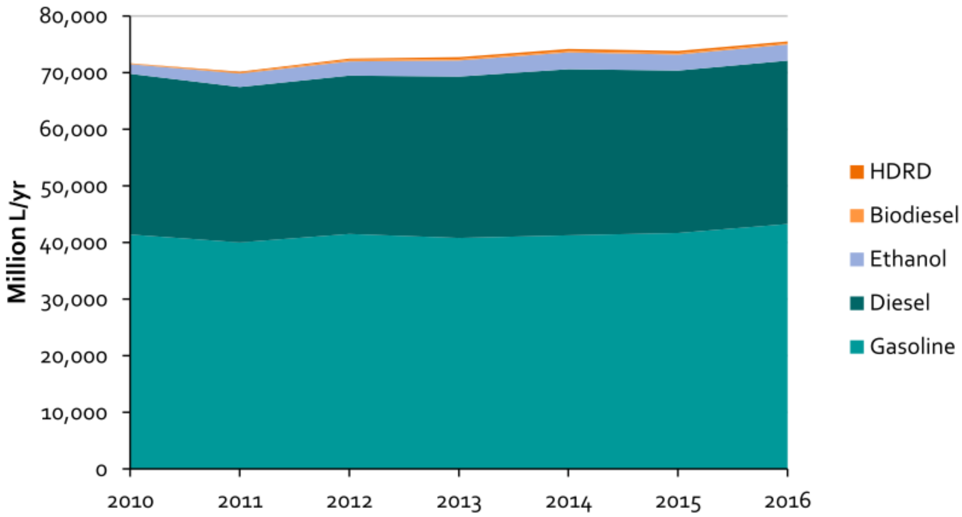

Figure 5-2. Fuel consumption in Canada, 2010-2016 (Navius Research, 2018)

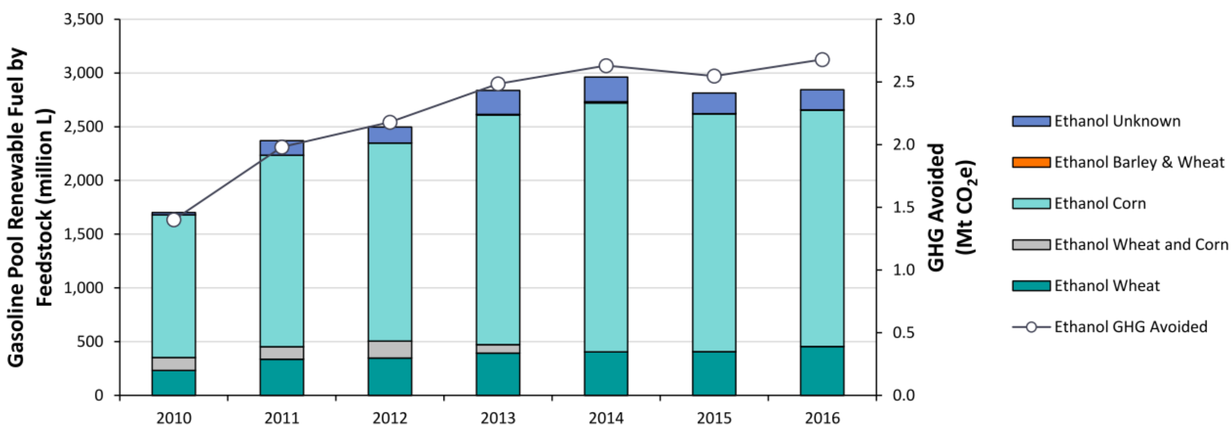

Figure 5-3. Consumption of ethanol in Canada by fuel type and feedstock, 2010-2016 (Navius Research, 2018)

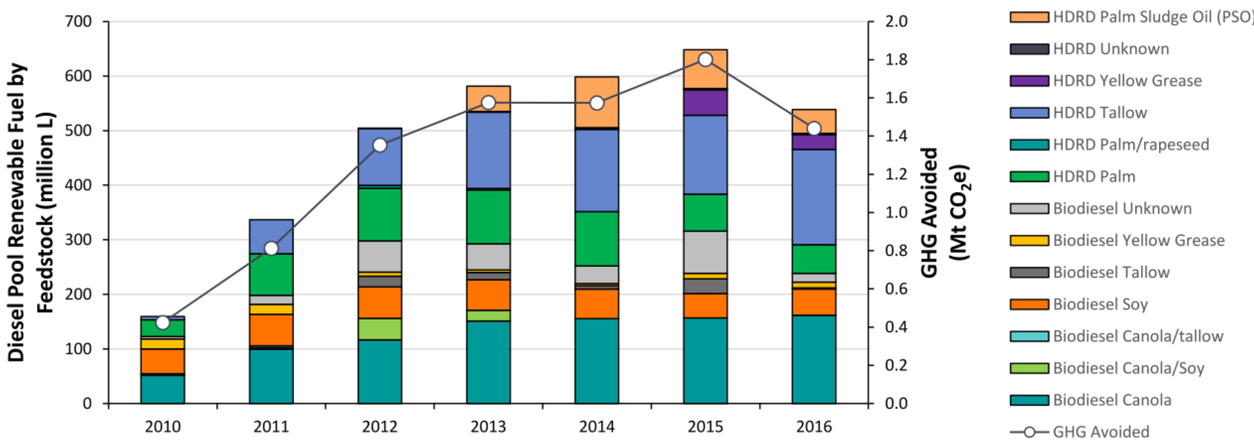

Figure 5-4. Consumption of biodiesel and HDRD in Canada by fuel type and feedstock, 2010-2016 (Navius Research, 2018).

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 (Renewable Industries Canada and NRCan, 2018). 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 (USDA Foreign Agricultural Service, 2018).

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 (USDA Foreign Agricultural Service, 2018). Feedstock choice for ethanol plants has largely been driven by differences in geography and agronomy. 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 (USDA Foreign Agricultural Service, 2018).

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 (USDA Foreign Agricultural Service, 2018).

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 (USDA Foreign Agricultural Service, 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, Renewable Identification Number (RIN) support, and US Environmental Protection Agency (EPA) rule-making for obligated volumes under the U.S. Renewable Fuels Standard (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 US legislation excluding foreign-sourced biomass-based diesel from the tax credit would severely reduce, if not completely halt, Canadian exports of biodiesel to the United States. Such a policy shift would be expected to push more Canadian biodiesel into Canadian distribution channels and reduce Canadian imports of biodiesel (USDA Foreign Agricultural Service, 2018).

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 (CRFA, 2013). A map of ethanol and biodiesel plants in Canada can be found here.

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6. Denmark

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Summary Box

- Since 2010, 5.75% blending mandates (volume basis) for both ethanol and biodiesel have been in place in Denmark.
- The use of ethanol and biodiesel was 1.2% and 4.6% of total road transport in 2016, respectively.
- There is no domestic production of ethanol. There are two biodiesel production plants using rapeseed and waste fat/oil as feedstock.
- In 2015, a 0.9% mandate for advanced fuels by 2020 was introduced. There is no current use of advanced biofuels in Denmark.
- There are no incentives for use of liquid biofuels only exemptions from CO_2 tax. Biogas used for road transport receives economical support. There is a CO_2 tax of € 0.06/liter of gasoline or diesel. Biofuels do not pay CO_2 tax and biogas receives a support of € 0.06/kWh.
- There is a large support for biogas production and use in Denmark. The biogas sector is expanding by a factor of 4-8. Manure and household waste are the main feedstocks but straw is increasingly being used and research is active on how to better include straw.
- There are funding programs for clean energy technologies R&D but there are no separate programs for biofuels.

6.1 Introduction

Denmark has a multi-faceted energy supply based on a variety of energy sources, a high degree of efficiency in energy consumption and a significant domestic production of oil, natural gas and renewable energy. According to the Government's national Energy Strategy 2025, from June 2005 the goal is to improve the use of market mechanisms and to promote more cost-effective initiatives. The Danish electricity and natural gas markets have been completely liberalised. With the implementation of the CO_2 allowance system in the European Union, a step has been taken towards flexibility in climate protection. It reduces energy costs and increases freedom of choice. Finally, developments in the energy system are to a large extent to be based on Danish knowledge and technology.

Denmark's national binding target for renewable energy as stated in the EU Renewable Energy Directive (2009/28/EC) is 30% of gross final energy consumption in 2020. The targeted shares of the three sectors heating/cooling, electricity and transport are shown in Table 6-1.

Table 6-1. Denmark's 2020 renewable energy targets

Sector	**Share in gross final consumption per sector**
Overall target	30%
Heating and cooling	40%
Electricity	52%
Transport	10%

The main vehicle to foster renewable energy is the Promotion of the Renewable Energy Act of 2009. The act provides detailed feed-in tariffs/premium for wind, biomass, biogas and other renewable energy sourced electricity production. In terms of biofuels, the blending quota accounts for 5.75% in diesel as well as gasoline (by energy content). The Danish energy sector recently implemented its own set of sustainability criteria for biomass that go beyond the binding rules of the Renewable Energy Directive, which only apply for liquid biofuels. The principles in the Danish rules are close to the UK legislation on a sustainable biomass supply.

By 2050, Denmark wants to become independent from fossil fuels. To this end, the Danish government adopted the "Energy Strategy 2050" in 2012. In the heating sector, a substantial district heating network, fed by renewable heat from biomass, will be the main motor of the energy transition. In the electricity sector, the Danish government focuses on wind energy, which is expected to provide for 40% of total electricity needs, and also on solid biomass and biogas. Transport will be based on electricity and biofuels.

A detailed description of all fiscal and non-fiscal supports for bioenergy development is available at: http://www.iea.org/policiesandmeasures/renewableenergy/?country=Denmark

Most of the bioenergy consumed in Denmark comes from solid biomass; its share accounts for three quarters of the total use of bioenergy or 117 PJ. Around one third of this bioenergy (42 PJ) is used directly in the residential sector. The second largest item is renewable municipal waste (22 PJ) followed by biodiesel (10 PJ) and biogas (9 PJ). Ethanol consumption is not significant.

6.2 Main drivers for biofuels policy

The national biofuel production is currently at a low level with no immediate expansion in sight. The main driver for expanded production of biofuels would be climate change mitigation and to some degree rural development.

6.3 Biofuels policy

6.3.1 Biofuels obligations

Biofuels on a larger scale were introduced in Denmark in 2006 when Statoil began selling E5 ethanol. Since 2010, 5.75% blends of ethanol and biodiesel (volume basis) have been mandatory. In 2015, a 0.9% mandate for advanced fuels by 2020 was issued. The current use of advanced fuels is zero.

The law mandating a blend of 5.75% biofuels in both diesel and gasoline can be found here: Lov om bæredygtige biobrændstoffer. An addendum was made in 2016 stating that by 2020, 0.9% of the biofuels should be advanced biofuels i.e. 2G fuels. The Danish oil industry has stated a goal of 2.5% by 2020; however, this does not appear to be a realistic goal. Furthermore, there is an order on fuel quality for use in vehicles: Bekendtgørelse om kvaliteten af benzin, dieselolie og gasolie til anvendelse i motorkøretøjer. With regard to assessing sustainability, there is a specific set of guidelines for sustainability assessment.

If other renewable fuels/types of energy (e.g., electric vehicles) are used in transport, the 5.75% mandate for biofuels can be correspondingly lowered. With regard to liquid biofuels, there is still a lot of debate whether the technology is the most effective way to use biomass, which creates uncertainty in funding, political direction and legislation. However, this discussion is being shaped in the context of Denmark following the EU directive on sustainability criteria.

According to an energy plan in 2012, a focus has been placed on biomass for combined heat and power (CHP) with no support for traditional biofuels. Denmark considers that the use of biomass for CHP production is a more cost-effective way to use the biomass resources than the present technology (first generation) for the production of biofuels. However, fossil fuel consumption in transport continues to increase and this needs to be addressed.

Denmark submitted a national action plan to the European Commission in June 2010, setting out how it plans to achieve the target of 10% renewable energy in transport by 2020. According to the action plan, biofuels are expected to make by far the biggest contribution to using renewable energy in the transport sector in the period to 2020.

6.3.2 Excise duty reductions

There is a CO_2 tax of € 0.06/liter of gasoline or diesel. Biofuels do not pay CO_2 tax and biogas receives a support of € 0.06/kWh.

6.3.3 Fiscal incentives

Not available.

6.3.4 Investment subsidies

Not available.

6.3.5 Other measures stimulating the implementation of biofuels

Danish research activities within bioenergy cover a large range of topics, i.e., pre-treatment of lignocellulosic biomasses for biogas production, integration of bioenergy in energy systems, optimal utilisation of solid biofuels, safety in handling and storage, and production of biofuels. An overview of all finalised and ongoing projects within research, development and demonstration can be found at https://energiforskning.dk. This is a website for all Danish research, development and demonstration funding programmes within energy and climate.

There is an allocation of €14 million as deficit guarantee for new fuel biorefineries. i.e. a yearly maximum of €2 million during the first 7 years. The guarantee is yet to be used.

There are funding programs for Research and Development but there are no separate programs for biofuels. Energy research funding has been cut 50% since 2015. As part of a new program to stimulate the economic growth, it was decided in November 2017 to allocate funds to promote production of advanced biofuels. Specific conditions have not been negotiated yet, but funding to be made available is anticipated to be around € 2.6 million annually for years 2019-2025.

The Danish energy agency is responsible for the energy technology development programme (EUDP). The program focus is on energy technologies in general and it is the only current research programme that includes biofuels in its strategy.

6.4 Promotion of advanced biofuels

Incentives for advanced biofuels include “double counting” of renewables targets of member states in the EU. However, it is argued by many in the industry that this has not worked and that targets for advanced biofuels should be set. There is a 0.9% blend mandate for advanced biofuels by 2020 in Denmark.

Inbicon's ethanol plant in Kalundborg has a treatment capacity of 100 dry tonnes feedstock per day yielding 10 million liters of cellulosic ethanol per year. The conversion technology uses enzymatic hydrolysis to break down lignocellulosic material into C5 and C6 sugars which are then fermented to cellulosic ethanol. The plant was inaugurated in November 2009, produced the first straw-derived cellulosic ethanol in December 2009 and has since sold 5 million litres to Statoil. The plant received €10.2 million in public support, with a total investment around €64 million. In 2015, the plant ceased production and it currently remains idle. It is speculated that this cessation is due to the greater resource allocations required for larger scale development.

Maabjerg Energy Center (MEC) is a joint venture between multiple stakeholders companies, among them Dong Energy and Novozymes. The concept of MEC is a large scale ethanol production facility coupled with a CHP plant and biogas plant. Annual production of ethanol and biogas is projected to yield 80 million liter and 50 million m^3, respectively. The first two legs of MEC, a biogas plant and a CHP-plant, have been established and the ethanol plant is scheduled to be finished in 2018.

There are two pilot scale facilities for HTL (hydrothermal liquefaction) of biomass to advanced biofuels including:

- Aarhus University: Current focus is on treatment of sludge eventually mixed with biomass fibers used as filter aid
- Aalborg University in collaboration with Steeper Energy (Hydrofaction technology). In November 2017, the Hydrofaction™ pilot plant in Aalborg, Denmark surpassed 4750 hours of hot operation, with a total of over 1750 hours of oil production. In December 2017, Steeper Energy partnered with Silva Green Fuel, a Norwegian-Swedish joint venture, to construct a $59M industrial scale demonstration plant in Norway[15].

There is a large support for biogas production and use in Denmark. The biogas sector is expanding by a factor of 4-8. Manure and household waste are the main feedstocks but straw is increasingly being used and there is research going on on how to better include straw.

6.5 Market development and policy effectiveness

There is no production of ethanol in Denmark. Two biodiesel producers exist in Denmark. Emmelev Mølle processes rapeseed oil and converts it to biodiesel, with an annual capacity of 150,000 tons (170.4 million liters). DAKA Denmark produces biodiesel from animal fats and slaughterhouse waste. Their annual production of biodiesel is 100,000 tons (113.6 million liters). Figure 6-1 shows the locations of pilot, demonstration and commercial biofuel plants in Denmark.

[15] https://steeperenergy.com/2017/12/15/steeper-energy-announces-eur-50-6-m-dkk-377-m-advanced-biofuel-project-with-norwegian-swedish-joint-venture-silva-green-fuel-in-licensing-deal/

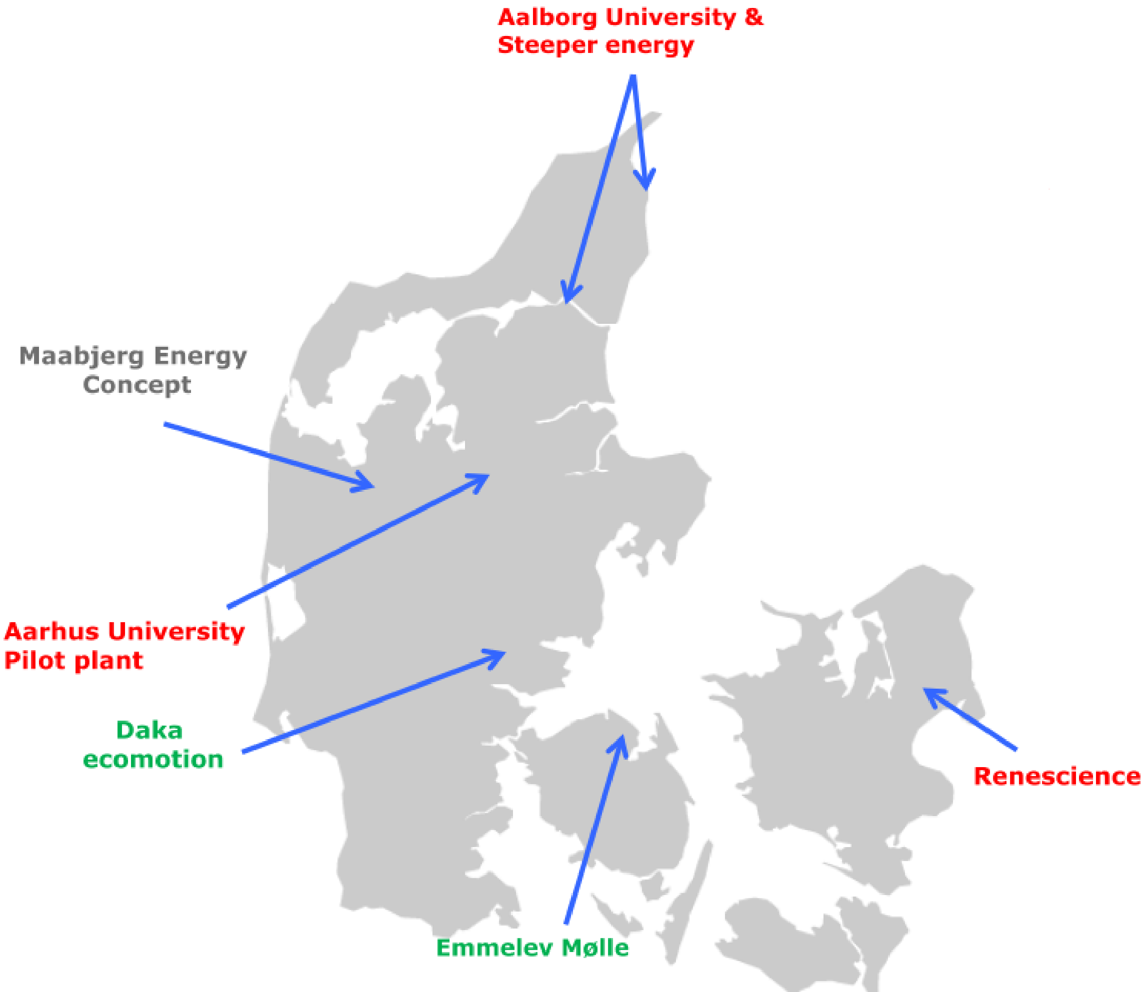

Figure 6-1. Pilot, demonstration and commercial biofuel plants in Denmark

Table 6-2. Biofuel blending mandates (% by volume)

Year	Ethanol	Biodiesel
2010	5.75	5.75
2011	5.75	5.75
2012	5.75	5.75
2013	5.75	5.75
2014	5.75	5.75
2015	5.75	5.75
2016	5.75	5.75
2017	5.75	5.75

Table 6-3. Biofuel production and market share – installed production capacity (ML/year)

Year	Biodiesel (FAME)	Ethanol	Cellulosic ethanol	Biogas as transportation fuel	Renewable diesel (from lipids)
2006	114	0	0	0	0
2007	114	0	0	0	0
2008	114	0	0	0	0
2009	114	0	0	0	0
2010	114	0	0	0	0
2011	114	0	0	0	0
2012	171	0	0	0	123
2013	171	0	0	0	123
2014	171	0	0	0	123
2015	171	0	0	0	123
2016	171	0	0	0	123
2017	171	0	0	0	123

Exact market shares cannot be indicated as there is a significant but unknown level of export.

Table 6-4. Summary of transport fuel consumption in Denmark (ML/year)

Year	Gasoline	Diesel fuels	Aviation fuel	Biodiesel	Ethanol
2006	2,594	2,393	547	NA	NA
2007	2,547	2,583	587	NA	NA
2008	2,423	2,593	562	NA	NA
2009	2,332	2,454	505	NA	NA
2010	2,172	2,563	597	fixed blend 5,75%	fixed blend 5,75%
2011	2,048	2,531	594	fixed blend 5,75%	fixed blend 5,75%
2012	1,940	2,420	563	fixed blend 5,75%	fixed blend 5,75%
2013	1,873	2,419	562	fixed blend 5,75%	fixed blend 5,75%
2014	1,883	2,487	584	fixed blend 5,75%	fixed blend 5,75%
2015	1,867	2,574	622	fixed blend 5,75%	fixed blend 5,75%
2016	1,831	2,620	720	fixed blend 5,75%	fixed blend 5,75%
2017	1,821	2,548	776	fixed blend 5,75%	fixed blend 5,75%

6.6 Sources

Funding organizations at national level related to environment or energy

Danish Energy Agency - Energy Technology Development and Demonstration Program (https://ens.dk/en/our-responsibilities/research-development/eudp)

Ministry of Environment and Food - The Danish Eco-Innovation Program (https://eng.ecoinnovation.dk/the-danish-eco-innovation-program/)

Innovationsfonden – a range of different programs (https://innovationsfonden.dk/en/programmes)

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Global Renewable Energy- Denmark https://www.iea.org/policiesandmeasures/renewableenergy/?country=Denmark&country=Denmark

Steeper Energy: https://steeperenergy.com/2017/12/15/steeper-energy-announces-eur-50-6-m-dkk-377-m-advanced-biofuel-project-with-norwegian-swedish-joint-venture-silva-green-fuel-in-licensing-deal/

7. European Union

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Summary Box

- The EU is the third largest producer of biofuels in the world. In 2017, North America, South & Central America and Europe had world shares of 45.5%, 26.9% and 16.8%, respectively.
- In 2018, the production of FAME biodiesel, HVO/HEFA fuels and conventional and cellulosic ethanol in the EU were estimated to be 12.2 million tonnes (14 billion liters), 2.2 million tonnes (2.84 billion liters), 4.3 million tonnes (5.48 billion liters) and 0.008 million tonnes (0.01 billion liters), respectively.
- The policy mechanisms stimulating increased production and use of biofuels within EU Member States are the EU's Energy Directive (RED, 2009/28/EC) and Fuel Quality Directive (2009/30/EC).
- In RED II, the overall EU target for Renewable Energy Sources consumption has been raised to 32% by 2030, up from 20% by 2020 previously. The transport sub-target requires Member States' fuel suppliers to supply a minimum of 14% renewable energy in the energy consumed in road and rail transport by 2030.
- Within the 14% transport sub-target, there is a dedicated target for advanced biofuels. The advanced biofuels must supply a minimum of 0.2% of transport energy by 2022, 1% by 2025, and at least 3.5% by 2030.
- Fuels used in aviation and maritime sectors can opt in to contribute to the RED II's 14% transport target but are not obligated. The contribution of non-food feedstock-based renewable fuels to these sectors will count 1.2 times their energy content.

7.1 Status of the biofuels industry in the EU

The EU is the third largest producer of biofuels in the world. In 2017, North America, South & Central America and Europe had world shares of 45.5%, 26.9% and 16.8%, respectively. The EU's biofuels production in 2018 is estimated to be about 18.8 million tonnes (22.21 billion liters) (. The main biofuels being produced are FAME biodiesel, renewable diesel produced by HVO/HEFA, as well ethanol and a small but growing amount of biomethane in some countries (e.g., Germany and Sweden). As shown in Figure 1-7, the production of FAME biodiesel, HVO/HEFA renewable diesel and conventional (first generation) and cellulosic (second generation) ethanol were estimated to be 12.2 million tonnes (14 billion liters), 2.2 million tonnes (2.84 billion liters), 4.3 million tonnes (5.48 billion liters) and 0.008 (0.01 billion liters) million tonnes, respectively. FAME biodiesel has the highest share of biofuels production in the EU (65%) due to the strong demand in EU Member States to meet blending mandates.

Figure 7-2 shows the estimated shares of different feedstocks in the production of FAME biodiesel in 2018.

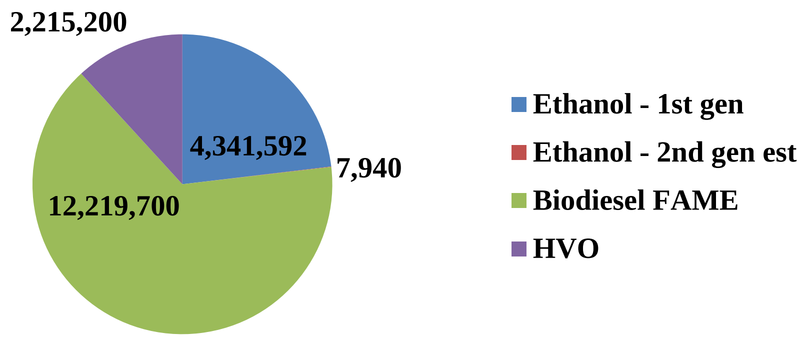

Figure 7-1. Estimated production of biofuels in the EU (tonnes), 2018 (USDA, 2018)

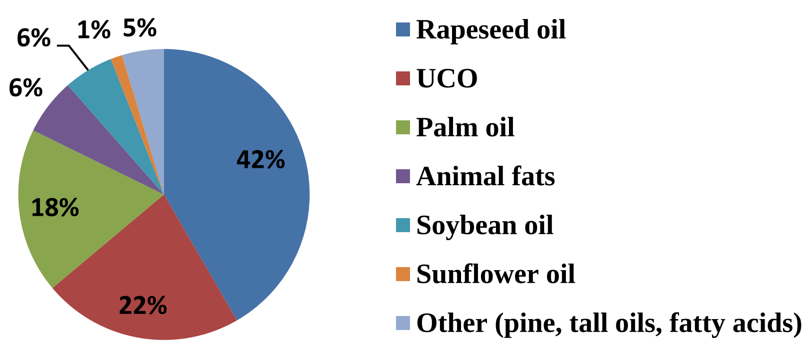

Figure 7-2. Estimated 2018 FAME biodiesel feedstock shares in the EU (USDA, 2018)[16]

A considerable percentage of FAME biodiesel production can be considered advanced, at least not coming from food or feed sources, due to the significant availability of used cooking oil (UCO) and waste animal fats (tallow) in the EU. The absolute figure for usage of non-food or feed feedstocks used to make biodiesel is difficult to estimate, however, as the translation of EU

[16] The data in Figures 1 and 2 are taken from the 2018 USDA Gain Report on biofuel production (USDA, 2018). While giving a good indication of the production status of the EU biofuels industry, it includes information - most notably for biodiesel feedstocks - not often publicised by industry.

legislation into national law allows for margins of flexibility resulting in different consideration being given to certain feedstocks, with palm fatty acids produced during the refining of palm oil being the most notable example. Ethanol production, in contrast, remains almost entirely conventional, i.e., from food crops, mainly sugar beet, corn and wheat. The small portion of cellulosic ethanol being produced is also from non-food feedstocks such as crop residues, however actual production figures for advanced (or second generation) ethanol remain difficult to find.

7.2 Policies driving the production and use of biofuels

The policy mechanisms stimulating increased production and use of biofuels within EU Member States are the EU's Renewable Energy Directive (RED, 2009/28/EC) and Fuel Quality Directive (2009/30/EC), as amended in 2015 by establishing – among others – a 7% cap for food/feed-competing feedstocks to comply with the mandatory 10% renewables transport sub-target in the RED (so-called ILUC Directive ((EU) 2015/1513). These EU directives are binding for all EU Member States and need to be implemented in their respective national laws. In November 2016, the European Commission published its 'Clean Energy for all Europeans' initiative. As part of this package, the Commission proposed a recast of the Renewable Energy Directive. The RED II was adopted by the Council on 4 December and was published in December 2018.

7.2.1 RED II

In RED II, the overall EU target for Renewable Energy Sources consumption has been raised to 32% by 2030, up from 20% by 2020 previously. A transport sub-target wasn't included originally, but has been introduced in the final agreement. This requires Member States' fuel suppliers to supply a minimum of 14% renewable energy in the energy consumed in road and rail transport by 2030. Each Member State will define and design its detailed trajectory to reach these targets in their respective Integrated National Energy and Climate Plans following the guidelines set out in the Energy Union Governance Regulation.

7.2.2 Sustainability criteria in RED II

The RED II defines a series of sustainability and greenhouse gas (GHG) emission criteria that transport biofuels must comply with to count towards the 14% target and to be eligible for financial support by public authorities. Some of these criteria are the same as in the original RED, while others are new or reformulated. In particular, the RED II introduces sustainability for forestry feedstocks as well as GHG criteria for solid and gaseous biomass fuels.

The RED II provides default GHG emission values and calculation rules in Annex V (for liquid biofuels) and Annex VI (for solid and gaseous biomass for power and heat production). The Commission can revise and update the default values when technological developments make it necessary. Producers have the option to either use default GHG intensity values provided in RED II or to calculate actual values for their respective production pathways.

Table 7-1.Greenhouse gas emissions savings thresholds in RED II

Plant operation start date	Transport biofuels	Transport renewable fuels of non-biological origin	Electricity, heating and cooling
Before October 2015	50%	-	-
After October 2015	60%	-	-
After January 2021	65%	70%	70%
After January 2026	65%	70%	80%

Biofuels, bioliquids and biomass fuels from agricultural biomass must not be produced from raw materials originating from specific land categories, as summarized Table 7-2.

Table 7-2. Non-eligible land categories for the production of biofuel feedstocks in RED II

High biodiversity land (as of January 2008), including: primary forests; areas designated for nature protection or for the protection of rare and endangered ecosystems or species; and highly biodiverse grasslands
High carbon stock land that changed use after 2008 from wetlands, continuously forested land or other forested areas with trees higher than five meters and canopy cover between 10% and 30%
Land that was peatland in January 2008

The RED II sustainability criteria apply to production plants above a minimum size, either a total rated thermal input above 20MW for installations producing power, heating, cooling or fuels from solid biomass fuels, or a total rated thermal input capacity equal to or exceeding 2MW for installations using gaseous biomass fuels.

The RED II also introduces new sustainability criteria for forestry feedstocks. Harvesting must be legally permitted, the harvesting level must not exceed the growth rate of the forest, and forest regeneration must take place. In addition, biofuels and bioenergy from forest materials must comply with requirements which mirror the principles contained in the EU Land Use, Land Use Change and Forestry (LULUCF) Regulation. These "forestry" criteria apply either at the country level or the forest sourcing area level; the Commission will define implementation guidelines by end of January 2021.

7.3 Advanced biofuels

Within the 14% transport sub-target, there is a dedicated target for advanced biofuels produced from feedstocks listed in Part A of Annex IX (see Table 7-3). These advanced biofuels must supply a minimum of 0.2% of transport energy by 2022, 1% by 2025, and at least 3.5% by 2030.

Table 7-3. Advanced feedstocks for biofuels in RED II

Part A (i.e. "advanced biofuels")	Part B
Algae, if cultivated on land, either in ponds or photobioreactors Biomass fraction of MSW from unsorted household waste Bio-wastes separately collected from households Biomass fraction of agro-industrial waste not fit for food or feed Straw Animal manure Sewage sludge Palm oil mill effluent and empty palm fruit bunches Tall oil pitch Crude glycerine Bagasse Grape marcs and wine lees Nut shells Husks Corn cobs (cleared of corn kernels) Waste and residues from forestry and forest products industries: bark, branches, pre-commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin, and tall oil Other non-food cellulosic material, including for instance perennial grasses, but also non-starchy cover crops before and after main crops as well as ley crops. This category also includes industrial residues after the extraction of vegetable oils, sugars, starches and proteins. Other ligno-cellulosic materials, including for instance woody short rotation crops, pulp logs and other forest-based biomass, but excluding veneer logs and saw logs.	Used cooking oil Animal fats with high risk for human health (Category 1) and animal fats suitable for soil enhancement and chemical industry (Category 2)

7.4 Caps and multipliers

The maximum contribution of biofuels produced from food and feed crops will be capped at 2020 consumption levels plus an additional 1%, with a maximum cap of 7% for road and rail transport fuels in each Member State. For comparison, the EU average is just above 5% today, with the 2018 EU Biofuels Barometer indicating that the current share of biofuels from food and feed crops is just over 4%. If the total share of conventional biofuels in any Member State is less than 1% by 2020, the cap for that country will still be 2% in 2030. Furthermore, if the cap on food and feed crops in a Member State is less than 7%, that country may reduce its transport target by the same amount (for example, a country with a food and feed crop cap of 5% could set its transport target as low as 12%). Notably, "intermediate crops" such as catch and cover crops are exempt from this cap.

Biofuels and bioenergy produced from wastes and residues listed in Annex IX only need to comply with the GHG minimum emission threshold sustainability criterion (Table 7-4). Advanced biofuels listed in Part A of Annex IX will be double-counted towards both the 3.5% target and the 14% target. Biofuels produced from feedstocks listed in Part B of Annex IX will be capped at 1.7% in 2030 and will also be double counted towards the 14% target.

Table 7-4. Implementation of RED II provisions towards 2030

The Commission will review the overall 32% target by 2023, as well as the 14% sub-target for transport, and could propose to increase, but not decrease the targets.
The Commission must review the feedstocks included in Annex IX every two years and may add feedstocks to the list, but cannot remove any.
The Commission must set out criteria by February 2019 to define both "high indirect land-use change-risk" and 'low indirect land-use change-risk' feedstocks. These findings will be reviewed by 2023.
The Commission must set a GHG reduction threshold for recycled carbon fuels by January 2021, and by December 2021 must specify the methodology for GHG accounting for these fuels and for renewable fuels of non-biological origin.
By January 2021, the Commission must define the operational guidance required to demonstrate compliance with the sustainable forest management criteria and the LULUCF requirements.
In 2026, the Commission must propose a regulatory framework for the promotion of renewable energy for the post-2030 period.

Fuels produced from feedstocks with "high indirect land-use change-risk" will be limited by a more restrictive cap at the 2019 consumption level, and will then be phased out to 0% by 2030 unless specific batches are certified as "low indirect land-use change-risk." Feedstocks with "low indirect land-use change-risk" include those that are produced on land not previously used for crop production.

Renewable electricity will count 4 times its energy content towards the 14% renewable energy in transport target when used in road vehicles, and 1.5 times when used in rail transport. The renewable electricity used in road vehicles and rail can be calculated on the basis of either the average share of renewable electricity in the EU or in the Member State where the electricity is supplied. The Commission will also develop a framework to guarantee that the renewable electricity used in transport is in addition to the baseline of renewable electricity generation in each Member State.

Fuels used in aviation and maritime sectors can opt in to contribute to the RED II's 14% transport target but are not obligated. The contribution of non-food feedstock-based renewable fuels to these sectors will count 1.2 times their energy content.

7.5 Flexibility

RED II grants individual EU Member States (MS) broader margins of flexibility compared to the original RED when translating this EU Directive into their national legislation, as summarized in Table 7-5.

Table 7-5. Flexibility clauses foreseen in the RED II with respect to the implementation of the Directive by EU Member States

EU MS can exempt or distinguish between different fuel suppliers and energy carriers when defining their trajectory to achieve the 14% minimum sub-target for the transport sector.
EU MS are free to choose the most suitable form of support for renewables in transport, for example volume mandates, energy mandates or GHG emission savings targets.
EU MS can distinguish between different types of conventional biofuels and set different limits for each category (for example, setting a lower cap on oil seed crops than other types of food and feed crops).
EU MS can set lower limits on food and feed-based biofuels than prescribed in the RED II and may also reduce the 14% renewable energy in transport target by the same.
EU MS can set a different cap for biofuels produced by feedstocks in Part B of Annex IX if justified by the local availability of such feedstocks, and can define additional sustainability criteria for bioenergy but not for biofuels.

7.6 Translation and implementation

EU Member States must translate RED II provisions into their respective national legislation by June 2021, with several technicalities and revision clauses being defined via delegated and implementing acts.

7.7 Advances and challenges in biofuels technologies

Consistent with EU's regulatory framework, technological and market research in Europe are largely focussed on 'advanced' biofuels from non-food or feed feedstocks, a situation which is expected to continue – or even consolidate – upon the formal adoption of RED II.

Technological advances are therefore sought in process technologies for converting feedstocks having no or only low indirect land-use change (ILUC) impacts. The RED II is also quite demanding on biofuel producers to achieve high minimum GHG emission reduction thresholds towards 2030 (Table 7-4) compared to the baseline.

Industry in the EU is focussed on three broad categories of feedstocks: ligno-cellulosic residues from agriculture and forestry; animal manures and the biogenic fraction of wastes and residues like municipal solid wastes; and biomass types not competing with production of food and feed, such as grass feedstocks, perennial and cover crops, and algae.

Two imperatives for the EU's biofuels industry are access to sustainable feedstocks in sufficient volumes and conversion processes able to perform well and at scale on such feedstocks. Three categories of conversion technologies are relevant to achieving the RED II's mandatory targets: biochemical, thermochemical, and oleochemical production routes. Oleochemical is the most proven and the use of waste and residues as feedstocks is expanding, and is expected to continue to do so as a result of regulation. Each one of these broad conversion categories includes a number of sub-technologies. The remainder of this section highlights the main identified challenges for each.

7.7.1 Biochemical conversion routes

A lot of research continues in this area (see Figure 7-3), however more and clearer public information on performance would be beneficial, particularly regarding cellulosic ethanol production systems. For anaerobic digestion, work continues to make production more profitable, in particular while using more challenging feedstocks.

A large part of EU research in this area aims to show or improve the robustness and efficiency of cellulosic ethanol production routes, with butanol production also attracting increasing attention. The increasing scale (and number) of production plants worldwide indicates some progress and a high degree of continued interest in this technological area exists both in the EU and in other world regions. However, the environmental and economic performance of the processes remain critical areas for improvement. While detailed information on production costs is limited, the low level of deployment and market success of these technologies at commercial scale suggests that production costs remain higher than previously forecast, likely because of high feedstock and enzyme costs among other factors.

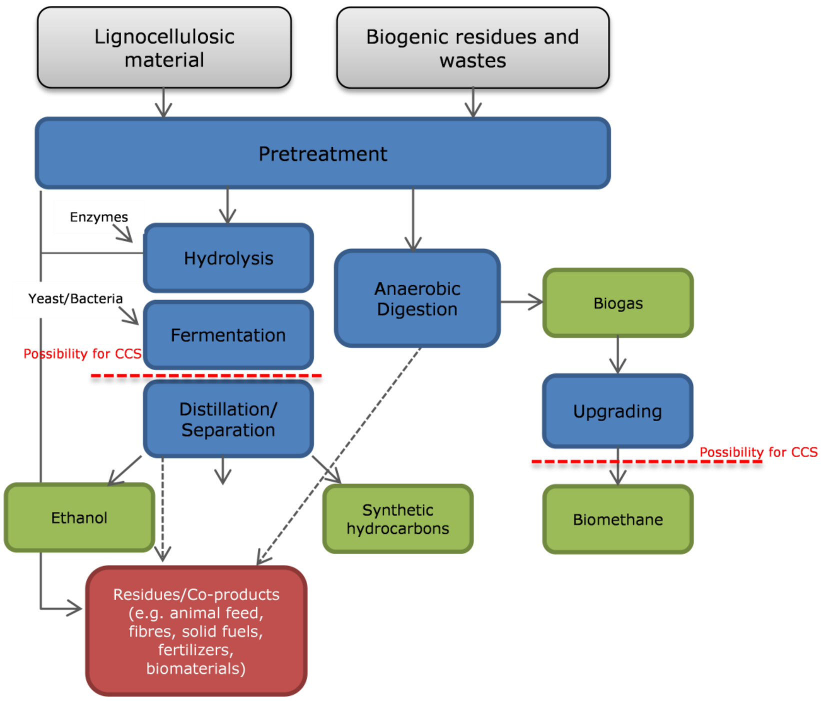

Figure 7-3. Biochemical conversion routes

For the anaerobic digestion (AD) sector, availability of sustainable feedstocks in sufficient volumes is among the key priorities for the EU-based biofuel industry, with specific attention being given to agricultural residues and other complex waste streams (e.g., wastewater sludges). AD processes are currently not economically viable and improvements in technology are paramount to demonstrate economic feasibility. Current research priorities include work to valorise AD digestate by recovering nutrients to co-produce market-ready products, or to embed the AD step as one of the processes in a biorefinery. Biogas upgrading to biomethane is another large goal of much new investment in AD. Public awareness about the potentials of AD is still limiting technical efforts in scaling down the technologies, so interesting possibilities to enlarge feedstock choices, for example by improving the recovery of waste streams at urban and peri-urban levels, remain under exploited.

7.7.2 Thermochemical conversion routes

This area comprises several sub-technology areas (see Figure 7-4). Overall, research on thermochemically-based biomass to liquid (BtL) technologies is attempting to achieve lower operating and capital costs to improve economic feasiblity. Again, it would be beneficial to have more and clearer information on performance and costs in the public domain.

Processes making various types of bio-crude oils are attempting to take advantage of possible opportunities to co-process their bio-crudes in existing petroleum refineries, and some of large oil refiners are engaged in this work.

There are no large-scale gasification plants in the EU producing BtL biofuels today. Improving gasification, syngas cleaning, and Fisher-Tropsch (FT) synthesis are all research areas with potential to enhance process efficiencies and in turn decrease production costs.

Smaller scales of operation requiring lower capital and operational costs to establish and run conversion plants have been identified as a promising way forward for process optimization. The energy balance of thermochemical production plants would especially benefit from enhanced integration of sub-processes to reduce external energy import requirements. Improving biomass handling to enable more flexibility towards a broader variety of feedstocks is another important research area. Others include novel clean-up systems for produced raw syngas that reduce the energy required to purify syngas, and also new catalysts that are more tolerant to impurities in syngas. Generally speaking, however, and with the exception of the AMBIGO initiative (Ambigo, 2018), this sector is not showing high confidence in the near-term possibility to profitably produce synthetic natural gas (SNG) via biomass gasification.

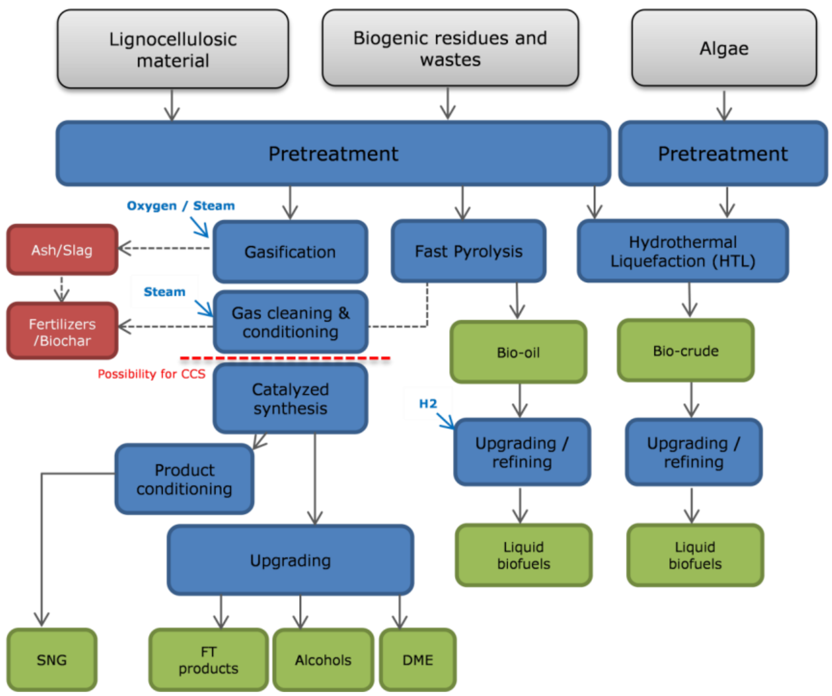

Figure 7-4. Thermochemical conversion routes

Considerable interest exists in the EU – and other world regions – to co-process FT products at existing crude oil refineries in order to achieve greater economies of scale and efficiencies than stand-alone production would permit. This approach would also provide a better opportunity to tailor fuels/products portfolios according to market needs.

For fast pyrolysis, there are opportunities to improve processes to maximise bio-oil yields and to use catalysts to promote higher selectivity and yield of desirable products. Catalyst improvements also provide opportunities for the subsequent upgrading step. Several technical developments are being researched in the EU to improve catalytic fast pyrolysis and up-grading via refining processes but these are not yet at commercial scale. Reducing hydrogen consumption during hydro-treatment is another important technical challenge being researched.

Co-feeding pyrolysis oils in petroleum refinery units using existing infrastructure and commercial technologies is another promising opportunity being investigated. Obtaining pyrolysis liquids from cheaper residual resource feedstocks while maintaining product quality that meets bio-liquid specifications is another important area of investigation.

Hydrothermal liquefaction (HTL) approaches for wet feedstocks are technologically proven at laboratory and/or pilot scales and appear promising with additional development for producing bio-crude oils that can – as for the previous technologies - be blended with traditional fossil crude for upgrading at existing petroleum refineries.

Scaling up production to close-to-market maturity remains a challenge but is critical for ongoing projects, such as the one led by Steeper Energy Aps (SEA) in Denmark, to validate process performance at large-scale and over realistic year-round operation. The potential for more cost-optimised routes that integrate HTL processing into other existing production facilities, such as with a paper mill in the case of Licella Pty Ltd in Australia, have not yet been explored in the EU.

Interesting developments brought forward by EU operators to progress upgrading of bio-oils are the initiatives of NesteOil (Neste Oil-2, 2018) and Repsol (REPSOL, 2016) which are testing at the scale of their production sites co-processing HTL with crude oil, albeit so far at very low blend levels.

7.7.3 Oleochemical conversion routes

For oleochemical routes (see Figure 7-5), the main issue for the EU (and worldwide) biofuel industry is the need to find increasing volumes – and variety – of sustainable feedstocks, and this is exacerbated by the move away from food-based feedstocks for biofuels. Unlike other routes discussed in this section, FAME and HVO pathways have proven reliable at industrial scale for many years.

In the EU, the need for FAME and HVO routes to be more flexible in terms of input feedstocks is currently driving the sector's technological development. At an individual production plant level, this translates into the need to include more complex pre-treatment units for the process. In parallel to input flexibility, HVO plants in particular are required to be increasingly flexible with respect to outputs. With a more diversified demand for final products to fuel road and other transport modes, namely aviation and marine, the product slate including diesel, kerosene and naphtha from HVO production needs to be able to swiftly adapt to match dynamic market demand.

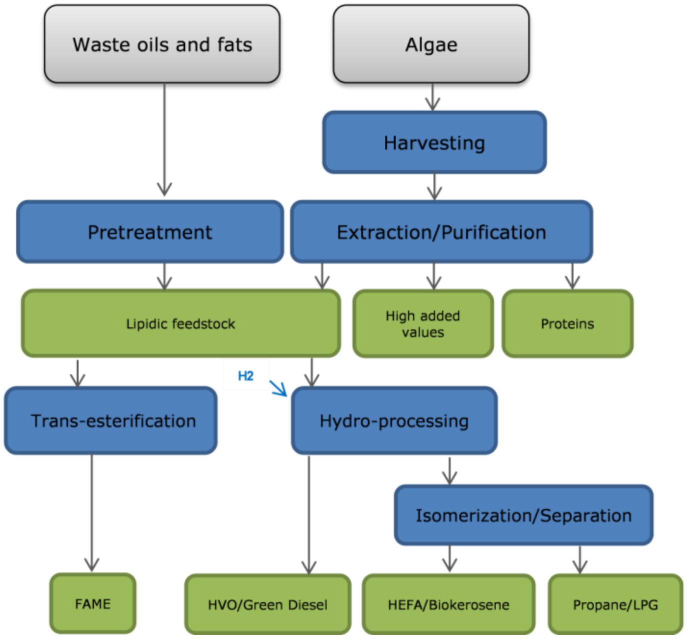

Figure 7-5. Oleochemical conversion routes

7.8 Broad indicator of funding by technology routes

Figure 7-6 shows an overview of the number of EU-funded advanced biofuels and biorefineries projects and how this funding is distributed across the different technical approaches for projects above 250k EUR in value and that are starting at greater than lab-scale Technology Readiness Levels (TRLs). It should be noted that some of the biorefinery projects incorporate biofuels within their product slate. Nonetheless, as this Figure shows, the majority of fuel focussed projects are in the anaerobic digestion area, followed by fermentation, while the latter has received the largest proportion of funding compared to the other approaches.

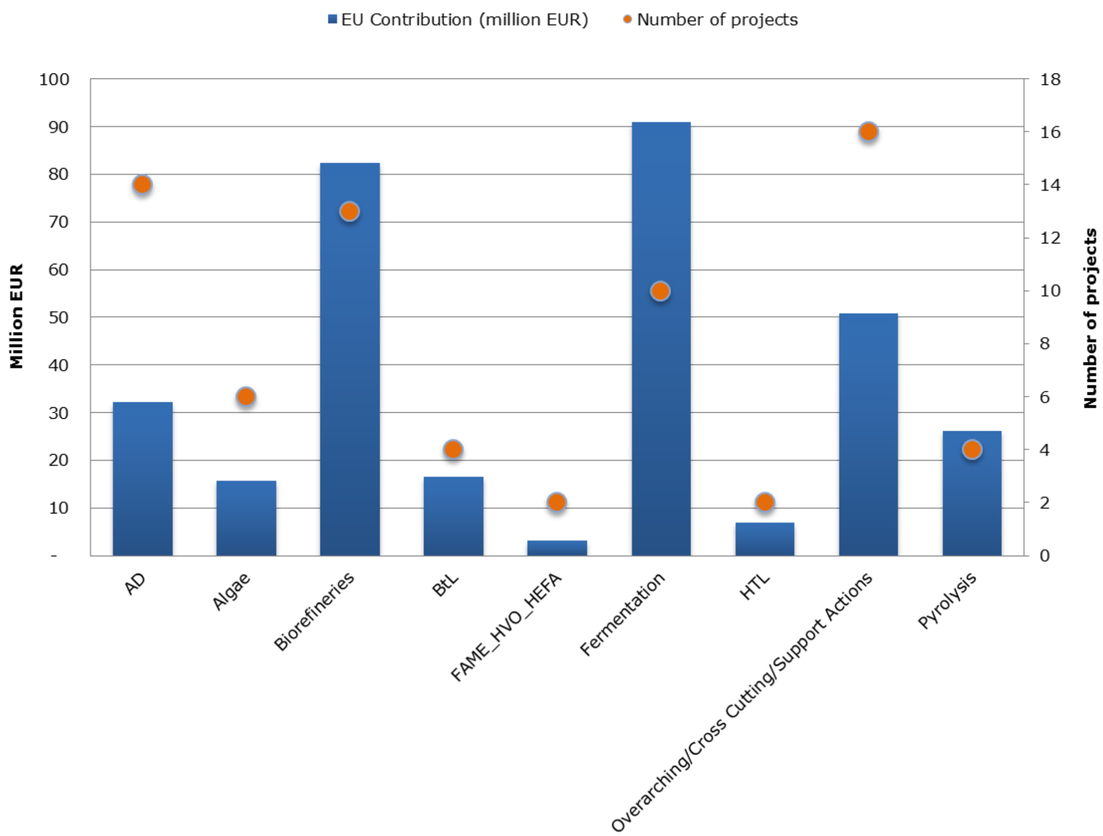

Figure 7-6. Distribution of EU funded advanced biofuel technologies projects above 250k EUR

7.9 Conclusions

The existing and forthcoming regulatory framework in the EU requires certain areas or aspects within each biofuel technology pathway to be further developed. Improvements in these areas will yield the greatest benefits towards making these biofuel pathways commercially successful in pursuit of the EU's established mandatory biofuels targets. For lignocellulosic pathways, a robust operation demonstrating steady and reliable production will be key to derisk further commercialization of the technology. Detailed and verifiable results from an operating facility will be highly beneficial to all parties; it is understood that results can be commercially sensitive, but without such clarity it is unlikely that future R&D investments will be targeted as efficiently as possible. For anaerobic digestion, further developments in the successful use of lignocellulosic feedstocks and other complex waste streams will help resolve the currently constraining issues of feedstock availability and sustainability; improving digestate valorisation and biogas upgrading to biomethane are other key elements that will enable this technology to be more widely implemented. For BtL, smaller scale operations and enhanced process integration may help to make these approaches more financially appealing. In general, co-processing of bio-crudes and bio-oils in existing refining infrastructure is an area of increasing focus, with obvious economic benefits to be realized by taking advantage of existing facilities and technologies. The fine tuning of the systems that produce such bio-crudes is also likely to reap considerable rewards, especially if this can produce materials that can be more easily upgraded. For FAME and HVO pathways, a on-going search for sustainable feedstocks remains the key issue, although there are some benefits to be gained by further improving the basic processes themselves.

7.10 Sources

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8. Germany

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Summary Box

- 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 of at least 2.8% biofuel in gasoline and 4.4% biofuels in diesel.
- As the first European Member State, Germany shifted from energetic related quota to a GHG related quota starting in January 2015. The GHG reduction targets are 3.5%, 4% and 6% in the fuel mix for the entire fuel sector from 2015, 2017 and 2020 onwards, respectively.
- According to Germany's Energy Tax Law, there is no tax relief for FAME biodiesel, HVO/HEFA fuels, vegetable oils and 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.
- Germany is evaluating specific policies to promote advanced biofuels. There are no specific policies promoting aviation biofuels.
- No financial incentives are available for advanced/new biofuels, making it quite difficult to penetrate into the fuel market, even with the GHG quota.
- There are various funding programs for R&D&D with emphasis on the use of diversified raw materials, decentralized-centralized concepts along value chains, promoting Germany's role as technology developer, and integration of renewable fuels based on biomass and electricity into the energy transition.

8.1 Introduction

In Germany, about 30% of total energy demand (~8,877 PJ in 2015) relates to the transport sector, of which just approximately 4% are renewable fuels (BMUB, 2016). 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 greenhouse gas (GHG) emissions from transport has slightly increased from 1990 to 2014 by 1% to reach 164 million tonnes (about 18% of all sectors in Germany; for comparison the transport share was 13% in 1990) (BMWi, 2015). In the light of the Paris agreement, CO_2-eq 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) (BMUB, 2016). 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) (BMVI, 2014). 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 implementing powertrains driven by electrical energy; electrical power is not an option or only to a minor extent for these transport sectors (Mueller-Langer et al., 2016).

8.2 Main drivers for biofuels policy

Following the Paris Agreement, the primary driver is to fight climate change by focusing on low-carbon technologies, CO_2 use and efficient renewable products from biomass and electricity. GHG savings are the primary driver for implementing German biofuel policies, and for that reason, Germany will be subject to Article 17 of the European Renewable Energy Directive (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).

8.3 Biofuels policy

The main 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 renewable energy directive (RED, Directive 2009/28/EC) and 6% GHG emission reduction from road fuel suppliers by 2020 according to the fuel quality directive (FQD, Directive 2009/30/EC); 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); 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 (i.e., 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.

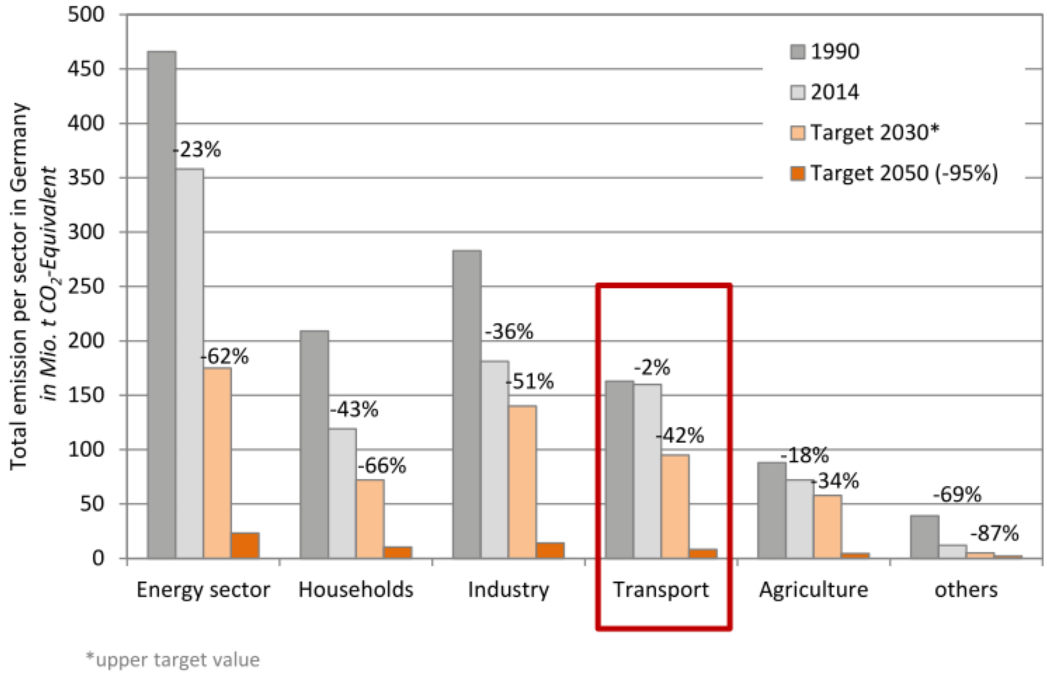


Figure 8-1. Climate protection plan of German Federal Government (©DBFZ, 2016)

Moreover, with the Directive on the deployment of alternative fuels infrastructure (AFID, Directive 2014/94/EU), 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.

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[17].

[17] Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the committee of the regions (2014) A policy framework for climate and energy in the period from 2020 to 2030 COM(2014) 15 final.

In 2016, the EU set an overall frame with its European strategy for low-emission mobility[18]. More recently, the EU approved a revised Renewable Energy Directive (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 (fuel quality directive) 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 fulfill the target, however other policy instruments are anticipated to follow. Because only actual emission savings count towards the quota (i.e., 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 fulfill the quota.

The quota target has to be achieved by companies placing fossil fuels on the market over the calendar year (i.e., 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-fulfillment of obligations, penalties of about 47 EUR ct/kg CO_2 equivalent are binding.

[18] Communication from the Commission to the European Parliament, the Council, the European economic and social Committee and the committee of the regions (2016) A European Strategy for Low-Emission Mobility COM(2016) 501 final

8.3.1 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 of at least 2.8% biofuel in gasoline and 4.4% biofuel in diesel, introduced by BlmSchG §37a.

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; maybe an appropriate advanced fuel quota will be established that will help contribute to the commercial implementation of such fuels.

The Federal government has authorized the “Bundesanstalt für Landwirtschaft und Ernährung” (BLE - Federal Institute of Agriculture and Nutrition) 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”.

8.3.2 Excise duty reductions

According to the German Energy Tax Law, 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. These regulations are also in force for E85 and advanced biofuels from 2016 onwards. 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.

8.3.3 Fiscal incentives

Not available

8.3.4 Investment subsidies

Not relevant for biofuels but for electro mobility, there is a financial support up to 4 000 EUR for plug-in battery electric vehicles (BEVs) and for loading stations up to 3,000 EUR (and for some municipalities up to 5,000 EUR).

8.4 Promotion of advanced biofuels

In Germany, the term "advanced biofuels" follows the definition given in the EU RED. Following this, there are recognizable projects on advanced transport biofuels at different technology readiness levels (TRL) or fuel readiness levels (FRL). Existing commercial FAME biodiesel, ethanol and biomethane plants generally also can be used to produce advanced biofuels based on residues or "waste" feedstocks. 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 biofuels).

There were and are different funding programs for R&D&D with different emphases (e.g., use of diversified raw materials, decentralized-centralized concepts along value chains, promoting Germany's role as a technology developer, and integration of renewable fuels based on biomass and electricity into the energy transition).

Table 8-1 shows an overview of ongoing transport biofuels RD&D projects at pilot and demonstration levels.

Table 8-1. Overview on ongoing transport biofuels research projects being carried out at pilot and demo levels in Germany (with no claim to completeness)

Type of biofuel / conversion route	**Process characteristics**	**TRL/FRL; Capacities**	**Stakeholders**	**Funding programs (examples)**
Biomass treatment to intermediate products				
Pyrolysis	Flash pyrolysis of different biomasses, slurry production	bioliq® demo plant, 2 MW pyrolysis, TRL 5	KIT	BMEL/FNR, federal funding
Direct liquefaction	Low pressure liquefaction by fluid cracking (e.g., of vegetable oils) and reactive destillation	TRL 4	Hochschule für Angewandte Wissenschaften Hamburg	BMEL/FNR, federal funding
Hydrothermal processes	Organosolv process	Fraunhofer CBP pilot plant in Leuna, operational since 2013, TRL 4-5 lignocellulose pre-treatment: 1 t wood/week	Fraunhofer CBP	Eranet, BMEL/FNR, BMBF/PTJ, federal funding
	Hydrothermal carbonization	Several demo plants, TRL 6-7	SunCoal, TerraNova, DBFZ, KIT/Uni Hohenheim, TU Braunschweig, ATB Potsdam	BMUB/BMWi, BMBF/PTJ

Type of biofuel / conversion route	Process characteristics	TRL/FRL; Capacities	Stakeholders	Funding programs (examples)
	Hydrothermal liquefaction	Lab / technical plants, TRL 3	DBFZ, KIT, Uni Hohenheim, TI	Eranet, BMBF/PTJ, BMEL/FNR
	Hydrothermal liquefaction & gasification	Pilot plant Verena, TRL 5-6	KIT	EU FP6, BMBF/PTJ
Biofuels for end use				
Ethanol (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)	Clariant	BMBF/PTJ, EU Horizon2020
	Ethanol & chemicals from wood; lignocellulose pre-treatment (organosolv method), fermentation, enzyme production, organosolv lignin, sugars (for ethanol and various platform chemicals)	Fraunhofer CBP Pilot plant in Leuna, fermentation + enzyme production: 10 to 10.000 l, TRL 5, FRL 5	With link to biofuels, e.g., Fraunhofer (FhG) CBP, DBFZ, Thyssen, Linde Engineering	BMBF/PTJ, 2012-2017
Isobutene (fermentation)	Fermentation	Demonstration plant, TRL 6, started operation in 2017	Global Bioenergies, Fraunhofer CBP	BMBF/PTJ
Isobutene oligomers	Oligomerisation and hydrogenation	Miniplant, TRL 4	Fraunhofer CBP / Global Bioenergies	-
HVO/HEFA	Hydrotreating processes, different feedstocks	Technical units, TRL 2-3	TU Bergakademie Freiberg (TU BAF)	BMWi/AiF
	HEFA out of micro algae	Pilot project, 2016 (AUFWIND project)	FZJ (Coord.), Nova-green, Phytolutions, HS Lausitz, OMV, RWTH Aachen, TU Munich, FhG, VERBIO, VT Schwedt, Airbus, DBFZ	BMEL/FNR, 2013-2016
BTL | Methanol / DME /gasoline	Entrained flow gasification, hot gas cleaning, synthesis	5 MW gasification 40-80 bar, TRL 6-7, 2 MW gasoline synthesis, TRL 7	KIT, CAC, Air Liquide, DBI	EU FP6 & FP7, BMEL/FNR, federal funding
BTL | Fischer-Tropsch	Micro-structured reactor module	2-50 bpd container plant, TRL 5	KIT/INERATEC	BMBF, federal funding
	Fluid bed gasifier, ABSART gas cleaning (40 bar), FT- and SNG synthesis	Modular process development units	CUTEC	EU FP6, federal funding

Type of biofuel / conversion route	Process characteristics	TRL/FRL; Capacities	Stakeholders	Funding programs (examples)
XTL | Methanol, gasoline	HP-POX gasifier (100 bar for liquid and gaseous fuels), synthesis	5 MW (gasifier), 2 MW (synthesis), TRL 6-7	TUBA Freiberg, Air Liquide, CAC	several
XTL | Oxymethylen-ether (OME)	Different catalytical routes investigated	TRL 3 with opportunity for scaling up	KIT and project partners; RWTH, FZJ	BMEL/FNR; BMBF
HTL | Hydrothermal liquid biofuels	2-stage hydrothermal liquefaction, refining	Technical plant, TRL 3	DBFZ, TU Dresden, Uni Leipzig, amtech	BMBF/PTJ
Biomethane via biogas (fermentation)	straw fermentation, fertilizer production; (additional: ethanol 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 ethanol + 480 GWh biomethane)	VERBIO AG	EU NER300
Biomethane via SNG	Gasification, gas conditioning, methanation	Plant units at technical labs	KIT/EBI, Uni Erlangen, DBFZ, ZSW, CUTEC, DBI	BMUB/BMWi | Energetic biomass use, federal funding
Biohydrogen	AER process (dual fluid bed with active bed material)	Process development unit	ZSW	EU, federal funding
Different fuels	Tailor-made fuels from biomass (TMBF) Biomass fractionation / pretreatment; enzymatic + catalytic biomass processing; process optimization; synthesis and conversion of biomass-based streams to platform molecules and fuels;	Lab units	RWTH Aachen, Fraunhofer IME, Max-Planck-Institut	DFG, BMBF

In addition, the topic of so-called PtX (ie., PtG or PtL fuels or chemicals) 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 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. All relevant issues identified by IEA are considered such as microreaction and other reaction technologies, PtG, renewable carbon from biomass, 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:

- Ministry of Education and Research (BMBF): “Kopernikus – project for the energy transition” with one project on PtX
- 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 multiblend jet fuel

Considering biofuels as one important renewable alternative for the transport sector is part of different ongoing strategies and initiatives:

- Federal government’s mobility and fuels strategy under the lead responsibility of the BMVI (cf. http://www.bmvi.de/SharedDocs/EN/Artikel/G/G-MKS/mfs-context.html?nn=86868)
- Biorefineries Roadmap as part of the German Federal government’s action plans for the material and energetic utilisation of renewable raw materials (cf. https://www.bmbf.de/pub/BMBF_Roadmap-Bioraffinerien_en_bf.pdf)
- National policy strategy on bioeconomy, renewable resources and biotechnological processes as a basis for food, industry and energy, BMEL 2013 (cf. http://www.bmel.de/SharedDocs/Downloads/EN/Publications/NatPolicyStrategyBioeconomy.pdf?__blob=publicationFile)
- ProcessNet initiative of Dechema and VDI-GVC: Sustainable Production, Energy and Resources (SuPER) Expert group on alternative fuels (cf. position paper https://processnet.org/en/-p-1000035-EGOTEC-844bca00fdee30c50e537961d6f4c071/_/PP_Alt.Brennstoffe 2018_engl_ezl.pdf)

Table ***8-2*** lists advanced fuels pilot and demonstration plants in Germany.

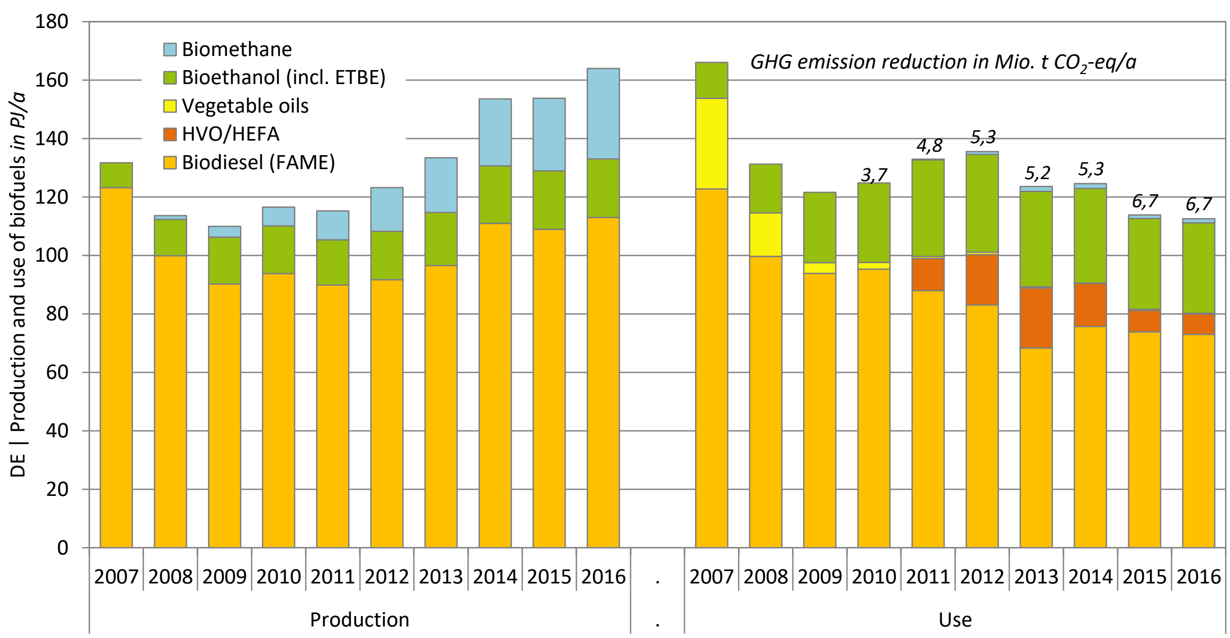
Table 8-2. Advanced Biofuels Pilot and Demonstration Projects in Germany

Name of company	**Status**	**Technology**	**Production capacity**
Clariant	Operational	Cellulosic ethanol	Demo plant sunliquid® in Straubing, operational since 2014, TRL 7, FRL 6 1,000 t/a (from 4,500 t/a straw)
Global Bioenergies, Fraunhofer CBP	Operational	Isobutene	Demonstration plant, TRL 6, started operation in 2017

KIT, CAC, Air Liquide	Operational	BTL	bioliq® demo plant, 2 MW pyrolysis, TRL 6 5 MW gasification 40-80 bar, TRL 6, 2 MW gasoline synthesis
Fraunhofer CBP, Thyssen, Linde	Operational	Cellulosic ethanol	pilot plant in Leuna, operational since 2013, TRL 4-5 lignocellulose pre-treatment: 1 t wood/week fermentation + enzyme production: 10 to 10.000 l, TRL 5, FRL 5
Verbio AG	Operational	Biomethane, ethanol	Commercial plant, 16,5 MW (136 GWh/a) from 40 kt/a straw, TRL 8, FRL 8 (260 kt/a ethanol + 480 GWh biomethane)

8.5 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 R&D&D activities however 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 Figure 8-2. 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 4.9 million t/a (5.6 billion liters/year) in 2016 (OVID, 2017)) are not presented separately due to these also being used as feedstocks for FAME biodiesel and several other uses.



© DBFZ, 10/2017, data base: Production: VDB, BDBe, BNetzA, dena; use: BAFA, BLE 2014-2017|
[a] for 2016 preliminary estimation DBFZ, [b] HVO / HEFA: no production in DE.; Biomethane: Production esp. for KWK and heat sector, [c] GHG reduction: 2009 + 2010: 35% acoording min. requirements of RED, 2011-2015: calculation based on BLE data

Figure 8-2. Development of conventional biofuels in Germany (©DBFZ 2017) (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)

Table 8-3. Biofuel production (Naumann et al., 2016; VDB, 2017; BDBE, 2017; Lenz et al., 2017); (no production capacities for HVO/HEFA fuels; PPO (Pure Plant Oil)/PVO production volume 2016 about 4.9 million t/a (5.6 billion liters/year); cellulosic ethanol capacity 1,262,000 liters/a)

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	3,351	934	25
2016	3,465	932	31

Unit conversion: 1 metric ton of biodiesel=1,136 liters and 1 metric ton of ethanol=1,262 liters.

In 2015, about 4.0% or 114 PJ/a of the transport fuels used were biofuels, of which about 73 PJ/a were biodiesel (FAME, about 70% based on rape oil, of which about 2/3 came from Germany), with 7 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).

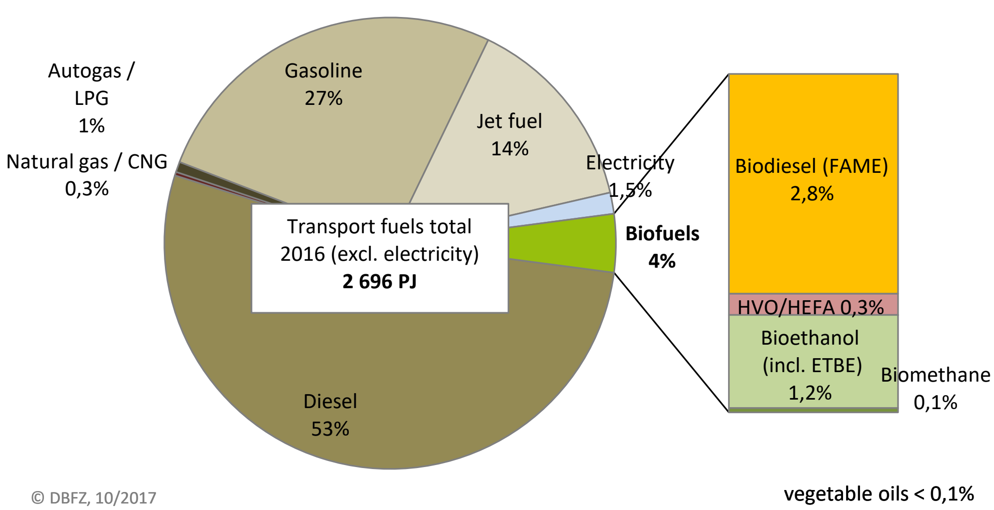


Figure 8-3. Biofuel use in Germany in 2016 (preliminary values; DBFZ based on Table 8-4)

The size of the biofuel market is indicated in Table 8-4.

Table 8-4. Biofuel consumption and market share (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 (2017); [a] assumption; [b] incl. electricity, cellulosic ethanol not relevant)

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 [b] (PJ/a)	Market share of biofuels (%, energy related)
2007	3,089	911	-	581	-	2,601	6.35
2008	2,584	436	-	790	-	2,571	5.05
2009	2,855	108	-	1,134	-	2,541	4.73
2010	3,786	66	-	1,291	-	2,559	4.91
2011	2,702	21	320	1,563	-	2,568	5.20
2012	2,550	10	502	1,583	1,06	2,559	5.28
2013	2,098	1	599	1,519	1,75	2,612	4.83
2014	2,326	6	427	1,479	1,63	2,616	4.77
2015	2,172	2	399	1,481	1,25	2,621	4.35
2016	2,102	4	385 [a]	1,483	1,40	2,696	4.30

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

Related to the increase in 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 amount of biofuels or renewable fuels used. The major driver for competiveness 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 amount of biofuels 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 (Lenz et al., 2017).

The 6% reduction target for the German GHG emissions quota continues after 2020. Despite this, the EU regulation is binding until 2030 (i.e., to achieve -40% GHG emissions reduction and incorporate 27% renewable energies into the energy mix) however 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).

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.

About 30 facilities with an overall combined capacity of about 4 million t/a (5.54 billion liters per year) are still producing biodiesel; this reflects some consolidation, as in 2012 there were about 51 production facilities) (Naumann et al., 2016). The most important producer companies are VERBIO AG, ADM, Cargill, ecoMotion GmbH, German Biofuels GmbH, Natural Energy West GmbH, REG Germany AG, and Mannheim Bio Fuel GmbH (Bunge) (Naumann et al., 2016).

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 VERBIO AG, CropEnergies AG, Suiker Unie GmbH & Co. KG and Nordzucker AG (BDBE, 2017).

Biomethane from upgraded biogas was produced by about 196 plants in 2016. The main companies producing biomethane for transport are VERBIO AG (biomethane from ethanol stillage and straw), E.ON Bioerdgas GmbH, and Berliner Stadtreinigungsbetriebe.

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9. **Japan**

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Summary Box

- There is a biofuels blending mandate of 854 million liters (500 million liters, crude oil equivalent) until at least 2022.
- Although the government has mandated the utilization of biofuels, it left the decision of how to meet the requirement to industry, which has chosen to use bio-ETBE (i.e., leaving biodiesel out of the picture). As the demand for biodiesel in Japan is very limited, biodiesel plays virtually no role in meeting the biofuels use goal.
- Consumption of ethanol was encouraged through a special tax incentive effective until March 2018. Diesel oil delivery tax is not charged for B100 (100% biodiesel) and many local governments are investigating the use of B100 for fueling municipal vehicles such as garbage trucks.
- The government plans to introduce 10 million liters (crude oil equivalent) of second generation biofuels and an as-of-yet undetermined quantity of biojet fuel into the market.
- The government maintains several incentive programs to promote the use of biofuels.

9.1 Introduction

Japan is the world's largest liquefied natural gas importer, second-largest coal importer, and third-largest net importer of crude oil and oil products. Japan has limited domestic energy resources that have met less than 9% of the country's total primary energy use since 2012, compared with about 20% before the removal of nuclear power following the Fukushima plant accident. Domestic production of renewable energy has therefore become important, including increased utilisation of wood wastes and increased import of wood pellets for bioenergy production (co-fired with coal). Bioenergy power production is promoted through a feed-in tariff system. Japan has committed to reduce its 2030 GHG emissions by 26% from 2013 levels and strives to meet energy security and climate mitigation goals.

Japan published its newest Basic Energy Plan for the next five years in 2014. Renewable energies form a key focus based on their potential to foster energy security, climate change mitigation and revitalisation of regional economies. After the Fukushima disaster, all nuclear reactors in Japan were shut down with the result that energy imports increased dramatically. However, some reactors are now restarting.

Japan's current renewable energy policy focuses on generating power from solar, wind, biomass, and geothermal sources, and biofuels are also part of this renewable energy policy. Japan is targeting 22-24% of its energy to come from renewable sources by 2030. For biofuels, the government plans to maintain its 500 million liters (crude oil equivalent) mandate until at least 2022. Additionally, the government continues to assess alternative sources for fuel ethanol, and in the future U.S. corn ethanol may be also designated as an eligible source under Japan's sustainability policy.

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

From 2009 to 2013, Japan's New Energy and Industrial Technology Development Organization (NEDO) focussed on "Development of an Innovative and Comprehensive Production System for Cellulosic Bioethanol" that coupled cultivation of feedstock that does not compete with food resources to a ethanol production process. In 2014, NEDO started the "Demonstration and Development Project of Production System for Cellulosic Bioethanol" in 2014 in order to prove out a comprehensive production process and establish scale-up technology. Consistent with the government's "Standards for Judgment for Oil Refiners regarding Implementation of Non-Fossil Energy Sources Use", demonstration and development of production system for cellulosic ethanol which satisfy 50% reduction in CO_2 emissions and fossil energy use will be carried out to verify suitable combinations of key process technologies.[Figures 9-1 and 9-2]. In addition, new technology developments in Japan and abroad will be researched and investigated. Concrete themes are as follows:

- Investigate and study superior technologies developed domestically or internationally

- Determine the best combinations of elemental process technologies and perform feasibility studies
- Develop technologies for integrated production of cellulosic ethanol from woody biomass that meets the Japanese standard for sustainability and conduct feasibility studies
- Develop and evaluate the use of steam explosion pretreatment of pulp for ethanol production

Large scale demonstrations will be scheduled based on research and investigation results.

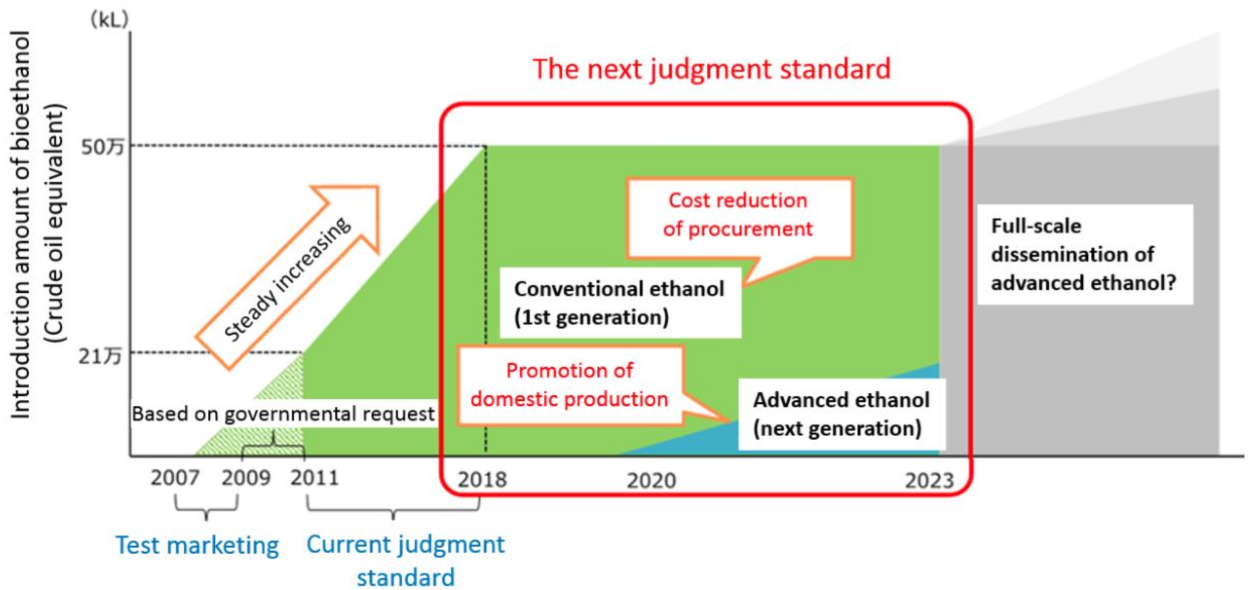

Figure 9-1. Pathway of biofuels production. The next judgment standard period is recognized as the "transition stage" in which it is most important to construct a cost effective as well as an environmentally effective system (meeting "3E" economic, energy and environmental objectives) for full-scale introduction of biofuels (domestic and advanced) (Source: Future vision concept of "the Next Judgment Standard" (draft), Agency for Natural Resources and Energy, January 2018). Note: 50 万 KL = 500 ML

9.2 Main drivers for biofuels policy

One of the key drivers for biofuels policy in Japan is environmental benefits, focusing on the reduction of CO_2 emissions as a countermeasure against global warming. Furthermore, the government has targeted reductions in oil dependency as a means of increasing national energy security. The production and utilization of biofuels can support this goal.

9.3 Biofuels Policy

9.3.1 Biofuels targets

In April 2014, Japan published its *Basic Energy Plan*, which is reviewed and revised every three to four years. For biofuels, the Basic Energy Plan states that "concerning biofuels, which are mostly imported, Japan will continue to introduce the fuels in light of international trends and technical developments in the next generation of biofuels." According to industry sources, this statement reflects the policy that biofuels should be sourced from non-food crops (e.g., cellulosic ethanol).

In 2017, Japan revealed its preliminary biofuel policy for 2018 to 2022, and it plans to maintain the 500 million liters mandate. It is also considering allowing the use of U.S. corn-based ethanol in imported bio-Ethyl TertButyl Ether (ETBE), in addition to Brazilian sugarcane ethanol. Another change, in the 2020-2022 period, is Japan's plan to introduce 10 million liters (crude oil equivalent) of second generation biofuels (potentially reducing the demand for first-generation ethanol) as well as an as-of-yet undetermined quantity of biojet fuel into the market. Japan's Ministry of Economy, Trade and Industry (METI) "Expert Committee to Discuss the Future of Biofuel Introduction in Japan," which is comprised of ten members from academia, non-profit organizations, and industry, will continue discussions until late 2017 in order to finalize these changes. After a public comment period in early 2018, the new policy is expected to be implemented in Japan's new fiscal year (which begins April 2018). As the demand for biodiesel in Japan is very limited, biodiesel plays virtually no role in meeting the 2017 goal. [Table 9-1]

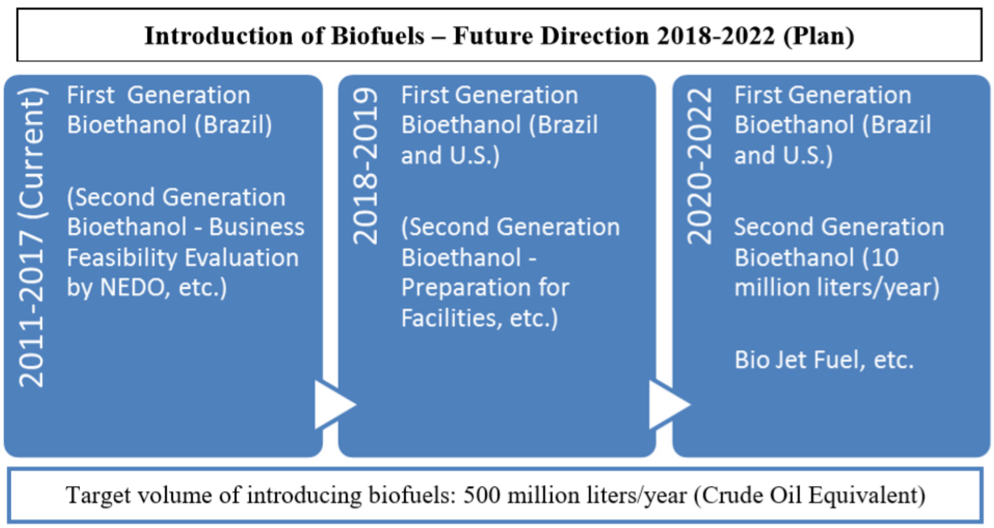

Figure 9-2. Phased plan for introducing biofuels, 2011-2022
Source: METI. http://www.meti.go.jp/meti_lib/report/H28FY/000069.pdf Note: FAS Tokyo created this table based on METI's information.

Table 9-1. Biofuel obligations/mandates (target volumes)

Year	Ethanol *	Biodiesel
2010	-	-
2011	359 ML (210 ML)	-
2012	359 ML (210 ML)	-
2013	444 ML (260 ML)	-
2014	546 ML (320 ML)	-
2015	649 ML (380 ML)	-
2016	751 ML (440 ML)	-
2017	854 ML (500 ML)	-

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

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

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

The blend level for biodiesel is 5% (B5), and is applied to cars, busses, and trucks. Of Japan's 33.6 billion liters of diesel used in 2015, approximately 76% (25.7 billion liters) was for on-road use. METI provides special approvals for operators to use biodiesel at a blend level higher than 5% for trucks and buses. Trade data shows that Japan's imports of biodiesel in 2016 grew by 19.7% (or 210,000 liters) from the previous year. According to industry sources, this trend may be attributed to increased use by small-scale power plants and large-scale oil-fired power plants.

The food-vs-fuel debate is a significant issue in Japan. Japan has a low level of food self-sufficiency – imports comprise the majority of the food it consumes. As a result, Japanese people are highly sensitive to rising food prices, leading some in Japan to question the use of food crops to produce biofuels.

9.3.2 Excise duty reductions

Diesel oil delivery tax is not charged for B100 (100% biodiesel). Therefore, in many local governments, the use of B100 as fuel is investigated for municipal vehicles such as garbage trucks. Consumption of ethanol is encouraged through a special tax incentive effective until March 2018. If gasoline contains 3% ethanol (volume basis), the gasoline tax is lowered by ￥1.6/L (= 1.5¢/L, under a currency exchange rate of US$1 = ￥ 110). The tax for unblended gasoline is ￥53.8/L. Import of bio-ETBE is encouraged through a zero tariff in place until March 2018.

9.3.3 Incentives, subsidies and other measures to promote biofuels

Although a number of ministries collaborate on Japan's biofuels policy, the two ministries that play major roles in developing and implementing Japanese biofuels policies are the Ministry of Economy, Trade and Industry (METI) and the Ministry of Environment (MOE). MOE is concerned with preventing global warming and meeting Japan's commitment to reduce its greenhouse gas (GHG) emissions. In May 2016, Japan committed to reduce its GHG emissions to 26% of its 2013 levels by fiscal year (FY) 2030 (April 2030 to March 2031).

METI's interest in biofuels is as supplemental sources of fuels for Japan, and in analyzing the costs and benefits of shifting to renewable fuels, including impacts on automobiles and infrastructure. METI collaborates with the oil industry on determine how and when to introduce biofuels into the Japanese market.

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

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

- In 2008, the "Quality Control of Gasoline and Other Fuels Act" was amended to lower the gasoline tax (¥53.8/liter) by ¥1.6 per liter (about $0.02/liter) if the fuel contains 3% ethanol. This incentive is effective until March 2018. METI has petitioned the Ministry of Finance to extend this incentive and is currently developing a proposal to extend the incentive through Japan FY 2018.

- In 2008, the "Customs Tariff Act" and the "Temporary Measures Concerning Customs Act" were amended to eliminate the 3.1% import tariff on bio-ETBE. Moreover, in 2016, these acts were further amended to eliminate the 10% import tariff on bio-ethanol for the production of bio-ETBE. As with the gasoline tax, the Customs Tariff Act must be renewed annually and is currently approved through March 2018. METI is developing a proposal to extend this incentive through March 2019.

- In 2008, MAFF proposed and the Diet passed the "Law Concerning the Promotion of Biomass Resources as Raw Materials for Biofuels." This law provides tax breaks and financial assistance to newly built biofuels production facilities that MAFF determines qualify for benefits. Although initially available only to ethanol producers, benefits now have been extended to producers of alternative forms of bio-energy (such as biodiesel, wood pellets, methane gas, or hydrogen gas). Under the scheme, newly built biofuel facilities that are approved for the program by 2018 will have their fixed property tax reduced by half for three years. The legislation authorizes MAFF to extend the repayment period of interest-free loans in two-year increments for a maximum of 12 years. MAFF records show that 21 projects have qualified for the benefits since the program began in 2008, though some have since ceased operations.

- In 2011, METI introduced the “Green Investment Tax Incentive.” Under this system, small and medium-sized businesses are eligible for a special 30% depreciation on the acquisition of renewable energy assets (such as facilities and vehicles), or a 7% reduction in corporate taxes. In 2015 (the latest data available), 11,889 operators received a total value of ¥558 billion (approximately $4.6 billion) in tax breaks.

9.3.4 Other measures stimulating the implementation of biofuels

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

9.4 Promotion of advanced biofuels

The government established sustainability standards in 2010 with the Ministry of Energy (MOE) releasing the “Life Cycle Assessment Guideline for Biofuels”. Oil distributors are required to only use ethanol enabling a 50% reduction in GHG emissions compared with gasoline, and biofuels may not compete with the food supply. Only sugarcane ethanol from Brazil produced on existing farmland qualifies under the sustainability standards, and thus most ethanol is imported from this country. It is not clear whether bio-ETBE has to qualify under the sustainability standards.

It is unclear whether any specific incentives are available to promote advanced biofuels, however significant research and development focuses on advanced biofuels. Japanese private companies and Japan’s scientific community, including universities and public and private research institutions, continue substantial basic and applied research related to biofuels. A major focus of research projects is on cellulosic and algal feedstocks and conversion technologies to produce biofuels at commercial scale in a sustainable way. Several joint research projects aim to produce commercial-scale biojet fuel from algae, with the goal of commercializing these fuels by 2030. Table 9-2 lists some of the industry-led advanced biofuels projects active in Japan. To utilize domestic biomass feedstock at its maximum potential, not only cellulosic biomass but also food waste will be investigated as feedstocks not competing with food.

Table 9-2. Partial list of company-led advanced biofuel projects in Japan

Company	City	Startup	Raw Material	Technology	Output Capacity
DINS Sakai	Sakai, Osaka	Jan 2007	woody biomass (construction wastes) (since Sep 2012, adding of sugar solution such as abolished juice)	saccharification with diluted sulphuric acid and fermentation using recombinant *E. Coli*, KO11	1.4 ML/year
Oji/JXTG （NEDO）	Hiroshima	Oct 2016 Pilot plant	woody biomass	simultaneous saccharification and cofermentation	100 kL/year
Biomaterial in Tokyo （NEDO）	Kawasaki, Kanagawa	Apr 2016 Pilot plant	cellulosic waste	simultaneous saccharification and cofermentation	100 kL/year

Ref.: http://www.dinsgr.co.jp/dins_sakai/business/baio_business/index.html; http://www.nedo.go.jp/content/100862614.pdf

As shown in Table 9-, future estimated gasoline demand decreases because of EV shift and structural reasons such as population reduction. However, demand for fuels to supply larger vehicles and airplanes that rely on high energy density fuels is expected to remain steady. In the medium- and longer-term, the possible introduction of biojet and biodiesel fuels is likely to be further investigated to better assess or estimate needed policy(ies), biomass resource supply and investment.

Table 9-3. Demand change of fuels in Japan, 2006-2021 (ML)

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

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

The Government wants to introduce biojet fuel for commercial flights in 2020, the year that the Summer Olympic Games and Paralympic Games will be held in Tokyo. In 2015, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and METI jointly established a “Committee for the Introduction of Biojet Fuel for the 2020 Summer Olympic Games and Paralympic Games in Tokyo.” The committee has two working groups: one studies the supply chain of biojet fuel, and the other examines fuel production. The committee may consider importing biojet fuel if the quantity of domestic production proves insufficient. The volume of Japan’s biojet fuel production in 2020 is ambitiously estimated to be 100,000 to 1 million liters (neat biofuel basis).

A venture firm in Tokyo whose official serves as a member of the Bio Jet Fuel Committee is building a facility in Yokohama City to produce and commercialize biojet fuel by 2020. The fuel will be made from Euglena species algae that it will grow on Ishigaki Island in Okinawa Prefecture. The facility will be operational in the first half of 2019, and will have an annual production capacity goal of 125,000 liters of biojet fuel.

9.5 Market development and policy effectiveness

Japan's total fuel ethanol consumption in 2017 was estimated to be 890 million liters, including both the pure ethanol equivalent of ETBE consumed plus a small amount of ethanol consumed in direct blending in gasoline. This translates to an effective national average blend rate of 1.7%; Japan's estimated gasoline consumption in 2017 was 51.5 billion liters. The government mandated the utilization of biofuels, leaving the decision of how to meet the requirement to industry, which is using bio-ETBE (leaving biodiesel out of the picture).

Japans number of conventional ethanol plants and their combined production capacity, which was as high as 6 plants with 35 million liters annual capacity, has diminished. Today, Japan has one refinery that annually produces approximately 0.2 million liters of ethanol for fuel use from domestic rice. This refinery is located in Niigata Prefecture and is operated by JA Zen-noh, the federation of agricultural cooperatives. It uses high yield rice grown specifically for biofuel production. The ethanol is used as part of an E3 blend, and the E3 gasoline is sold at six affiliated gas stations around Niigata Prefecture. Two projects in Okinawa Prefecture that were producing ethanol for fuel from molasses were terminated in recent years. Until 2015, the two facilities produced a combined 1.9 million liters of ethanol annually from molasses obtained from the processing of sugarcane, with the ethanol sold in E3 and E10 blends at gas stations on the two islands.

In 2010, Japan Biofuels Supply LLP started to produce ETBE domestically. Each year, the company produces 140 million liters of ETBE, using 59 million liters of ethanol. Previously, mostly imported ethanol with some domestically produced ethanol added were used to make ETBE, but following the closure of two ethanol refineries in Hokkaido in 2014, the company became fully reliant on imported ethanol.

In 2016, Japan imported 757 million liters of ethanol for transportation, consisting of 696 million liters of ethanol imported as ETBE and 61 million liters of ethanol to be used for domestic ETBE production. Due to sustainability requirements, all imported ethanol used in domestic ETBE production has come from Brazil, and all imported ETBE from the United States, made using Brazilian ethanol. The government of Japan is assessing alternative sources for fuel ethanol, and U.S. corn ethanol may be designated as eligible under Japan's sustainability policy (see Policy and Programs section for more information on Japan's requirement to reduce GHG emission by at least 50%). The use of ETBE is expected to increase further, as the Petroleum Association of Japan (PAJ) aims to start supplying 1.94 billion liters of ETBE annually by 2017. Accordingly, the PAJ is forecasted to continue to supply the same amount of ETBE in 2018. The PAJ expects to import most of its supply (annually 1.8 billion liters of the 1.94 billion liters of ETBE) from the United States. There are no import tariffs on ETBE derived from biomass or on ethanol used to make ETBE until at least March 2018. Japan does not export either ETBE or ethanol.

Japan's biodiesel market is extremely limited, meeting just 0.04% of national on-road transportation demand for diesel fuel, and there is no renewable diesel market. As cited in the USDA's 2017 GAIN Japan Biofuels Annual report, Post estimates 16 million liters of biodiesel was produced in 2016 based on National Biodiesel Fuel Utilization Council (NBUC) data.

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

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

Post forecasts that in 2017 biodiesel production will increase to 17 million liters due to a minor increase in exports, primarily to the Netherlands, with little to no change in consumption and imports. However, no further change in supply and demand is expected in 2018. Domestic demand for biodiesel remains small mainly because no established distribution channels exist for the fuel, few established larger-scale collection systems for feedstock exist, and its use is largely limited to small fleets of municipal vehicles in local and regional programs.

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

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

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

While Japan's imports of biodiesel have increased in recent years, they remain limited. According to some industry sources, biodiesel may be imported for generating power at oil-fired power plants. In 2016, Japan imported 1.27 million liters of biodiesel, 98% from Malaysia [Table 9-4]; there is no import tariff on biodiesel from Malaysia under a bilateral economic partnership agreement.

Table 9-2. Key suppliers of biodiesel to Japan (ML) (The World Trade Atlas)

Supplier	**2012**	**2013**	**2014**	**2015**	**2016**
World	0.08	0.49	0.61	1.06	1.27
Malaysia	-	0.42	0.44	1.02	1.24
Philippines	-	-	-	-	0.2
United Kingdom	-	-	-	-	0.01
Germany	0.03	0.03	0.04	0.04	0.01

The Bioethanol Division of a private company in Sakai City, Osaka Prefecture, operates recycling facilities to process waste products and materials, and began producing ethanol from wood and cellulosic lumber waste in 2007 [Table 9-2]. Its annual ethanol production capacity is 1.4 million liters. For the first several years, the company supplied its ethanol to a couple of oil distributors making E3 gasoline to sell at the distributors' affiliated gas stations. However, because E3 gasoline did not come into wide use, there is little demand for the company's fuel ethanol. The company is currently using most of the ethanol it produces to generate power for its facility, and it sells the rest to an industrial alcohol distributor.

Biofuels production capacity and market share trends since 2006 for are shown in Table 9-5, and transport fuel consumption trends are shown in Table 9-6.

Table 9-3. Biofuel production and market share – installed production capacity (ML/year)

Year	FAME Biodiesel	Ethanol	Cellulosic ethanol	Biogas as transportation fuel	Renewable diesel (from lipids)
2006	-	-	0	-	-
2007	-	-	1.4*	-	-
2008	-	-	1.4	-	-
2009	-	-	1.4	-	-
2010	-	31.75	1.4	-	-
2011	-	31.75	1.4	-	-
2012	-	32.75	1.4	-	-
2013	-	32.75	1.4	-	-
2014	-	32.75	1.4	-	-
2015	-	32.75	1.4	-	-
2016	-	2.0	1.4	-	-
2017	-	2.0	1.6	-	-

* http://www.env.go.jp/press/7859.html (Commercial plant started at Sakai in January 2007)

Table 9-4. Summary of transport fuel consumption (ML)

Year	Gasoline	Diesel fuels	Aviation fuel	Biodiesel*	Ethanol**	Market share (%) of biofuels ***
2006	-	-	-	5.0	0.03	
2007	-	-	-	5.0	0.09	
2008	-	-	-	10.0	0.2	
2009	-	-	-	8.6	14.7	
2010	52,964	27,186	7,925	8.7	386	0.7
2011	53,266	25,990	7,623	8.6	359	0.7
2012	54,439	25,904	8,040	8.4	365	0.7
2013	53,689	25,681	8,572	9.7	440	0.8
2014	52,192	25,685	9,150	14.9	539	1.0
2015	51,502	25,679	9,494	15.4	700	1.4
2016	51,354	25,455	9,909	-	786	1.5

*Based on survey replies; it could be 20-25 ML/year
**Based on 1G bioethanol
*** Market share of biofuels in total transport fuel consumption. Bioethanol in Gasoline (Biodiesel in Diesel: <0.1%)
Ref: http://www.mlit.go.jp/k-toukei/22/annual/22a0excel.html;
http://www.mlit.go.jp/k-toukei/cgi-bin/search.cgi

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MAFF (Ministry of Agriculture, Forestry and Fisheries)
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MOE (Ministry of the Environment)
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Ref; http://www.jst.go.jp/alca/kadai/prj_07.html#h22_02

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10. The Netherlands

Timo Gerlagh, Netherlands Enterprise Agency (RVO.nl)

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Summary Box

- There is 16.4% biofuels mandate (both ethanol and biodiesel) in energy content for 2020.
- The Dutch regulation included a sub-target for the use of advanced biofuels at 1.0% level in 2020 (including double counting).
- There are production capacities of ethanol, biodiesel, HVO and biomethanol in the Netherlands.
- There is not market-based mechanisms such as carbon tax and emissions trading (cap-and-trade) in the Netherlands.
- Aviation industry has no obligation to consume a certain percentage of biofuel, but can use an opt-in system, where biofuels for aviation can be used for the generation of tradable units.
- No financial incentives (e.g. subsidies, credits, incentives) are provided for biofuels. The blending of biofuels is encouraged with the quota obligation for fuel suppliers.

10.1 Introduction

The total primary energy supply (TPES) of the Netherlands in 2016 amounted to 3,115 Petajoule (PJ) and is still overwhelmingly dominated by fossil fuels (92%) [Figure 10-1]: 1,257 PJ natural gas, 1,181 PJ oil products, 427 PJ coal products and a small fraction of non-renewable waste of 36 PJ. 18 PJ of electricity is imported, which represents 0.6% of Dutch TPES. Renewable energy sources have a share of 5.1% or 158 PJ – 3.8% bioenergy and 1.3% other renewable energy forms.

Compared to 5 years earlier (2011), the share of natural gas has gone down from 44.2% to 40.3%. In the same period, the share of coal increased from 9.5% to 13.7%, while the share of oil products, nuclear energy and waste remained stable, and the share of renewable energy increased from 4.2% to 5.1%.

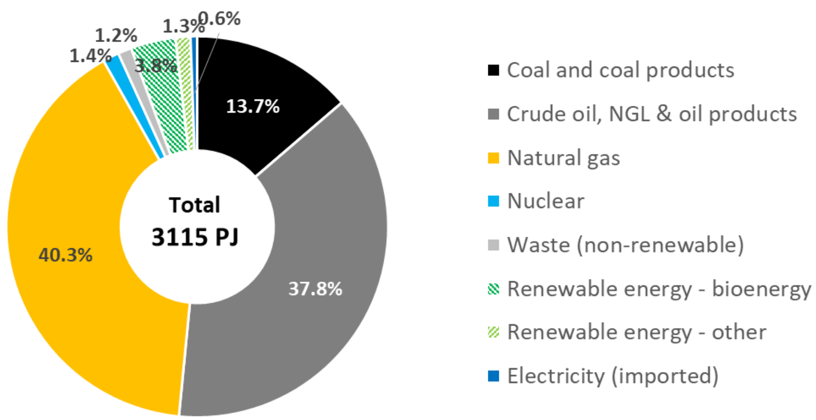

Figure 10-1: Total primary energy supply in the Netherlands in 2016 (Source: World Energy Balances © OECD/IEA 2018)

The TPES of renewable energy sources in the Netherlands is three quarters covered by energy from biomass, with bioenergies supplying 119 PJ of the total 158 PJ [Figure 10-2]. Wind energy contributes almost 20% at 29 PJ and solar energy almost 5% at 7 PJ. Geothermal energy accounts for 3 PJ. The role of hydropower is insignificant.

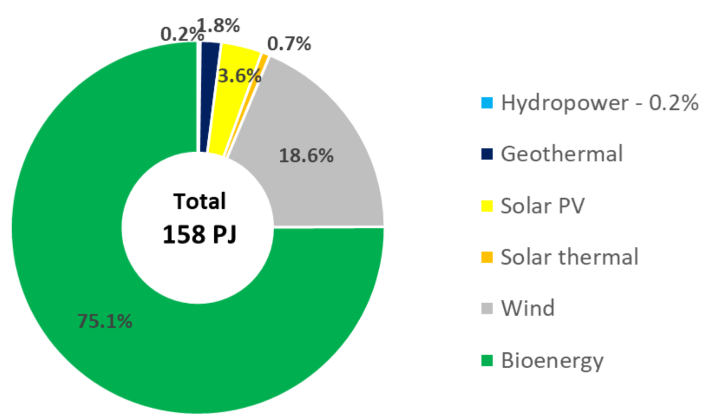

Figure 10-2: Total primary energy supply of renewable energy sources in the Netherlands in 2016 (Source: World Energy Balances © OECD/IEA 2018)

The share of renewables in the total primary energy consumption has continually increased from 2.4% in 2005 to 3.5% in 2008, 4.4% in 2012, 5.8% in 2015 and 6.6% in 2016. The share of renewable energy is expected to continue to grow in coming years. The Renewable Energy Directive (RED) targets are 14% renewable energy overall and 10% share of renewable energy in final consumption of energy in transport by 2020.

Energy policies in the Netherlands focus on developing a mix of resources that will assure reliable, affordable supply while recognizing the need to reduce reliance on carbon-intensive resources. There are two recent developments that can have major impact on the energy policy: the decision to reduce the extraction of natural gas out of the Groningen field (the main source of natural gas in recent decennia) and the targets of the Rutte II administration to reduce greenhouse gas emissions 49% by 2030. The latter will be implemented in a “climate agreement”.

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

The Netherlands is implementing the EU Directive by gradually raising its share of energy from renewable sources such as biofuels, biogas, and electricity for road transport. The 10% target of renewable energy in the final consumption of energy in transport is to contribute 36 PJ to final renewable energy use in 2020.

10.2 Main drivers for biofuels policy

The main driver for biofuel consumption in the Netherlands is the target for renewable energy in transport as defined in the European Renewable Energy Directive for 2020 and the national energy agreement for 2023. The policy for reducing greenhouse gas emissions from transport as part of the climate policy is a second driver that will be formulized in a Climate agreement between the government and stakeholders.

10.3 Biofuels policy

The biofuel policy in the Netherlands is closely linked to European policy and the Paris agreement. The Ministry of Infrastructure and Water management is responsible for biofuels policy. Since 2007, a quota obligation for fuel suppliers was introduced, which became later part of implementation of the RED (2009/28/EC). For this directive, it provides a contribution to an overall target for renewable energy and the specific target for 10% renewable energy in transport in 2020. The implementation of the original RED and the Fuel Quality Directive (2009/30/EC) was completed in 2011. In the same year, the Dutch Emissions Authority (NEa) was appointed as the authority in charge of monitoring compliance with national legislation. In 2015, the RED was changed, partly because of the discussion on the land use change impact of biofuels. Renewable Energy Directive (2009/28) and Fuel Quality Directive (2009/30) (both revised in iLUC directive (2015/1513)) implemented in Besluit hernieuwbare energie vervoer 2015 (and under revision as part of implementation the iLUC directive). The new RED (RED II) includes a cap on crop-based fuels (7%) and a sub-target for advanced biofuels (0.5%). This is implemented in “Besluit energie vervoer”, published June 2018.

In the coalition agreement (November 2017) of the Rutte II administration, new targets were set for emission reduction in 2030 (49%). Implementation of this agreement will be the basis of new regulation.

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10.3.1 Biofuels obligations

Mandatory targets to blend at least 3.5% biofuels in both petrol and diesel were removed by the legislation that came into force in 2015. However, the Netherlands still has a mandatory national biofuels target that requires fuel suppliers to ensure a minimum level of blending of biofuels into transport fuels. In 2015, fuel suppliers were obliged to blend fossil fuels with at least 6.25% biofuels in energy content. A fuel suppler that fails to fulfill the quota obligation is liable to pay a penalty. The enforcement of the annual obligation has a legal basis.

Currently a 5% cap for first generation biofuels and a 0.5% subtarget (both 2020 targets) for advanced biofuels are implemented as part of implementing the EU iLUC directive. Emissions of biofuels are also taken into account based on the European Fuel Quality Directive (2009/30/EC) that requires well to wheel emission reduction (WTW) of 6% in 2020 compared to 2005. For transport in the Netherlands, there are no market-based mechanisms such as a carbon tax or emissions trading (cap-and-trade).

Since 2011, fuels from wastes/residues and lignocellulosic materials count double in the Netherlands. As part of implementing the EU iLUC directive (2015/1513/EC), a specific sub-target stimulates advanced fuels. In the Netherlands, double counting remains part of the regulation up to 2020. In RED, sustainability criteria for biofuels are defined in article 17, mass balance and governance demands in article 18, and advanced fuels in Annex IX A.

The aviation industry has no obligation to consume a certain percentage of biofuel, however it can do so via an opt-in system where aviation biofuels can be used to generate tradable renewable energy units (HBEs). In 2018, 3 types of tradable units were introduced, HBE-C (conventional), HBE-A (advanced) and HBE-O (others), to facilitate meeting the sub-target for advanced biofuels and limiting conventional biofuels.

Table 10-1 provides information on current obligations for biofuels in the Netherlands. Obliged parties are oil companies that bring petrol and diesel from excise warehouses into the Dutch fuel market. Only biofuels that are proven to be sustainable are eligible to meet the obligation. Sustainability can be proven by using one of the EU accepted voluntary schemes (see link to European Commission website).

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

Table 10-1. Biofuel obligations/mandates (% by energy content)

Year	**Total Biofuels (% renewable energy in the transport market, obligation to market parties**		**Subtarget advanced (Annex IX A)**	**Limit conventional**
	Target	Achieved		
2010	4%	Unknown		
2011	4.25%	4.31%		
2012	4.5%	4.54%		
2013	5%	5.05%		
2014	5.5%	5.54%		
2015	6.25%			
2016	7%			
2017	7.75%			
2018	8.5%		0.3%	3.0%
2019	12.5%		0.4%	4.0%
2020	16.4%		0.5%	5.0%

From January 2015, administration of obligations has been through an automated digital register managed by NEa. Companies in noncompliance with their obligation are subject to a financial penalty.

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

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

10.3.2 Excise duty reductions

Not available.

10.3.3 Fiscal incentives

No financial incentives (e.g., subsidies or credits) are provided for biofuels. The blending of biofuels is encouraged within the quota obligation for fuel suppliers.

10.3.4 Investment subsidies

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

10.3.5 Other measures stimulating the implementation of biofuels

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

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

Through the programme Refuelling Pumps for Alternative Fuels (Tankstations Alternatieve Brandstoffen, TAB), the Dutch government as well as other governmental bodies have invested together to expand the refueling pump infrastructure for alternative fuels including biofuels. In the first tender in 2008, a total subsidy of €1.8 million was granted to build and install 68 ethanol fuel pumps and 31 natural gas refueling pumps, of which 24 and 11 new alternative fuel pumps, respectively, were realized. The second tender started at the end of 2009, and in 2010 a total subsidy of €3.6 million was granted for 53 refueling pumps for natural gas, 3 for E85 and 4 for B30 that are currently being built.

In 2010, there was also a tender of the subsidy programme “Effective and efficient digestion chains”, which also included pilot and demonstration projects for renewable gas production, including associated infrastructure and supply. A total amount of €7 million of subsidy was granted. In 2011, a subsidy programme started aiming to promote the purchase and the use of vehicles using biogas and high biofuel blends.

10.4 Promotion of advanced biofuels

The new Dutch regulation includes a sub-target for the use of advanced biofuels at 0.5% level in 2020. For implementing RED II, an increase of advanced biofuels up to 1.75% (3.5% with double counting) is needed.

10.5 Market development and policy effectiveness

There are two ethanol plants in the Netherlands, the former Abengoa plant of 384 kton (484.6 million liters) annual capacity, recently taken over by Alcogroup. The second plant is operated by Cargill and has an annual capacity of 32 kton (40.4 million liters). Table 10-2 shows the biodiesel plants. Table 10-3 lists installed production capacities of biofuels plants.

Table 10-2. Biodiesel plant capacities (ML) in the Netherlands

Biodiesel Kampen BV	120
Biopetrol AG Industries	400
Ecoson/Vion	5
Greenmills/ Biodiesel Amsterdam (now Simadan)	100
Sunoil Biodiesel B.V.	72
Eco-Fuels Netherlands	50
Total annual capacity: 747 kton (848.6 million liters)	

There is also one renewable diesel (HVO) plant operated by Neste with an annual capacity around 1 Mton (1.2 billion liters) and one BioMCN plant producing 200 kton biomethanol.

Table 10-4 shows the steady increase in biofuels consumption for transport since 2006.

Table 10-3. Biofuel production– installed production capacity (ML/year)

Year	Biodiesel (FAME/HVO)	Ethanol (conventional)	Cellulosic ethanol***	Biogas as transport fuel (Mm^3) **	Renewable diesel (from lipids)
2006	18	11	-	-	-
2007	85	10	-	-	-
2008	83	7	-	-	-
2009	274	0	-	-	-
2010	382	-	-	-	-
2011	491	-	-	9	-
2012	1,177	-	-	12	-
2013	1,375	414	-	11	-
2014	1,720	-	-	6	-
2015	1,629	420 *	-	5	-
2016	1,462	420 *	-	5	-
2017	1,932	420 *	-	5	-

* RVO, market data, no official statistics
** Amount of biogas used for the transport obligation. The feed-in of sustainable biogas into the grid and delivery of gas from the grid to transport are proven
*** unknown

Table 10-4. Summary of transport fuel consumption (ML/year)

Year	Gasoline	Diesel fuels	Aviation fuel	Biodiesel	Ethanol	CNG (Mm^3)	Market share of biofuels (%)
2006	5,793	9,252	-	22	28	2	
2007	5,811	9,350	-	271	132	3	
2008	5,797	9,420	-	287	163	4	
2009	5,793	8,813	-	328	213	8	
2010	5,789	8,830	-	109	208	12	
2011	5,882	8,929	-	220	231	23	4,8
2012	5,610	8,658	-	273	193	31	4.9
2013	5,464	8,055	-	274	194	35	5,1
2014	5,318	7,550	-	322	199	45	6,2
2015	5,408	7,551	-	251	220	48	5,3
2016	5,540	7,463	-	182	187	48	4,7
2017	5,680	7,500	-	260	267		5,7

* Ethanol and biodiesel are the amounts blended into normal gasoline and diesel and are also included in the gasoline and diesel fuel amounts in this table.
** Market share is the percentage renewable energy in transport as calculated according to the renewable energy directive, including double counting and use of electricity for transport.

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Netherlands- Energy System Overview https://www.iea.org/media/countries/Netherlands.pdf

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

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- Policy letter on biofuels of Government to parliament - March 2006.
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    - http://www.agentschapnl.nl/en/programmas-regelingen/dutch-biofuels-policy-2006-2010-uk
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11. New Zealand

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Summary Box

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

11.1 Introduction

New Zealand is a geographically-isolated country with a long skinny geography, a land area of 268,000 km^2, and a comparatively small population (4.8 M). It has a temperate climate, with an export-focussed economy which is highly dependent on agriculture, particularly dairy products, meat, forestry and horticulture. Per-capita use of transport fuels is also relatively high due to the country's low population density and the nature of the economy.

Almost all New Zealand's liquid fuel needs are met by imported fossil oil (7.8 Mt in 2017), mainly for use in the country's transport sector. These liquid fuels are imported mainly as crude oil for refining at New Zealand's only oil refinery. Domestic crude oil production currently accounts for around 35% of domestic demand, however almost all domestic production is exported as it is light and sweet, whereas the refinery is configured to process sour crude.

New Zealand has committed to reduce its GHG emissions by 30% below 2005 levels by 2030 and also has a further longer-term target to reduce emissions by 50% below 1990 levels by 2050. The new government is developing a Zero Carbon bill which looks likely to set a net zero target by 2050. Work is also underway to define the best available options to meet Paris GHG reduction targets such as buying international credits, reducing emissions or expanding forest plantations.

GHG emissions from liquid fuel consumption, driven by transport, accounted for over 58% of energy sector emissions in 2015, or around 23.5% of total gross emissions. Liquid fuel emissions doubled between 1990 and the early 2000's and have been largely responsible for the rise in New Zealand's energy sector emissions. Reducing emissions from liquid fossil fuel use, particularly for transport, represent one of the few options to significantly reduce the country's emissions, as the country already has a high proportion of renewable electricity (85% in 2016), a growing population and almost half the country's emissions come from agriculture where ways to significantly reduce emissions without reducing production are challenging.

New Zealand's emissions trading scheme (ETS) is considered to be the country's key tool for reducing carbon emissions. It is based on tradable units and includes most sectors of the economy, including transport. However, agriculture, which is responsible for 49% of New Zealand's GHG emissions, currently remains outside the scheme. Carbon emissions from international aviation and shipping are also outside the scope of New Zealand's ETS.

11.2 Main drivers for biofuels policy

While all the main drivers for global growth of biofuels – environmental benefits, rural economic development and security of fuel supply – exist in New Zealand, to date only limited encouragement has been given to large-scale deployment and use of biofuels, with biofuels still making up less than 0.1% of the country's liquid fuel use. The New Zealand Energy Strategy 2011-2021 sets the strategic direction for the energy sector and the role energy will play in the New Zealand economy. This strategy has been developing renewable energy resources, as one of its two key focus areas, and biomass is recognised as a resource having considerable potential. However, biofuels do not feature prominently in this or the more recently-released New Zealand Energy Efficiency and Conservation Strategy 2017-2022.

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

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

11.3 Biofuels policy

The ETS zero-rates the biofuel component of any transport fuel, so should provide an incentive for biofuel production if the carbon prices are sufficiently high. However, the impact on consumers to date has been comparatively modest, up to about 3.1 cents per litre for petrol and 3.3 cents per litre for diesel; well within the normal range of variation in fuel prices seen at the pump as a result of fluctuations in oil price and exchange rates.

Fuel quality standards allow retail sale of blends of ethanol in fossil petrol of 10% and up to 7% blends of biodiesel in fossil diesel, although higher blends can be sold as long as there is a commercial contract or agreement in place with the customer.

Carbon emissions from international aviation (~76% of the aviation fuel offtake in New Zealand) and international use of marine fuels are not currently covered by the ETS, so this policy provides no incentive for biofuel substitution into these sectors.

11.3.1 Biofuels obligations

There is currently (Sept 2018) no mandate on biofuel use or any biofuel volume obligations.

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

11.3.2 Excise duty reductions

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

11.3.3 Fiscal incentives

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

11.3.4 Investment subsidies

There are currently no investment subsidies supporting biofuel deployment.

11.3.5 Other measures stimulating the implementation of biofuels

In spite of a limited amount of government support, a number of potential end-users remain interested in using biofuels. These include Air New Zealand, the national airline, and New Zealand Rail, the operator of the main ferry service between the two islands. While not a policy measure, such end-user interest may well stimulate biofuel production and use within New Zealand.

11.4 Promotion of advanced biofuels

There are currently no specific policies promoting advanced biofuels deployment. However, other Government funding mechanisms (e.g., Primary Growth Partnerships) can be used to support biofuel research and development (R&D) if other criteria for that fund are satisfied. For example, the Ministry of Primary Industries previously has provided substantial financial support for an industry partnership to investigate the commercial feasibility of producing liquid biofuels from forestry residues.

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

11.5 Market development and policy effectiveness

The bulk of the ethanol produced in New Zealand is produced at 3 plants, all owned by Anchor Ethanol Ltd, by fermentation of whey, a by-product of cheese making. DB Breweries and Gull (an independent fuel distributor) have entered into a partnership to produce small volumes of ethanol from a by-product of beer production.

Domestic biodiesel production was 0.6 million litres in 2015. The largest current domestic producer of biodiesel is Green Fuels, which produces biodiesel from recycled vegetable oil. Biodiesel production is set to rise in 2018, with fuel distributor Z Energy currently commissioning a 20 million litre per year plant to produce biodiesel from tallow.

Table 11-1 summarizes domestic biofuel production since 2007.

Table 11-1. Biofuel production (ML/year)

Year	Biodiesel (FAME)	Ethanol (conventional)	Cellulosic ethanol	Biogas as transportation fuel	Renewable diesel (from lipids)
2007	1.20	0.30	-	-	-
2008	1.20	0.11	-	-	-
2009	1.15	3.70	-	-	-
2010	1.61	3.10	-	-	-
2011	2.35	4.81	-	-	-
2012	1.27	5.67	-	-	-
2013	0.24	4.97	-	-	-
2014	0.90	3.25	-	-	-
2015	0.56	2.87	-	-	-
2016	0.47	4.84	-	-	-

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https://www.scionresearch.com/science/bioenergy/nz-biofuels-roadmap
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Norske Skog, Z Energy (2014) Norske Skog Tasman/Z Energy stump to pump project.
These are all domestic production figures.
2017 data is not yet available.
Some ethanol is also imported.
Some biogas is produced (2.7 – 3.3 PJ/yr), but very little of this is used for road transport.

Table 11-2 summarizes domestic fuel consumption for transport since 2007.

Table 11-2. Transport Fuel consumption (ML/year)

Year	Gasoline	Diesel fuels	Aviation fuel	Biodiesel	Ethanol	Market share of biofuels (%)
2006	3,121	1,853	478	-	-	-
2007	3,177	1,915	394	-	-	-
2008	3,126	1,952	425	-	-	-
2009	3,082	1,934	404	-	-	-
2010	3,101	2,000	396	-	-	-
2011	3,051	2,059	378	-	-	-
2012	2,985	2,077	322	-	-	-
2013	2,974	2,143	335	-	-	-
2014	2,972	2,180	335	-	-	-
2015	3,061	2,274	335	-	-	-
2016	3,124	2,350	368	-	-	-

http://www.mfe.govt.nz/climate-change/what-government-doing/climate-change-programme
https://www.scionresearch.com/science/bioenergy/nz-biofuels-roadmap
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Norske Skog, Z Energy (2014) Norske Skog Tasman/Z Energy stump to pump project.

It should be emphasized that the numbers in Table 11-2 are for total domestic transport use only. Most aviation fuel is used for international travel, with a total aviation fuel offtake in 2015 of 1,418 million litres. Consumption of biofuels is not monitored in New Zealand, but is likely to total <0.1% of total transport fuels.

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Bioenergy Association of New Zealand https://www.bioenergy.org.nz/

12. South Africa

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Summary Box

- There is no mandate for biofuel use nor any biofuel volume obligations. There is not yet a market for biofuels.
- There are no large industrial ethanol production facilities. There are some smaller biofuels production facilities, primarily to convert used vegetable oils and fats to FAME biodiesels for local consumption.
- The challenges hindering biofuel development in the country span energy security to economic and social concerns, such as impacts on food security, commodity prices, biodiversity and environmental degradation due to land use changes.
- Ethanol falls outside the fuel tax net and is 100% exempt from fuel tax. Biodiesel falls within the fuel tax net and biodiesel manufacturers receive a rebate of 50% on the general fuel levy.
- Research projects are underway at a number of South African universities on the production of biofuels, including biodiesel from algae and ethanol from lignocellulosic biomass.

12.1 Introduction

South Africa is the largest consumer of energy among Africa's 53 nations, accounting for about 31% of total primary energy consumption in Africa in 2012. The transport sector is a large consumer of energy and accounts for about one quarter of South African energy consumption. According to the BP Statistical Review of World Energy 2013, South Africa consumed an energy equivalent of 124 Mtoe in 2012, of which coal accounted for 72.5%, followed by oil (21.7%), natural gas (2.8%), nuclear (2.6%), and renewables (0.4%, primarily from hydropower). According to the US Energy Information Administration (US EIA), South Africa contributed approximately 1.4% of global CO_2 emissions and was responsible for 40% of Africa's emissions in 2011, thus making South Africa the leading CO_2 emitter in Africa and the 14th largest worldwide. South African consumption of energy has increased CO_2 emissions by 18% from 2001 to 2011.

South Africa has limited oil reserves and imports a significant amount of oil to meet the nation's oil requirements. South African proven oil reserves are about 2.4 billion litres (15 million barrels) and the total South African oil production was 28.8 million litres (181 000 bbl) per day at the end of 2012.

South Africa needs alternative sources to cope with energy security and emission issues and reduce foreign exchange spent on imported oil. Renewable fuels, such as biofuels, have the potential to extend and diversify South Africa's energy supply, which will help reduce South Africa's dependence on imported fuels and reduce its carbon footprint. Biofuels can also help South Africa to achieve its renewable energy goals, increase local energy access, uplift its agricultural sector and market as well as boost economic and rural development within the country. Biomass energy (including liquid biofuels) along with wind, solar and small-scale hydropower are considered in the South African Policy on Renewable Energy, also known as the White Paper on Renewable Energy. The country targets exploiting renewable sources to produce 10,000 GWh of renewable energy by 2013.

Nearly all of the total primary energy supply of renewable energy sources is covered by energy from biofuels and wastes (98.6%), with the remaining 1.4% is split between hydropower, solar and wind energies.

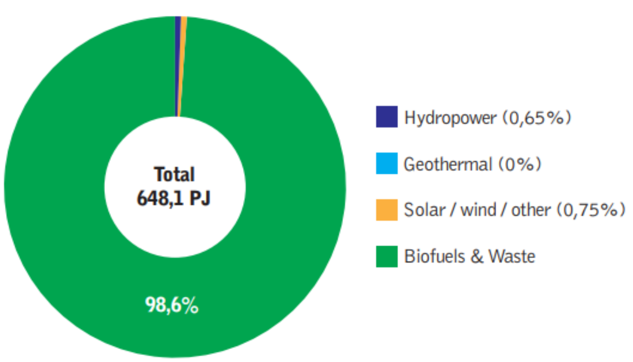

Figure 12-1. Total primary energy supply of renewable energy sources in South Africa in 2013 (Source: World Energy Balances © OECD/IEA 2015)

All of the bioenergy consumed in South Africa comes from solid biofuels (651 PJ), mostly being used in traditional ways (i.e., cooking, heating, open fire); modern boilers are not common. There are also annually approximately 12 PJ of charcoal exports.

12.2 Main drivers for biofuels policy

In South Africa, the primary drivers for biofuels production are job creation, supporting the agricultural industry and rural development (Department of Energy, State of Renewable Energy in South Africa: http://www.energy.gov.za/files/media/Pub/State-of-Renewable-Energy-in-South-Africa.pdf).

South Africa had record corn harvests in the early 2000s and with deregulation of the corn price, farmers faced hardship. A group of farmers visited the US and after examining its biofuels industry wanted to initiate several biofuel projects in South Africa. The government initiated the Biofuels Industrial Strategy in 2006, initially suggesting a target of 4.5% biofuels penetration. However, during the publishing of the final BIS document in Dec 2007, this target was reduced to 2% after corn grain was excluded as a feedstock for biofuel production because it is considered food. This stalled the farmer initiative. South Africa still does not have a biofuels industry due to this situation in addition to many interferences by government, which wants to tightly regulate the industry to exclude established businesses, such as the sugar industry, and to use biofuels as a way to achieve job creation and uplift rural development. With no mandatory blending requirement and on-going delay publishing the final position paper on the Biofuels Regulatory Framework, the development of a domestic biofuels industry remains stalled and many would-be investors have moved elsewhere.

12.3 Biofuels policy

The Biofuels Industrial Strategy (BIS) started in 2006, proposing a draft strategic target of 4.5% biofuels share, however this target was reduced to 2% in the final strategy published in Dec 2007 because maize (i.e., corn grain) was excluded. However, the Department of Energy stalled so long on creating initiatives and making biofuels blending compulsory that most parties lost interest, especially after major existing industries, such as the sugar industry, were not allowed to participate. With relatively low oil price and no incentives from government, the biofuels strategy for the country remains stalled.

The main legislation related to biofuels includes:
1. DME, 2007. Biofuels Industrial Strategy of the Republic of South Africa.
http://www.energy.gov.za/files/esources/renewables/biofuels_indus_strat.pdf(2).pdf
2. DoE. 2012. Regulations regarding the Mandatory Blending of Biofuels with Petrol and Diesel. Department of Energy. http://www.energy.gov.za/files/policies/Mandatory%20Blending%20Regulations%2024%20 August%202012.pdf
3. DoE. 2014. Draft Position Paper on the South African Biofuels Regulatory Framework. Department of Energy. http://www.gov.za/documents/national-energy-act-regulations-position-paper-south-african-biofuels-regulatory-framework. The final positions paper has not been published – there are discussions to present it for approval to the Cabinet in March 2019.

In summary, biofuel development has stalled legislatively and biofuel is yet to be commercially produced at a large scale. The challenges hindering biofuel development in South Africa include energy security to economic and social concerns, such as impacts on food security, commodity prices, biodiversity and environmental degradation due to land use changes.

12.3.1 Biofuels targets

The development of the South African Biofuels Regulatory Framework was postponed in 2014, however there is renewed interest for it to be finalized in March 2019. Still, no production of advanced biofuels is on the horizon yet.

12.3.2 Excise duty reductions

Ethanol falls outside the fuel tax net and is therefore 100% exempt from fuel tax. Biodiesel falls within the fuel tax net, and biodiesel manufacturers receive a rebate of 50% on the general fuel levy. The South African Biofuels Association and other stakeholders have requested further incentives to stimulate the industry and rapid implementation of biofuels policy. Lack of incentives continues to hamper the development of the biofuels industry in South Africa.

12.3.3 Fiscal incentives

This is the main challenge area, since the government is hesitant to commit to financial incentives, without which the industry remains stalled. Failure to publish the final position paper on the Regulatory Framework has stalled all developments in biofuels because without incentives, the industry will not develop. The proposed incentive in the draft position paper had suggested a 15% guaranteed return on assets for biofuels producers.

12.3.4 Investment subsidies

Not available.

12.4 Promotion of advanced biofuels

Research projects are underway at a number of South African universities on the production of biofuels, including biodiesel from algae (University of the Western Cape, Durban University of Technology, University of the North West and University of Cape Town) and ethanol from biomass (Stellenbosch, Rhodes, Free State Universities). Significant progress has been made in the conversion of cellulosic feedstocks, such as agricultural residues, to biofuels at Stellenbosch University.

When advanced biofuel technologies such as cellulosic ethanol come to fruition and 50% of the residual lignocellulosic biomass (almost 50 Mt on an annual basis) is used, biofuels could play a significant role in South Africa’s transport fuel future. If integrated biomass-to-liquid fuels (BtL) technologies (using biochemical and/or thermochemical conversion processes) are used, the contribution from biofuels could represent 25% from agricultural residues, 8.2% from forestry residues, 26% from burned grasses, and 10.8% from invasive plants. The production of biofuels from 50% of available lignocellulosic biomass could potentially replace 70% of current fossil fuel usage, which would far exceed the expectations of the BIS if advanced technologies are realized.

In South Africa, the Boeing Company is working on identifying biofuel feedstocks that could be used to produce sustainable aviation fuel (SAF). Boeing is collaborating with the South African government, South African Airways (SAA), the Roundtable on Sustainable Biomaterials (RSB), the World Wide Fund for Nature (WWF), and SKYNRG on this initiative. The feedstock of choice is tobacco plants grown in the Marble Hall region in Limpopo, South Africa. In July 2016, South African Airways (SAA) and low-cost carrier Mango celebrated Africa's first sustainable biofuel flight. The SAA and Mango flights from Johannesburg to Cape Town, operated by a Boeing 737-800, used SAF produced from Sunchem's nicotine-free tobacco plant Solaris, and subsequently refined by AltAir Fuels and supplied by SkyNRG.

12.5 Market development and policy effectiveness

Currently, there is no market for biofuels. If previously proposed government policies are finalized, the market share will become 2%, representing a market demand of 400 million liters biofuels per annum.

Mandatory biofuels blending was proposed by the Department of Energy on 23 August 2012: As of 1 October 2015, the minimum concentration for biodiesel blending would have been 5%; for bio-ethanol, there would be a minimum blending level of 2% and a maximum of 10%. The Department of Energy's draft position paper on the South African Biofuels Regulatory Framework proposed in January 2014 an incentive of a guaranteed return on assets of 15% for biofuels manufacturers. The department undertook to publish the final position paper later the same year, however as of early 2016 this paper has not been published. In the meantime, eight licenses for major biofuel manufacturers have been granted or issued that together would already cover the proposed mandatory target for 1 October 2015. However, with this position paper not yet published, none of the manufacturers have committed to build commercial plants yet so mandatory blending cannot commence. Thus, the biofuels industry in South Africa remains undeveloped. There are no industrial ethanol production facilities yet. Some small facilities exist, primarily to convert used vegetable oils and fats to FAME biodiesels for local consumption.

Table 12-1 summarizes biofuel mandates since 2010.

Table 12-1. Biofuels mandates

Year	Ethanol	Biodiesel	Other advanced fuels)
2010	-	-	-
2011	-	-	-
2012	-	-	-
2013	-	-	-
2014	-	-	-
2015	2%	5%	Mandatory blending should have been initiated Oct 2015, but with no incentives, industry is stalled
2016	-	-	-
2017	-	-	-

Table 12-2 summarizes domestic fuel consumption for transport since 2006.

Table 12-2. Summary of transport fuel consumption (ML/year)

Year	Gasoline	Diesel fuels	Aviation fuel	Biodiesel	Ethanol	Market share of biofuels (%)
2006	11,279	8,708	2,260	-	-	-
2007	11,558	9,755	2,402	-	-	-
2008	11,069	9,762	2,376	-	-	-
2009	11,321	9,437	2,349	-	-	-
2010	11,455	10,170	2,308	-	-	-
2011	11,963	11,225	2,434	-	-	-
2012	11,714	11,262	2,367	-	-	-
2013	11,153	11,890	2,223	-	-	-
2014	11,344	13,169	2,197	-	-	-
2015	12,072	14,178	2,441	-	-	-
2016	10,160	10,846	2,121	-	-	-

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13. **South Korea**

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Summary Box

- The main drivers for biofuel production are the National GHG Reduction Target and the Renewable Fuel Standard (RFS).
- The biodiesel blending level into conventional diesel, which had been 2% (B2), since July 2015 has increased to 2.5% and will increase to 3.0% from 2018 to 2020.
- Ethanol blending is being evaluated at E3 and E5 levels for compatibility with current Korean infrastructure. Biomethane is also under evaluation.
- The share of biofuels for transport is modest at 1.4%.
- Funding programs are available to support R&D for projects such as ethanol and biodiesel from algae however there is no financial assistance in the form of loan guarantees or grants.
- Significant efforts are dedicated to commercializing algal biofuels. Due to limited availability of land, algal biofuels are regarded as a promising option to meet the country's implementation target for transport biofuels.

13.1 Introduction

South Korea is the fifth largest petroleum importer in the world and the tenth largest CO_2 emitter in the world, emitting 550 million tons in 2007. The National GHG Reduction Target (2015) was set to reduce emissions by 37% from business-as-usual (BAU) levels by 2030 (851 MTon down to 536 MTon). In 2010, the government introduced an emission trading scheme to start in 2013. The new government's energy policy includes increasing renewable energy to 11% of primary energy consumption by 2035, and this policy includes the Renewable Fuel Standard (RFS) being introduced in 2013 and becoming effective starting in 2015. Figure 13-1 graphically shows these two main policies that promote the production and use of biofuels in South Korea.

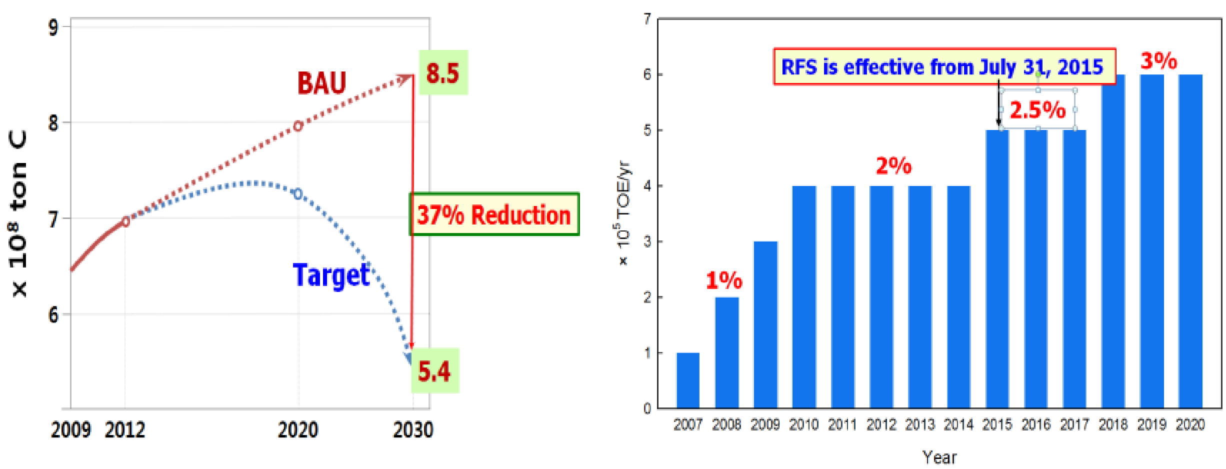

Figure 13-1. Main drivers for biofuels production and use in South Korea: National GHG Reduction Target (left) and Renewable Fuel Standards (RFS) (right)

The share of renewable energy in South Korea was about 4.7% in 2016. The total primary energy supplied by renewable energy sources was dominated by energy from biomass which alone accounted for 75% (135 PJ) of combined renewable energy production. Solar energy contributed 11% (19 PJ), with the balance spread between hydropower (10 PJ), geothermal energy (7 PJ), wind energy (6 PJ) plus a small fraction of tide, wave and ocean energy (2 PJ). Over half of the bioenergy comes from solid biomass (77 PJ), of which around 6 PJ is consumed in the residential sector. Biodiesel accounts for 21 PJ (15%), other liquid biofuels for 15 PJ (11%), renewable municipal solid waste (MSW) for 16 PJ (12%), and biogas for 7 PJ (5%), as shown in Figure 13-2.

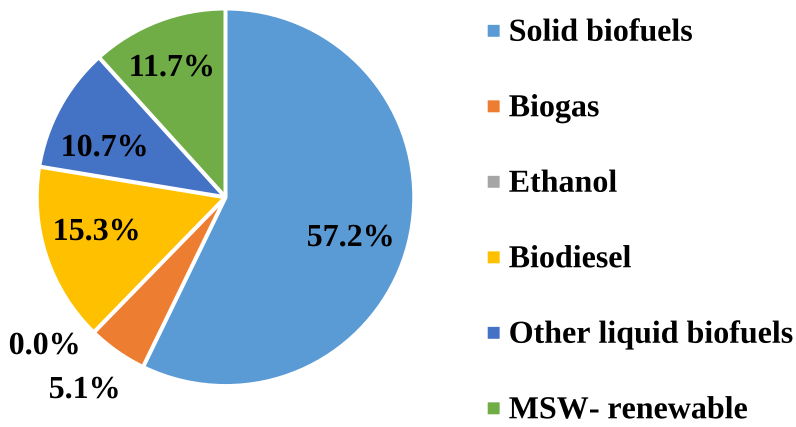

Figure 13-2. Total primary energy supply from bioenergy in South Korea in 2016 (135 PJ) (Source: World Energy Balances © OECS/IEA 2018)

Approximately 19% of energy consumption is for transportation. The share of renewables in primary energy is expected to increase four-fold from 2012 to 2035, with the total bioenergy share increasing by a factor of 4.8 over this same period.

In terms of feedstock, over 50% needs to be sourced domestically. Based on current biomass supplies, significant sourcing from other countries would still be needed. In response, research and development efforts have focused on options including algae for both ethanol and biodiesel production. As the strategy for securing a stable biomass supply, the South Korean government is investigating three options:

1) Utilize domestically available biomass (i.e., organic wastes, agricultural and forestry residues),
2) Identify new biomass feedstocks (i.e., aquatic biomasses, energy crops),
3) Source foreign biomass (e.g., plantation residues).

13.2 Main drivers for biofuels policy

In 2008, the Government's Energy Policy emphasized Low Carbon Green Growth and identified green technology development as the new growth engine to improve the quality of life and to contribute to global progress. Core green technologies of this Green New Deal include photovoltaics, wind, fuel cells, integrated gasification combined cycle (IGCC) and nuclear, while "clean fossil fuels" of interest include those that can be used in clean fuel cells or enable carbon capture and sequestration (CCS). Energy efficiency, smart grid, LED, energy storage, combined heat and power (CHP), and heat pumps were also identified as important technologies.

13.3 Biofuels policy

13.3.1 Biofuels targets

The main driver for biofuel production is the Renewable Fuel Standard (RFS) for biodiesel. Table 13-1 shows the biodiesel mandates since 2007. Since July 2015, biodiesel has been blended at a level of 2.5% into conventional diesel; the biodiesel blending level increases to 3.0% from 2018 to 2020. Oil refinery companies are responsible for meeting required fuel mixture targets and try to find the most economical way of including bio-based (non fossil) components in their fuels.

While biodiesel is currently applied as B2.5, it is expected that biodiesel blends will reach B5 by 2020. Ethanol blending is also being evaluated at E3 and E5 levels for compatibility with current South Korean infrastructure (at 4 gas stations over 1 year). In addition, biomethane is under evaluation. An option under consideration is whether local residues can be used as feedstocks or whether feedstocks will be imported. Another option is whether ethanol will be directly blended or used as ETBE. The share of biofuels within transport remains modest at 1.4%.

Table 13-1. Targets and mandates for biofuels

Year	**Biodiesel (%)**	**Ethanol (%)**
2005	-	-
2006	-	-
2007	0.5% (target)	-
2008	1.0% (target)	-
2009	1.5% (target)	-
2010	2.0% (target)	-
2012	Mandate effective for biodiesel	-
2013	Mandate for other biofuels under review	-
2020	5.0% (target)	5.0% (target)

13.3.2 Excise duty reductions

Supportive biofuel policies in South Korea have relied on a tax exemption scheme. Biodiesel was initially exempted from taxation, however since 2015 biodiesel blending mandates have replaced tax exemptions.

13.3.3 Fiscal Incentives

Not available

13.3.4 Investment subsidies

Not available

13.3.5 Other measures stimulating the implementation of biofuels

Funding programs are available for R&D such as ethanol from algae at $16 million and biodiesel from algae at $200 million but there is no financial assistance in the forms of either loan guarantees or grants. The main funding agencies are the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Korea National Science Foundation (KNSF). Major research projects focusing on biofuel production are carried out at the Advanced Biomass R&D center (2010-2019) and also on jet engine testing with bio-jet fuel (2017-2021).

13.4 Promotion of advanced biofuels

South Korea is dedicating significant efforts toward algal biofuel commercialization. Due to limited availability of land, algal biofuels are regarded as a promising option to meet South Korea's implementation target for transport biofuels. Uncertainty about the availability of algal biomass is the major barrier for commercialization of such biofuels. To improve the economics of algal biofuels production, a biorefinery-based approach based on multi-disciplinary collaboration may be required. Active R&D isbeing performed to reduce some of the technical uncertainties.

South Korea has had two major projects involving algae. The ethanol from macroalgae (*Gelidium amansii*) project ran from 2010 to the end of 2012 with a budget of $16 million. The project's objective was to establish an ethanol production pilot plant producing at levels of 400 L/day and to evaluate the cost of producing ethanol from macroalgae. This project developed a continuous saccharification process and achieved ethanol yields and concentrations of 0.2 (w/w biomass) and 3.5% (w/v). After developing and operating the pilot process (capacity: 0.4kL/day), the project was halted due to poor economic feasibility.

The longer-term project on biodiesel production from microalgae has been underway since 2010 and is expected to conclude in 2019. This $150 million project seeks to identify suitable algal strains (freshwater and marine), investigate the feasibility of low cost photobioreactors (PBR) for mass cultivation, and to demonstrate a pilot-scale production system. Sea-floating photobioreactor systems for marine microalgal culture have been developed and a pilot system is under construction, with the various unit processes (e.g., open pond, vinyl bag, harvesting, dewatering, extraction, biodiesel/green diesel conversion, utilization of residual biomass) proposed and under on-going optimization. Oil yields are currently approximately 3 $L/m^2/yr$ (for land-based systems).

13.5 Market development and policy effectiveness

Table 13-2, Table 13-3 and Table 13-4 respectively summarize South Korea's biofuel blending mandates, biofuel production capacity, and overall transport fuel consumption and biofuels' market share over the past decade.

Table 13-2. Biofuel obligations/mandates (% by volume)

Year	Ethanol	Biodiesel
2010	0	2.0
2011	0	2.0
2012	0	2.0
2013	0	2.0
2014	0	2.0
2015	0	2.5
2016	0	2.5
2017	0	2.5

Table 13-3. Biofuels production– installed production capacity (ML/year)

Year	Biodiesel (FAME)*	Ethanol (conventional)	Cellulosic ethanol	Biogas as transportation fuel	Renewable diesel (from lipids)
2006	300	-	-	-	-
2007	300	-	-	-	-
2008	600	-	-	-	-
2009	600	-	-	-	-
2010	600	-	-	-	-
2011	800	-	-	-	-
2012	800	-	-	-	-
2013	789	-	-	-	-
2014	789	-	-	-	-
2015	789	-	-	-	-
2016	869	-	-	-	-
2017	1,162	-	-	-	-

*Installed production capacity of the operating plants.

Table 13-4. Transport fuel consumption (ML/year)

Year	Gasoline	Diesel fuels	Aviation fuel	Biodiesel	Ethanol	Market share of biofuels (%)
2006	9,520	17,800	31,900	40	0	0.13
2007	9,930	18,100	33,100	100	0	0.32
2008	10,000	17,000	31,700	200	0	0.66
2009	10,400	16,500	33,300	300	0	0.99
2010	10,900	16,700	35,700	400	0	1.28
2011	11,000	16,600	36,000	400	0	1.28
2012	11,400	17,000	38,200	400	0	1.24
2013	11,600	17,900	38,600	400	0	1.19
2014	11,700	18,300	40,700	400	0	1.17
2015	12,200	19,800	43,500	500	0	1.38
2016	12,600	21,100	46,500	500	0	1.30

Source: KEEI, http://www.keei.re.kr/main.nsf/index.html

Currently, there are 15 biodiesel producers with a combined production capacity of 1,044 ML/y, with primary feedstocks being palm oil (48%), used cooking oil (28%), soybean oil (23%), and rapeseed oil (1%). Table 13-5 shows lists the biodiesel producers in South Korea. There are no ethanol, renewable diesel or other advanced biofuel production facilities in the country.

Table 13-5. List of biodiesel producers in South Korea

Biodiesel Plant	Location	Installed capacity (ML/year)	Feedstock	Status
M Energy	Pyongtaek	148	Used cooking oil	Mothballed
Danseok Industry	Siheung Pyongtaek	113 180	Vegetable oil, used cooking oil	In production
Emac Bio	Soonchun Jeongeup	50 32	Used cooking oil	In production
SK Chemcial.	Ulsan	227	Palm fatty acid distillate (PFAD)	In production
JC Chemical	Ulsan	120	Used cooking oil	In production
Aekyung Petrochem	Ulsan	200	Used cooking oil	In production
GS Bio	Yeosu	120	Vegetable oil, used cooking oil	In production
Eco solution	Jeongeup	120	Used cooking oil, tallow	In production
Bioenergy Holdings	Yeoju	60	Used cooking oil, tallow	Mothballed
Total		1,370		

Source: Korea Bioenergy Association (KBEA), 2016.

South Korea's limited biomass resources coupled with the relatively high cost of producing biofuels are major barriers to achieving the country's 2035 implementation targets. To solve this dilemma, a systematic approach for identifying and mass producing or aggregating novel biomass residues such as algae and plantation residues is now being undertaken. Research activities are also targeting the commercialization of advanced biofuels. With all these efforts, biofuels are expected to be cost competitive by 2020 and as a result, South Korea may be successful achieving its 2035 bioenergy implementation target.

13.6 Sources

IEA Bioenergy- Country reports, 2018. Republican of Korea– 2018 update Bioenergy policies and status of implementation.

http://www.egnret.ewg.apec.org/meetings/egnret36/EP3A-%20EGNRET_Korea%20Presentation.pdf

http://www.4thintegrationconference.com/downloads/Session%201-6_Konkuk%20University_Park.pdf

14. **Sweden**

Tomas Ekbom, Swedish Bioenergy Association
Leif Jonsson, Umea University

Summary Box

- The main legislation impacting biofuels are a tax exemption on biofuels distributed as transport fuels and a "pump law" on distribution of biofuels. The tax exemption has varied from full to reduced tax exemption however starting in January 2018 all biofuels are fully exempted from the fuel tax.
- A quota mandate system has been in place since July 2018. This policy mandates emissions reductions for petrol and diesel sectors, targeting reductions of 2.6% for petrol and 19.3% for diesel by December 2018. In 2020, these reduction targets will increase to 4.2% for petrol and 21.0% for diesel.
- Biofuels for transport has expanded quickly in the market in recent years and in 2016 biofuels accounted for 18.8% of all transport fuels sold compared to 5.1% in 2011. The largest share biofuel was HVO fuel, which accounted for two thirds of all biofuels sold, equivalent to 25% of all diesel sold.

14.1 Introduction

In 2012, the share of renewable energy in Sweden surpassed the EU Renewable Energy Directive (2009/28EC) target of 49%, as well as the Swedish parliament national overall renewable energy target of 50%. In addition, it should be noted that by 2011 Sweden had already met its binding 10% national target for renewable energy in transport (all EU Member States have this transport target). Sweden has opted not to divide its renewable energy target into subtargets by sector.

Apart from the targets set by the EU RED, Sweden has no specific targets for bioenergy. However, general policy aims for a fossil free society by 2050, and the new government in 2014 declared that Sweden shall become a “fossil free welfare state”. In 2016, the framework agreement on energy stated, “At the latest in the year 2045, Sweden shall have no net emissions of greenhouse gases to the atmosphere, and will thereafter achieve negative emissions”. In addition, the Swedish parliament decided in 2009 that Sweden’s vehicle fleet shall be fossil fuel independent by 2030.

As shown in Figure 14-1, bioenergy production at 485 PJ represents 63% of total primary energy supply from renewable energy sources, followed by hydropower (222 PJ, 29%) and wind energy (56 PJ, 7%); the role of solar energy is marginal.

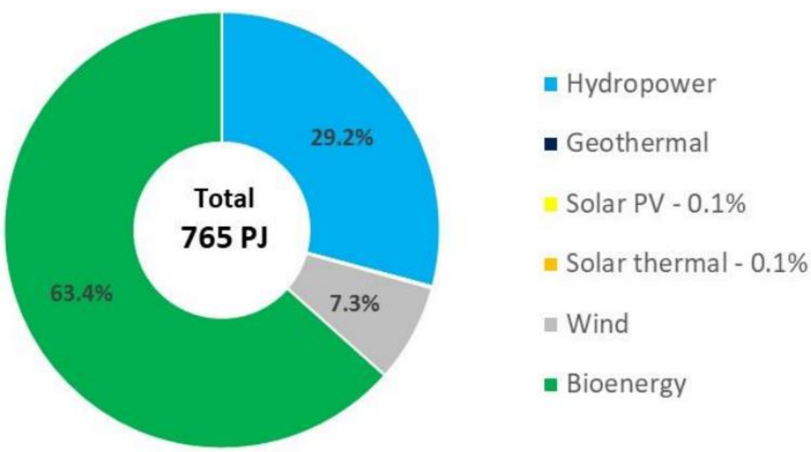

Figure 14-1. Total primary energy supply from renewable energy in Sweden in 2016 (Source: World Energy Balances © OECS/IEA 2018)

As shown in Figure 14-2, bioenergy in Sweden is predominantly produced from solid biomass, with a share of 81% (394 PJ), mostly in forest based industries (using chips, bark and sawdust feedstocks) and pulp and paper industries (using black liquor as feedstock), where it is used to produce process heat and electricity. It should be noted that black liquor (158 PJ) is counted in the category of solid biofuels. Another 38 PJ of bioenergy from solid biomass is used in the residential sector. Apart from solid biomass, the next largest contributor to bioenergy production is biodiesel (41 PJ), followed by renewable MSW (35 PJ) and smaller shares of biogas (7.3 PJ), biogasoline (ethanol) (4.7 PJ) and other liquid biofuels (3.1 PJ).

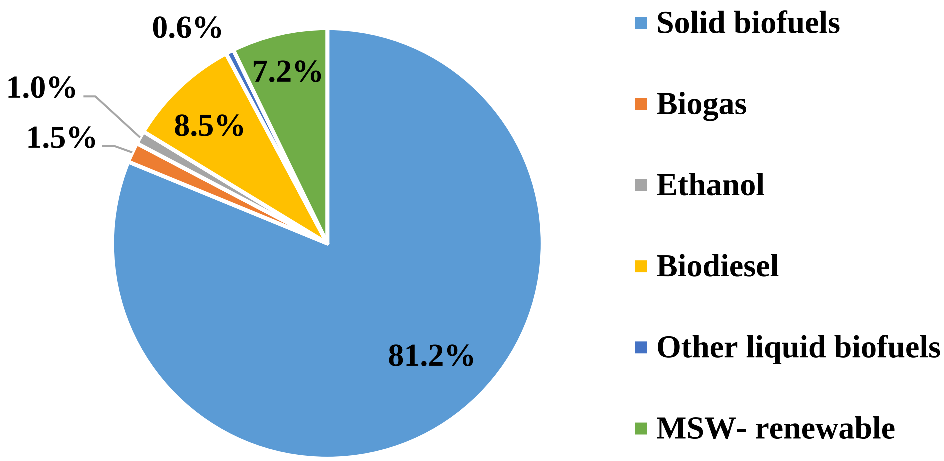

Figure 14-2. Total primary energy supply from bioenergy in Sweden in 2016 (485 PJ) (Source: World Energy Balances © OECS/IEA 2018)

14.2 Main drivers for biofuels policy

The main drivers for biofuels are climate change mitigation and reduction of carbon emissions. Other important drivers are energy security, technology development for a circular bioeconomy and job creation. Sustainability is of utmost important in policies for energy and the environment. http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/

14.3 Biofuels policy

14.3.1 Biofuels obligations

Transport fuels are subjected to an energy tax and a carbon tax as well as a value-added tax (VAT). The VAT (25%) is added to the total sum which means that the taxes are also subject to VAT. The energy tax has been revised every year to remain above the minimum tax on fuels set by the European Union 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 over-compensating some fuels, e.g., ethanol E85 and Rapeseed Methyl Esters (RME) from 2015. Since January 2018, this policy has been reversed and all biofuels are once again fully tax exempt.

Since July 2018, a quota mandate system has been in place with emissions reduction targets for petrol and diesel. This policy mandates a reduction in carbon dioxide emissions of 2.6% for petrol and 19.3% for diesel by December 2018. These targets increase in 2020 to 4.2% emissions reduction for petrol and 21.0% for diesel. Highly concentrated biofuels such as bio-CNG, E85, HVO100, B100 and others outside the petrol and diesel standard are not included and enjoy full tax exemption, at least through 2020.

In addition, there are longstanding policies on vehicles to incentivize efficiency, i.e., such as classifying cars based on their environmental performance for elibibility to receive bonuses or

other benefits, that have impacted biofuel consumption. There are other initiatives that have also had impacts but the these are the most important and relevant.
http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/

The reduction quota obligation for petrol and diesel and full tax exemption on high-blend, highly concentrated biofuels came into effect in July 2018. The 2030 goal is to achieve a 70% reduction in carbon emissions and an approximate biofuels 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 14-1.

Table 14-1. Reduction quota system with mandated reduced carbon emissions for each fuel type.

Reduction	**July 2018**	**January 2019**	**January 2020**	**January 2021**
Petrol	2.6%	2.6%	4.2%	?
Diesel	19.3%	20.0%	21.0%	?

http://www.regeringen.se/artiklar/2017/09/bonusmalus-och-branslebytet/
http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/

It is noted that a state investigation is on-going about proposing policy for increased production and use of biojet fuels in Sweden.

14.3.2 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. 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).
http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/

The gasoline/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.

14.3.3 Fiscal incentives

The "pump law" mandates fuel retailers that have a fuel turnover above 1500 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.

14.3.4 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 Swedish Energy Agency provides 25% investment support and the Swedish Environmental Protection Agency (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 2020). The current fuel tax is €0.60 per liter gasoline or diesel.

As of July 2018, car buyers can receive a maximum SEK 60,000 bonus for certain more fuel efficient vehicles, or conversely be penalized for vehicles emitting more than 95 gCO_2/km. The penality (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 SEK100 per gram.

14.3.5 Other measures stimulating the implementation of biofuels

Various funding agencies and programmes are dedicated to supporting research on hydropower, wind power, solar cells, sustainable biomass production and conversion into district heating as well as CHP plants. Major funding agencies and sources in Sweden include the following:
Swedish Energy Agency
Swedish EPA
FORMAS
Vetenskapsrådet
Mistra-stiftelsen
KK-stiftelsen
Vinnova
http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/

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: 1) gasification of black liquor; 2) saccharification and fermentation of woody cellulose; and 3) synthesis of liquid fuels via gasification. These technologies are all considered central to advancing Sweden's current use of bioenergy. In 2018, the Swedish Energy Agency announced it was contributing €50 million to a large project to set up and operate a pilot plant to test hydrogen-based steel production, however the biomass component within this project is relatively small.

Within the Swedish Energy Agency's thermochemical biofuels program ("Termokemiska biodrivmedelsprogrammet"), there are more than 10 research projects focused on biofuels.

The largest research, development and demonstration (RD&D) project in the country in terms of production and budget is the biomass gasification and biomethane synthesis pilot demonstration plant in Gothenburg. However, this project has not been funded by the Swedish Energy Agency.

The other project funded on same terms is the RenFuel pilot plant for organic catalysis of lignin to biocrude with a capacity of 3000 tonnes per year. This biocrude is intended to be used for HVO (renewable diesel) production externally. Another large project is the Bio-DME plant in Piteå producing DME via black liquor gasification.

The Swedish EPA also has a climate 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 (i.e., pyrolysis of biomass and biogas plants) which are intended to commence plant construction in the next two years.
http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/
www.naturvardsverket.se

14.4 Promotion of advanced biofuels

Following 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 (i.e., EU sustainability criteria) and fuel quality standards. Table 14-2 lists operational and planned advanced biofuels projects in Sweden.

Table 14-2. Operational and planned advanced biofuels projects in Sweden

Name of company	**Status**	**Technology**	**Production capacity**
Gothenburg Energy	Closing	Biomass gasification for biomethane	20 MWth biomethane
Domsjö Fabriker	Operational	Cooking digester, ethanol	19.5 ML
SunPine	Operational	Tall oil separation to raw tall diesel for HVO	100 ML
Preem	Operational	Hydrogenation to HVO	200 ML
SunPine	Planned	Tall oil separation to raw tall diesel for HVO	50 ML
Preem	Planned	Hydrogenation HVO	500 ML
Södra	Planned	Separation to methanol	5 ML
Setra	Planned	Wood pyrolysis to biooil for HVO	26,000 tonnes
SCA	Planned	Tall oil separation to raw tall diesel for HVO	100 ML
St1	Planned	Hydrogenation to HVO	200 ML
RenFuel	Planned	Organic catalysis to biocrude for HVO	50 ML
Domsjö Fabriker	Planned	Biofuels	400 ML

Note: St1 in Gothenburg and Agroetanol in Norrköping use bakery wastes and grain to produce ethanol.
http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/

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 will be in the range of € 0.55 per litre gasoline equivalent (feedstock 35% of cost) at the current feedstock price for woody biomass in the region. The demonstration was finalized in March 2018 and the plant is at present maintained to be able to be recommissioned if the right market condition develop. 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 tall oil to produce HVO on a commercial scale (100,000 tonnes/year) at its new factory in Piteå. Preem and Vattenfall recently published plans to use electrolysis to produce the hydrogen gas used for HVO production. Preem and RenFuel are assessing, in collaboration with Rottneros, the construction of the world's first lignin plant for biofuels, at a pulp mill in Vallvik, Söderhamn. This plant is expected to produce an annual volume of 25,000-30,000 tonnes of lignin, and will be completed in 2021.

14.5 Market development and policy effectiveness

Biofuels for transport has expanded quickly in recent years as shown in Table 14-3. In 2016, biofuels accounted for 18.6% 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.

Table 14-3. Transport fuel consumption (ML) and biofuels market share (%), 2006-2017

Year	Gasoline	Diesel fuels*	Aviation fuel	Biodiesel	Ethanol	Biofuels market share (%)
2006	5,128	3,654	251	66	324	3.1
2007	5,049	3,774	251	132	376	4.1
2008	4,691	3,794	231	165	427	5.0
2009	4,602	3,704	201	210	393	5.4
2010	4,322	4,055	191	232	393	5.8
2011	3,997	4,146	211	298	410	6.9
2012	3,661	4,025	211	408	393	8.4
2013	3,460	3,965	211	596	359	10.3
2014	3,325	3,865	211	894	324	13.4
2015	3,191	3,945	201	1,158	256	15.7
2016	3,236	4,577	221	1,611	222	18.6
2017	3,101	4,608	-	1,854	205	20.8

*Diesel fuels exclude heating oils.
http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/

Table 14-4 shows Sweden's biofuel mandates. There is a ethanol mandate for E5. While E10 is also technically possible, it is not pursued by gasoline 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. 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 2018, that apply similarly for households and industry.

Until 2010, bioethanol was the most important liquid biofuel in Sweden. Since then it has lost market share. 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 (from 1.2 PJ in 2005 to 7.3 PJ in 2016).

Table 14-4. Biofuel obligations/mandates (% by volume)

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 not obligated, only B5.
2011	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated. B7 is allowed but not obligated, only B5.
2012	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated. B7 is allowed but not obligated, only B5.
2013	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated. B7 is allowed but not obligated, only B5.
2014	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated. B7 is allowed but not obligated, only B5.
2015	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated. B7 is allowed but not obligated, only B5.
2016	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated. B7 is allowed but not obligated, only B5.
2017	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated. B7 is allowed but not obligated, only B5.
2018	5 vol.%	5 vol.%	E10 is allowed but only E5 obligated. B7 is allowed but not obligated, only B5.

http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/

There are two ethanol plants in Sweden, the St1 Refinery in Gothenburg with a 5 ML/year capacity (raw material is bakery waste) and the Agroetanol plant in Norrköping with a capacity of 230 ML/year; during some years one production line was closed and the capacity was 160 ML/year (initial start-up production capacity). Perstorp in Stenungsund have capacity today to produce 155 ML RME (FAME biodiesel) per year. Ecobränsle in Karlshamn have capacity to produce 55 ML RME/year. There are also a number of very small plants where farmers produce FAME for their own or local consumption.

Sunpine in Piteå produces 100 ML Raw Tall Diesel (RTD) per year. In 2020, one more plant with an additional 50 ML RTD per year capacity will come 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 14-5 summarizes biofuels production capacities.

Table 14-5. Biofuel production – installed production capacity (ML/year), 2006-2017

Year	**Biodiesel (FAME)**	**Ethanol (conventional)**	**Cellulosic ethanol**	**Biogas as transportation fuel (consumption)**	**Renewable diesel (from lipids)**	**Other advanced biofuels**
2006	55	230	19.5	0.2 TWh	0	1)
2007	55	230	19.5	0.3 TWh	0	1)
2008	203	230	19.5	0.3 TWh	0	1)
2009	203	230	19.5	0.4 TWh	0	1)
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 very small in comparison with other Swedish biofuels plants) and 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.
http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/

14.6 Sources

IEA Bioenergy - Country reports, 2018. Sweden– 2018 update Bioenergy policies and status of implementation.

Websites sourced:
http://www.energimyndigheten.se/fornybart/hallbarhetskriterier/
www.svebio.se
www.naturvardsverket.se
www.scb.se

15. **United States**

James D. McMillan, National Renewable Energy Laboratory

Summary Box

- The federal RFS2 is the primary policy encouraging biofuels use in the United States. Besides the RFS2, another strong policy driving increased biofuels production and use in the US is California's Low-Carbon Fuel Standard (LCFS).
- Compared to the RFS2 program in which there are volumetric mandates for renewable fuels, California's LCFS is fuels agnostic and incents low carbon fuels, with credits or deficits generated based on a fuel's carbon intensity.
- In addition to federal and state legislations supporting the production and use of biofuels to help decarbonize the US's transportation sector, increasing Corporate Average Fuel Economy (CAFÉ) standards have been contributing to the decarbonization of the transportation sector by reducing energy consumption through higher fuel economy of light duty vehicles (cars and trucks).
- There are also blenders credits 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.
- In 2017, a total of 15.8 billion gallons (59.8 billion liters) of fuel ethanol was produced and diesel biofuels production reached about 2.5 billion gallons (9.5 billion liters). Total production of renewable diesel, cellulosic biofuels, and biojet in 2017 was 453, 10, and 1.7 million gallons (1715, 38, 6.5 million liters), respectively.

15.1 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 15-1, 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).

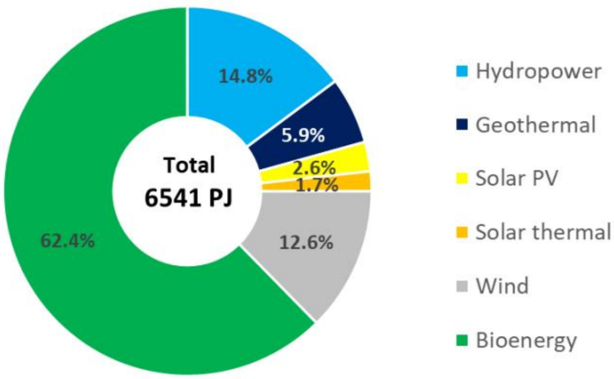

Figure 15-1. Total primary energy supply from renewable energy in the US in 2016 (Source: World Energy Balances © OECS/IEA 2018)

Figure 15-2 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.

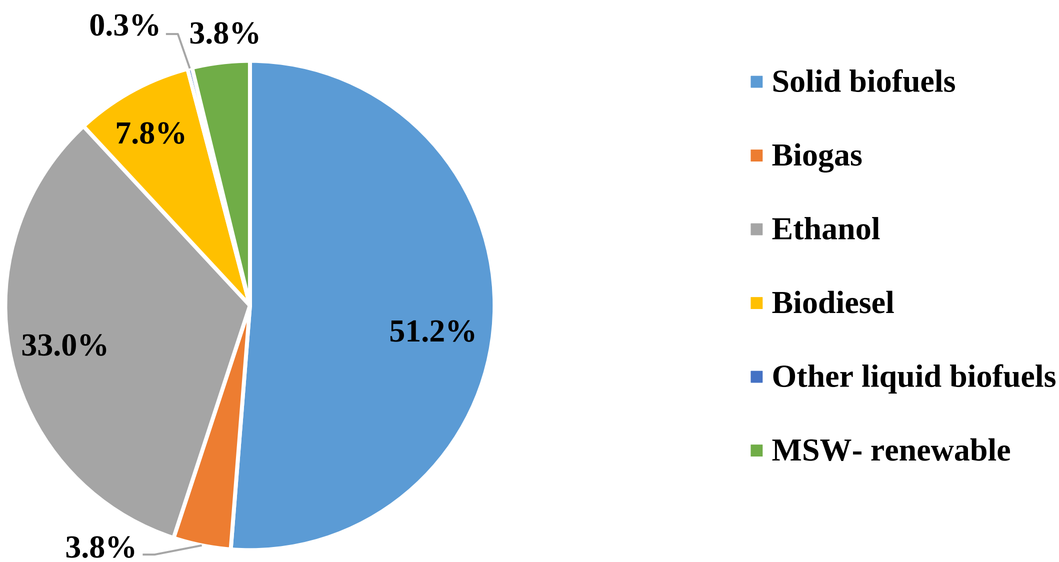

Figure 15-2. Distribution of total primary energy supply from bioenergy in the US in 2016. Total bioenergy supply in the US in 2016 was 4079 PJ. (Source: World Energy Balances © OECS/IEA 2018)

15.2 Main drivers for biofuels policy

The main drivers currently are job creation, rural development and energy security, together bundled as "advancing a thriving bioeconomy." (https://energy.gov/eere/bioenergy). 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.

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.

15.3 Biofuels policy

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 (EIA, 2018). As shown in Figure 15-3, 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 US energy exports.

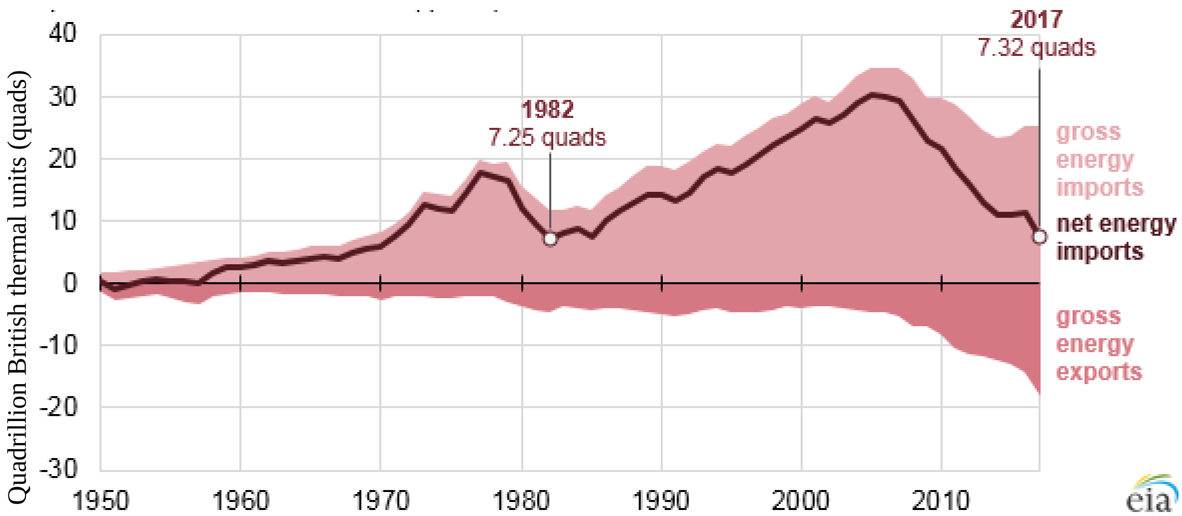

Figure 15-3. US gross and net energy trade (1950-2017)

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 won't likely change until the future of both the federal renewable fuel standard (RFS2) and the corporate average fuel economy (CAFÉ) 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.

15.3.1 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 Renewable Fuels Standard (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 15-4, this comprises 15 BGY of conventional corn starch-based ethanol (~ 57 billion liters) and 21 BGY of advanced, cellulosic and biodiesel biofuels (~ 80 billion liters) (i.e., 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 15-1 shows the four categories of renewable fuels mandated under the RFS program.

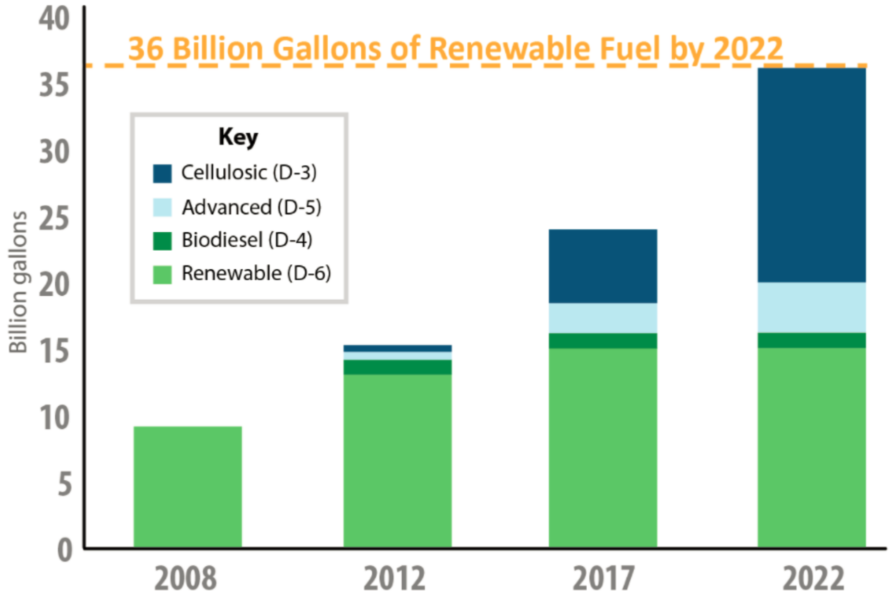

Figure 15-4. Volume targets for renewable fuels under revised RFS2 as orginally enacted in 2007.

Table 15-1. Renewable fuels categories under the RFS program

Category	**Code**	**Minimum GHG reduction requirement**[1]	**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

[1] compared to the petroleum baseline

In November 2018, EPA finalized volume requirements under the RFS program for 2019. Table 15-2 lists these volumes for four categories of biofuels. The volume requirements has increased for all biofuels categories. The highest change is seen in cellulosic biofuels with over 100 million gallons increase in 2019 compared to 2018.

Table 15-2. Biofuels volume requirement under EPA RFS program (Biofuels Digest, 2019)

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%

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

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 "Renewable Identification Numbers" (RINs) 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 gasoline and diesel fuel 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: 1) "assigned RINs" are directly associated with a batch of fuel and purchasers obtain both the renewable fuel and the RINs together; and 2) "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 15-5 shows a schematic of a RIN's lifecycle under the RFS program.

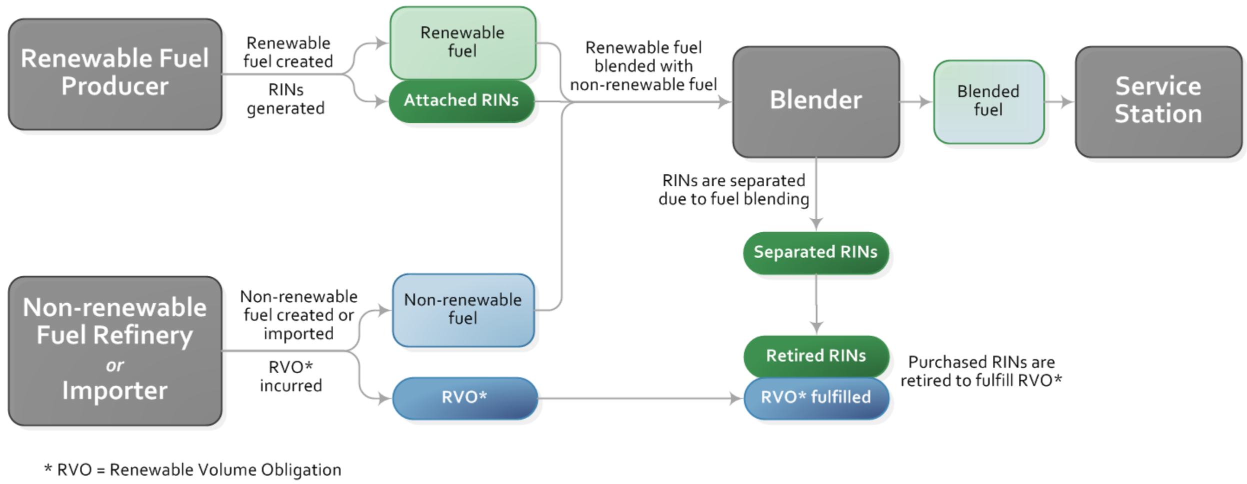

Figure 15-5. Lifecycle of a Renewable Identification Number (RIN) under RFS program (US EPA, 2017)

Besides the RFS, another strong policy driving increased biofuels production and use in the US is California's 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, biojet 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.

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\ carbon intensity (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 (i.e., 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. An overview of California's LCFS program and its history of development is provided at: https://www.arb.ca.gov/fuels/lcfs/lcfs.htm. Beyond California and structured to more broadly support bio-based production, Iowa has developed a bio-based chemicals production credit program: https://tax.iowa.gov/legislative-summaries/renewable-chemical-production-tax-credit-program).

A variety of fuels are being sold into California, but the main product is ethanol, as shown in Figure 15-6. Ethanol is coming mostly from US midwest 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., GBEP indicators) however more work is needed to develop consensus reporting requirements and certification procedures.

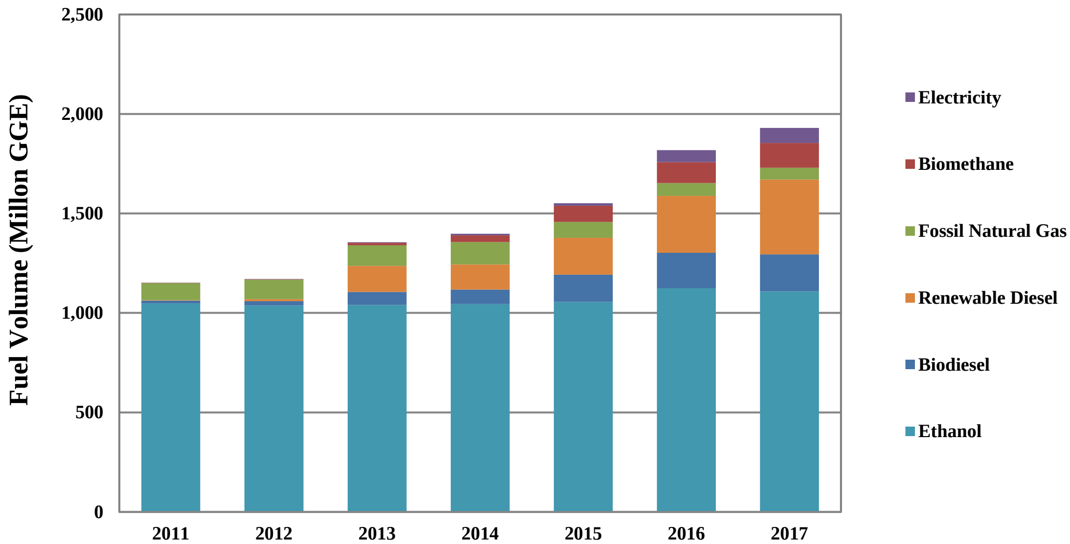

Figure 15-6. Alternative low-carbon fuel volumes used in California (California Air Resources Board, 2019)

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 Greenhouse Gases, 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, i.e., 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 indepenent 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[19].

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 midwest 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 midwest 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.

15.3.2 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 fueled vehicles, e.g., flex-fuel, in the past, but none at present except for electric or fuel cell vehicles.

15.3.3 Fiscal incentives and investment subsidies

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

[19] http://www.ethanolproducer.com/articles/15575/lcfs-matures

and emerging technologies for advanced biofuels, renewable chemicals and bio-based products by providing loan guarantees of up to $250 million for first of a kind 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. The USDOE's Alternative Fuels Data Center provides a good single site for finding/searching these many laws and incentives at both federal and state levels: https://www.afdc.energy.gov/laws.

In addition to federal and state legislations supporting the production and use of biofuels to help decarbonize the US's transportation sector, increasing Corporate Average Fuel Economy (CAFÉ) 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 CAFÉ standards have been highly effective in reducing demand for transport fuels. More information on the US's CAFE standards can be found at: https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy.

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.

15.3.4 Other measures stimulating the implementation of biofuels

The USDA and US 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. 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 municipal solid waste (MSW) and CO/CO_2 rich gases. Over the past 10 years (2007–2017), three Bioenergy Research Centers (BRCs) supported by the Genomic Science program within DOE's SC BER Office have made significant advances toward the bio-based economy. These centers are the Great Lakes Bioenergy Research Center, the Joint BioEnergy Institute, and the BioEnergy Science Center (now becoming the Center for Bioenergy Innovation). In February, a fourth DOE-funded center also began operating, the Center 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.

15.4 Promotion of advanced biofuels

Despite the substantial presence of conventional biofuels (i.e., 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 biojet 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 15-3 lists operational, under construction and planned biojet and renewable diesel production facilities in the US.

Table 15-3. Operational and planned jet fuel and renewable diesel production facilities in the US.

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 fiber being implemented in existing corn dry mills:** Ethanol production from corn fiber has become an area of active R&D and commercialization since 2014, when the EPA classified corn kernel fiber as a crop residue, with multiple routes now being commercialized to convert some or most of the corn kernel fiber byproduct 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 fiber 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 fiber (Table 15-4).

Table 15-4. List of ethanol plants approved to generate RINs from corn kernel fiber

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 (see Figure 15-7), 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.

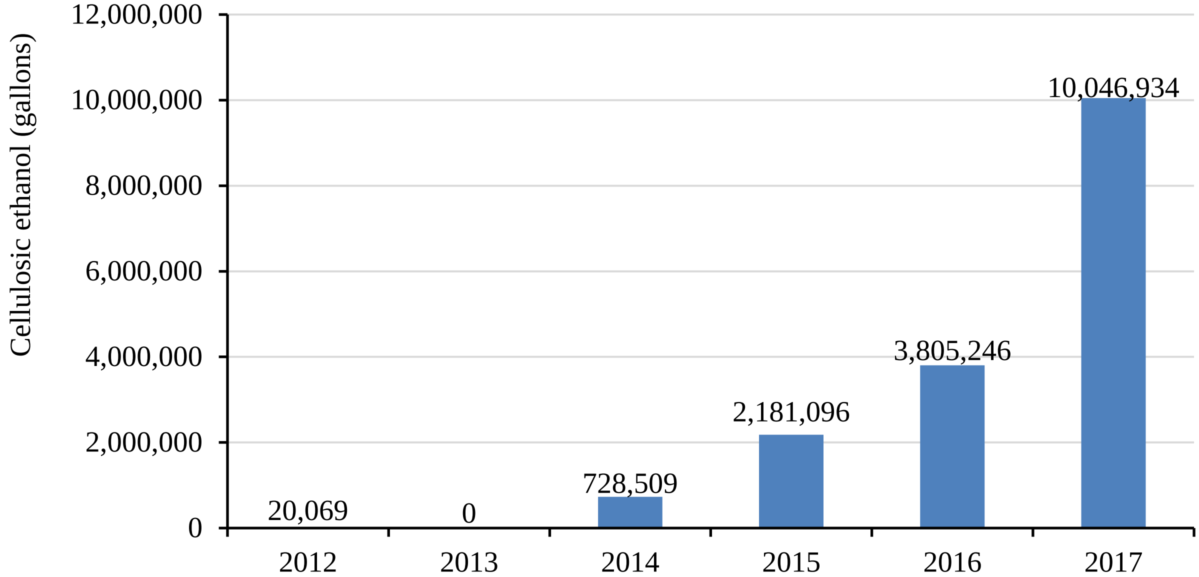

Figure 15-7. Production of cellulosic ethanol, 2012-2017 (based on EPA RIN data)

- **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.
- **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 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 run 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. More information on Co-Optima can be found at: https://www.energy.gov/eere/bioenergy/co-optimization-fuels-engines.
- **Algae-based biofuels:** Algae have significant potential to support an 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 favorable 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 biojet 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.

15.5 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. 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%).

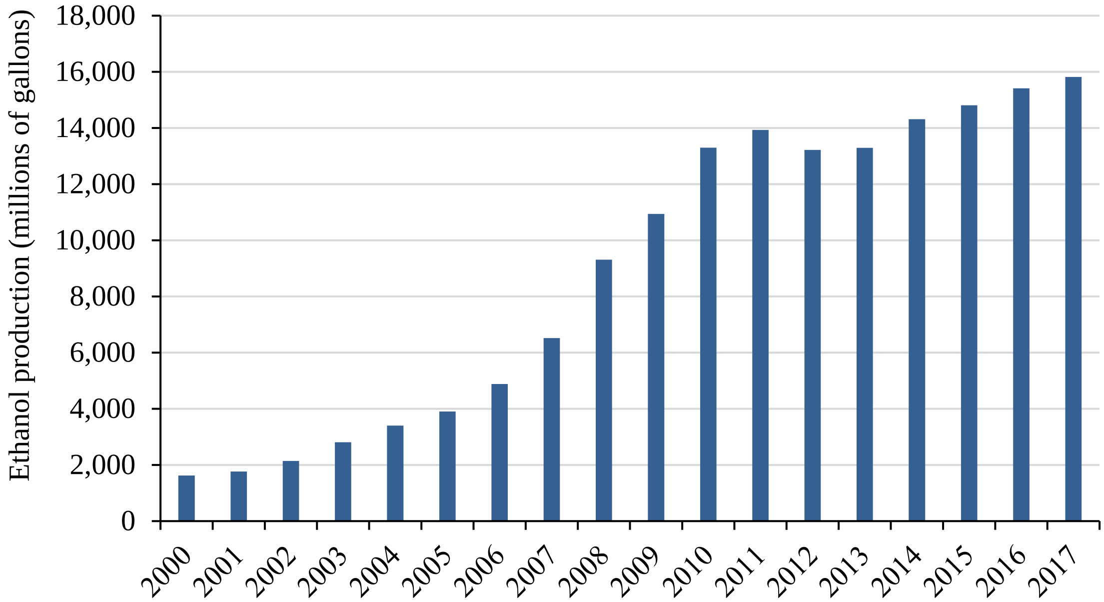

Figure 15-8. Historical production of ethanol in the US, 2000-2017

Corn is the primary feedstock for ethanol production in the US, and large corn harvests in recent years have contributed to increased production. The US Department of Agriculture (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 shown in Figure 15-9, 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.

Table 15-5 shows transport fuel consumption in the US from 2006-2017.

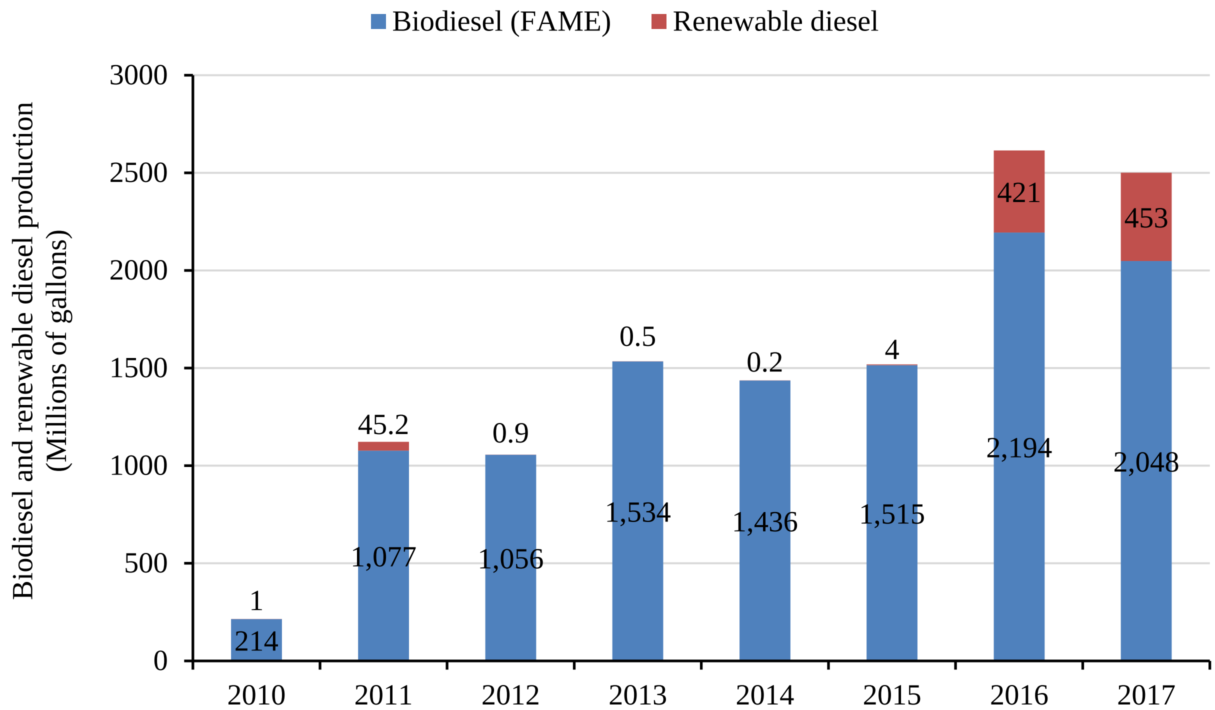

Figure 15-9. Diesel biofuel production in the US, 2010-2017 (based on EPA RIN data)

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 15-5. Summary of transport fuel consumption (ML/year)

Year	Gasoline[2]	Diesel fuels	Aviation fuel (jet only) [2]	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

[1] Based on projecting 10 month "through October 2017" results to full calendar year 2017.
[2] Aviation gasoline consumption also reported
[3] Based on projecting 11 month "through November 2017" results to full calendar year 2017
[4] https://www.eia.gov/energyexplained/?page=us_energy_transportation

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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

The Renewable Fuels Association (www.ethanolrfa.org/) maintains industry statistics. A summary table and map of ethanol-based biorefinery locations is provided at http://www.ethanolrfa.org/resources/biorefinery-locations/.

FAME biodiesel producers in the US are summarized by state by EIA at: https://www.eia.gov/biofuels/biodiesel/production/table4.pdf. Biomass magazine also has a good listing that lists specific producers (not just by state): http://www.biodieselmagazine.com/plants/listplants/USA/.

The National Biodiesel Board also has some data on total production of both FAME biodiesel and renewable diesel – see http://biodiesel.org/production/production-statistics.

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16. **China**

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Summary Box

- There is no official national mandate for using biofuels in the transportation sector.
- Ethanol blending: As of 2017, 11 provinces and cities (known as pilot provinces and cities) have been selected as fuel ethanol pilot zones for mandatory E10 blending.
- Biodiesel blending: A small trial program using 2% and 5% biodiesel blends has been carried out in some regions of China such as Hainan and Shanghai.
- The 2020 biofuels targets are to produce 12.67 billion liters of ethanol and 2.28 billion liters of biodiesel (based on the current consumption of gasoline and diesel fuels).
- There is an excise tax exemption for waste oil-based biodiesel production and export but no tax exemption for ethanol production and use. There are import tariffs on US-origin ethanol.
- The Chinese government is currently trying to integrate the country's biofuel R&D efforts at a national level. Four Chinese national biofuel research centres have recently been established with each having different research foci (e.g. biomass breeding, cultivation and logistics research, liquid biofuels, technology implementation, development and integration).
- Biofuels policy support in China distinguishes between conventional, 1.5 generation and second generation feedstocks. With policies that biofuel development should not compete for arable land designated for food crops, China promotes ethanol production based on the use of cassava, sweet sorghum, and other non-food grain feedstocks.
- China began producing commercial-scale cellulosic ethanol in 2013, but also faces the same technological challenges that have limited expansion of cellulosic ethanol production elsewhere in the world.

16.1 Introduction

China is the world's largest energy user, surpassing the US as the largest crude oil consumer in 2017. China's gasoline market is now the second largest in the world. It exceeded the EU's demand a few years ago and now is only exceeded by the US. However, unlike the U.S. market, which has slowing gasoline consumption, China's gasoline market continues to expand rapidly with year-to-year growth surpassing all other markets. Although China's transport diesel market is the third largest in the world, China's annual diesel use is growing at a rate comparable to the US and the EU, two much larger markets. In the medium- to long-term, energy analysts forecast that China's rapid expansion of gasoline and diesel demand will slow due to flatter economic growth, and saturated automotive markets in major cities (GAIN, 2018).

In 2000, China's national fleet totaled less than 20 million passenger vehicles. However, from 2005 to 2015, China's passenger car fleet increased by a factor of ten. In 2018, China surpassed the US as the largest car market in the world and now totals more than 322 million vehicles. China recognizes the strategic value of energy independence. Biofuels offer a means to stretch the economic value and efficiency of imported fuel supplies. Future prospects for China's transportation fuel demand depend on macroeconomic factors, the adoption rate of New Energy Vehicles (NEVs) such as electric cars and advanced fuel vehicles; and implementation of China's ambitious new drive to reach a national E10 fuel ethanol target (GAIN, 2018).

16.2 Main drivers for biofuels policy

Biofuels are part of China's long-term strategy to conserve resources, improve air quality, and reduce its dependence on imported fossil fuels. The increasing demand for fossil fuels has contributed to the country's increasing energy security concerns. As a result, China has taken steps to secure energy supply through various strategies such as intensive domestic exploration, investment in overseas oil companies, securing long-term contracts with suppliers of fossil fuels, such as natural gas from Russia and investing heavily in renewable forms of energy. As China's economy has rapidly grown, it has also become the world's largest CO_2 emitter and faces growing concerns over air pollution. Thus, climate change mitigation and pollution abatement, particularly in its large cities, have also become important policy drivers for the country. This is indicated by China's signing of the recent UNFCCC COP21 agreement and the country's 13th Five-Year Plan that was released in March 2016. This most recent Five-Year Plan described a large number of binding commitments to aid in environmental reform (van Dyk et al., 2016).

16.3 Biofuel Policy

Over the past two decades, through a series of four Five-Year Plans (FYPs), China has transformed itself from producing zero biofuels into the world's fourth largest producer in 2017. Throughout this period, China's policymakers have internally debated about how to manage grain prices, rural welfare, and food security. As a result, China's fuel ethanol policies often reflect the current grain stocks situation, which fluctuate between long, slow accumulations of massive grain stocks, and relatively rapid drawdowns. When stocks are building, China uses policy measures to restrict grain processing into ethanol. When stocks are liquidated, China uses other policy measures to promote a rapid expansion of national fuel ethanol production capacity and throughput (GAIN, 2018).

The key climate policy targets in China are to lower emissions per unit of GDP by 60% - 65% by 2030 below 2005 levels; to increase the share of non-fossil fuels in primary energy consumption to around 20% including 12.7 billion liters of ethanol use by 2020 (Biofuture platform, 2018). Although the Chinese government has set ambitious targets of producing 12.7 billion litres of ethanol and 2.3 billion litres of biodiesel by 2020, it is highly unlikely that these production targets will be met. As an example, biofuels receive limited attention in the country's recently released 13th Five-Year Plan.

The guidance documents on fuel ethanol and biodiesel development in China are summarized in Table 16-1.

16.3.1 Biofuels obligations

In 2007, the Chinese government established biofuels production targets for the first time under the Medium and Long Term Development Plan for Renewable Energy (NDRC, 2007; van Dyk et al., 2016). One goal was to produce 2 million tons of ethanol (≈ 2.53 billion liters) and 0.2 million tons (≈ 0.23 billion liters) of biodiesel by 2010. The 2007 Medium and Long Term Development Plan for Renewable Energy also established the important policy, applicable to both ethanol and biodiesel, that domestic production of feedstocks for biofuels should not compete with land needed for food or feed production and must not inflict harm to the environment ((NDRC, 2007; van Dyk et al., 2016). The 12th Five Year Plan covering the period of 2011-2015 targeted production of 4 million tons (≈ 5.1 billion liters) of ethanol by 2015. However, this target was not achieved (China, 2011; van Dyk et al., 2016).

The recent targets are set for 2020 to produce 10 million tons (≈ 12.67 billion liters) of ethanol (E10) and 2 million tons (≈ 2.28 billion liters) of biodiesel. China's latest E10 target is planned to follow an incremental expansion by pilot provinces and cities until the program is implemented nationwide. As of 2017, 11 provinces and cities were selected as fuel ethanol pilot zones for mandatory E10 blending (Figure 16-1). In September 2017, a joint ministerial announcement publicized a nationwide target for the adoption of E10 ethanol-gasoline blend use by 2020 that expands the mandatory use of E10 fuel from 11 trial provinces to the entire country by 2020. Beyond environmental benefits, a key motivation for the E10 mandate is to reduce China's large corn stockpiles, which peaked in 2015/2016 at over four billion bushels (Li, et al., 2017).

Currently, China consumes 151.42 billion liters of gasoline and 3.78 billion liters of ethanol (~2.5% of total gasoline pool). Projections show that by 2020 gasoline consumption will reach 174 billion liters (GAIN, 2017a). Meeting the national E10 mandate would require an extra 13.62 billion liters of ethanol, putting China ahead of the EU to become the world's third-largest ethanol consumer. Since details of the mandate have not been disclosed, it is not yet clear how China will generate more than four-fold output growth within three years. Currently, production capacity utilization rate is about 85% (GAIN, 2017a), therefore a short-term production spur can be achieved with existing facilities. Beyond that, a dramatic increase in capacity is needed. Since it takes one to two years to build a large scale generation 1 or 1.5 refinery in China, it is possible that China will be able to construct the physical facilities in time (Li, et al., 2017).

Table 16-1. Guidance documents on fuel ethanol and biodiesel development in China (Hao et al., 2018)

Year	Policy document	Highlight contents
2002	Dedicated plan on the development of fuel ethanol and ethanol gasoline during the tenth five-year planning period	• The scale of fuel ethanol use is planned to reach 1.02 million tons (Mt) (1.29 billion liters) during the tenth five-year planning period
2002	Planning on the pilot demonstration of ethanol gasoline use	• The pilot cities are Zhengzhou, Luoyang, Nanyang in Henan province, and Harbin, Zhaodong in Heilongjiang province • The fuel ethanol for the demonstration in Henan province is provided by Tianguan Group LLC; the fuel ethanol for the demonstration in Heilongjiang province is provided by Jinyu Group LLC • The retail price of ethanol gasoline is the same with pure gasoline with the same grade
2004	Planning on expanding the demonstration of ethanol gasoline use	• The pilot regions were expanded to cover five provinces (Heilongjiang, Jilin, Liaoning, Henan, Anhui) and 27 cities in other four provinces (Jiangsu, Shandong, Hubei, and Hebei) • Jilin fuel ethanol LLC, with the 300,000 tons (368 million liters) of fuel ethanol capacity co-established by CNPC, will be responsible for providing fuel ethanol to Jilin and Liaoning; Huarun ethanol LLC, with the 100,000 tons (126 million liters) of fuel ethanol capacity, will be responsible for providing fuel ethanol to Heilongjiang; Tianguan group LLC, with the 300,000 tons (368 million liters) of fuel ethanol capacity co-established by Sinopec, will be responsible for providing fuel ethanol to Henan, Hubei and Hebei; Fengyuan LLC, with the 320,000 tons (403 million liters) of fuel ethanol capacity co-established by Sinopec, will be responsible for providing fuel ethanol to Anhui, Shandong, Hebei and Jiangsu • The trade price between fuel ethanol producers and petroleum companies is specified to be the price of 90# gasoline multiplied by a coefficient of 0.9111 • The retail price of ethanol gasoline is the same with pure gasoline with the same grade (same with previous document)
2006	Urgent notification on strengthening the management of corn processing projects	• No new corn-based fuel ethanol projects will be approved • All existing corn-based fuel ethanol projects should be thoroughly examined regarding their land use, environmental impacts and financial conditions
2006	Notification on strengthening the management of fuel ethanol projects, and promoting the healthy development of fuel ethanol industry	• Non-food crops are prioritized as the feedstock for fuel ethanol, with tuber crops, sugar sorghum, and cellulosic crops as focuses • The establishment and expansion of fuel ethanol capacities are strictly controlled
2007	Notification on promoting the healthy development of corn deep processing industry	• The amount of corn used for deep processing should be controlled below 26% of total corn consumption
2007	Mid-long term planning on the development of renewable energy	• By 2010, non-food crop-based fuel ethanol consumption will reach 2 Mt (2.52 billion liters); biodiesel consumption will reach 0.2 Mt (252 million liters) • By 2020, fuel ethanol consumption will reach 10 Mt (12.6 billion liters); biodiesel consumption will reach 2 Mt (2.52 billion liters)

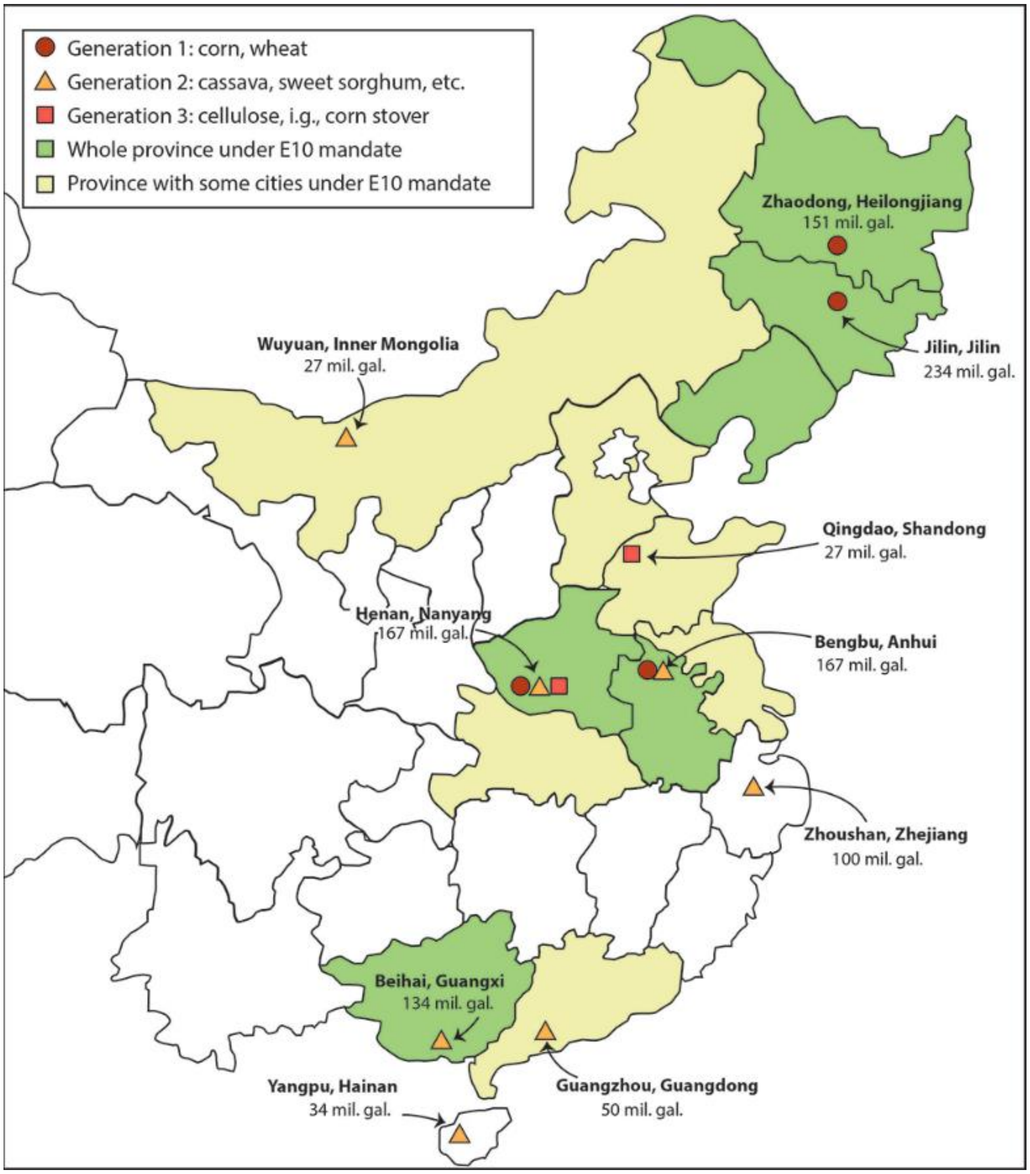

Figure 16-1. China's regional E10 mandate trial areas and ethanol refineries (annual production capacity is under location name) (Li, et al., 2017)

The government continues to emphasize that demand for feedstocks directed towards fuel ethanol production should not compete with inventories for food stocks, and promotes ethanol production using cassava, sweet sorghum and other non-food grain feedstocks. Central government production subsidies for grain-based ethanol were eliminated in 2016. Meanwhile, from October 2016 to June 2017, several provincial governments in North East China offered subsidies to state-owned ethanol processors who purchased and processed old-crop corn inventories from the State Grain Administration to produce corn starch, amino acids, industrial alcohol, and fuel ethanol (GAIN, 2018).

The government has unofficially set a target to produce 3.8 billion liters of cellulosic and non-grain based ethanol by 2020. According to China's Ministry of Agriculture, the potential collectable resource of crop residue is 687 million tons. One-third of this volume of feedstock will yield an estimated 40 to 50 million tons (50.7 to 63.4 billion liters) of cellulosic ethanol annually. 2018 advanced biofuels production is forecast at 395 million liters, up from 2017 on expanded production capacity. The implementation plan concerning the expansion of ethanol production and promotion for transportation fuel also calls for China to shift renewable fuel production to commercial scale cellulosic ethanol by 2025 (GAIN, 2017).

Biodiesel market penetration in transportation fuel is estimated at 0.2% and this is not expected to increase. Unlike ethanol, there is no official national (or even provincial) mandate for biodiesel use in the transportation sector, although a small trial program using 2% and 5% biodiesel blends was carried out in Hainan province. The state-owned oil companies, CNPC and Sinopec, control over 90% of the gas stations in China and the sale of biodiesel has not been encouraged. Thus, producers either have to sell to brokers who mix the fuel or sell it directly to end-users at small, private gas stations (van Dyk, et al., 2016).

Currently, Shanghai is the only local authority implementing a biodiesel program. In October 2017, Sinopec Shanghai began offering B5 diesel at a $0.05 per liter (0.3 yuan) discount to regular diesel as part of a pilot program. With full market maturity, Shanghai will consume as much as 682 million liters (600,000 tons) of B5 (or 34 million liters of pure B100 biodiesel) each year (GAIN, 2018). China does not apply sustainability criteria to imports or domestic use of biofuels.

16.3.2 Excise duty reductions

In terms of the taxation policy, the early published government documents specified that the excise tax for fuel ethanol production is exempted, and the Value Added Tax (VAT) for fuel ethanol production is reimbursed. However, with the change of the government's attitude towards fuel ethanol development, the tax incentive for food crop-based fuel ethanol production gradually phased out. Specifically, the VAT for food crop-based fuel ethanol production was reimbursed by 80% in 2011, 60% in 2012, 40% in 2013, 20% in 2014 and no reimbursement from 2015 on. The excise tax for food crop-based fuel ethanol production was 1% in 2011; 2% in 2012; 3% in 2013; 4% in 2014; and 5% from 2015 on. Despite this, the tax incentive for non-food crop-based fuel ethanol was retained. Regarding biodiesel, the excise tax for waste oil-based biodiesel production is exempted. In addition, the Biodiesel Industrial Development Policy released in 2014 specified that China should launch dedicated price, taxation, finance and investment incentives to promote biodiesel development (Hao, et al., 2018). Table 16-2 summarizes the taxation policy for ethanol and biodiesel since 2002.

In 2017, China's General Department of Taxation lowered the effective VAT applied to exported ethanol products from 13% to 11%. Biodiesel exports made from used animal and vegetable oils also enjoy a 70% VAT rebate. Qualified producers also benefit from a 90% discount on taxable income from relevant products. To support biodiesel development, tax authorities have issued policies to waive consumption taxes on B100 biodiesel produced using UCO (0.8 RMB/L tax). With the exception of minor tax incentives for the consumption tax and export rebates, biodiesel does not receive any subsidies nor mandate support that fuel ethanol enjoys, and must compete with other markets for used cooking oil feedstock. This being the case, the market for biodiesel remains very limited and the national average blend have never moved off of 0.2 to 0.3% (GAIN, 2018).

Table 16-2. Taxation and subsidy policy for biofuels production in China (Hao et al., 2018)

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

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

16.3.3 Fiscal incentives and investment subsidies

Policy support distinguishes between conventional, 1.5 generation and second generation feedstocks. With policies that biofuel development should not compete for arable land designated for food crops, China promotes ethanol production using cassava, sweet sorghum, and other non-food grain feedstocks.

The subsidy scheme for fuel ethanol production experienced frequent changes. Figure 16-2 shows the trend of subsidies for ethanol from conventional, 1.5 generation and second generation feedstocks. Although subsidies for conventional grain ethanol were as high as RMB 2000 (about $300) per tonne in 2009, these subsidies have been gradually phased out and no longer exist since 2016. Subsidies for 1.5 generation ethanol (from cassava or sweet sorghum) were introduced in 2013 at RMB 750 per tonne (about $114), while cellulosic ethanol started receiving a subsidy in 2014 at RMB 800 per tonne (about $120). No other subsidies or incentives are available for advanced drop-in biofuels such as renewable diesel and biojet (van Dyk, et al., 2016). Production subsidies for non-food grain feedstocks will phase out by 2018, as shown in Figure 16-2. The advanced cellulosic ethanol production subsidy is $0.07 per liter (600 RMB per ton). In 2018, there have been no additional announcements, or updates to the original subsidy program (GAIN, 2018).

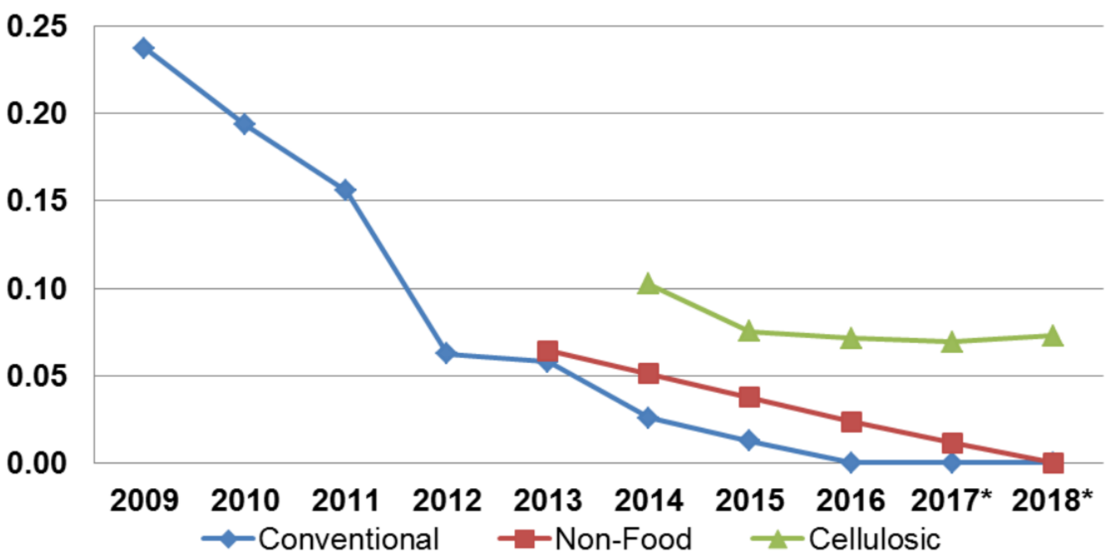

Figure 16-2. Fuel ethanol subsidies in $/liter, 2017 and 2018 exchange rates are forecasts (Innovation Center for Energy and Transportation; and Pacific Exchange Rate, GAIN, 2017)

Biodiesel producers and consumers do not receive subsidies or government support through a nationwide mandate, or provincial mandates as is the case for fuel ethanol.

Table 16-2 summarizes the subsidy policy for ethanol and biodiesel since 2002.

16.3.4 Other measures stimulating the implementation of biofuels

The Chinese Centre Government is currently trying to integrate the country's biofuel R&D efforts at a national level. In a similar fashion to the three US Department of Energy (DoE) funded research centres of Great Lakes, Oak Ridge and Joint BioEnergy Institute (JBEI), four Chinese National biofuel research centres have recently been established (Table 16-3) with each of these national biofuel research centres having a different focus. For example, the National Energy R&D Center for Non-food Biomass, which is led by the China Agricultural University, has the major responsibility for biomass breeding, cultivation and logistics research, while the National Energy Research Center of Liquid Biofuels, which is led by COFCO (a major Chinese Energy Enterprises), is mainly focussed on technology implementation. The other two national research centres put their major efforts into technology development and integration (van Dyk et al., 2019).

Table 16-3. China National biofuel research centers (van Dyk et al., 2016)

China National biofuel research centers	**Leading institute**
National Energy R&D Center for Biorefinery	Beijing University of Chemical Technology
National Energy Research Center of Liquid Biofuels	COFCO
National Energy R&D Center for Non-food Biomass	China Agricultural University
National Energy R&D Center for Biofuels	Guangzhou Institute of Energy Conversion

16.4 Promotion of advanced biofuels

Ethanol from non-food grain feedstocks is considered an advanced biofuel in China. After the initial development of ethanol production facilities based on stale grain reserves in 2007, the government limited further ethanol development based on grains and phasing-out national production supports with China's 11th Five Year Plan for 2006-2011 (China, 2006; van Dyk et al., 2016). This Plan described a new policy which prohibited the construction of any new ethanol production facilities based on grains (i.e., maize/corn, wheat) due to concerns over food security. According to the policy, any new ethanol facilities in China could only use so-called 1.5 generation feedstocks (non-grain sugar or starch crops), such as cassava, sweet sorghum, sweet potato and sugarcane, or lignocellulosic feedstocks such as forestry or agricultural wastes. Although so-called 1.5 generation feedstocks are used as food in many cases, the main emphasis in this category was the move away from using grains for biofuel production. However, the current national E10 mandate relaxes the government's previous stance against corn-based ethanol (Li, et al., 2018; van Dyk et al., 2016).

Cassava- and sweet sorghum-based ethanol production remain in research and exploratory phases of commercialization. High operating costs have limited expansion of production capacity using these feedstocks. China depends on imported cassava for most of its non-food grain ethanol production. High-costs and logistics hampered full-scale operations. Lastly, ethanol production subsidies for non-food grain, non-cellulosic feedstock use were discontinued after 2017 (GAIN, 2018) (Figure 16-2).

According to the 12th Five Year Plan (2011-2015) for strategic emerging industries, China aimed to develop biomass energy sources to develop second generation biofuels including production of

5,068 million liters (4 million tons) of cellulosic fuel ethanol, and 1.1 billion liters of algae-based biodiesel. In May 2017, China's Central Government announced its 13th FYP for Biological Innovation. The plan focuses on promoting innovation in biological-based technologies, including new energy sources using bio-based feedstocks like cellulosic ethanol. Cellulosic ethanol is prominently featured in the joint announcement by China's National Development and Reform Commission (NDRC) and other ministries in September 2017, "Implementation Plan for the Expansion of Ethanol Production and Promotion for Transportation Fuel".

Figure 16-3 shows the biomass and biofuel classifications in China.

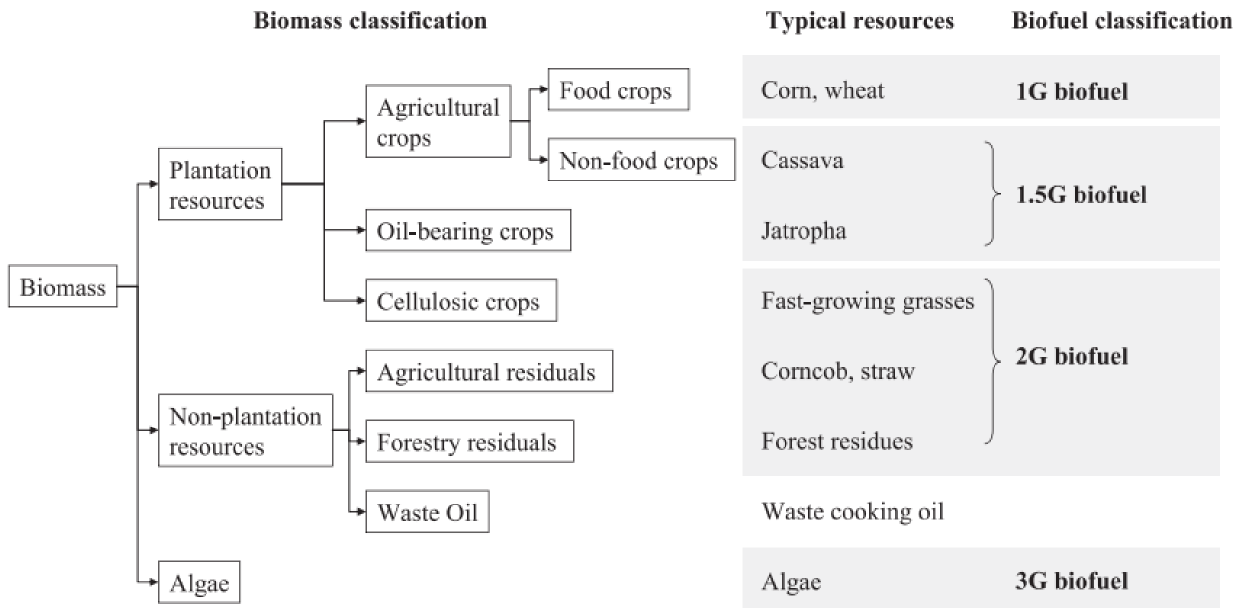

Figure 16-3. Biomass and biofuel classifications in China (Hao et al., 2018)

China is the country with the greatest number of advanced biofuels facilities, with eight projects (Table 16-4). There is currently one operating commercial scale plant, producing 220 million liters of butanol per year, and the remaining operational projects are either pilot or demonstration plants, including Tian Guan Fuel Ethanol Co Nanyang, Shandong Longlive and COFCO lignocellulosic ethanol plants, which have a joint capacity of 135 million liters per year. Beta Renewables announced plans to build a commercial scale cellulosic ethanol facility in 2016, however low oil prices delayed its construction along with other planned facilities (Biofuture platform, 2018).

The existing pilot projects began in 2009 with the Henan Tianguan Group followed by Kaidi Biomass Gasification Plant (2012) and by Green Biologics (2013). The Green Biologics' facility trialled lignocellulosic butanol from residual corn waste and was completed with commercial scale production of n-butanol becoming operational in 2012, in Songyuan, through Laihe Rockley Biochemicals, a partner company. The other pilot projects produce 4 million liters per year each. The Kaidi Biomass Gasification Plant uses biogenic waste as feedstock, while the Henan Tianguan Group produces lignocellulosic ethanol from wheat, corn stover and straw (Biofuture platform, 2018).

As shown in Table 16-4, China began producing commercial-scale cellulosic ethanol in 2013, but also faces the same technological challenges which have limited the expansion of cellulosic ethanol production elsewhere in the world. As a result, China has not been able to sustain annual cellulosic ethanol production levels above 40 million liters. According to Asiachem's 2018 Fuel Ethanol Annual Report, China's cellulosic fuel ethanol production capacity, projects operating and under construction, is forecast to reach about 4 billion liter in 2018 (GAIN, 2018). Cellulosic ethanol production is forecast at 20 million liters in 2018 as China's major cellulosic projects have been idled, or remain under development. Expanded cellulosic ethanol production will depend on lowering the costs of production relative to crude oil prices, which includes more efficient feedstock handling. Although global benchmark crude oil prices have risen in recent months, current crude oil prices remain less than $100 per barrel, or less than the economic breakeven point for China's cellulosic ethanol producers. Although nascent, China's projects that convert coal and industrial waste-gas to ethanol (synthetic fuels and non-bio-based) appear to be expanding incrementally (GAIN, 2018).

Table 16-4. Current advanced biofuels facilities in China (Biofuture platform, 2018)

Owner/Date	**Biofuel**	**Feedstock**	**Capacity (million liters/ year)**	**Type of Plant**
Laihe Rockley Biochemicals, Songyuan /2012	Biobutanol	NA	220	Commercial
Beta Renewables/ 2016	Cellulosic ethanol	Wheat straw, corn stover, popular residuals and straw	253	Commercial
Tian Guan Fuel Ethanol Co, Nanyang / 2011	Cellulosic ethanol	NA	12	Demonstration
Shandong Longlive / 2012	Cellulosic ethanol	Residual corn waste	60	Demonstration
Green Biologics / 2013	Cellulosic ethanol	Residual corn waste	NA	Pilot
Kaidi Biomass Gasification Plant / 2012	FT Diesel	Biogenic waste	4	Pilot
Henan Tianguan Group / 2009	Cellulosic ethanol	Wheat, corn stover and straw	4	Pilot
COFCO Heilongjiang / 2007	Cellulosic ethanol	Corn stover	63	Demonstration

COFCO pledged to build several 63-million-liter capacity cellulosic fuel ethanol plants in future. In March 2018, Songyuan Guanghe Energy in Jilin province proposed the construction of a 1.6-million-ton-throughput-capacity agricultural waste biorefinery project that will have annual capacity to produce 253 million liters of cellulosic ethanol. In 2018, Jilin province solicited investment capital for the relaunch of a 126.7-million-liter-per year cellulosic ethanol plant. The project was originally a joint venture between DuPont Pioneer and Jilin Province New Tianlong Industry in July 2015, using DuPont technology and enzymes in partnership with Jilin provincial land and capital. However, ground breaking on the project stalled (GAIN, 2018).

The first, partially fueled, biojet flight in China took place in October 2010. This was a result of a collaboration between the China National Petroleum Corporation, Air China, Boeing, Honeywell, the China National Aviation Fuel Group and Pratt & Whitney. The Sinopec Corporation, another Chinese national oil company, built a biofuel facility in Southeast China's Hangzhou in 2011 with a supposed production capacity of 6,000 tonnes of aviation bio-fuel each year from used cooking oil. Sinopec also built a blending facility within its Zhenhai Refinery to produce aviation bio-fuel products. Biojet developed by Sinopec was used in a demonstration flight in 2013 and in February 2014, the Civil Aviation Administration of China (CAAC) granted China's first biological jet fuel airworthiness certificate to Sinopec Corporation (van Dyk, et al., 2016).

Sinopec has a cooperative biojet initiative with China Eastern Airlines, while China's top oil and gas producer, China National Petroleum Corporation, has a joint biojet initiative with Air China. The first, commercial passenger flight using biojet took place in March 2015 (Biofuels International, 2015; van Dyk et al., 2016). This was a collaboration between Hainan Airlines, Boeing and Sinopec. Boeing has been very involved in biojet fuel development in China and the company has collaborated with a range of stakeholders including the Commercial Aviation Corp. of China (COMAC) and several research institutions, such as the Chinese Academy of Science's Qingdao Institute of Bioenergy and Bioprocess Technology (QIBEBT). Boeing and the Commercial Aircraft Corp. of China (COMAC) opened a demonstration facility in 2014 that will produce biojet fuel from used cooking oil at about 650 liters per day. The project's goal was to assess the technical feasibility and cost of producing higher volumes of biofuel (Schroeder, 2014; van Dyk et al., 2016). However, the current status of this project is unclear. Ongoing research on the potential of biojet fuel production is currently carried out at several Chinese institutions.

In January 2018, Enerkem, a Canadian biofuels producer, and Sinobioway, a Chinese bioenergy firm, signed a $100 million agreement of intent to jointly construct about 100 municipal solid waste-to-ethanol plants by 2035 (GAIN, 2018).

After the limits in 2007 on the use of grains as the feedstock for new biofuels facilities, Jatropha and other oilseed-bearing trees were highlighted as potential biodiesel feedstocks. All of these potential crops had to be cultivated on marginal land so as not to compete with food production. The Chinese definition of marginal land refers to land with poor natural conditions for crop cultivation, which nevertheless has potential to be developed for growing adaptable energy crops/trees (Yan et al., 2008, van Dyk et al., 2016), including shrub land, sparse forest land, moderate dense grassland and sparse grassland (Jiang et al, 2014; van Dyk et al., 2016). The plan to use jatropha oil as a biodiesel feedstock never materialized. Trees covering hillsides in Southwest China were abandoned years ago because they failed to pollinate and lacked sufficient water.

16.5 Market development and policy effectiveness

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

Total ethanol production (fuel and other industrial chemicals) is forecast at 9.8 billion liters in 2018, up 559 million liters from 2017 on expanding industrial alcohol capacity. Fuel ethanol production is forecast lower at 2.9 billion liters in 2018, down 127 million liters, due to recent ethanol plant closures. In the short-term, China has abundant grain feedstocks to produce ethanol. However, China's ability to accommodate a rapid shift in national ethanol consumption from the current 3.7 billion liters to the proposed target to meet national E10 adoption of 18.6 billion liters in 2020 is considered uncertain by most experts (GAIN, 2018).

Over the first ten months of 2018, trade data indicate that global exports to China reached 659 million liters. Recently implemented import tariffs on U.S.-origin ethanol have ended an arbitrage opportunity for the largest foreign supplier of ethanol to China. With rising gasoline prices and a target of 10% blend use nationwide by 2020, it is expected imports will be needed to fill a shortfall in domestic ethanol supplies. However, because the US is the largest volume supplier at competitive prices, China's additional tariffs on U.S.-origin ethanol limit the volume of China's ethanol imports (GAIN, 2018).

At this time, Chinese law restricts fuel ethanol processing to licensed facilities that produce and supply fuel ethanol to national refiners and fuel marketing companies. Provincial Development and Reform Commissions (DRCs) are responsible for the distribution of franchise licenses for fuel production, refining, and marketing. In anticipation of government policies to begin approvals and certification of new ethanol processors, independent, non-licensed producers have invested in expanded capacity to pre-emptively capture market share. Table 16-5 lists 12 authorized ethanol plants in China. The trend in the number, capacity and actual production of ethanol authorized plants from 2009 to 2018 is shown in Figure 16-4. Combined capacity of China's twelve licensed fuel ethanol processors account for over 5 billion liters. Fuel ethanol accounts for less than 3.2 billion liters of the total. Major feedstocks are corn (70%), cassava (25%) and molasses from either cane of beet sugar (5%).

Table 16-5. Production Capacity of China's Fuel Ethanol Licensed Producers- 2018 Estimates (GAIN, 2018; Hao et al., 2018)

Ethanol producer	**Production Capacity (million liters)**	**Comments**
Jinlin Fuel Alcohol	887	
Henan Tianguan	887	Production reportedly suspended in 2018
COFCO Biochemical (Anhui)	798	
COFCO Bioenergy (Zhaodong)	507	
SDIC (Zhanjiang)	190	
Shandong Longlive	63	Production reportedly suspended in 2018
COFCO Bioenergy (Guangxi)	253	
ZTE Zonergy (Inner Mongolia)	38	Production reportedly suspended in 2018
SDIC (Tieling)	380	Production on line in September 2018
Liaoyuan Jufeng Biochemical	380	
Jilin Boda Biochemistry	507	
Jiangsu Lianhai Biotechnology	152	
Total	5,042	

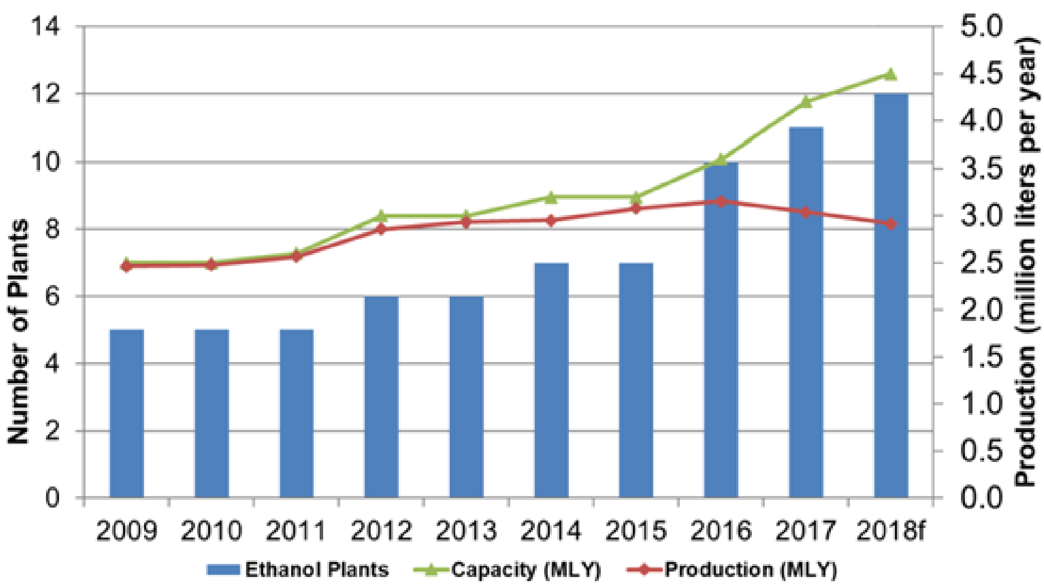

Figure 16-4. Number, capacity and actual production of authorized ethanol plants in China, 2009-2018 (GAIN, 2018)

Overall Chinese fuel ethanol demand is rising due to both policy and economic incentives. Rising crude oil prices, new tax requirements for independent refiners, production subsidies in selected provinces, more stringent environmental standards for airborne emissions and expanded transportation fuel demand have incentivized fuel refiners to blend fuel ethanol into their finished fuel products to lower production costs and narrow margins (GAIN, 2018).

According to the Chinese Academy of Sciences (CAS), China's name plate biodiesel capacity in 2015 was between 3.4 to 4 billion liters. However, industry sources report that many of China's largest biodiesel processors are idled and national production capacity is now near 1.2 to 1.7 billion liters. 2018 biodiesel production is forecast higher at 1.2 billion liters, up 100 million liters from

2017, due to greater domestic use and rising exports to the EU. Consumption is forecast at 1.1 billion liters, up 263 million liters from 2017, supported by higher imports. In China, biodiesel is used primarily to fuel electrical power generation, fishing vessels, and farm equipment. On-road transport accounts for about one-third of total demand (GAIN, 2018). One major reason for this type of preferred usage is the low quality of the biodiesel that is produced (van Dyk et al., 2016).

Although there is approximately equal demand for gasoline and diesel in China's transportation supply chain, biodiesel market penetration and production targets have been very low compared to ethanol. From 2013 to 2014, as benchmark crude oil prices remained above $100 per barrel, biodiesel demand expanded as a lower-cost substitute. At the time, consumption reached a record 2.1 billion liters evenly supplied by domestic production and imports. Following the oil price collapse of 2014, and with no subsidy supports, biodiesel consumption in China collapsed. Following a partial collapse in 2015, biodiesel demand is recovering incrementally. However, without financial support and prospects for a nationwide blending mandate, China's biodiesel market remains extremely limited subject to lower priced competition from fossil-based diesel (van Dyk et al., 2016).

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

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

Very little information is available on production of biofuels other than ethanol or biodiesel. For example, there is little information on biobutanol, renewable diesel (HEFA/HVO) or other drop-in biofuels. However, the Chinese government has been encouraging the production and sale of natural gas vehicles, with the 12th Five-Year Plan targeting that 8% of transportation energy demand should to be met from natural gas by 2015 (Clean Energy Compression, 2014; van Dyk et al., 2016).

There has also been some information published in the Chinese media about biojet fuels in recent years. According to the Civil Aviation Administration of China (CAAC), 20 million tons (25.2 billion liters) of jet fuel was used by aircraft in China in 2012 and this is expected to increase to 40 million tons (50.4 billion liters) by 2020. The report also indicated that China hoped to produce 12 million tons of biojet fuels, although how this would be done or over what type of timeframe was not clear (Asia Biomass Office, 2016; van Dyk et al., 2016).

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17. India

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Summary Box

- In 2018, a new National Policy on Biofuels was announced that expanded the scope of feedstocks to be used for biofuel production and targeted achieving 20% ethanol blending in petrol and 5% biodiesel blending in diesel by 2030 (note: these blending targets are not yet official national biofuels mandates).
- There are no excise tax exemption/reductions for ethanol and biodiesel.
- Biofuel imports are banned but import of feedstock for producing biodiesel is permitted to the extent necessary.
- The country is on target to achieve an ethanol blend level of 3.2% in 2018, the second highest ever achieved, however still far short of aspirational targets. The rate for on-road biodiesel blending with diesel is estimated at 0.14% in 2018, only marginally higher than in recent years.
- Biofuels development is overall led by the Ministry of Petroleum and Natural Gas. However, the Ministry of Science and Technology, through its Department of Biotechnology, has also been supporting feedstock development and improved biofuel production technology, with a major focus on second generation ethanol.
- Joint ventures and foreign investments in the biofuel sector are encouraged. A 100% Foreign Direct Investment (FDI) in biofuel technologies is encouraged through an automatic approval route provided the biofuels produced are for domestic use only.
- There are two operational advanced biofuel facilities - one pilot and one demonstration plant - with a production capacity of 1.75 million liters per year.

17.1 Introduction

India is one of the fastest growing economies in the world. It is the third-largest importer of crude oil after China and the US and continues to rely largely on imports. In the last five years, annual import volumes of petroleum and petroleum products have risen 25% to 307 billion liters. Additionally, India is the fourth largest consumer of primary energy at 24.9 quadrillion British thermal unit (BTUs), following China, the US and Russia. It is also the eighth largest energy producer at 14.18 quadrillion BTUs. As a result, despite notable fossil fuel resources, India is increasingly dependent on energy imports (GAIN, 2018).

The industry and transport sectors are the largest end users of energy in India and account for half of the total energy consumed. The main fuels supplying this demand are coal (in industry), petroleum (in transport), and electricity (in buildings, industry, and agriculture). Growth in the transport sector will continue to increase petroleum consumption. Transportation consumes close to 70% of the total diesel supply, 66% of which is used by passenger and commercial vehicles. Gasoline is also used for light-duty transportation, 60% for two-wheelers such as motorcycles and scooters. Currently, diesel alone meets an estimated 46% of transportation fuel demand, followed by gasoline at 24%. Gasoline and on-road diesel consumption combined are forecast to rise over the next 5 years from the current estimate of 98 billion liters in 2018 to 126 billion liters by 2023 (GAIN, 2018).

The Government of India has proposed a multi-pronged strategy to reduce its dependence on crude oil imports by 10% by 2022: increasing domestic output; promoting energy efficiency and conservation; and encouraging greater use of alternative fuels, including biofuels. Growth in the biofuel market will partly reduce import dependence on crude oil and encourage optimal use of other renewable energy resources, particularly when strong economic growth prospects drive higher demand for gasoline and petroleum products (GAIN, 2017).

In October 2016, India ratified the Paris agreement on climate change to become the 62nd nation to join. As part of its initial commitments to the agreement, over the next 15 years India plans to reduce its carbon emissions per unit GDP by 33% from 2005 levels, and it aims to use non-fossil fuels to produce 40% of its installed electric generation capacity by 2030. This implies India will have to shift significantly from coal-based power generation to renewable energy sources. It will have to produce 100 gigawatts from solar, 60 gigawatts from wind, 10 gigawatts from biomass, and 5 gigawatts from small hydropower by 2022. Another commitment in the agreement requires India to increase its forest cover by five million hectares along with improving the quality of green cover by an equal measure by 2030 (GAIN, 2018).

17.2 Main drivers for biofuels policy

Energy security and the promotion of the use of sustainable local resources are the main drivers for biofuel deployment. In addition, meeting the energy needs of India’s vast rural population by stimulating rural development and creating employment opportunities and addressing global concerns about containment of carbon emissions through use of low carbon biofuels are among the drivers for biofuel support by the Government of India (GAIN, 2017).

17.3 Biofuel Policy

India's climate target is to reduce its GDP's emission intensity to between 33% - 35% below 2005 levels before 2030. A 20% share of non-fossil fuels in primary energy by 2030 is considered in the climate target plan. A low carbon transportation infrastructure plan is also included, and among other measures, it includes a National Biofuels Policy. This policy sets an aspirational biofuel blending target of 20% for ethanol and 5% blending of biofuels in diesel (volume basis) (Biofuture platform, 2018).

The government demonstrates growing interest in developing India's biofuels sector. The Ministry of Petroleum and Natural Gas (MOPNG) has prepared a road map to accelerate the implementation of its biofuel program by increasing domestic biofuels production and consumption. A Working Group has been constituted to create synergies among stakeholder Ministries, develop awareness and implement the program. The 2018 National Policy on Biofuels is expected to boost the biofuel sector and may contribute to help achieve higher ethanol blends. Another measure supporting biofuels development and the ethanol blending program (EBP) program is establishing twelve cellulosic (2G) ethanol biorefineries in eleven states that will aid rural economies by creating employment opportunities and providing remunerative income to farmers for their otherwise discarded agricultural residues (Biofuture platform, 2018).

17.3.1 Biofuels obligations

With the announcement of its 2018 National Policy on Biofuels, India has expanded the scope of feedstocks targeted to be used for biofuel production and envisions reaching 20% ethanol blending in petrol and 5% biodiesel blending in diesel by 2030 (volume basis). In June 2018, the government released a new National Policy on Biofuels, which proposed that the blending targets of E20 and B5 be met by 2030 through: 1) growth in domestic biofuel production (conventional (1G), cellulosic (2G), and other advanced routes (3G)); 2) use of multiple feedstocks; and 3) encouraging increased biofuel blending to supplement gasoline and diesel in energy and transportation, as well as in stationary and portable applications.

The new biofuel policy of 2018 builds on the achievements of the 2009 National Policy on Biofuels and resets the agenda going forward to be consistent with emerging developments in the renewable sector. In both past and current biofuel policies, there are consumption mandates but no production mandates for biofuels. In the 2009 policy, a similar aspirational target of 20% blending of biofuels by 2017 was proposed, both for biodiesel and ethanol. Progress towards that goal was only marginal for ethanol, with the maximum average national blend level reaching only 2% - 3.3% in recent years. The mandate under the National Biodiesel Mission (NBM) was unmet due to a host of agronomical and economic factors and constraints. The market for biodiesel (B100) is still nascent (GAIN, 2018).

The major focus of the new policy is to ensure availability of biofuels produced from indigenous feedstocks. As a step in this direction, a countrywide appraisal of available biomass is planned to create a National Biomass Repository database. The revised EBP stipulates ethanol must be procured that is produced directly from B-heavy molasses, sugarcane juice, or damaged food grains such as wheat and broken rice. Use of damaged food grains is only allowed when they are unfit for human consumption and in surplus. The policy also allows conversion of surplus quantities of food grains to ethanol if approved by the National Biofuel Coordination Committee (GAIN, 2018).

With continued reliance on conventional molasses-based ethanol (with cane juice supplementation), and planned use of as yet commercially unproven, alternative feedstocks for conventional biofuels production, as well as an increased emphasis on cellulosic and other advanced biofuels, which are not yet commercialized, it is unlikely the new blending targets will be met on schedule if biofuel imports remain banned as set forth in the new policy.

India is set to achieve an average ethanol blending level of 3.2% in 2018. This is the second highest blending level ever achieved but still far short of the 20% target. In 2017, India achieved a national average ethanol blend rate of 1.9%. Demand for ethanol in the potable alcohol sector and chemical/ industrial sectors limits the amount of ethanol that can be used for fuel and thus constrains the national fuel ethanol blending average. In theory, if all ethanol available in 2018, were exclusively used for ethanol-blending, India would have achieved a 6.5% national ethanol blending average.

The rate for on-road biodiesel blending with diesel is estimated to be 0.14% for 2018, only marginally higher than in recent years. The relatively low amount of biodiesel production is due to limited feedstock availability and lack of an integrated and dedicated supply chain, coupled with restrictions on imports. To date, biodiesel is manufactured from imported palm stearin, small volumes of non-edible oils, UCO and animal fats (domestically sourced). The raw materials identified for production of biodiesel under the new policy include non-edible oilseeds, used/waste cooking oil (UCO/WCO), animal tallow, acid oils, and algal feedstock, to name a few. There is a renewed focus on imposing stringent rules to eliminate UCO entry into the food supply, and developing a suitable collection mechanism to increase UCO availability for biodiesel production (GAIN, 2018).

17.3.2 Excise duty reductions

India's biofuels market is relatively nascent, despite having had since 2007 a zero excise duty and a zero Value Added Tax (VAT) on biofuels in 5 states (West Bengal, Uttar Pradesh, Uttarakhand, Chhattisgarh and Rajasthan). A recent change in tax regimes threatens to make biodiesel substantially more expensive than regular diesel, as it envisages an additional 12% Goods and Services Tax (GST) on biodiesel. India's Biodiesel Association asserts that as soon as biodiesel is blended with diesel, taxes can become as high as 20-30% depending on the state, with a litre of biodiesel becoming ~EUR 0.01 more expensive than fossil diesel (Biofuels International, 2017). As a result of this taxation conundrum and other constraints, the previously proposed biodiesel blending level of 20% in fossil diesel by 2017 was not achieved, highlighting the need for a revised policy that keeps this somewhat frail industry from perishing (Biofuture platform, 2018).

Under the new GST regime, starting July 2017 biodiesel, industrial alcohol, and ethanol/fuel ethanol (excepting potable alcohol) will all be taxed at 18%. For states in which the new GST rate is higher than the current VAT rate, the cost of production inputs to produce biofuel will increase. Note that for an unspecified time, crude oil, natural gas, high speed diesel (HSD), and aviation turbine fuel (jet fuel) have been exempted from GST (GAIN, 2018).

17.3.3 Fiscal incentives and investment subsidies

India encourages joint ventures and investments in the biofuel sector. A 100% Foreign Direct Investment (FDI) in biofuel technologies is fostered by an automatic approval route provided the biofuels to be produced are for domestic use only. Plantations of inedible oil-bearing plants are not elegible for FDI participation (GAIN, 2018).

Schemes will be launched to move forward India's "Advanced Biofuels" program. In addition to exploring opportunities for generating carbon credits, the National Bank for Agriculture and Rural Development (NABARD) and other public sector banks will be encouraged to provide funding and financial assistance through soft loans, etc. These developments remain to be realized, however; no concrete information is yet available regarding specific benefits and impacts to biofuels producers (GAIN, 2018).

The National Biofuel Policy proposes to set up a National Biofuel Coordination Committee (NBCC) to be headed by the Prime Minister. Given the role of different agencies and ministries in the biofuel program, the role of NBCC is to provide high level coordination, policy guidance and review on different aspects of biofuel development, promotion and utilization. The policy also provides for formation of a Biofuel Steering Committee to be headed by a Cabinet Secretary that will oversee implementation of the policy. Various state governments will work closely with their respective research institutions, forestry departments, and universities to develop and promote biofuel programs in their respective states, albeit few states have so far drafted policies and set up institutions for promoting biofuel in their states. To deal with different aspects of biofuel development and promotion in the country, several ministries have been allocated specific roles and responsibilities, as shown in Table 17-1.

Table 17-1. Role of ministries in biofuel development and promotion in India (GAIN, 2018)

Ministry	Role
Ministry of Petroleum and Natural Gas (MoPNG)	Overall coordinating ministry for development of biofuels, overseeing: • National Biofuel Policy & its implementation • Research, development & demonstration on production and use of biofuels • Marketing and distribution of biofuels • Blending levels of biofuels • Development & implementation of pricing & procurement policy • Dispute redressal • Foster international collaboration for advanced biofuel research and capacity building • Municipal Solid Waste (MSW) to transportation fuels
Ministry of Rural Development	• Feedstock planting and supply chain activities along with rural livelihood
Department of Agriculture & Cooperation (Ministry of Agriculture & FW)	• Production of plant materials through nurseries and planting feedstocks for biofuels in coordination with other ministries
Ministry of Environment, Forest and Climate Change (MoEF&CC)	• Biofuel feedstocks planting in forest lands and environmental issues concerning biofuels • Involvement of communities in maintenance of feedstock growing areas and supply chain
Ministry of Science and Technology (Department of Biotechnology and Department of Science & Technology)	• RD&D on various feedstocks and technology improvements for biofuel development • Promote innovation and new research in the biofuel area • Develop technologies for bio-refinery and value-added products
Ministry of Road Transport and Highway (MoRTH)	• Encourage consumption/usage of biofuels in the transport sector
Ministry of Railways	• Encourage consumption/usage of biofuels
Department of Consumer Affairs (Ministry of CA, F&PD)	• Developing specifications, standards and codes for ensuring quality control of biofuels for end uses
Ministry of Heavy Industries and Public Enterprises	• Advise equipment manufacturers on making equipment compatible with biofuels available in the market
Ministry of New & Renewable Energy	• Co-produce energy and bio-power through biogas including enriched biogas, bio-CNG, etc. from biomass/urban, industrial and agricultural wastes
Ministry of Housing & Urban Poverty Alleviation	• Coordinate with states and ULBs for the availability of municipal solid waste (MSW) as an important feedstock for biofuels, including MSW in urban areas
Ministry of Consumer Affairs, Food & Public Distribution, Department of Food & Public Distribution	• Provide suitable financial incentives for the sugar sector to set up ethanol distilleries

17.3.4 Other measures stimulating the implementation of biofuels

The Ministry of Science and Technology, through its Department of Biotechnology (DBT), has been supporting feedstock development and improved biofuel production technology, with a major focus on cellulosic (so-called second generation) ethanol. DBT is also promoting cutting edge research and innovation in biofuels production and use for the last eight years through its Center of Excellence, fellowships, training and international collaboration. It focuses on topics such as lignin valorization, algal biofuels, waste biomass to energy (and value-added bioproducts), biobutanol and biohydrogen, among others, generally in a biorefinery context and including LCA. More than US $30 million have been invested in biofuels R&D to date, and cellulosic ethanol production technology has been successfully demonstrated by one of the bioenergy centers supported by the Government of India. Many cost effective biofuel production technologies are being developed and demonstrated at pilot scale (Biofuture platform, 2018).

Targeted areas of intensive R&D work include: 1) biofuels feedstocks production; 2) advanced conversion technologies for identified feedstocks; 3) technologies for end-use applications including modifications for biofuels; and 4) utilization of biofuels production byproducts (GAIN, 2018).

17.4 Promotion of advanced biofuels

In India, there are two operational advanced biofuel facilities - one pilot and one demonstration plant - with a combined production capacity of 1.75 million liters per year. Indian Glycols built the first plant in the country, in 2016, at their Kashipur site in Uttarakhand. Their cellulosic pilot plant uses technology developed by the Center for Energy Biosciences at the Mumbai Institute of Chemical Technology (DBT-ICT). It has a 750,000 liters annual production capacity. Praj Biofuels built the country's second facility in 2017, an integrated cellulosic ethanol bio-refinery, which once in full operation will produce 1 million liters of ethanol per year from agricultural residues such as rice, wheat straw, cotton stalk and bagasse. In 2018, Shell Bangalore completed a demonstration plant which will use an innovative waste-to-fuels technology and is expected to produce 50 million liters per year. More recently, in early 2018, Chempolis, Fortum and Numaligarh Refinery announced forming a joint venture to build a biorefinery in Assam that will convert bamboo into ethanol, furfural, acetic acid and biocoal (Biofuture platform, 2018). Table 17-2 lists India's operational, recently completed and planned advanced biofuels plants.

Table 17-2. Operational, recently completed and planned advanced biofuels plants in India (Biofuture platform, 2018)

Owner/Date	**Biofuel**	**Feedstock**	**Capacity (ML)**	**Type of Plant**	**Status**
Indian Glycols Kashipur/ 2016	Cellulosic ethanol	Wood chips, cotton stalk, cane bagasse, corn stover and bamboo	0.75	Pilot	Operational
Praj Biofuels/2017	Cellulosic ethanol	Agri-residues, e.g., rice straw, wheat straw, corn cobs, corn stover, cotton stalk and bagasse	1	Demonstration	Operational
Shell Bangalore/2018	Drop-in fuels	Agricultural and municipal waste	50	Demonstration	Completed
Chempolis/Fortum/NRL Numaligarh/2018	Ethanol	Bamboo	60	Commercial	Planned

India’s new biofuel policy encourages the use of “wastelands” for increased production of feedstocks such as non-edible oilseed bearing trees and crops such as *Pongamia pinnata* (Karanja), Melia azadirachta (Neem), castor, Jatropha carcus, Callophylum innophylum, Simarouba glauca, and Hibiscus cannabbinus in order to augment current domestic feedstock supply for biodiesel production. It is noted that the National Biodiesel Mission (NBM) had previously identified jatropha (jatropha curcas) as the most suitable inedible oilseed feedstock to help reach the proposed biodiesel blend level of 20% by 2017. However, using jatropha has so far proved to be untenable due to a host of agronomic and economic constraints (GAIN, 2018).

Farmers have been encouraged to grow a variety of different biomass crops including oilseeds on their marginal lands as inter-crops, and as a second crop wherever only one crop is historically cultivated under rain-fed conditions. Suitable supply chain mechanisms, feedstock collection centers, and fair price mechanisms for the engaged communities are planned for development in coordination with local bodies, states, and concerned stakeholders. In addition, Oil Marketing Companies (OMCs) have agreed to sign Ethanol Purchase Agreements (EPAs) with cellulosic ethanol suppliers for a period of 15 years to provide a more secure market outlook for private investors and stakeholders as well as to support cellulosic ethanol production initiatives. Bio-compressed natural gas (bio-CNG) is one of the major potential by-products of cellulosic ethanol bio-refineries and also a transport fuel and so will also be provided with offtake assurances by the public sector gas marketing companies (GAIN, 2018).

17.5 Market development and policy effectiveness

India’s total ethanol consumption in 2018 will be higher than its domestic production for the fourth consecutive year due to an uptick in fuel ethanol purchases by industry and a steadily rising demand from industrial and potable sectors. Growth in ethanol consumption (8% annual, 5 year average) is higher than growth in production although both have risen, albeit in response to different demand drivers: the rise in fuel prices has contributed to growth in ethanol consumption and a strong recovery in sugarcane production in 2018 has contributed to production growth.

Total annual ethanol consumption is expected to reach an all-time record high of 3.1 billion liters in 2018. The Government of India’s mandatory use of ‘indigenous ethanol only’ for fuel under the EBP is expected to rise from 675 million liters in 2017 to a record 1.25 billion liters in 2018. This represents an 85% increase over 2017 and is also marginally higher than the 1.1 billion liters blended in 2016. The remaining 1.85 billion liters that won’t be blended will be used for non-fuel uses by the industrial and potable alcohol sectors (which are exempted from GST) (GAIN, 2018).

In 2018, an estimated 2.55 billion liters (all time record) of ethanol was produced, 52% higher than in 2017. An anticipated rise in sugarcane production in 2018 and consequent increase in molasses availability is expected to bring an additional 875 million liters of conventional ethanol into the supply chain compared to 2017. It is anticipated that the OMCs may be able to procure upwards of 1.3 billion liters of domestically produced ethanol in 2018. With around 166 refineries, the annual production capacity of India’s combined plants in the last ten years has risen by 800 million liters to reach 2.3 billion liters in 2018. Going forward, India is likely to continue to be a net importer of ethanol (across all end uses) despite a substantial rise in domestic production. The US has become the near sole supplier of India’s ethanol imports, and exports will rise on growing demand from African nations and neighboring countries (GAIN, 2018).

The market for biodiesel is still nascent and can grow only if there is a strong commercially viable strategy for building a sustainable biodiesel industry. Presently, India has six biodiesel production plants with combined installed capacity sufficient to produce about 650 million liters of biodiesel per year. The production capacities of existing plants ranges widely, from 11 million liters to 280 million liters. As previously described, biodiesel is mainly produced from palm stearin, UCO and animal fats. Past field trials using jatropha species and other non-edible oilseeds grown on non-arable, rain-fed lands have failed to support the development of a commercially viable biodiesel industry, and there is little indication that this model (i.e., use of dedicated non-edible oilseed feedstock) can ever succeed to cost-effectively produce significant volumes of biofuel feedstock. India does not currently produce drop-in renewable diesel or HVO biofuels (GAIN, 2018).

Although conservative by some estimates, the annual consumption of biodiesel is reported to be growing steadily at an annual rate of 2-3%. It is estimated that transport by road and rail account for roughly half of all biodiesel use, with the other half consumed for off-road farm transport and in various stationary applications. The national average blend rate for on-road transport and stationary applications are each estimated at one-seventh of 1% (0.14%) today, or a little more than threefold higher than the estimated 0.04% blend rate being achieved ten years ago.

Locally produced biodiesel is usually offered at an 8-10% discount relative to the prevailing retail price of diesel, which means its price is roughly equal to diesel after accounting for the slightly lower energy density of biodiesel. The GST rate on biodiesel is 12% (as of January 2018). Previously, with the implementation of GST in July 2017, excise duty tax levied on biodiesel increased from 6% to 18%, which made it unviable for producers and end users. Industry experts acknowledge that without incentives to cover a portion of production costs or a tax policy that favors biodiesel over diesel at the pump, India’s biodiesel sector won’t be able to expand (GAIN, 2018).

India will produce upwards of 185 million liters of biodiesel in 2018, 18 million liters more than in 2017. Biodiesel producers use non-edible industrial oil (palm stearin), UCO, animal fats, tallows and ‘other oils’ (sludge, acidic oils, and tree borne oils, etc.) to produce biodiesel, thereby utilizing close to 29% of the installed capacity. While the use of animal fats and tallows has remained constant, use of other feedstocks has shown steady growth, namely non-edible industrial oil and UCO. The new biofuel policy for biodiesel focuses on stringent norms to prohibit UCO from reuse in the food supply, and developing suitable collection mechanisms to increase the aggregation and availability of UCO for biodiesel production.

For sustainable biodiesel production to grow, there is a need for a strong strategy to achieve commercial viability, as capacity utilization remains less than 30%. In the past, measures such as deregulating diesel prices, allowing bulk sale of neat biodiesel (B100) by authorized dealers, and authorizing joint ventures by OMCs and private manufacturers to supply to bulk consumers have been used to support increased production (GAIN, 2018).

The Indian biofuels industry, both private and public sector elements, claim some success in developing conversion technologies to produce biofuels from wood and agricultural biomass wastes (corn cob, bagasse, stalk of forage crops, etc). Trials, mostly at the R&D stage, are also underway to process MSW and microalgal cell mass feedstocks into advanced biofuels. The new biofuel policy to promote advanced biofuels development and production program includes a variety of fiscal incentives to foster investment in RD&D (including with foreign collaboration) and a differential pricing structure for advanced biofuels, with details still to be be decided by the NBCC.

Overall, the current share of biofuels in the transport sector is 1.2%.

The main concern over further biofuels deployment in India is availability of indigenous feedstocks for conventional (1G) biofuel production and uncertainty of future biomass supply due to the absence of established supply chain logistics networks operating at the required scales (Biofuture platform, 2018). Ethanol sourced from sugarcane-derived molasses remains the main biofuel used for blending in gasoline. For biodiesel, the majority of production comes from palm stearin, a non-edible by-product of palm oil production. Depending upon availability of domestic feedstocks and blending requirements, the import of feedstocks for producing biodiesel will be permitted to the extent necessary. Feedstock import requirements under this policy will be decided by the NBCC. As domestic availability of biofuels is much lower than India's requirements, export of biofuels will not be allowed (GAIN, 2018).

17.6 Sources

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18. Compare and contrast transport biofuel policies

18.1 Policy landscape on a global scale

The interaction of policies, markets and on-going technology development has led to rapid changes in the energy sector, prompting both proactive and reactive responses from policy makers. As market and regulatory environments continue to evolve to better support sustainable development, many countries are introducing new policy mechanisms designed to accelerate investment, innovation and the use of smart, efficient, resilient and environmentally sound technology options. Renewable energy policies are just one component of broader energy sector policies, such as fossil fuel subsidies or carbon pricing. As shown in Figure 18-1, direct policy support for renewable energy in 2017, as in past years, continued to focus primarily on power generation, with less direct support for renewable technologies in the heating, cooling and transport sectors.

A trend is emerging towards coupling of the thermal (heating and cooling), transport and power sectors, as well as towards increasing linkages between renewable energy and energy efficiency, although such measures remain limited. For example, in 2017 Indonesia outlined goals to reduce its energy intensity by 17% across industry, transport, residential and services sectors, and for renewables to achieve a 23% share of primary energy by 2025. Switzerland also introduced new cross-sectoral policies in 2017 (REN21, 2018). In 2016, the Government of Canada announced its intention to develop a Clean Fuel Standard (CFS) to reduce Canada's annual GHG emissions by 30 Megatonnes by 2030 through the increased use of lower carbon fuels, energy sources and technologies; this Clean Fuel Standard is intended to go beyond transportation fuels to also include fuels used in industry and buildings (Government of Canada, 2016).

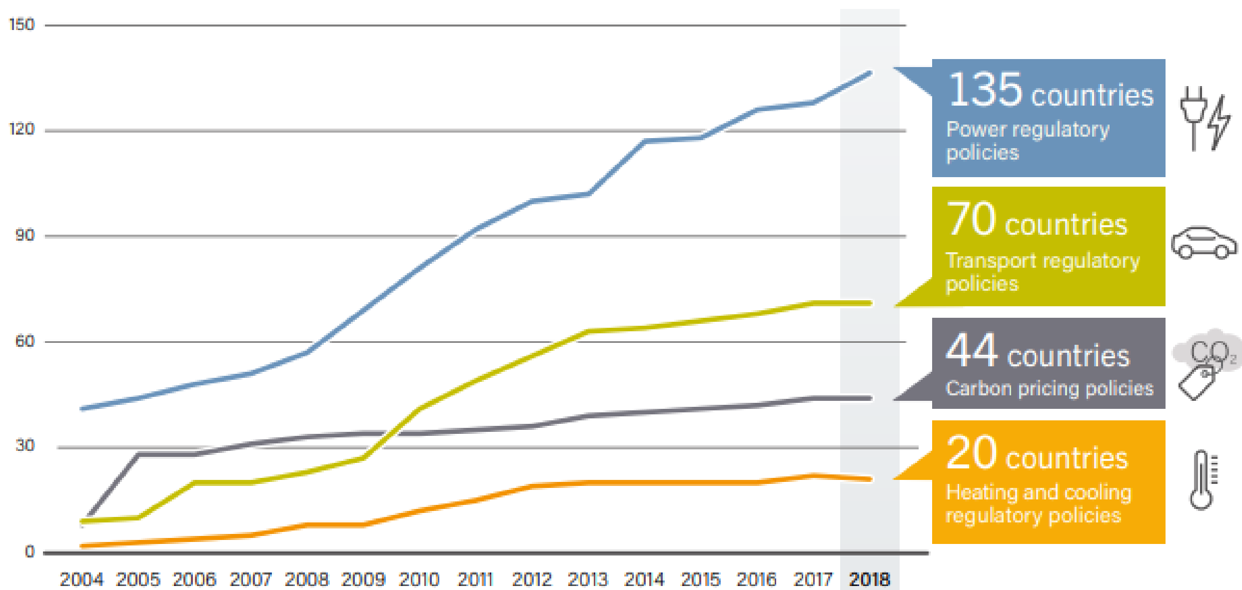

Figure 18-1. Number of countries with Renewable Energy Regulatory Policies and Carbon Pricing Policies by sector, 2004-2018 (REN21, 2019)

By the end of 2017, 41 countries had established targets for renewables in transport energy use. Policies to promote renewable energy for transport continued to focus primarily on road transport, especially at the national level. Other transport sectors such as rail, aviation and shipping have drawn comparably less policy attention despite also being large energy consumers. However, action at the local level is expanding the traditional focus on road transport, with many cities taking steps to integrate renewable solutions into public transport fleets, including city rail systems (REN21, 2018). The remainder of this chapter summarizes and compares existing biofuels policies that have been implemented to spur the production and use of biofuels to decarbonize transport. This assessment is based on information obtained from IEA Bioenergy Task 39's 14 member countries through a questionnaire (Appendix I), (Chapters 2-15 of this report), China (Chapter 16), India (Chapter 17) as well as recent relevant publications.

18.2 Compare and contrast biofuel policies for the transport sector

Biofuels policies have and continue to support the growth of biofuels production and use. Policies to promote biofuels take many forms, including blending mandates, excise taxes and renewable or low carbon fuel standards, fiscal incentives and public financing, and can be applied at different stages of biofuel production and consumption. Some countries, for example, provide fiscal incentives for flex-fuel vehicles that can run on different gasoline-ethanol blends, while others provide tax credits for biofuels or allow eligible biofuel production plants to be tax-free (UN, 2016). Development of infrastructure and technologies have also played a major role in increasing biofuels production and use. Countries planning to develop a domestic biofuel industry will be able to draw important lessons, both positive and negative, from the successes and challenges of the biofuel policies developed and implemented in the leading biofuel producer and user countries, in particular Brazil, the EU and the US (Global CCS Institute, 2018).

18.2.1 Biofuel blending mandates

Biofuel blending mandates remain one of the most widely adopted mechanisms for increasing renewable fuel use in the transport sector. Such mandates are prevalent across all geographic regions and in countries at all economic development levels. As in past years, in 2017 national and sub-national governments continued to require specific shares of biodiesel or ethanol to be blended into transport fuels (REN21, 2018). Biofuels mandates typically require minimum blending of ethanol in all fossil gasoline and biodiesel in all fossil diesel consumed in a jurisdiction, with blending levels usually based on volume, energy content or GHG reduction. Biofuels mandates are implemented at both national/federal and state/provincial levels. In addition to blending mandates for conventional biofuels, the US and some EU member states, including Austria, Denmark, Italy and the Netherlands, have developed/are developing blending mandates for advanced biofuels.

Currently, 64 countries have biofuels mandates and targets worldwide. The majority of mandates continue to be within the EU-27, where the RED II policy specifies a 10% renewable content by 2020. Fourteen countries in the Americas (North, Central and South America) have mandates or targets in place or under consideration, 12 in the Asia-Pacific region, 11 in Africa and the Indian Ocean region, and 2 from non-EU countries in Europe (BiofuelsDigest, 2019). The major blending mandates that have been driving global demand are those set in the US, China and Brazil – each of which targets blend levels in the 15-27% range by 2020-2022 (IRENA, 2018). In some countries such as China and Colombia, blending mandates are adjusted based on feedstock or biofuels supply availability as well as global supply and demand projections and tariffs (Biofuels Digest, 2019). REN21 (2017) provides a list of the countries, states and provinces that had biofuels blending mandates in place in 2017.

In 2017, ethanol blend mandates were enacted or revised in five countries. At the national level, Argentina increased its mandate to E12, Romania increased its mandate from E4.5 to E8 for 2018, and Zimbabwe returned its ethanol mandate to E10 after a temporary reduction to E5 in response to supply challenges. Mexico raised the limit on ethanol content from E5.8 to E10 except in the cities of Guadalajara, Mexico City and Monterrey; however, this action has been temporarily halted by the courts. In South America, Brazil's biodiesel B8 mandate went into effect, and was then increased to B10 in early 2018, and Colombia increased its biodiesel mandate for specific regions of the country from B8 to B9. At the sub-national level, Australia's state of Queensland enacted an E4 blending mandate in July 2018. New or revised mandates for biodiesel also were enacted during 2017, although to a lesser extent than those for ethanol. In the US, the state of Minnesota increased its biodiesel mandate to B20 effective May 2018. During the months of April through September, diesel fuel sold in the state must be at least B20. Diesel fuel sold during the remainder of the year must contain at least 5% biodiesel (B5). From April 1 to April 14, diesel fuel sold in the state can be less than 20% biodiesel (B20), but not less than 10% biodiesel (B10). In 2017, Slovenia legislated that 10% of all heavy-duty trucks must run entirely on biodiesel (REN21, 2018).

Few direct support policies target the use of renewable fuels in aviation, marine and rail sectors. The exception is Indonesia. In 2017, Indonesia introduced a 2% renewable jet fuel mandate which increases to 5% by 2025. A proposed European directive would require aviation biofuels to count more highly in the contributions towards the region's renewable transport target. In addition to new policy developments in 2017, the Netherlands, Norway and the US have had policies in place for several years aimed at promoting alternative jet fuel production. As of year-end 2017, five renewable jet fuels were certified for blending with traditional petroleum jet fuels through the ASTM D7566 aviation turbine fuel qualification process (REN21, 2018; DOE, 2017).

Table 18-1 summarizes biofuel policies implemented in IEA Bioenergy Task 39 member countries as well as in China and India. As shown in this table, all Task 39 member countries have biofuels mandates in place except South Africa and New Zealand. In China, there is not yet an official national mandate for ethanol and biodiesel use in the transportation sector. However, 11 provinces and cities (known as pilot provinces and cities) have been selected as fuel ethanol pilot zones for mandatory E10 blending (GAIN, 2017). In addition, small trial programs using 2% and 5% biodiesel blends have been carried out in a few provinces. Similar to China, India does not yet have official national mandates for ethanol or biodiesel, however blending targets for biodiesel and sugar/starch ethanol of 5% and 20%, respectively, are being considered. The governments of both China and India are contemplating implementing national mandates for biofuels in the near future. A brief summary of blending mandates and their effectiveness in these countries is provided below:

Australia: There is no national renewable fuels target; this is left to individual states. So far, only two states have mandates, Queensland and New South Wales (NSW). In Queensland, the mandate is 0.5% biodiesel and 4% ethanol, and in NSW it's 5% biodiesel and 6% ethanol. Production of ethanol is relatively stable. In contrast, production of biodiesel has collapsed due to low world oil prices coupled with high costs for feedstocks such as tallow. The NSW mandate is ineffective, despite being in place since 2007, as it is not enforced. There is no mandate for advanced biofuels and there is not yet any production or use of HVO/HEFA fuels.

Austria: There are national biofuels mandates for ethanol (3.4%) and biodiesel (6.3%) and overall for biofuels (5.75%). These mandates have been fulfilled and the federal government aims to achieve a minimum overall biofuel share of 8.45% in transport fuels based on energy content by October 2020. A 0.2% advanced biofuels target will be also implemented by 2022.

Brazil: The ethanol mandatory blend level is currently 27% (E27). 100% hydrated ethanol is also marketed in all gas stations in Brazil. The biodiesel mandatory blend level is currently 10% (B10).

Canada: There are both federal and provincial biofuel mandates. Federal use mandates are 5% ethanol and 2% biodiesel. The five provinces of British Columbia, Alberta, Saskatchewan, Manitoba and Ontario have established blending requirements of 5% to 8.5% for ethanol in gasoline and 2% to 4% for renewable content in diesel. In 2017, there was no commercial production of renewable diesel. 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. There is as yet no mandate for advanced biofuels use.

Denmark: There is a mandate for overall biofuels use in the transport sector (5.75% based on energy content for both ethanol and biodiesel). There is no production of conventional ethanol. There is a 0.9% blend mandate for advanced biofuels by 2020.

EU: The recent RED II recast (2018/2001/EC) targets 14% renewable energy in 2030 in member states, including the option to implement double counting. Advanced biofuels have a sub-target of 3.5% (defined on feedstock bases) by 2030. Interim targets of 0.2% by 2023 and 1.0% by 2025 are included as well as a maximum cap on use of food and feed crops of 1% above 2020 consumption, not to exceed a maximum of 7%. The use of high iLUC crops should be phased out by 2030 (unless they are certified to be low-iLUC).

Germany: From 2010- 2014, mandated use of at least 6.25% biofuel (based on energy content) in all transport fuel. During this period, differentiated biofuel targets were also in place for at least 2.8% biofuel in gasoline and 4.4% biofuel in diesel. In 2015, the biofuels blending obligation shifted from an energy related quota to a GHG emissions-based reduction quota. Germany is the first EU member state to implement a GHG-related quota for the entire fuel sector: from 2015, 3.5% GHG mitigation (compared to fossil gasoline and diesel references); from 2017, 4%; from 2020, 6%. Both FAME biodiesel and ethanol are produced in Germany but there are not yet any production capacities for HVO/HEFA fuels. In 2016, about 4.0% of the transport fuels used were biofuels, including FAME biodiesel, HVO/HEFA, ethanol and also biomethane from biogas.

Japan: The mandate to use 500 million liters of ethanol per year is fulfilled by both domestic production and imports from Brazil. Japan's biodiesel market is extremely limited, meeting just 0.04% of national on-road transportation demand for diesel fuel, and there is no renewable diesel market. Japan is in the process of introducing 10 million liters (crude oil equivalent) of cellulosic (2G) biofuels production capacity.

The Netherlands: There is 16.4 % biofuels mandate (for both ethanol and biodiesel) based on energy content by 2020. Regulations include a sub-target to use 1% advanced biofuels by 2020 (including double counting). The main framework for future policy will be implementation of European regulation and the national climate agreement. There are production capacities for ethanol, biodiesel, HVO and biomethanol.

New Zealand: There is currently no mandated biofuel use. However, there are small capacities for ethanol and biodiesel production. A biodiesel grants scheme ran from July 2009 to June 2012 to support the growth of a domestic biodiesel manufacturing industry by providing a grant of up to 42.5 cents per litre for biodiesel production, subject to certain conditions. This policy led to a steady increase in biodiesel production over this period, but since the scheme ended in June 2012, production of biodiesel has plummeted.

South Africa: There is no mandate on biofuel use nor any type of biofuel obligation.

South Korea: The Renewable Fuel Standard (RFS) for biodiesel is the main driver for biofuel production. There is 2.5% biodiesel mandate (volume basis).

Sweden: A quota system is in place since July 2018, with climate reduction targets for petrol and diesel. This targets biofuels shares of 2.6% for petrol and 19.3% for diesel by December 2018. These targets increase to 4.2% for petrol and 21.0% for diesel by 2020. Other low carbon biofuels such as bio-CNG, E85, HVO100, B100 and others outside the petrol and diesel standard are fully tax exempt, at least until the end of 2020.

US: There are volume mandates for biofuels including conventional and advanced ethanol and biodiesel biofuels. Together, these include 57 billion liters of conventional corn starch-based ethanol, and 80 billion liters of advanced, cellulosic and biodiesel biofuels (i.e., 61 billion liters of cellulosic biofuels, 15 billion liters of advanced biofuels, and 4 billion liters of biomass-based biodiesel).

China: There is no official national mandate for using biofuels in the transportation sector. As of 2017, 11 provinces and cities (known as pilot provinces and cities) have been selected as fuel ethanol pilot zones for mandatory E10 blending. In addition, small trial programs using 2% and 5% biodiesel blends are being carried out in Hainan and Shanghai.

India: India does not yet have official national mandates for biofuels, however blending targets for biodiesel and sugar/starch ethanol of 5% and 20%, respectively, are being considered.

Biofuel blending mandates have proven to be effective for establishing biofuels markets and shielding biofuels from low oil prices. However, mandates alone have not proven sufficient as policy mechanisms for expanding or maintaining strong markets for biofuels without proper enforcement and accompanying measures. An example is the collapse of biodiesel production in Australia's state of New South Wales, where biofuels mandates in place since 2007 have been ineffective. Mandates by their nature are also not helpful for growing markets beyond mandated levels.

The reasons biofuels mandates have not worked well in some jurisdictions are varied and include lack of secure supply of feedstock, high costs for feedstocks due to competing uses, low crude oil prices, shortage of infrastructure such as fuel pumps to dispense biofuels, food security concerns and sustainability issues such as the potential to exacerbate detrimental impacts of indirect land use change (ILUC). While biofuel mandates have helped to reduce transport sector greenhouse gas (GHG) emissions, they have not always enabled GHG emissions reduction targets to be met since mandated biofuel obligations are based on biofuels' volume or energy content rather than decarbonisation potential. In other words, biofuel mandates alone often have not provided sufficiently strong incentives to spur producers to continue to innovate to reduce the carbon intensity of the biofuels they produce.

Table 18-1. Policies for production and use of biofuels in Task 39 member countries and China and India

Country	Biofuels mandates	Fuel excise tax reduction/exemption	Other policy mechanisms
Australia	- No national renewable fuels target - New South Wales: 5% biodiesel and 6% ethanol (volume) - Queensland: 0.5% biodiesel and 4% ethanol (volume)	- Producer grant scheme (fuel excise reduction)	-
Austria	- 6.3% biodiesel, 3.4% ethanol and 5.75% biofuels (energy content) - 0.2% advanced biofuels target by 2022 (energy content)	- Tax concessions for fuels with a biofuel share of at least 4.4% - Pure biofuels exempted from mineral oil tax	-
Brazil	- 27% ethanol and 10% biodiesel (volume) - 100% hydrous ethanol is also marketed in all gas stations in Brazil	- There are tax incentives for biofuel producers, blenders and users including tax incentives for ethanol-flex fuel vehicles, tax incentives for ethanol fuel and federal tax exemptions and incentives for biodiesel production	-
Canada	- Federal use mandates: 5% ethanol and 2% biodiesel (volume) - Five provinces of British Columbia, Alberta, Saskatchewan, Manitoba and Ontario established a blending requirement of 5% to 8.5% for ethanol and 2% to 4% for biodiesel (volume)	-	- British Columbia's Carbon Tax and Low Carbon Fuel Standard - Ontario's auction for carbon allowances - Alberta's carbon levy
Denmark	- 5.75% biofuels (both ethanol and biodiesel) (volume) - 0.9% for advanced biofuels by 2020	- CO_2 excise exemptions for biofuels	-
European Union (EU)	- Cap on food and feed crops of max 1% above 2020 consumption with a maximum of 7% (energy content) - Sub-target for advanced biofuels of 0.2% for 2023, 1.0% for 2025 and 3.5 for 2030 (energy content) - Use of high iLUC crops should gradually decrease to 0% in 2030 unless they are certified to be low-iLUC	-	-
Germany	- GHG reduction of 3.5%/4%/6% in the fuel mix for the entire fuel sector from 2015/2017/2020 onwards	There is no tax relief for FAME biodiesel, HVO/HEFA fuels, vegetable oils and 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	- A carbon tax is indirectly applied via CO_2 tax for passenger cars
Japan	- 500 million liter ethanol mandate (volume) - Introducing 10 million liters (crude oil equivalent) of second generation biofuels (volume)	- No diesel oil delivery tax for B100 - A special tax incentive for the consumption of ethanol - Import of bio-ETBE encouraged through a zero tariff	-

Table 18-1. Policies for production and use of biofuels in Task 39 member countries and China and India (continued)

Country	Biofuels mandates	Fuel excise reduction/exemption	Other policy mechanisms
Netherlands	- 16.4% biofuels (both ethanol and biodiesel, double counting advanced biofuels) (energy content) - 1.0% for advanced biofuels in 2020	-	-
New Zealand	- No mandate on biofuel use or any biofuel volume obligations	- Fuel excise exemption for ethanol (including imported ethanol) - No excise exemption for biodiesel	- Emissions trading scheme
South Africa	- No mandate on biofuel use or any biofuel volume obligations	- Fuel excise exemption for ethanol - Biodiesel manufacturers receive a rebate of 50% on the general fuel levy	-
South Korea	- 2.5% mandate for biodiesel (volume)	-	-
Sweden	- GHG emissions reduction of 2.6% for gasoline and 19.3% for diesel	- The tax exemption has varied from full to reduced tax exemption but from January 2018 all biofuels are fully exempted from tax	-
The United States (US)	- Volume targets for biofuels including conventional corn-based ethanol and advanced, cellulosic and diesel biofuels	-	- California's Low-Carbon Fuel Standard (LCFS) - Biodiesel producer's credit
China	- No official national mandate for ethanol and biodiesel use in the transportation sector - 11 provinces and cities (known as pilot provinces and cities) selected as fuel ethanol pilot zones for mandatory E10 blending (volume) - Small trial program using 2% and 5% biodiesel blends carried out in a few provinces (volume)	- An excise tax exemption for waste oil-based biodiesel production - No excise tax exemption for ethanol	- Fuel ethanol subsidies: halted since 2016 for conventional grain ethanol (1 G); subsidies for 1.5 generation ethanol (from cassava or sweet sorghum) since 2013-2017 but phased out in 2018; cellulosic ethanol production subsidy of \$0.07 per liter (600 RMB per ton) - Import tariffs on US-origin ethanol
India	- No official national mandate for ethanol and biodiesel use in the transportation sector - The 20% and 5% blending targets are proposed (volume)	- No excise tax exemption/reductions for ethanol and biodiesel	- Deregulated diesel prices - Allow 100% foreign direct investment in biofuel technologies - Over \$30 million USD investment in biofuel R&D and second generation ethanol technology - Biofuel imports are banned but the import of feedstock for production of biodiesel is permitted to the extent necessary

18.2.2 Fuel/CO_2 tax excise reduction/exemption or zero tariff

In some jurisdictions, additional measures to support the uptake of biofuels have been developed and implemented to foster stronger biofuels market growth such as fuel excise tax reduction or exemption. Fuel excise tax reduction/exemption-based policies mainly have been used to make the production of biofuels economically competitive with fossil fuels in the short- and mid-term. As biofuels production becomes more cost competitive, e.g., as the price of petroleum rises, fuel excise reduction/exemption incentives are often either reduced or eliminated. This type of policy has been employed in 10 IEA Bioenergy Task 39 member countries including:

Australia: There is a Producer Grant Scheme to reduce fuel excise for ethanol and biodiesel but with excise incrementing year on year until the biodiesel reaches 50% of the fossil diesel price. Ethanol excise is capped at a lower price than biodiesel due to its lower energy content.

Austria: Excise tax exemptions are now granted for fuels containing a biofuel share of at least 4.4% (energy content). However, to be eligible for an excise tax exemption, the fuel must also be sulphur-free (less than 10 mg sulphur per kg of fuel). The use of pure biofuels as fuels has been exempted from the mineral oil tax since January 2000.

Brazil: There are tax incentives and exemptions for ethanol and biodiesel biofuel producers, blenders and users, and also for ethanol-flex fuel vehicles.

Denmark: There is a CO_2 tax of €0.06/liter of gasoline or diesel. Biofuels do not incur the CO_2 tax and biogas receives a support of €0.06/kWh.

Germany: According to Germany’s Energy Tax Law, there is no tax relief for FAME biodiesel, HVO/HEFA fuels, vegetable oils and ethanol. FAME biodiesel, HVO/HEFA fuels and vegetable oils have the same fuel tax as diesel fuel (€ 0.4104/liter). Ethanol also has the same fuel tax as gasoline fuel (€ 0.6545/liter). The fuel tax for CNG and biomethane is € 0.0139/kWh until 2023.

Japan: The diesel oil delivery tax is not charged for B100 (100% biodiesel). Therefore, in many local governments, the use of B100 as fuel is investigated for government vehicles such as garbage trucks. Consumption of ethanol was encouraged through a special tax incentive effective through March 2018. If gasoline contained 3% ethanol (volume basis), the tax was lowered by ￥1.6/L (= 1.5¢/L, under a currency exchange rate of US$1 = ￥110). The tax for unblended gasoline is ￥53.8/L. Import of bio-ETBE is encouraged through a zero tariff (in place through March 2018).

New Zealand: Ethanol (including imported ethanol) is exempt from excise duty (NZD 0.595/L compared to current retail petrol price of NZD 2.3/L). This exemption does not currently apply to biodiesel or other biofuels.

South Africa: Ethanol is 100% exempt from fuel tax, as it is categorized to be outside the fuel tax scope. Biodiesel falls within the fuel tax scope, however, and biodiesel manufacturers receive a rebate of 50% on the general fuel levy.

Sweden: The level of tax exemption has varied from full to partial, however since January 2018, all biofuels are fully exempted from tax.

US: Tariffs and restrictions on imports of biodiesel (until 2017) and ethanol (continuing).

China: There is an excise tax exemption for waste oil-based biodiesel production and export but no tax exemption for ethanol production and use. There are import tariffs on US-origin ethanol.

India: Biofuel imports are banned but the import of feedstock for producing biodiesel is permitted to the extent necessary.

Tax incentives have been used successfully to spur biofuel production and reduce biofuel prices at the pump in countries such as Brazil, Germany, and Sweden. However, implementing fuel excise reduction/exemption-based policies as the major biofuel policy to drive biofuels expansion in a jurisdiction has not been sufficient to grow biofuels markets. This is, for example, seen in the case in New Zealand and South Africa where there are no or only small levels of biofuels production and use capacities.

In addition to being applied to stimulate the increased production and use of biofuels, tax incentives have been considered for the production of biomass feedstocks such as dedicated energy crops (e.g., switchgrass, carinata, willow) in order to ensure sufficient feedstock supplies are available to be able to produce conventional and advanced biofuels and ultimately achieve mandated levels of production and use. Such policies encourage and facilitate the deployment of the entire biofuels supply chain, from feedstock cultivation through biofuel end use, making it more likely that future usage and emissions reductions targets set by mandates will be achieved (Paulsworth, 2013; Smolinski and Cox, 2016).

18.2.3 Low Carbon Fuel Standards

A newer type of policy that is proving powerful for decarbonizing the transportation sector is low carbon fuel standards (LCFS) that incentivize reductions in the carbon intensity of renewable fuels, including biofuels, rather than mandate defined production volumes or blending levels. In addition to encouraging more efficient production of conventional biofuels, LCFS-based policies also spur the development and production of lower carbon intensity advanced biofuels. Under LCFS-type policies, fuels that can be produced at a lower carbon intensity compared to petroleum-based gasoline and diesel generate higher carbon credits, which translates into higher market values for these fuels. California in the US and British Columbia in Canada are two jurisdictions at the forefront of implementing LCFS-based policies. Germany and Sweden have also implemented GHG reduction quota obligations for biofuels use in their transport sectors.

California's LCFS and its emissions Cap-and-Trade Program are two policies that work in concert to cut the use of high-carbon fuels for transportation and create low-carbon alternatives and the infrastructure needed to support their use. These policies, in turn, are spurring investors, entrepreneurs, scientists, and engineers to develop innovative low-carbon transportation technologies and strategies. LCFS-based policies reward efficiency and are also spurring innovations in conventional biofuels production to reduce its carbon intensity. One example is the development of bolt-on and integrated conversion technologies enabling existing corn-ethanol dry mills in the US to convert corn kernel fibre coproduct into cellulosic ethanol. Another example is reusing or selling the carbon dioxide (CO_2) produced by ethanol fermentation instead of designating the CO_2 coproduct stream as a waste. Beyond these innovations, existing (conventional) ethanol plants can also lower their carbon footprint by transitioning away from fossil fuel-based energy to obtain required heat and/or electricity from renewable sources such as biogas/renewable natural gas or agricultural and forest biomass.

In addition to helping improve conventional biofuels, LCFS policies are spurring increased production and use of lower carbon advanced biofuels including HVO/HEFA fuels. The high credits generated by lower carbon advanced biofuels can make their production more economical. Most of the drop-in biofuels being produced today are made from oleochemical/lipid-rich feedstocks (i.e., HVO/HEFA fuels); over 4.4 billion liters per year of HVO/HEFA biofuels are now being produced worldwide (see Table 1-2). Due to the higher production cost of HVO/HEFA fuels compared to conventional FAME biodiesel, HVO/HEFA fuels are mainly sold in markets such as California and British Columbia where LCFS policies are in force to incentivize biofuels based on their carbon intensity, or where there are other supporting policies based on GHG emission reductions such as in Germany and Sweden.

California's LCFS policy is administered by the state of California's Air Resources Board (CARB), which is working on a handful of refinements and updates to this policy, including: 1) revising the California Greenhouse Gases, Regulated Emissions and Energy Use in Transportation (GREET) model used to quantify the carbon intensity of biofuels production pathways, specifically for ethanol production pathways, to create more credit generation; 2) adding additional crediting mechanisms so there are some new ways to make credits, one of these being through the use of alternative jet fuel; 3) proposing a protocol that would enable carbon capture and sequestration (CCS) also to be recognized and generate credits; and 4) allowing third-party consulting to review and verify newly proposed fuel production pathways or compliance documents to confirm their integrity, suitability and completeness (Ethanol Producer Magazine, 2018).

Other policy mechanisms that have been successful stimulating the production and use of biofuels within EU member states are the EU's Fuel Quality Directive (FQD) (2009/30/EC) and original and recently revised Renewable Energy Directive (RED, 2009/28/EC, and RED II). The original RED had a goal to obtain 20% final energy consumption from renewable sources by 2020, with a specific sub-target for a 10% share of renewable energy to be used in the transport sector by 2020. The FQD requires a minimum 6% reduction in GHGs per energy unit of transport fuel by 2020. The 20% renewable energy consumption target has to be met by the EU as a whole through the attainment of individual national targets. All EU countries must also ensure that at least 10% of their transport fuels come from renewable sources by 2020.

Both of these directives include sustainability criteria for biofuels: at least 35% savings in GHG emissions as compared to fossil fuels that the biofuels displace was required by 2013, which increased to at least 50% by 2017 and to at least 60% by 2018 for biofuels produced in new facilities. The recently revised and approved RED II required reduction of at least 65% after 2020, 70% after 2021 and 80% for locations starting production after January 2026. EU directives are binding for all EU member states and need to be transposed and implemented into member states' respective national laws. The EU recently adopted renewable energy directive, REDII, recasting objectives at the 2030 time horizon and increasing the level of both breadth and stringency of sustainability criteria acting as eligibility criteria to count towards the mandatory targets. The REDII continues to include a biomass and biofuel sustainability policy as well as quotas for production of advanced biofuels and the cap on food/feed-competing fuels. For biofuels, RED II requires at least 14% of transportation fuel to come from renewable sources by 2030. Conventional crop-based biofuels are capped at 2020 levels with an extra 1% but can not exceed 7% of final consumption of road and rail transport. In addition, the share of advanced biofuels and biogas must be at least 1% in 2025 and at least 3.5% in 2030. Food and feed crops, such as palm oil, that can result in high indirect land use change (ILUC)), are to be phased out through a certification process for low-ILUC biofuels.

The UK's recently implemented Renewable Transport Fuel Obligations Order (RTFO II) creates a specific target for Development Fuels that allows an incentive of up to GBP 1.6 per liter for certain types of advanced biofuels including aviation and high blends.

18.2.4 Other measures stimulating the implementation of biofuels (Technology-push instruments)

Market-pull instruments including biofuels blending mandates and fuel/CO_2 excise tax reduction/exemptions are broadly effective to support technologies that are relatively mature, as they create a demand for biofuels, which is typically met with commercial conversion technologies such as conventional ethanol or biodiesel. However, such instruments can be limited in their ability to pull early-stage technologies into the market, since these are often not yet commercially viable, typically more expensive and struggling to compete against fossil fuels and already established biofuels. In contrast, regulatory frameworks such as California's LCFS, Brazil's RenovaBio and Canada's Clean Fuel Standard (CFS) are examples of policies that aim to pull advanced biofuels into the market by providing a fuel agnostic incentive to products with the lowest carbon intensity.

Despite the dominance of market-pull instruments (i.e., biofuels blending mandates, fuel/CO_2 excise reduction/exemptions and LCFS), a significant policy focus has been to support technology research, development and demonstration (RD&D) through grant instruments, particularly for advanced biofuels. Such technology-push instruments or measures are typically effective for driving early stage technologies such as advanced biofuels towards demonstration and commercialization. Technology-push instruments reduce the cost of research and development to drive new ideas and reduce technology cost, helping take early stage technologies through the valley of death that so often exists between early technology development and profitable commercial operation (Biofuture Platform, 2018). Figure 18-2 shows a combination of technology-push and market-pull biofuel policies in different stages of technology development.

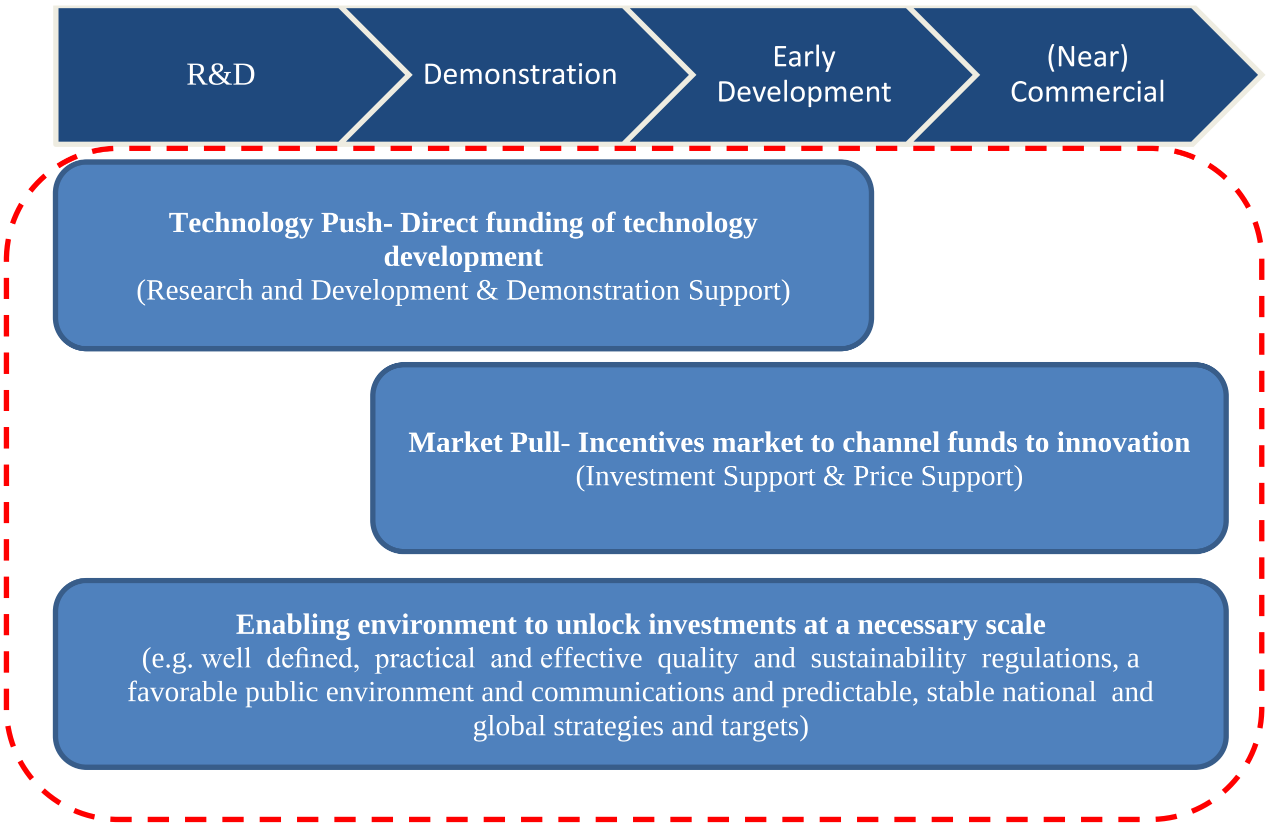

Figure 18-2. Technology-push and market-pull biofuel policies (Adapted from Carbon Trust & Element Energy, 2014, and Biofuture Platform, 2018)

Various jurisdictions have begun to restrict the production and/or use of conventional biofuels, favouring advanced biofuels produced using non-food crop feedstocks. However, progress in the production of such advanced biofuels has been hampered by a slow rate of commercialisation and the fact that advanced biofuels, at this stage of development and in the current market and policy environment, remain non-cost-competitive with starch or sugar-based biofuels. Due to the relative immaturity of advanced biofuels supply chains in terms of feedstock production and supply logistics, feedstock sustainability, and conversion technology efficiency, most existing pilot, demonstration and pre-commercial advanced biofuels projects in IEA Bioenergy Task 39 member countries as well as China and India are supported by various government financial support schemes, including:

- Grants for conversion technology development to increase technology readiness levels to de-risk the technology and supply chain development. Various grants and financial programs intend to de-risk early market development and initial commercialisation for technologies with long-term market potential but high investment risk
- Loan guarantees to buy down the financial risk of constructing first-of-a-kind larger-scale commercial facilities
- Corporate tax breaks to newly built biofuel facilities
- Guaranteed return on renewable energy assets
- Compensation for depreciation of acquired renewable energy assets

- Rebates and bonuses to car buyers for the purchase of certain vehicles such as flex-fuel vehicles (FFVs) and other rebates such as reduced license fees and tax credits. For example, Brazil has successfully introduced policies expanding their fleet of FFVs. This has facilitated the widespread deployment of higher-level biofuels blends in FFVs (e.g., high blend of 27% ethanol) as well as the use of unblended biofuels like hydrous ethanol
- Funding available from municipalities and companies for buying alternative fuel vehicles

In addition to de-risking commercialization of advanced biofuel production, financial schemes and incentives also often are targeted to improve enabling energy infrastructure or address sustainability concerns that would otherwise slow acceptance among users as new technologies and systems are introduced. Ideally, such schemes will also foster improved understanding by decision makers in the energy and transport sectors so as to enable ever more effective integrated planning and policy design.

Despite increased production and use of biofuels globally over the past decade, investments in biofuels have declined substantially in recent years mainly due to low oil prices. As shown in Figure 18-3, annual global investments in biofuels peaked at over $US 27 billion in 2006 and 2007 but have since declined dramatically, decreasing to less than $US 2 billion in 2015. During 2013-2016, annual investments averaged around $US 1.7 billion, however they fell to $US 0.25 billion in 2016. New biofuel plants have financially struggled due to the low prices of traditional fossil fuels, forcing policy-makers to reconsider how to better level the playing field between fossil fuels and lower carbon alterative fuels including biofuels (Hoefnagels and Junginger, 2018; IRENA, 2016).

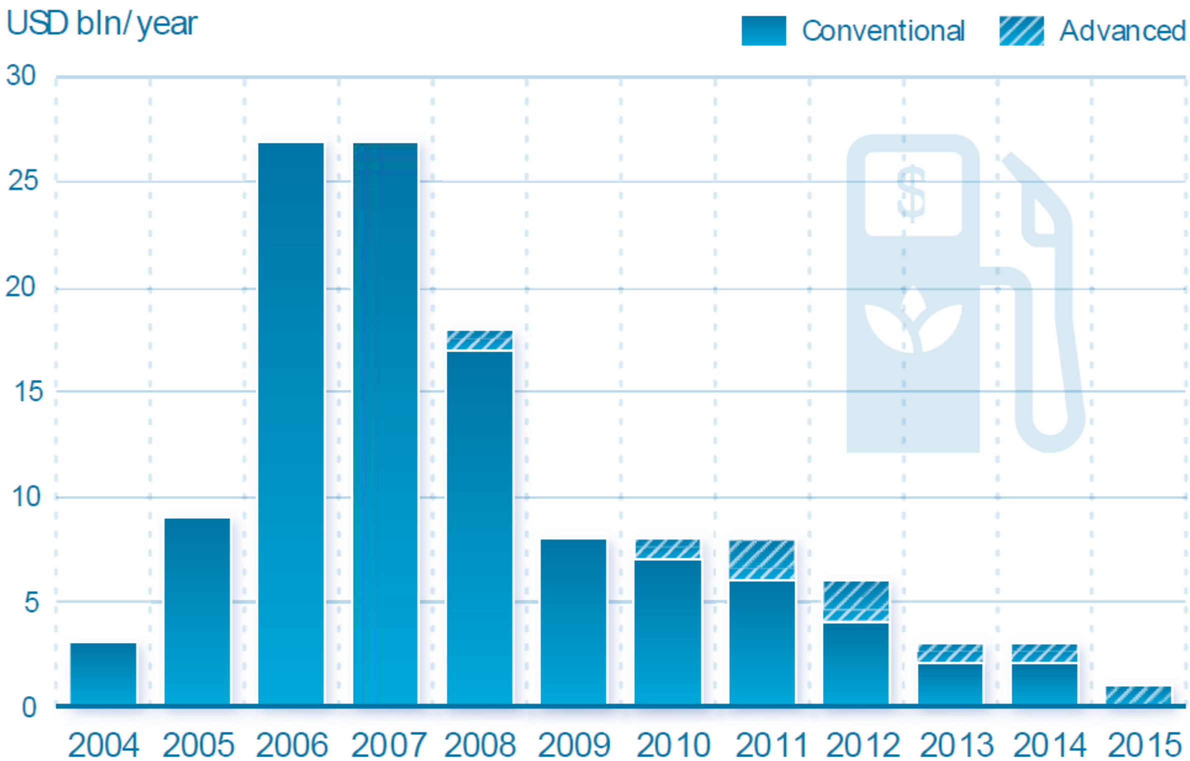

Figure 18-3. Global investment in advanced and conventional biofuels, 2004-2015 (IRENA, 2016; Hoefnagels and Junginger, 2018)

18.2.5 Biofuels sustainability criteria

Sustainability criteria for biofuels have been inherent to biofuel policies in some regions. For instance, the EU's criteria envision progressively stringent minimum reductions in greenhouse gas emissions compared with fossil fuels starting from 50% reductions and moving on to over 65% with the new RED II; it also excludes biofuels grown in areas converted from land with previously high carbon stock (e.g. wetland or forest) or producing them from raw materials obtained from land with high levels of biodiversity (e.g. primary forest or grassland). Only biofuels that comply with all sustainability criteria are eligible to receive support and can contribute to national renewable energy targets (EC, 2018). Canada has released a set of guiding principles for sustainable biofuels and the state of California has established an LCFS policy framework that requires a reduction in life-cycle carbon intensity for transport fuels (IEA-RETD, 2015). In some cases, sustainability concerns have lead to revisions in support policies. For example, the new package of clean energy and emissions reduction goals proposed by the European Commission includes a ramp down in use of conventional biofuels for transport and an increasing role for advanced biofuels and other low-carbon alternatives, such as renewable electricity (IRENA, IEA and REN21, 2018).

Governments can help address sustainability concerns by introducing specific mandates for more sustainable advanced biofuels and putting in place direct financial incentives. Currently, Austria, Denmark, Italy, Netherlands and the US have mandates for use of advanced biofuels. The US through the RFS2, and California through its LCFS, also support advanced biofuels by valuing them higher than conventional biofuels in trading mechanisms. The US and other countries, including Australia, continue to support the development of advanced biofuels with grants for research and development (REN21, 2017). Looking ahead, transport policies and industry efforts are increasingly focusing on biofuel deployment within the heavy-duty vehicle, aviation and shipping transport sectors where electrification is more challenging. If power-to-X fuels reach commercial production, they could also contribute to these sectors. [20]

Table 18-2 summarizes the strengths and limitations of existing biofuels policies.

[20] Power-to-X technologies use electricity to transform water and carbon dioxide into liquid fuel which could be used just like liquid fossil fuels.

Table 18-2. Strengths and limitations of existing biofuels policies

Policy instrument	**Strengths**	**Limitations**
Biofuel blending mandates	- Effective for developing a biofuel market at early stages - Effective in establishing biofuels markets and in shielding biofuels from low oil prices - Greater certainty of increased development - Broadly effective to support technologies that are relatively mature, as they create a demand for biofuels, which is typically met with commercial conversion technologies such as conventional ethanol or biodiesel	- Need to balance costs of infrastructure while demand is low in early stages - Need suitable governance to ensure compliance - Not necessarily so useful in expanding /maintaining markets - Not necessarily successful for meeting GHG reduction targets - Limited in their capacity to pull early-stage technologies into the market, since these are often not commercially viable, or are typically more expensive to be produced commercially - struggling to compete against first generation biofuels
Excise duty reductions/exemptions	- Increases the competitiveness of biofuels with fossil fuels, especially at early stages of development, if fossil vs renewable fuels are taxed differently - Can be also considered for the production of biomass such as dedicated biomass crops (e.g. switchgrass, carinata, willow) in order to ensure sufficient feedstocks for production of conventional and advanced biofuels and ultimately achievement of mandates for use - Broadly effective to support technologies that are relatively mature, as they create a demand for biofuels, which is typically met with commercial conversion technologies such as conventional ethanol or biodiesel	- As fuel excise rates vary, this may not be a strong enough driver to foster the biofuels market as an stand-alone policy - Limited in their capacity to pull early-stage technologies into the market, since these are often not commercially viable, or are typically more expensive to be produced commercially - struggling to compete against first generation biofuels
Low carbon fuel standards (LCFS)	- Technology neutral - Favours technologies able to offer the most significant decarbonisation relative to cost - Spurs the development and production of more life cycle efficient advanced biofuels	- Unlikely to simulate demand for higher cost, less-developed technologies with long-term potential - Determining life cycle emissions is complex and time consuming and requiring big data collection

Table 18-2- Strengths and limitations of existing biofuels policies (continued)

Policy instrument	Strengths	Limitations
Low carbon fuel standards (LCFS)	- Encourages conventional biofuel producers to lower their carbon footprint by transitioning away from fossil fuel-based energy and making better use of their by-products such as CO_2	- Results of life cycle analysis depend on system boundaries, allocation methods and other assumptions and are subject to debate - Need suitable governance to ensure compliance - Need suitable verification process to measure the carbon intensity of biofuels produced from different feedstock-conversion technology pathways
Research and development, demonstration funding and financial de-risking measures, mainly for advanced biofuels and power-to-X technologies	- Necessary to support early market technology development and initial commercial projects with longer-term market potential but high investment risk - Successful in de-risking technology and catalyzing private investment for subsequent stages, somewhat sparing public budgets as technologies advance into commercial stages	- Financial risks associated with potential project failures
Sustainability policy	- Propel the production and use of advanced biofuels using non-food crop feedstocks such as municipal solid waste (MSW), used cooking oil, and agricultural and forest residues	- Could constrain further production of conventional biofuels from food crops, even for cases where there is little potential for detrimental indirect land use changes - Could make waste production profitable, which is not in line with overall waste reduction initiatives and polices

18.2.6 Biofuels policies in the aviation and shipping sectors

In 2016, the aviation sector accounted for 11% of final transport energy consumption, however there are few direct support policies targeting the use of renewable fuels in air transport (US EIA, 2016). Aviation fuels generally are not included in transport mandates for biofuels (Takriti et al., 2017). The aviation industry recognises the need to address climate change and has adopted a number of targets, including a 50% reduction in net aviation CO_2 emissions by 2050 compared to 2005 levels (IATA, 2017). There have also been some policy developments in support of the uptake of renewables in the aviation sector. In 2016, after eight years of negotiation, ICAO adopted the Carbon Offset and Reduction Scheme for International Aviation (CORSIA) to ensure that CO_2 emissions are reported and emission increases are offset. As of January 2018, 73 countries, representing 87.7% of international aviation activity, have voluntarily participated in the pilot-phase of the scheme (ICAO, 2018). Although CORSIA doesn't come into effect until 2021, and participation is voluntary until 2027, it could help foster the production and use of sustainable bio-jet fuels and the purchase of carbon offsets over the longer term, and both are likely to be needed to meet the industry's decarbonisation targets. United Airlines, among other airlines, has begun to use commercial-scale volumes of low carbon jet fuels for regularly scheduled flights (Robinson, 2017; Jong et al., 2017).

As a complement to ICAO regulations, and often with the objective of surpassing ICAO minimum standards, some governments have facilitated the deployment of renewable aviation fuels. The EU's ETS includes aviation, although this regulation is valid only for inter-European flights (under pressure from ICAO members, on a temporary basis the European Union excluded flights from or to non-EU countries) (Waltz, 2017; EEA et al., 2019).

Some countries provide direct support for sustainable aviation biofuels or other renewable fuels, mainly in the form of mandates, obligations or financial incentives. In 2017, Indonesia introduced a 2% renewable jet fuel mandate, which is set to increase to 5% by 2025 (IATA, 2018). A proposed European Union directive would require aviation biofuels to count more highly in the contributions towards the region's renewable transport target (Stefanni, 2017). In addition to policy developments in 2017, the Netherlands, Norway and the United States also have policies in place from prior years aimed at promoting alternative jet fuel production (IRENA, 2017).

Australia has awarded funding to construct a bio-crude and advanced biofuel laboratory, potentially resulting in the capability to produce renewable diesel and jet fuel from plant material. Under the Sustainable Biofuels Innovation Challenge, the US provided funding for development of a demonstration-scale facility capable of producing renewable diesel and renewable jet fuel from carbonaceous industrial waste gases (REN21, 2017). The US Renewable Fuel Standard also includes domestic aviation. In the Netherlands, a public-private partnership aims at establishing a bio-jet fuel supply chain to provide significant quantities of sustainable jet fuel to Schiphol Airport. Bioport Holland involves aviation and bio-jet fuel stakeholders at the main Dutch ports and airports. Geneva, Montreal, Oslo and Stockholm are participating in similar initiatives. The Canadian government has announced a nationwide challenge to Canadian technology development companies to develop innovative sustainable and affordable bio-jet fuel production pathways to produce SAFs that can be used to reduce the aviation sector's carbon footprint.

Shipping is the most efficient means of transporting cargo across the globe and also one of the fastest growing sectors within transport. The shipping sector mainly uses heavy fuels that contain sulphur and heavy metals, which increases the sector's environmental footprint, especially air pollution. Along with aviation, marine/ocean transport is one of the hardest transport sectors to decarbonise. Apart from technological challenges, the deployment of renewables in shipping faces numerous barriers, such as the large price gap between renewable and conventional fuels and limited regulations, particularly regarding the CO_2 content of maritime fuels. International shipping is regulated by the International Maritime Organisation (IMO). Since the Paris agreement (which did not include international shipping), the IMO has developed reduction strategies for both GHG emissions and air pollution.

In 2016, the IMO agreed to a 0.5% sulphur cap by 2020. Implementing this cap will have cost implications for the on-going use heavy fuel oil and bunker fuels as fuels for long-haul shipping, and also offers opportunities for the development of low sulfur renewable-based fuels. As it is more costly to desulfurize fossil fuels to produce 0.5% sulphur blends, it is likely that the majority of the shipping industry will switch to using marine diesel oil or a low sulphur fuel oil. A smaller proportion of the shipping industry is considering using heavy fuel oil in combination with the installation of on board scrubbers or by switching to liquefied natural gas. However, capital costs for adding scrubbers or switching to gas are high, and therefore this will likely be considered for only a small proportion of new ships. Advanced biofuels and synthetic fuels could serve as alternatives but are currently much more expensive (REN21, 2017; Lasek, 2017). International agreements enable shipping fuels to be exempt from national taxes, and the shipping sector is thus currently subject to low or no fuel taxes – another challenge not yet sufficiently addressed within the IMO's decarbonization strategy for shipping. The EU has already indicated that shipping would be integrated into its Emissions Trading Scheme (ETS) by 2023 if no significant progress has been made by the IMO by then. China has embarked on an ambitious national program to decarbonise its shipping sector through carbon pricing (OECD Observer, 2018).

In 2018, the IMO reached an agreement on an "initial strategy" for reducing CO_2 emissions from shipping. According to this initial strategy, the country member delegates of the IMO's Marine Environment Protection Committee (MEPC) target cutting the shipping sector's overall CO_2 output by 50% by 2050, beginning emissions reductions as soon as possible, and pursuing efforts to phase out carbon emissions entirely. While this initial strategy creates goals for future action, it does not provide a timeline for establishing new regulations on CO_2 (The Maritime Executive, 2018).

18.2.7 Barriers to the further growth of biofuels markets

Despite on-going R&D projects and advances in conventional and advanced biofuels technologies and large potential to further increase biofuels production and use globally, the biofuels industry faces challenges. Petroleum prices remain modest and future policies for renewable fuels and vehicle efficiency standards remain highly uncertain. Changes in policy directions and funding programs to support both conventional and advanced biofuels are major obstacles to accelerating biofuels development in some of the key biofuels producing jurisdictions. Worldwide, the food versus fuel debate has seen a drive towards development of advanced biofuels over the last 7-8 years, with countries putting in place specific targets for advanced biofuels and caps on conventional biofuels. However, commercialization of these technologies has been very slow with very limited volumes produced locally, with the result that these targets have not been met.

Extensive research and development into production of advanced fuels is on-going, however, with the research focus shifting towards drop-in biofuels and co-processing of bio- and fossil-based feedstocks at oil refineries.

A recent survey conducted by the Biofuture Platform among its member countries shows that the two central factors holding back further development of biofuels markets are limited availability of financial resources (whether for R&D, demonstration support or investment support) and competition from fossil fuel alternatives, which are often subsidised. Unfavorable policy frameworks have also negatively affect biofuels production and use.

Figure 18-4 summarises barriers to the development of biofuels markets. Countries are implementing mechanisms to overcome such barriers to some extent, but a lot more support will be needed to drive the further development of biofuels markets.

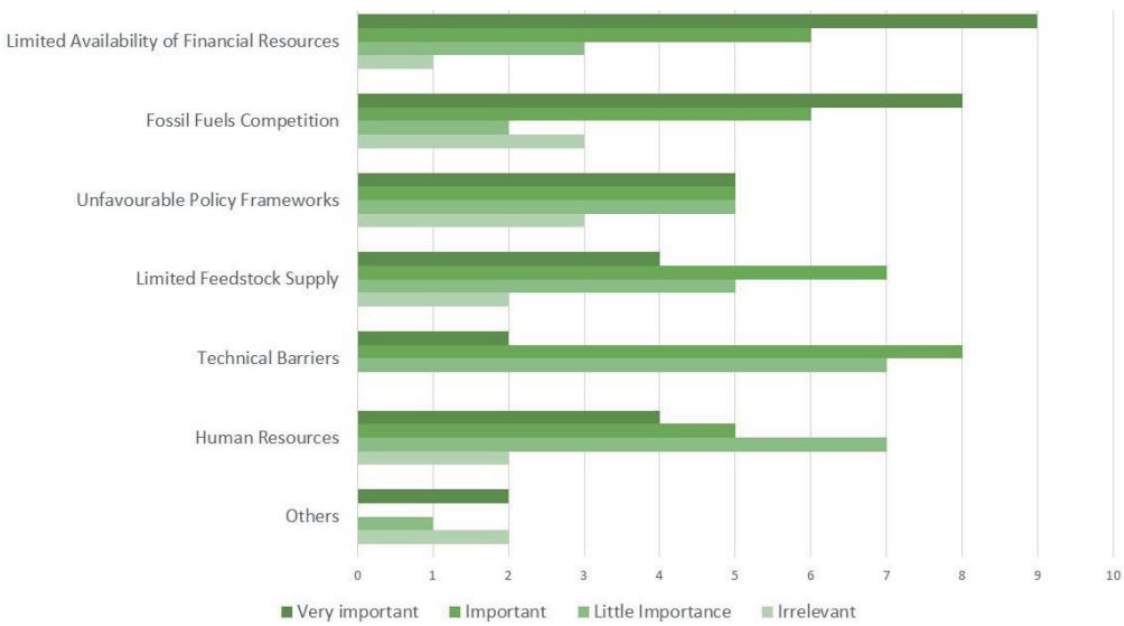

Figure 18-4. Primary barriers to the development of biofuels and bioproducts markets (Biofuture Platform, 2018).

18.3 Conclusions

The transport sector is a significant contributor to global carbon dioxide (CO_2) emissions, representing 23% of all such global energy-related emissions; thus, decarbonising the transport sector is key to decarbonising the energy sector. It is a huge task that requires a fundamental change in the nature and structure of transport demand, improvements in efficiency and changes in the energy mix. This transition requires technology developments, behavioural changes and a major policy push. With the exception of biofuels, there is little practical experience fostering renewables in transport. Most policy interventions to date are related to biofuels. To achieve a rapid increase in biofuels production that can be sustained over the long term, policies are needed that are consistent, long-term and supported by broad stakeholder participation. They should also be a part of larger transportation goals.

Policies have been and will to continue to be essential if we are to foster the growth of biofuels used to decarbonize transport, particularly long-distance transport. Various types of policies have and continue to be successfully used, including blending mandates, excise tax reductions or exemptions, renewable or low carbon fuel standards, as well as a variety of fiscal incentives and public financing mechanisms. These policies have been applied at different stages of the production and consumption biofuel supply chains. To date, most of the policies used to promote transport decarbonisation have focused on increasing the use of biofuels in cars-and-trucks, at a national level. Other key transport sectors such as aviation, shipping and rail have drawn considerably less policy attention despite being significant energy consumers and carbon/GHG emitters.

The countries that have achieved the most success in growing the production and use of biofuels have used a mixture of market-pull and technology-push policies. It is apparent that a balanced distribution of policy efforts between demand-pull and technology-push has been most successful in fostering the development and deployment of biofuels technologies and the growth of biofuels markets.

Biofuel blending mandates remain the primary biofuels policy tool that have been used globally and they have helped reduce transport sector GHG emissions. However, historically, these obligations have been based on the volume or energy content of the biofuel, rather than its decarbonisation potential. Consequently, this has not maximised the potential to reduce the carbon intensity of the biofuel. In contrast, more recent policies, such as the LCFS, have spurred the development and production of lower carbon intensity fuels, including both conventional and advanced biofuels. As a result, several jurisdictions such as Canada, Brazil, California and British Columbia have shifted their focus from mandating blending levels to the lowering the carbon intensity of biofuels.

While the production and use of transport biofuels has more than doubled over the last decade, progress in expanding biofuels production remains well below the levels required to decarbonize transport significantly. While policies have been essential in promoting the on-going growth of biofuels, they have not been sufficient to drive the level of development that is needed. Several factors continue to impact the effectiveness of biofuels policies such as; relatively low petroleum and fossil fuel prices; uncertainty about future policy and funding programs to support conventional and advanced biofuels; the inconsistent regulation of global trade of biofuels; and continuing concerns related to food security, land use change and overall sustainability. However, sustainability requirements are increasingly being incorporated into biofuels policies, with LCFS-type policies, that incentivize reductions in the carbon intensity and assure sustainability, increasingly used. These types of policies should lead to more stable and increased markets, promoting the greater production and use of biofuels, particularly in sectors such as aviation and marine, where appropriate biofuels can be readily integrated and used.

No single perfect policy instrument can guarantee the steady growth of biofuels markets in mid and long terms and a mix of policies needs to be tailored to specific country contexts. Biofuels can be promoted through a combination of regulatory measures and fiscal incentives, such as biofuel production subsidies, biofuel blending mandates, tax incentives and exemptions, grants, direct subsidies, LCFSs and others. These measures are effectively applied at different stages of the biofuels production and consumption chain.

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Appendix I: Implementation agendas Questionnaire

Request for information for completion of Country sections

Country:

Names and affiliation of authors contributing to the report:

Please provide links to websites and documents at every question

INTRODUCTION AND MAIN DRIVERS FOR BIOFUELS IN THIS COUNTRY
Describe the main drivers for biofuels production in your country (e.g. energy security, climate change mitigation, rural development, job creation)

Briefly describe the historical development of biofuel policy in your country

BIOFUELS POLICY
List the main legislation that impact biofuels in your country e.g. Renewable Fuel Standards, low carbon fuel standard

IDENTIFY WHICH OF THE FOLLOWING POLICIES ARE USED IN YOUR COUNTRY TO PROMOTE BIOFUELS

Type of policy	Yes/No (Provide Details /Comments)
Mandates or biofuel volume obligation: Ethanol (e.g. E5) Biodiesel (e.g. B2) Other biofuels (e.g. advanced biofuels such as cellulosic ethanol)	
Indicate whether the carbon intensity or emissions of biofuels are taken into account	
Indicate if financial incentives provided (e.g. subsidies, credits, incentives): For the biofuel producer (producer credit based on volume of production) For the biofuel blender (blender's credit based on volume blended) For the biofuel consumer (e.g. reduced license fees, tax credit for purchase of flex-fuel vehicles or natural gas vehicles, etc.) Financial incentives for feedstock development (e.g. grants for new feedstock development or new supply chain development) Tax credits Elimination of excise tariffs	
Indicate financial assistance (e.g. loan guarantees, grants)	

For construction of pilot, demo or pioneer facilities For development of distribution infrastructure, e.g. fuel stations for E85 For improvement or upgrading of existing biofuel production to improve the carbon intensity of biofuels	
Indicate if funding is provided for Research and Development	
Indicate if you have a Low Carbon Fuel standard or Clean Fuel Standard (e.g. specific emission reduction targets for transportation fuels)	
Other market based- mechanisms: Carbon tax Emissions Trading (cap-and-trade)	
Do you have specific policies promoting advanced biofuels (specify – blend mandate, etc.)	
Do you have any sustainability measurement/verification process for biofuels	
Do you have specific policies promoting aviation biofuels (e.g. can they qualify for incentives)	
How easy is it for new biofuels to enter the market and/or earn incentives	
Any other policies that promote biofuels production and consumption	

Expand on any policies with a short paragraph and a link to further documents or websites

COMPLETE THE TABLE BELOW INDICATING THE MANDATES FOR ETHANOL, BIODIESEL, AND ANY OTHER BIOFUEL. INCLUDE FEDERAL AND PROVINCIAL MANDATES.

Table - Biofuel obligations/mandates (% by volume or target volumes)

Year	Ethanol	Biodiesel	Other (specify e.g. advanced fuels)
2010			
2011			
2012			
2013			
2014			
2015			
2016			
2017			

MARKET DEVELOPMENT AND POLICY EFFECTIVENESS

Indicate the size of the biofuel market by completing the following tables.
Distinguish between biofuel production and consumption

Table - Biofuel production and market share – installed production capacity (million L/a)

Year	Biodiesel (FAME	Eethanol (conventional)	Cellulosic ethanol	Biogas as transportation fuel	Renewable diesel (from lipids)	Other advanced biofuels (specify)
2006						
2007						
2008						
2009						
2010						
2011						
2012						
2013						
2014						
2015						
2016						
2017						

Table - Summary of transport fuel consumption (ML)

Year	Gasoline	Diesel fuels	Aviation fuel	Biodiesel	Eethanol	Market share (%)
2006						
2007						
2008						
2009						
2010						
2011						
2012						
2013						
2014						
2015						
2016						
2017						

BIOFUEL FACILITIES AND MAIN COMPANIES

How many ethanol (conventional) facilities in your country? (number of facilities and list names and capacity (unless too many companies, then provide totals)

How many Biodiesel (FAME) facilities in your country? (Number of facilities and list names and capacity (unless too many companies, then provide totals)

How many Renewable diesel (hydrotreated vegetable oils) facilities in your country (Number of facilities and list names and capacity)

Please provide the following information on other advanced biofuel producers

Name of company	Status (planned; operational; closed)	Technology	Production capacity

RESEARCH AND DEVELOPMENT AND ADDITIONAL INFORMATION
List any funding agencies and sources

List any major research projects focusing on biofuel production

Provide any additional information that may be relevant (e.g. biojet initiatives)

SOURCES OF INFORMATION
List any documents, websites that was used as a source of the above information

IEA Bioenergy

Further Information

IEA Bioenergy Website
www.ieabioenergy.com

Contact us:
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