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**A Report from the Advanced Motor Fuels TCP and IEA Bioenergy TCP**

Technology Collaboration Programme on Advanced Motor Fuels

IEA Bioenergy
Technology Collaboration Programme



# The Role of Renewable Transport Fuels in Decarbonizing Road Transport

## Key Strategies in Selected Countries

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## Summary / Abstract

*This report constitutes Part 1 of the report on "**The Role of Renewable Transport Fuels in Decarbonizing Road Transport**". In this report the term decarbonization includes all options to reduce GHG emissions and make road transport cleaner, including low(-fossil)-carbon energy carriers such as biofuels, e-fuels, and renewable electricity. This part of the report deals with the key strategies that the selected countries have developed to decarbonize road transport.*

In the light of climate change, there is an urgent need to decarbonize our societies. The transport sector, and within it in particular the road transport sector, is specifically challenging, as transport demand is growing, and so are the sector´s GHG emissions. Decarbonization includes all options to reduce GHG emissions and make road transport cleaner, including low(-fossil)-carbon energy carriers such as biofuels, e-fuels, and renewable electricity. None of these will be able to solve this grand challenge alone, and renewable transport fuels have an essential role in bridging the gap between GHG emission reduction targets and the prospected emission reductions.

Most countries are aware that ambitious action is needed to abate the climate crisis. GHG emissions from all sectors have to be reduced dramatically, and the transport sector is among the hardest one to decarbonize. Measures can be taken according to the avoid-shift-improve principle, i.e. avoid excessive transport, shift to less carbon-intensive transport modes, and improve the carbon intensity of all transport modes. The use of renewable energy carriers such as biofuels, e-fuels and green electricity for electric vehicles constitutes one of the main measures to improve the carbon intensity of transport.

Consequently, many countries have set up legislation that mandates or encourages the use of renewable transport fuels. The European Union has introduced the Renewable Energy Directive RED and its recast RED-II, mandating all EU member states to cover 10 % of their transport energy demand from renewable sources by 2020, and 14% by 2030. In the USA the Renewable Fuel Standard (RFS) established volume requirements for renewable fuel based on life-cycle GHG emission reduction thresholds across several fuel categories. Annual volume targets in the initial legislation culminate at 36 billion gallons (136 billion liters) of total renewable fuels per year in 2022. In Brazil, the RenovaBio system shall gradually reduce the average GHG intensity in the Brazilian transport system by around 10% in 2030, relative to 2017.

Finland, Germany and Sweden (all EU member states) have set even more ambitious targets for biofuels than mandated by the EU RED. Finland has a target of increasing the share of biofuels (by energy content) in road transport fuels to 30% by 2030. Germany has a target of reducing GHG emissions from the transport sector stepwise to 95 million tons by

2030 which is about 42% compared to 1990. One measure for achieving this is a GHG-based quota system which obligates fuel suppliers to sell a fuel mix which achieves a 6% GHG mitigation a year compared to fossil gasoline and diesel mix from 2020 onwards. Finally, Sweden has a target to reduce emissions from the road transport sector by at least 70% by 2030, compared with 2010. One measure to achieve this is a GHG reduction obligation, which entails an obligation for fuel suppliers to reduce GHG emissions from sold volumes of gasoline and diesel fuels by incorporating biofuels. In 2020 the reduction obligation is 4.2 % for gasoline and 21 % for diesel. The reduction obligation will be increased over time with an indicative target of 40% overall reduction in 2030, indicatively composed of 28 % for gasoline and 66 % for diesel.

In the USA, besides the federal RFS, California was the first state to introduce a mandate on transport fuel GHG emission reductions based on GHG intensities of fuels. The Low-Carbon Fuel Standard (LCFS) sets annually decreasing carbon intensity benchmarks for gasoline, diesel, and their replacement fuels. The LCFS has a goal of reducing the carbon intensity of its transportation fuel pool by 20% by 2030 (relative to a 2011 baseline). The State of Oregon has a program similar to the LCFS requiring reduction of carbon intensity of its transport fuels. Some Mid-West states are exploring similar clean fuel programs to reduce transport fuel GHG emissions.

Other countries are more focusing on electric vehicles in order to decarbonize the transport sector. China has committed to lower its overall carbon intensity and to peak its national carbon emissions by 2030 or earlier. In the transport sector, China is primarily focusing on the introduction of electric vehicles (so-called new energy vehicles), but also promoting the use of E10. Japan has committed to reduce GHG emissions from the transport sector from 225 million $t_{CO2eq}$ in FY 2013 to 163 by 2030, constituting a reduction of 27%. Measures include the promotion of next-generation automobiles, and transport-system level measures.

All mentioned countries have also implemented legislation to gradually increase the fuel efficiency of vehicles, directly resulting in GHG emission reductions.

## Authors and acknowledgements

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Further to this part "Key Strategies in Selected Countries", the following report parts have been published:

- Production Technologies and Costs
- Scenarios and Contributions in Selected Countries
- Deployment Barriers and Policy Recommendations
- Summary Report

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The IEA Bioenergy TCP is an international platform of cooperation working in the framework of the IEA´s Technology Collaboration Programmes.  IEA Bioenergy's vision is to achieve a substantial bioenergy contribution to future global energy demands by accelerating the

production and use of environmentally sound, socially accepted and cost-competitive bioenergy on a sustainable basis, thus providing increased security of supply whilst reducing greenhouse gas emissions from energy use.
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The Advanced Motor Fuels (AMF) TCP also is an international platform of cooperation working in the framework of the IEA´s Technology Collaboration Programmes. AMF´s vision is that advanced motor fuels, applicable to all modes of transport, significantly contribute to a sustainable society around the globe. AMF brings stakeholders from different continents together for pooling and leveraging of knowledge and research capabilities in the field of advanced and sustainable transport fuels.
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# Introduction

This report constitutes Part 1 of the report on "**The Role of Renewable Transport Fuels in Decarbonizing Road Transport**". It contains descriptions of the key strategies of seven countries to reach their individual targets for decarbonizing and cleaning the road transport sector. Each chapter was written by experts with respect to transport technologies and transport policies who are involved in either the IEA Bioenergy TCP or the Advanced Motor Fuels TCP. The main work on this part of the report was done in 2019, so part of the values cited have 2017 or 2018 as reference year.

The countries that have contributed to this report are Brazil, China, Finland, Germany, Japan, Sweden and USA; also, a section on the European Union has been added. This selection of countries has introduced remarkable strategies and policies to reduce GHG emissions from the road transport sector and/or to make road transport cleaner, and best practice examples for successful policies can be observed in these countries. Yet they also face challenges, and so it is worth studying whether their current policies will be sufficient to reach their ambitious goals (as is done in Part 3 of the overall report). The fact that this selection of countries is a very diverse group with large differences in land area, population, population density, transport work, GDP etc. allows to observe how different framework conditions affect what strategy will be most effective.

Every country chapter first describes the current energy supply and demand in general and specifically in the transport sector, future scenarios for energy supply to the transport sector, the targets set for the transport sector, and main strategies and policies to reach these targets. As bioenergy and biofuels policies of Finland, Germany and Sweden follow the respective EU legislation, the main parts of EU legislation are described upfront.

It should be noted that the term "advanced biofuel" is defined differently in different jurisdictions and is thus not consistent with respect to the biofuel pathways covered by the term. More details on the definitions are provided in Part 2 of the overall report ("Production Technologies and Costs").

## Renewable energy related legislation in the European Union

### The Renewable Energy Directive of 2009 (RED)[1]

The main regulatory framework in the EU currently in force regarding biofuels is the RED (Renewable Energy Directive)[2], which establishes an overall policy for the promotion of production and consumption of energy from renewable sources in the EU. The RED contains a general consumption target for renewable energy as well as the requirement for EU Member States to obtain a share of energy from renewable sources in all forms of transport of at least 10% by 2020. It is generally accepted that biofuels will be the main renewable energy source in attempting to reach this target, although renewably produced electricity and hydrogen are also eligible to count towards the target as well. By means of an amendment (the so called ILUC Directive) implemented in 2015[3], a limit of 7% has been imposed for biofuels produced from food and feed crops grown on agricultural land for contributing to the 10% target. This 7% limit was introduced to address concerns related to the possible risks of indirect land use change (ILUC) of such feedstocks. In order to promote the use of certain feedstocks, including wastes and residues (listed in part A of Annex IX of the RED), the RED also includes an indicative target of 0.5% for advanced biofuels. Finally, advanced biofuels, as well as (other) biofuels produced from used cooking oil and animal fats may be double counted towards the 10% target. Double counting is up to the individual EU Member States to implement in their national legislation or not.

In order to be counted towards the target biofuels must meet certain sustainability criteria, irrespective of whether they were produced using raw materials cultivated inside or outside the EU. This is to ensure that the biofuels consumed in the EU are sustainable. The sustainability criteria consist of various requirements. First, the GHG emission savings from the use of biofuels as compared to the use of fossil fuels must amount to at least 60% for biofuels produced in installations starting operation after 5 October 2015. With respect to installations that were in operation on or prior to this date, the GHG emission savings had to

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1 Extracts from ART Fuels Forum, Advance Biofuels in India: A comparative analysis between India and the EU for cooperation and investment, Final Report, Radhika Singh, Stamatis Kalligeros & Jai Uppal, October 2018

2 Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, as amended.

3 Directive (EU) 2015/1513 of the European Parliament and of the Council of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources, OJ

amount to at least 35% until 31 December 2017, and as of that date they must amount to at least 50%. Furthermore, in order to meet the sustainability criteria biofuels may not be made from raw material deriving from land with high biodiversity value, high carbon stock, or peatland, as defined in the RED. The RED provides for several possibilities for producers to calculate the GHG emission saving levels of a particular type of biofuel, namely by:

- relying on default values for GHG emission savings that assign a standard GHG emission saving value for each type of biofuel depending on the raw material used;
- calculating the actual GHG emission savings themselves, using a method provided for in the Directive;
- or calculating actual values for one or more steps in the production process, while relying on disaggregated default values for the remaining steps.

In case an economic operator can realise a better GHG performance than the default values (which are set conservatively), it is attractive to make own calculations of actual GHG emission reduction values. Details regarding the calculation of GHG emission reduction values are provided in the RED.

In order to further increase the flexibility of the measure, the Commission recognised via Comitology procedures independent voluntary certification schemes. There are several recognised voluntary certification schemes that market operators can use[4]. Finally, financial support for the consumption of biofuels may only be given to biofuels meeting the sustainability criteria. EU Member States must report to the European Commission every two years the progress they have achieved with respect to their implementation of the RED, including with respect to biofuels. The European Commission must monitor several elements under the RED in general, but also specifically related to biofuels, and publish consolidated reports for the EU based on its monitoring as well as the Member State reports.

### The recast of the Renewable Energy Directive – RED-II[5]

The RED-II was adopted on of 11 December 2018 and the Member States will have to transpose the RED-II by 30 June 2021 and the original RED will be repealed as from 1 July 2021.

[4]See https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/voluntary-schemes.

[5] Directive (EU) 2018/2001 (recast) on the promotion of the use of energy from renewable sources; 11 December 2018

The RED-II like the RED defines advanced biofuels as biofuels that are produced from feedstocks as listed under part A of Annex IX. The RED-II puts forth a Union binding overall target to ensure that the share of energy from renewable sources in 2030 is at least 32%. Furthermore, a requirement is imposed on EU Member States to require fuel suppliers to ensure that the share of renewable energy supplied for final consumption in the transport sector is at least 14% by 2030. This share is calculated as the sum of all biofuels, biomass fuels (subject to fulfilling the sustainability and greenhouse gas emissions saving criteria set out in the directive) and gaseous and liquid transport fuels of non-biological origin used in the transport sector. Also Recycle Carbon Fuels, renewably produced electricity and hydrogen can be included, an option open to the member states but not compulsory.

Recycle carbon fuels are fuels recovering energy by using fossil wastes to produce fuels. There will be Delegated Regulations defining the methodology to estimate and a threshold for GHG reductions required to qualify as a recycle carbon fuel.

For the purpose of the calculation of the 14% target, the use of energy from biofuels and biogas produced from feedstocks listed in Part B of Annex IX i.e. used cooking oil and animal fat, is limited to 1.7%. This contribution can be double-counted towards the 14% target, as an option open to the member states but not compulsory. The Commission can add feedstocks to Part B of Annex IX, but not remove them. The feedstocks it can add to Part B of Annex IX are those that can be processed with mature technologies. Similarly, for the purpose of the calculation of the 14% target, the contribution of fuels supplied in the aviation and maritime sector will be considered to be 1.2 times their energy content. The share of biofuels, bioliquids and biomass fuels produced from food or feed crops in each Member State may not be more than 1% higher than their share in 2020. However, their share is capped at 7% of the gross final consumption in road and rail transport. Moreover, in case this share is below 1%, the contribution may be increased to a maximum of 2%. If a Member State’s share of biofuels, bioliquids, biomass fuels produced from food or feed crops is less than the aforementioned 7%, the Member State may reduce the overall 14% target accordingly by maximal 7 percentage points. For example, in case a Member State has limited the contribution from biofuels, bioliquids, biomass fuels produced from food or feed crops to 2%, it may reduce the overall 14% target to 9%.

The RED-II defines advanced biofuels as biofuels that are produced from feedstocks listed in Part A of Annex IX of the directive. It provides that the share of biofuels and biogas produced from these feedstocks shall equal to at least 0.2% in 2022, 1% in 2025 and 3.5% in 2030, gradually increasing over time. Furthermore, the contribution of advanced biofuels may be double-counted towards the 14% target, as an option open to the member states but not compulsory. The Commission can add feedstocks to Part A of Annex IX, but not remove them. The feedstocks it can add to Part A of Annex IX are those that can only be processed with advanced technologies.

The RED-II lays down certain sustainability and greenhouse gas emissions saving criteria for biofuels, bioliquids and biomass fuels in order for them to be counted for the contribution towards the Union target and Member States renewable energy share in compliance with renewable energy obligations; and eligible for financial support. These criteria apply irrespective of the geographical origin of the biomass. The RED-II for the purposes of the sustainability criteria differentiates between biofuels, bioliquids and biomass fuels produced from agricultural biomass and those produced from forest biomass. Therefore the sustainability criteria for the two differ.

Default GHG emission values and calculation rules are provided in Annex V (for liquid biofuels) and Annex VI (for solid and gaseous biomass for power and heat production) of the RED-II. The Commission can revise and update the default values of GHG emissions when technological developments make it necessary. Economic operators have the option to either use default GHG intensity values provided in RED-II or to calculate actual values for their pathway. Table 1 below outlines the Greenhouse gas savings thresholds in RED-II.

*Table 1: GHG saving thresholds in RED-II*[6]

| 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%[7] | 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:

- 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;

[6] See https://ec.europa.eu/jrc/en/jec/renewable-energy-recast-2030-red-ii

[7] However, the baseline fossil comparator was raised from 84 to 92 g/MJ, i.e. in absolute emission, the change from 2015 to 2021 is only 2 %.

- 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.

## ANNEX IX of RED-II

ANNEX IX Part A. Feedstocks and fuels, the contribution of which towards the target referred to in the first subparagraph of Article 3(4) shall be considered to be twice their energy content:

- (a) Algae if cultivated on land in ponds or photobioreactors.
- (b) Biomass fraction of mixed municipal waste, but not separated household waste subject to recycling targets under point (a) of Article 11(2) of Directive 2008/98/EC.
- (c) Bio-waste as defined in Article 3(4) of Directive 2008/98/EC from private households subject to separate collection as defined in Article 3(11) of that Directive.
- (d) Biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in part B of this Annex.
- (e) Straw.
- (f) Animal manure and sewage sludge.
- (g) Palm oil mill effluent and empty palm fruit bunches.
- (h) Tall oil pitch.
- (i) Crude glycerine.
- (j) Bagasse.
- (k) Grape marcs and wine lees.
- (l) Nut shells.
- (m) Husks.
- (n) Cobs cleaned of kernels of corn.
- (o) Biomass fraction of wastes and residues from forestry and forest-based industries, i.e. bark, branches, pre- commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil.
- (p) Other non-food cellulosic material as defined in point (s) of the second paragraph of Article 2.
- (q) Other ligno-cellulosic material as defined in point (r) of the second paragraph of Article 2 except saw logs and veneer logs.
- (r) Renewable liquid and gaseous transport fuels of non-biological origin.
- (s) Carbon capture and utilization for transport purposes, if the energy source is renewable in accordance with point (a) of the second paragraph of Article 2.

- (t) Bacteria, if the energy source is renewable in accordance with point (a) of the second paragraph of Article 2.

Part B. Feedstocks, the contribution of which towards the target referred to in the first subparagraph of Article 3(4) shall be considered to be twice their energy content:

- (a) Used cooking oil.
- (b) Animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009 of the European Parliament and of the Council

There is a cap on the Annex IX Part B biofuels of 1.7 % in 2030, or lower if a member state decides so.

## The EU transport sector

Final energy consumption in the EU28 transport sector has increased from 344 Mtoe in 2000 to 382 Mtoe by 2018. While fossil fuels dominate the energy mix, the Renewable Energy Directive (RED) has driven a significant increase in biofuels mainly between 2005 and 2010, and particularly for bio-diesel and bio-diesel blends (see Figure 1 on the next page)[8].

Under the 2018 revised RED, liquid biofuels are projected to increase to 10% of the transport sector energy mix, compared to approximately 5% in 2018. Over half are expected to be advanced biofuels. Scenarios in which energy policy is further revised to match a 55% emission reduction target in 2030 project biofuels to make up 13-14% of the transport energy mix by 2030. In the same scenarios, electric vehicles are expected to reach 9-11% of the transport energy mix by 2030 while very small amounts of synthetic and recycled carbon fuels enter the market[9].

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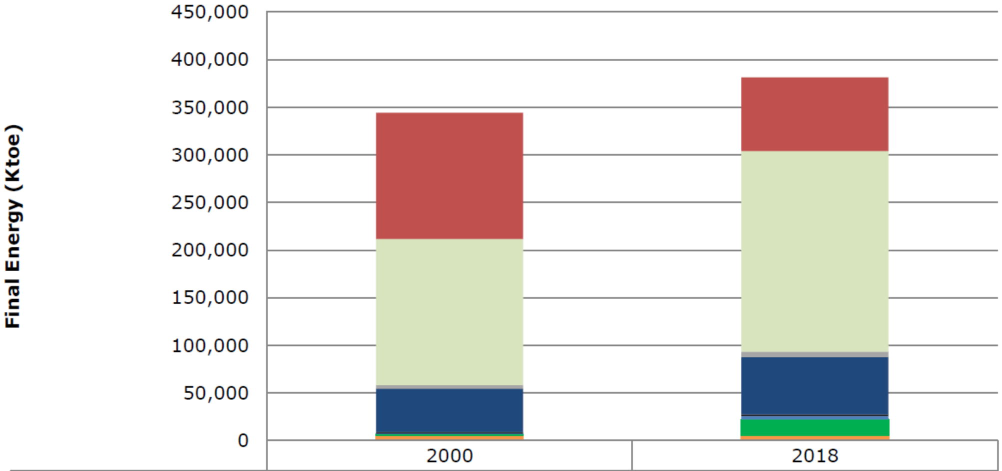
[8] JRC, Energy Consumption and Energy Efficiency Trends in the EU-28, 2000-2018, 2020. doi:10.2760/847849, JRC120681

[9] European Commission, 2020: Staff Working Document SWD/2020/176: Impact Assessment on Stepping up Europe's 2030 climate ambition Investing in a climate-neutral future for the benefit of our people.




| | 2000 | 2018 |
|---|---|---|
| Gasoline | 132,463 | 77,627 |
| Diesel | 153,516 | 210,361 |
| LPG | 3,685 | 6,032 |
| Jet fuel | 45,587 | 60,112 |
| Heavy fuel | 1,390 | 1,425 |
| Natural Gas | 855 | 3,557 |
| Biofuels and renewables | 620 | 16820 |
| Electricity | 6,024 | 5,496 |
| Solids fossil fuels | 10 | 11 |

*Figure 1: Final energy mix in the transport sector of the EU28 in 2000 compared to 2018 (Source: JRC 2020)*

# Finland

**Key facts for Finland (2018)**

Total fuel consumption of the road transport sector:
3,900 ktoe, of which 368 ktoe are renewable

Number of vehicles in use:
3.2 million, of which 32,000 are alternative fuel vehicles (incl. electric vehicles)

Current GHG emissions from the road transport sector:
11.7 $t_{CO2eq}$ in 2018

In the current policies scenario the energy consumption of the road transport sector in Finland is projected to decrease some 4 % from 2018 to 2030.

The target is to reduce GHG emissions from the transport sector by 50% compared to 2005 by 2030.

Measures to achieve this target include energy efficiency throughout the whole transport system, electrification and 30% share (actual) of biofuels in 2030 (2030 biofuel obligation already written into law). In addition to the biofuel obligation, additional measures to reach the target have to be taken.

Scenarios show that it seems possible to achieve this target.

## Energy supply and demand

### Introduction

Finland is a relatively large country, with an area of 338,000 $km^2$ (391,000 $km^2$ including water areas), roughly the same as the size of Germany. The population, however, is small, only some 5.5 million, compared to the 83 million of Germany.

Finland has no indigenous resources of oil, gas or coal, all of which are imported. Wood fuels, by-products from the large pulp and paper industry, are an important contributor to the Finnish energy mix (Figure 2, the year 2018 is the latest year for which complete data is available in February 2020).

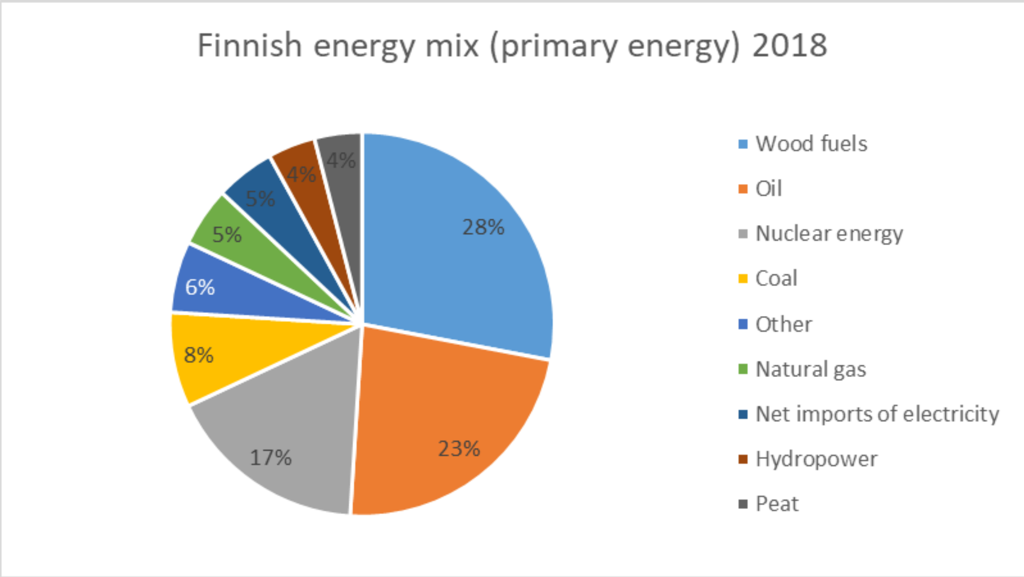



*Figure 2: The Finnish energy mix (primary energy supply) in 2018[10]*

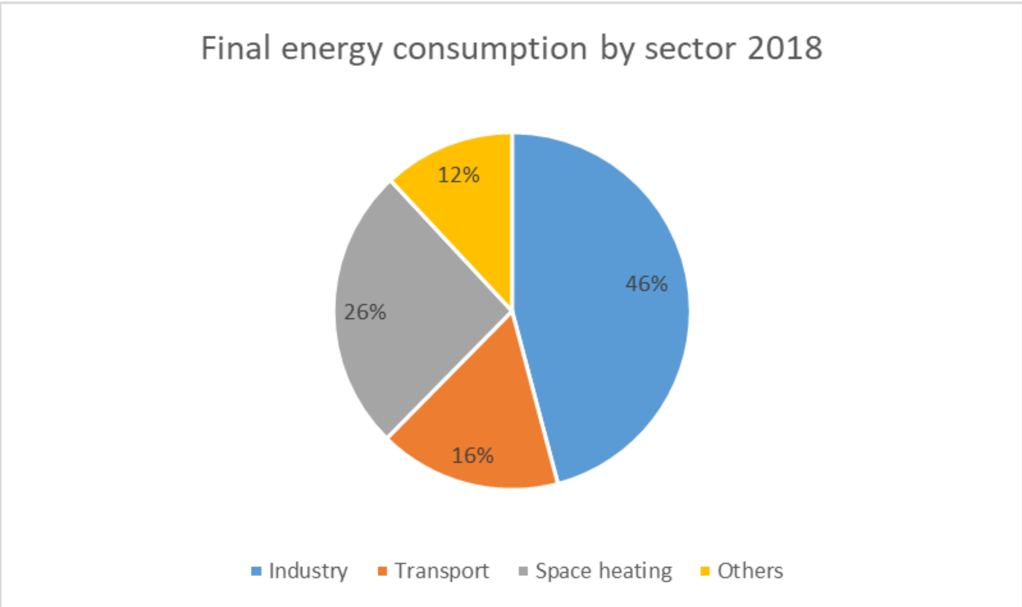



*Figure 3: The Finnish final energy consumption by sector in 2018[10]*

Primary energy consumption in 2018 was 1,381 PJ (33.0 Mtoe). The share of renewable energy was 36%. Final energy consumption was 1,128 PJ (26.9 Mtoe). Figure 3 shows final energy consumption by sector[10]. Transport in total is 181 PJ (4.3 Mtoe), or 16% of final energy consumption. Energy consumption in road transport was 165 PJ (3.9 ktoe), 91% of

[10] http://www.stat.fi/til/ehk/index_en.html

transport and 15% of total energy use.

In 2018, the total $CO_2$ emissions were 56.5 Mt[11]. The total $CO_2$ emissions from transport were 11.7 Mt, and the emissions from road transport 11 Mt[12]. The relative shares of $CO_2$ emissions were 21% (transport total) and 19% (road transport), road transport representing 93% of transport emissions. Three Finnish companies, namely Neste (focus renewable diesel), UPM (focus renewable diesel) and St1 (focus ethanol) are active in liquid biofuels[13]. In addition, the Finnish gas company Gasum is the leading company for both biogas and LNG in the Nordic countries[14].

The current (2018) domestic production capacity of liquid biofuels by the three actors is in the order of 535 ktoe/a, and the capacity abroad (Neste Rotterdam, Singapore) is 2.3 Mtoe/a[13]. For the production of biofuels in Finland, Neste mainly uses imported feedstocks, whereas UPM and St1 use indigenous feedstocks.

### Road transport energy

Diesel fuel dominates the energy supply for road transport, with a share of close to two thirds, or 2.6 Mtoe. Gasoline fuels (E5, E10 and E85) were in total 1.3 Mtoe. The contribution from methane (biogas and natural) is low, only some 8 ktoe or 0.2%. The share of electricity in road transport is still even lower than for gaseous fuels, the estimate for 2018 is some 4 ktoe[6].

Since 2008, Finland has an obligation for liquid biofuels. The obligation for 2018 was, taking into account double counting, 15%, the target for 2020 being 20%[15]. In 2018 the actual share of liquid biofuels was 9.3% (and the overall share of biofuels including biogas was 9.4%). The renewable content was 6 % in gasoline and 11 % in diesel. As the greater part of the biofuels supplied to the Finnish market were eligible for double counting, the obligation was fulfilled, with the calculatory value somewhere between 15 and 20%.

The share of renewables in gasoline was 6% and 11% in diesel. Some two thirds of the gasoline in Finland is E10. The contribution from E85 is low, in the same order of magnitude as for methane. The bio-component in diesel is mainly drop-in type paraffinic diesel (HVO).

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[11] https://www.stat.fi/til/khki/2018/khki_2018_2019-05-23_kat_001_fi.html

[12] https://www.liikennefakta.fi/ymparisto/paastot_ja_energiankulutus

[13] http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161074/63-2018-Biopolttoaineiden_kustannustehokkaat_toteutuspolut_vuoteen_2030_.pdf?sequence=1&isAllowed=y

[14] https://www.gasum.com/en/for-businesses/

[15] Saarinen, J. (2013). The Finnish Biofuel Policy. CEN/TC 19 Conference. Helsinki, 27 May 2013.

Close to 60% of the methane used in transport was renewable bio-methane.

The biofuels obligation allows banking and year-to-year flexibility. Consequently, there has been quite significant variations in biofuel volumes supplied to the Finnish market, much depending on the demand on other markets. Especially the demand for renewable diesel is high. Figure 4 shows the development of biofuel volumes from 2010 to 2018.

The amount of biocomponents in gasoline (ethanol, ETBE and some hydrocarbons from HVO production) has been fairly constant, 70 - 90 ktoe/a, whereas there have been significant fluctuations in renewable diesel (HVO) use. In 2014 and 2015, more than 400 ktoe of renewable diesel was used, but much less was used in 2016. The variations are so huge that they have an impact on the total transport $CO_2$ inventories reported to the Commission.

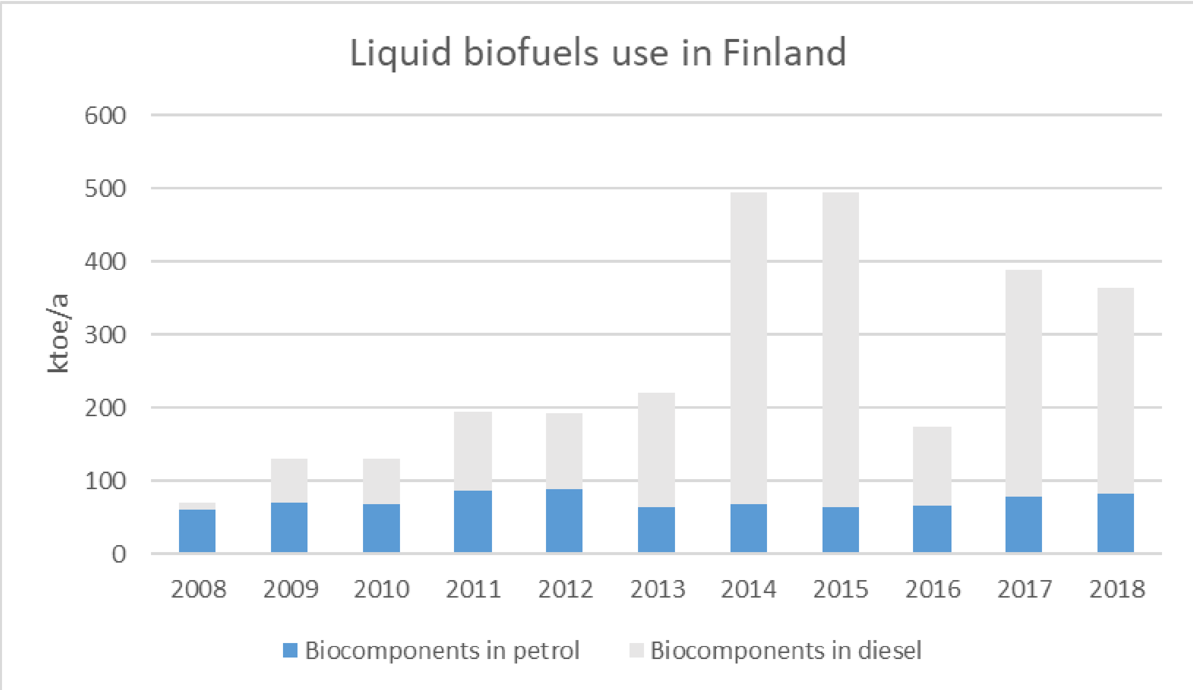


*Figure 4:* Volumes of liquid biofuels in Finland[1]

## Vehicle fleet

Table 2 shows the Finnish vehicle fleet (without 2- and 3-wheelers) in 2019. The passenger car fleet is some 2.7 million units. The average age of the passenger car fleet is quite high, some 12 years[16].

[16] http://www.aut.fi/en/statistics

*Table 2:* The Finnish vehicle fleet[6].

| | **2019** |
|---|---|
| **Passenger cars** | **2,735,276** |
| *Gasoline* | **1,916,961** |
| *FFV* | **8,773** |
| *Diesel* | **781,658** |
| *Natural gas (CNG)* | **7,556** |
| *PHEV* | **16,634** |
| *BEV* | **3,695** |
| **Vans** | **325,036** |
| **Buses and coaches** | **12,628** |
| **Trucks without trailer** | **69,369** |
| **Trucks with trailer** | **27,026** |

In 2018, 120,505 new passenger cars were registered[17]. In addition, some 40,000 used passenger cars were imported to Finland. In new registrations, gasoline dominates with 70%, and diesel has a share of 24%. Alternative fuel vehicles represent all in all 6% of new registrations, roughly 1% each for both methane vehicles and BEVs, and some 4% for plug-in hybrids. FFVs have vanished from the market. At the end of 2019, there was a total of some 4,000 BEVs, 17,000 PHEVs, 8,000 methane fueled cars and 9,000 FFVs (part of these converted vehicles) in Finland.

## Targets for emission reductions in road transport

The base trajectory for road transport towards 2030 is the so-called ALIISA 2016 "business as usual" baseline[6], sanctioned by the Ministry of Transport and Communications

The ALIISA 2016 baseline makes the following assumption for road transport in 2030:

- passenger car stock: 2,957,532 units
  - electric passenger car stock (PHEVs + BEVs): 120,000 units
- total transport work (all road vehicles): 55,591 million km
- total energy use: 3,420 ktoe
  - fossil liquid fuels 2,904 ktoe (84.9%)
  - liquid biofuels 462 ktoe (13.5%)
  - natural gas 8 ktoe (0.2%)
  - biogas 8 ktoe (0.2%)

[17] http://trafi2.stat.fi/PXWeb/pxweb/fi/TraFi/TraFi__Ensirekisteroinnit/030_ensirek_tau_103.px/

- electricity 37 ktoe/427 GWh (1.1%)

- total TTW $CO_2$ emissions 8.99 Mt (-24% compared to the reference year 2005)

**The 2016 Finnish national energy and climate strategy for 2030**, presented in November 2016, calls for a 50% reduction of $CO_2$ emissions from transport by 2030, the reference year being 2005. Three key measures to reduce emissions are listed:

- Improving the energy efficiency of the transport system
- Improving the energy-efficiency of vehicles
- Replacing oil-based fossil fuels with renewable and/or low emission alternatives

Within the three key measures, several detailed measures or sub-targets are mentioned. For renewable and low-emission energy carriers the following measures and targets are listed:

- Increasing the physical share of biofuels (energy content) in road transport fuels to 30%
- Expanding the refueling infrastructure for alternative energies in transport (recharging of electric vehicles, gaseous fuels including hydrogen)
- Encouraging the uptake of alternative vehicles, the minimum targets set for 2030 being:
  - 250,000 electric vehicles (battery electric vehicles, plug-in hybrids, fuel cell vehicles)
  - 50,000 gas fueled vehicles

**The 2019 Government Program of Prime Minister Antti Rinne/Sanna Marin**, in addition to energy efficiency throughout the transport system, highlights sustainable biofuels for heavy-duty vehicles and aviation, synthetic carbon-neutral fuels, recharging infrastructure for EVs and biogas in transport. Biogas is seen as an important element in the circular economy. A program for recirculation of nutrients will be developed, and this will include increasing production of biogas and creating a market for recirculated nutrients.

Biogas is currently not taxed in Finland. Including biogas in the biofuels obligation means that biogas would have to be put under tax.

Figure 5 shows the ALIISA baseline $CO_2$ inventory from 2005 (reference year) to 2030 (target year) and the trajectories needed to reach -39 (the overall emission reduction target for Finland in the non-emission trading sector/European effort sharing) or -50% by 2030. The oscillations in the $CO_2$ emissions around 2015 are a result from variations for biofuels delivered to the Finnish market. The reference value for 2005 is 11.7 Mt $CO_2$. The baseline lands at 8.9 Mt $CO_2$ or -24% compared to 2005. The emission reductions for 2030 have to be based on a combination of:

- energy efficiency
- use of biofuels/carbon neutral fuels
- electrification of vehicles

The 2016 national energy and climate strategy assumes that intensified energy efficiency measures (other than electrification of vehicles) throughout the transport system could bring about emission reductions of 1.6 Mt of $CO_2$ in 2030. Subtracting this from the ALIISA 2016 baseline would result in 7.3 Mt $CO_2$, a reduction of 38%. Thus additional volumes of biofuels and increased numbers of EVs will be needed to reach the targeted 50% reduction.

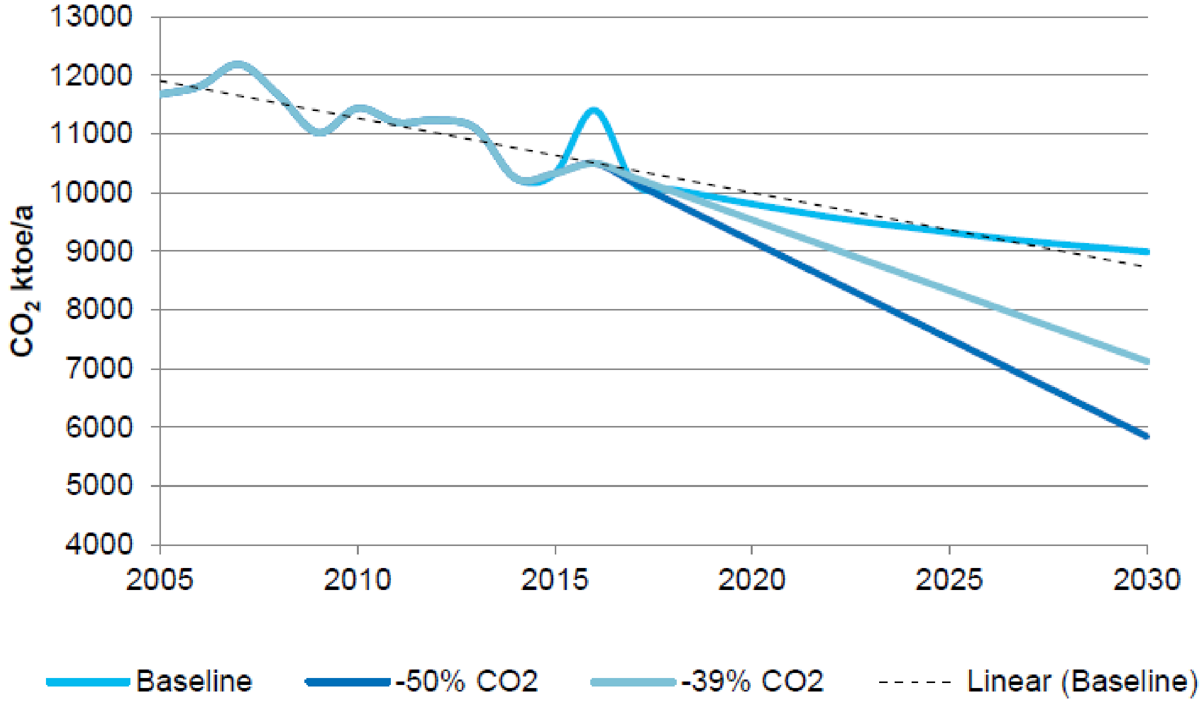


*Figure 5: Road transport $CO_2$ inventory from 2005 (reference year) to 2030 (target year) and the trajectories needed to reach emission reductions of -39 or -50% by 2030[4].*

## Measures to promote reduced $CO_2$ emissions from road transport

In Finland, the use of biofuels is seen as an important way to reduce greenhouse gas emissions from road transport. In several studies looking towards 2030, biofuels are predicted to render the biggest $CO_2$ reductions in transport, having more impact than improvements in energy efficiency and electrification of transport. Notwithstanding, it is realized that the emission reductions in transport cannot rely on biofuels only.

The list of measures to reduce $CO_2$ emissions from road transport includes, among other things:

- obligation for liquid biofuels[7,18]
- fair taxation system for liquid transport fuels[15]
- $CO_2$ based vehicle taxation (passenger cars)[19]
- acquisition support for BEVs[20]
- scrapping premium for old cars[21]
- support for conversions of vehicles (passenger cars)[22]
- support for refueling  infrastructure[23]

The support measures thus cover renewable fuels, energy efficiency (through $CO_2$), electrification and fleet renewal. The biofuels obligation and the $CO_2$ based vehicle taxation are probably the two measures, which have delivered the most significant $CO_2$ reductions in transport in Finland.

For several years, Finland has had a consistent policy for **biofuels in transport**. Biofuels related R&D activities have received funding, and there has been funding (investment support) available for demonstration projects as well. The first biofuels obligation was set in 2008. The obligation was revised in 2010, accompanied by a tax reform treating biofuels in a fair way. The target for 2020 is 20% biofuels in road transport, taking into account double counting for advanced biofuels.

In the spring 2019, the biofuels obligation was revised again, and the pathway towards 2030 was set. The biofuel target for 2030 is 30%, and this time actual energy contribution without double counting. There is also a separate sub target for advanced biofuels, 10%, i.e., one third of the total contribution[13]. In addition, a 10% biocomponent obligation was set for light fuel oil[24].

The **$CO_2$ based vehicle taxes** (purchase tax as of 2008 and annual tax as of 2010) has brought down the $CO_2$ emissions significantly, from 179 g/km in 2007 to 118 g/km in 2018

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[18] https://www.finlex.fi/fi/laki/alkup/2019/20190419

[19] Parkkonen, L. (2013). Taxation of petroleum products and vehicles in Finland. CEN/TC 19 Conference. Helsinki, 27 May 2013.

[20] https://www.traficom.fi/fi/asioi-kanssamme/sahkoauton-hankintatuki

[21] https://www.traficom.fi/sites/default/files/media/publication/Romutuspalkkiokampanja_2018_Traficomin_tutkimuksia_11_2019.pdf

[22] https://www.traficom.fi/fi/asioi-kanssamme/muuntotuki

[23] https://energiavirasto.fi/liikenteen-infratuki

[24] https://www.finlex.fi/fi/laki/alkup/2019/20190418

(Figure 6). In 2019, the minimum purchase tax is 2.7% (BEVs) and maximum 48.9% (WLTP $CO_2$ >360 g/km)[25]. The progressive $CO_2$ tax is a strong indirect support to BEVs and PHEVs. In the case of high-performance vehicles, PHEVs are significantly cheaper to buy than their gasoline or diesel counterparts. This is a kind of casting defect in the system, supporting high performance cars, which in fact may never be operated on electricity.

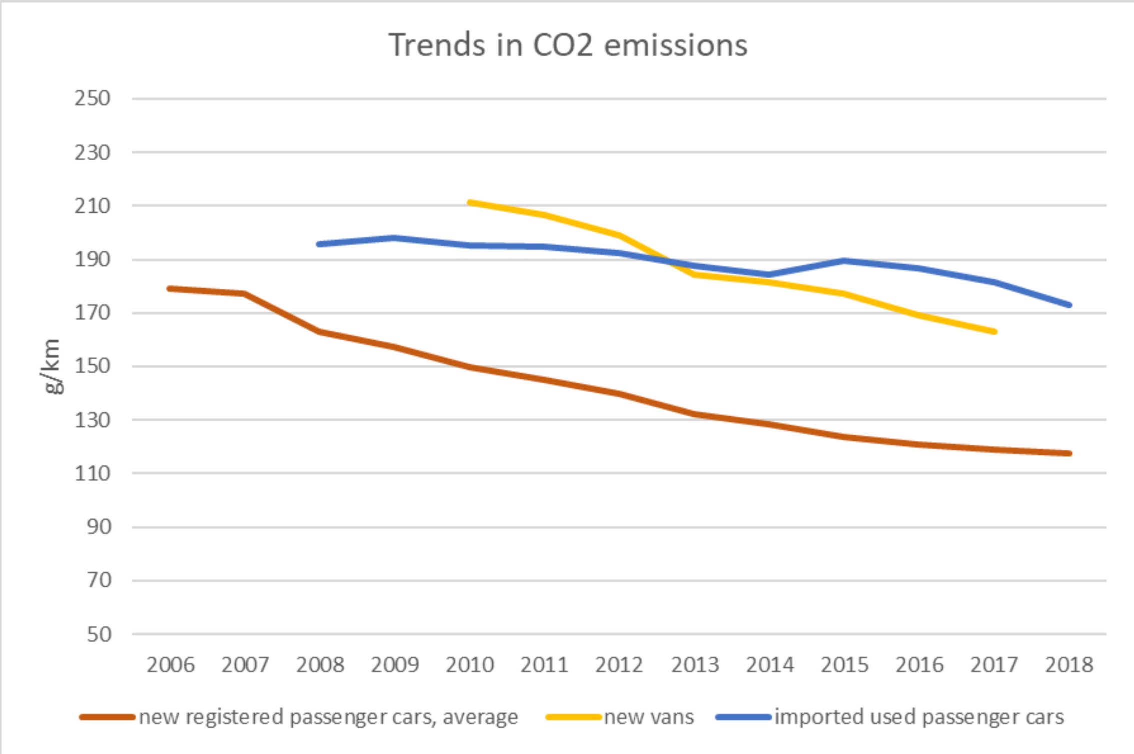


*Figure 6: Trends in $CO_2$ emissions of new passenger cars and vans and used imported passenger cars8.*

The **acquisition support for BEVs** in itself has probably not helped uptake of BEVs significantly. However, the combination of vehicle and energy taxes provide a significant incentive for BEVs. Parkkonen[14] has estimated, that the tax benefits for a BEV compared to a gasoline or diesel car are in the order of 15,000 € over a time period of 10 years.

In 2018, the **scrapping premium** was used for some 7,000 vehicles. The average $CO_2$ value for the new replacement vehicles was 100 g/km, 18 g/km lower than the average new cars in 2018. However, the scrapping premium has not been a sufficiently strong instrument to lower the average age of the passenger car fleet in Finland.

The idea behind the **conversion support** is to enable older vehicles to switch to renewable fuels (E85 and biogas). However, the impact of the conversion support has been rather

[25] https://www.vero.fi/globalassets/henkiloasiakkaat/autoverotus/verotaulukko-1a_1365_2018.pdf

limited. E85 or flex-fuel conversions are only allowed for MY 2007 and older vehicles. Retrofitting to methane again in most cases imply significant loss of luggage space.

The support for **refueling infrastructure** is probably also of limited impact. The Energy Authority has so far launched two competitive biddings, in 2018 and 2019[26]. The total support in the 2018 bid was 3 M€. Support was given to 6 methane refueling facilities and to 5 high power charging stations. The 2019 bid will close in September 2019.

## Projections

In 2018, in preparation for the update of the biofuels mandate for 2021 to 2030, the Prime Minister's Office (PM Juha Sipilä) launched a tender for a study with the title "Cost effective pathways of biofuels until 2030". A consortium led by Pöyry Management Consulting Ltd won the tender. The other partners were VATT Institute for Economic Research and TEC TransEnergy Consulting Ltd. The final report of the study was published in early October 2018[27] ("Biofuels 2030"). The study confirmed the definition of policy set in the 2016 national energy and climate strategy, Finland will need some 30 % liquid biofuels in 2030 to meet a 50 % emission reduction target in road transport.

The main conclusions of the Biofuels 2030 study can be summarized as follows (with comments):

- *Finland can reach a 50% emission reduction by 2030 with a combination of improved energy efficiency, 30% liquid biofuels (800 ktoe), 250,000 EVs and 50,000 biogas vehicles*
    - confirmation of the definition of policy set in the 2016 national energy and climate strategy
    - mandate set at 30% (actual) for 2030
- *The current and planned indigenous production capacity would be sufficient for a 30% share of liquid biofuels, but the production would for the greater part be based on imported feedstock*
    - a separate subtarget of 10% advanced biofuels to speed up development of indigenous biofuels based on, e.g., lignocellulosic feedstocks

[26] https://energiavirasto.fi/liikenteen-infratuki

[27] http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161074/63-2018-Biopolttoaineiden_kustannustehokkaat_toteutuspolut_vuoteen_2030_.pdf?sequence=1&isAllowed=y

- *The effect of the new biofuel mandate on pump prices (with tax) is estimated to be +5% on an average (-3…+14%), which with current prices and taxation system would mean +7 cnt/l (relative to the current mandate of 20 % with double counting)*
    - fluctuations in current daily pump prices of fuels can easily be ±5 cnt/l, so the impact can be considered to be relatively marginal
- *The cost increase for the various business sectors and the end-users induced by the new mandate would, on an average, be moderate*
- *The effects of the new mandate on the state economy is limited as well, as the effect on tax revenues is estimated to be less than 0.3%, while increase in VAT compensates for reduced fuel taxes*
    - with the current tax system (energy and vehicle taxes) a drop-in tax revenues will be an issue when moving towards electrification of vehicles

A summary of the Biofuels 2030 study is available as appendix to this report.

## Sweden

| **Key facts for Sweden** |
|---|
| Total fuel consumption of the road transport sector:<br>6,700 ktoe, of which 1,500 ktoe are renewable |
| Number of vehicles in use:<br>5.5 million of which 0.3 million are alternative fuel vehicles (incl. electric vehicles) |
| Current GHG emissions from the road transport sector:<br>15 $Mt_{CO2eq}$ in 2017 |
| The energy consumption of the road transport sector in Sweden is projected to decrease due to more energy efficient vehicles. |
| The target is to reduce GHG emissions from the transport sector (excl. aviation) by 70% compared to 2010 by 2030. |
| Measures to achieve this target include Bonus-Malus and reduction obligation. |
| Scenarios show that it seems possible to achieve this target. However, measures for increased transport efficiency are needed in order to meet the targets in a sustainable way. |

### Energy supply and demand

#### Introduction

Figure 7 below illustrates the supply of energy in Sweden from 1970 to 2018. The amount of energy supplied within the Swedish energy system has been about the same since the mid-1980s, between 550-600 TWh per year (1,980-2,160 PJ). The industrial sector used 141 TWh (508 PJ) in 2018, mainly biofuels and electricity to run processes. The residential sector used 147 TWh (529 PJ), mainly district heat, electricity and biofuels. The transport sector used 84 TWh (302 PJ), mainly petroleum products but also biofuels and electricity.

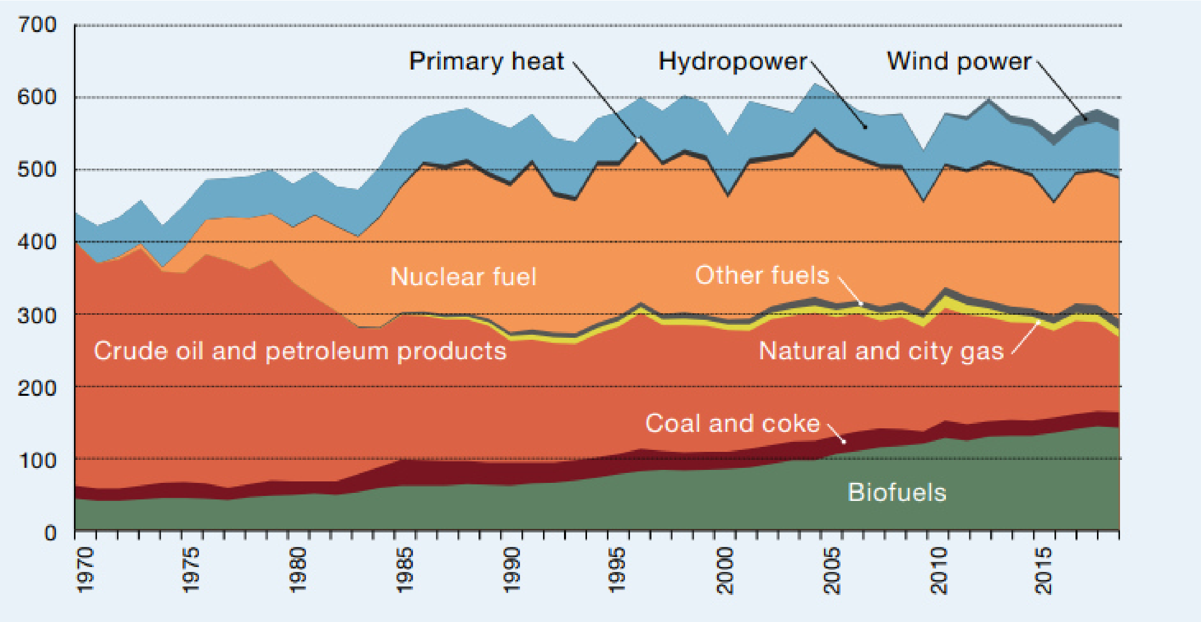


*Figure 7: Supply of energy in Sweden 1970-2018, TWh, Sources: Swedish Energy Agency and Statistics Sweden*

## Transport sector

The transport sector uses mainly petroleum products but also some electricity and a growing share of biofuels. In the transport sector, petroleum products accounted for 76% of the energy use in 2018. During the last few years the amount of biofuels has increased significantly. Road transport accounted for 92% of the final domestic transport sector energy use in 2018. Figure 8 shows the final use in TWh in 2018.

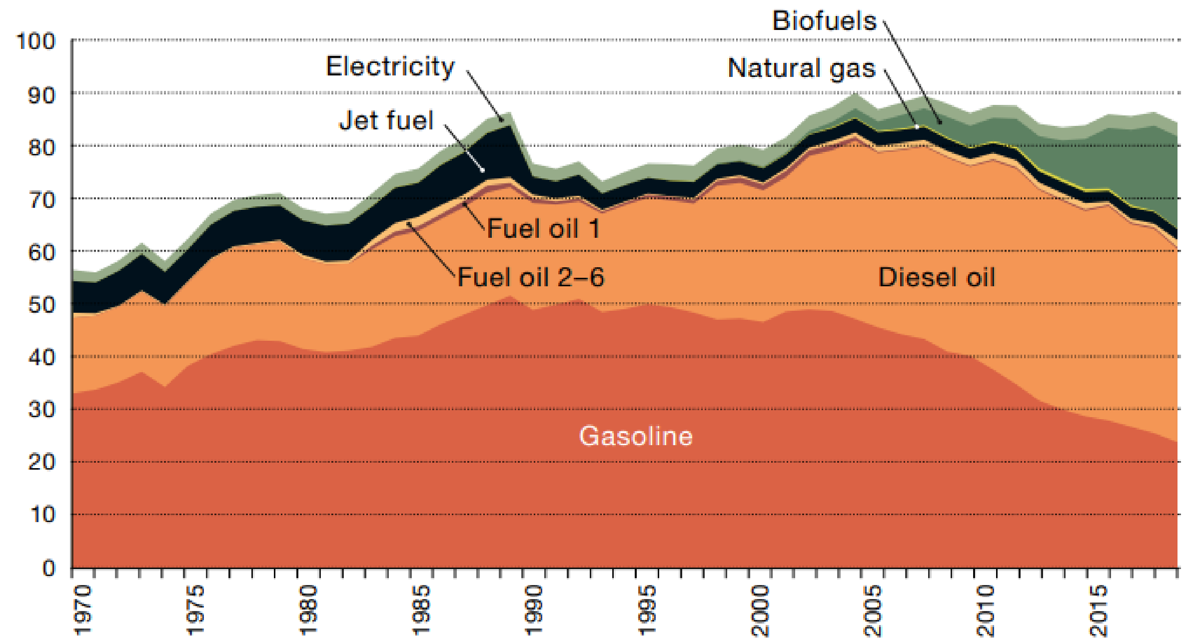


*Figure 8: Energy use for transport 1970-2018, TWh, Sources: Swedish Energy Agency and Statistics Sweden*

Almost all energy for transport is imported, both fossil and biofuel products. When HVO was introduced on the Swedish market, it was produced from crude tall oil from Sweden, Finland, and the United States. As the demand for HVO increased, the number of feedstocks and countries of origin increased. Today, the raw materials are slaughterhouse wastes, Palm Fatty Acid Distillate (PFAD), crude tall oil, palm oil, corn oil and rapeseed (see Figure 9). The majority of feedstock for HVO is imported (Figure 10).

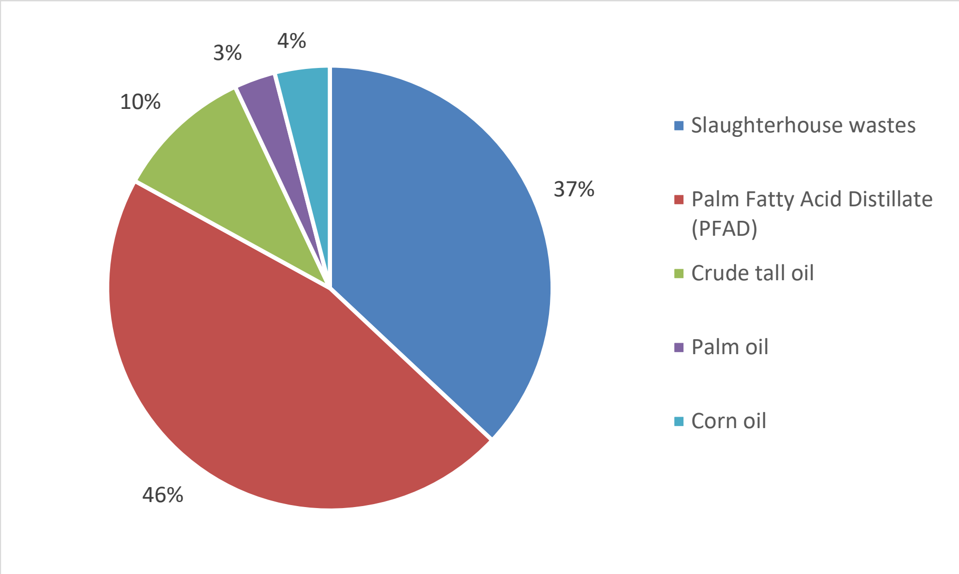


*Figure 9: Raw materials for HVO used in Sweden 2018. Source: Swedish Energy Agency*

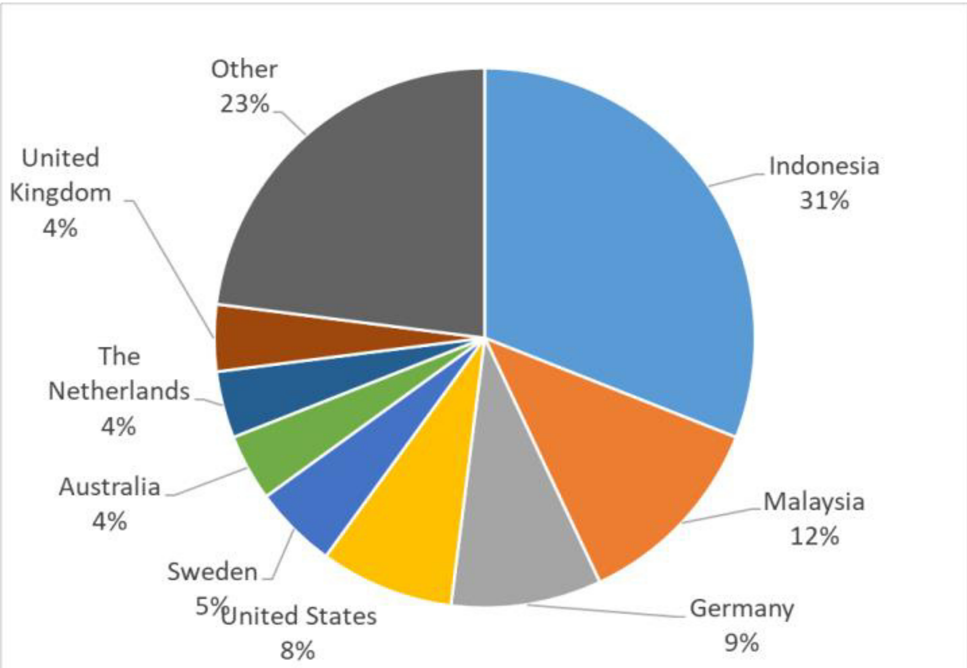


*Figure 10: Country of feedstock origin for HVO consumed in Sweden in 2017*

The current Swedish biofuel production includes ethanol, FAME, HVO and biogas and is shown in Table 3.

*Table 3: Current Swedish biofuel production, ktoe*

| | Ethanol | FAME | HVO | Biogas | Total |
|---|---|---|---|---|---|
| Ktoe | 126 | 177 | 179 | 120 | 602 |
| TWh | 1,5 | 2,1 | 2,1 | 1,4 | 7,1 |

A clear trend of the increasing use of biofuels within the transport sector can be seen in Figure 11, especially of biodiesel (both FAME and HVO). The use of biofuels amounted to 17 TWh (61 PJ) in 2017 which corresponds to 21 % of the transport sector's energy use. The electricity use within the road transport sector is close to zero. However, around 3 TWh (11 PJ) of electricity is used in railways.

Almost 84% of the renewable fuel used for road transport in Sweden during 2018 was low blending of hydrotreated vegetable oil (HVO) and fatty acid methyl ester (FAME) in diesel.

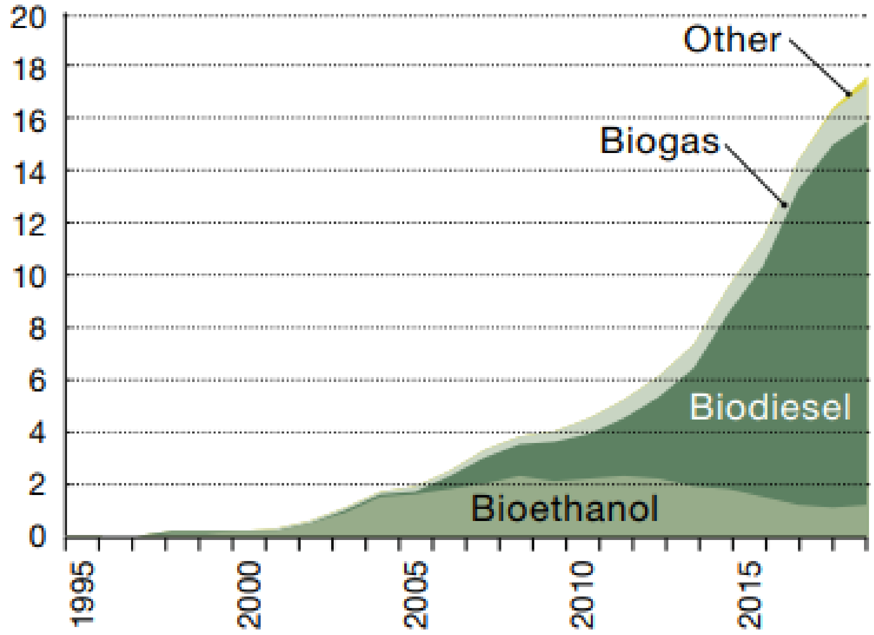


*Figure 11: Biofuel use in Sweden 1995-2018. Source: Swedish Energy Agency*

## Targets for emission reductions in road transport

Swedish energy policies aim to promote ecological sustainability, competitiveness and security of supply. The energy policies are based on the EU regulatory framework.

EU goals by 2030

- Reduce energy consumption by 32.5 % through increased energy efficiency
- At least 32 % of energy consumption provided from renewable sources
- 14 % of energy consumption by the transport sector provided from renewable energy
- Reduce GHG emission for Sweden by 40 % compared with 1990[28]

Swedish energy and climate goals

- 50 % more efficient energy consumption by 2030 compared to 2005
- 100 % of electricity production shall be from renewable sources by 2040
- 2045, at the latest, Sweden will have no net emissions of greenhouse gases (GHG)
- For the transport sector, a reduction in emissions (not including domestic air travel) of at least 70% by 2030, compared with 2010

## Measures to promote reduced $CO_2$ emissions from road transport

The overall goal of Sweden's environmental policy is to be able to pass on to the next generation a society in which major environmental problems have been solved, without increasing environmental and health problems beyond the country's borders. Sweden aims to become one of the world's first fossil-free welfare countries. To achieve this, the fossil-fuel dependency of the transport sector needs to be broken. Several measures are needed, such as reducing the total energy demand of the transport sector (through energy efficient vehicles and a transport efficient society) and ensuring that the remaining energy is both renewable and sustainable.

In 2017 a new climate policy framework was approved. The long-term climate goal means that by 2045, at the latest, Sweden will have no net emissions of greenhouse gases (GHG). In more precise terms, the long-term climate goal means that emissions from activities on Swedish territory will be cut by at least 85% compared with emissions in 1990. To achieve net zero emissions, flexibility measures are included (i.e. investments in other countries to reduce emissions). For the transport sector, a reduction in emissions (not including domestic air travel) of at least 70% by 2030, compared with 2010, has also been adopted.

In the strategy on living cities, the government has decided on a milestone goal that

[28] sectors not included in the EU Emissions Trading System

passenger transport by public transport, walking and cycling shall account for at least 25 % of passenger transport in the country by 2025 and the share shall double in the long term. This goal also means limiting the growth of passenger car traffic which in the long run cannot increase if this goal is to be achieved. These goals are not matched to the climate target, and it may require more or less of these parts to reach the climate target in 2045.

In mid-2018 the Government introduced what is known as a bonus-malus system, whereby environmentally adapted vehicles with relatively low carbon dioxide ($CO_2$) emissions (up to 60 g/km) are awarded a bonus at the time of purchase, and vehicles with relatively high $CO_2$ emissions (above 95 g/km) are subject to a higher tax (malus) during the first three years. The system includes cars, light buses, and lights trucks. The bonus is limited to a maximum of SEK 60,000[29].

Another important measure introduced in mid-2018 is the GHG reduction obligation, which entails an obligation for fuel suppliers to reduce GHG emissions from sold volumes of gasoline and diesel fuels by incorporating biofuels.

In 2020 the reduction obligation is 4.2 % for gasoline and 21 % for diesel. The reduction obligation will be increased over time with an indicative target of 40% overall reduction in 2030, indicatively composed of 28 % for gasoline and 66 % for diesel.

The biofuels included in the reduction obligation system are subject to the same energy and $CO_2$ taxation as fossil fuels. Biofuels outside the reduction obligation scheme have reduced taxes.

The reduction obligation has reduced climate impact from gasoline and diesel. The fuel suppliers have so far fulfilled the reduction obligation according to the current levels in the scheme. Fuel producers seem to have shifted focus from high-blended and pure biofuels to low-level blending into gasoline and diesel. There is no incentive for the fuel suppliers to exceed the obligation, which means that the reduction obligation is both a floor and a roof for biofuel use.

For a more extensive list of policy measures, the effects and lessons learned, see the report *The contribution of Advanced Renewable Transport Fuels to transport decarbonization in Sweden - 2030 and beyond* *(https://www.ivl.se/download/18.20b707b7169f355daa77ae0/1561538469463/C416.pdf).*

[29] 1 SEK is around 0.12 USD

## Projections

The Swedish Transport administration makes different types of projections, both business-as-usual (BAU) and scenarios with different developments. In the current BAU-projection, transport demand is expected to increase by around 25% from today to 2040. The share of vehicle kilometers by electric vehicles would reach 38% by 2040. The share of renewable fuels is assumed to stay on the same level as today, since the reduction obligation scheme is on the same level 2040 as today in the BAU-projection.

The Swedish transport administration also has scenarios that reach the climate targets for Sweden, i.e. 70% reduction of $CO_2$-emissions to 2030 compared to 2010 and zero emissions in 2045. The scenarios combine three areas of action to reach the targets set for the Swedish transport sector in the future, namely:

- A transport efficient society
- More efficient vehicles and propulsion
- Transition to renewable energy

The starting point is that the route chosen includes all these three areas of action. The reason is that the expected rapid transition requires multiple parallel measures for effects to vindicate. Moreover, to simultaneously pursue several tasks is a way to diversify and minimize risks. It is also important to pick a clear path that others may follow. Furthermore, given the fact that the resources needed for the transition such as raw materials for biofuels and batteries, vehicles and infrastructure, are limited on a global scale, allowing a multitude of actions increases the chances for success. Finally, there are synergistic effects from the actions working in combination, primarily from a more transport efficient society.

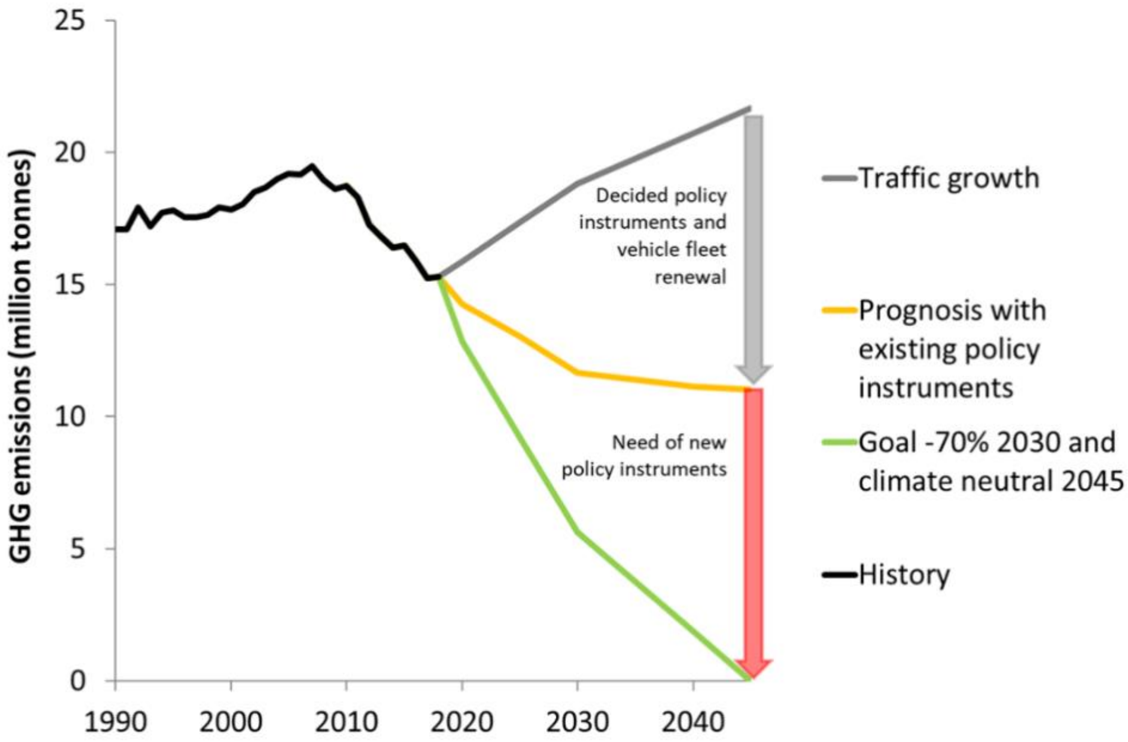


*Figure 12: The gap between BAU scenario and the goals for the Swedish transport sector. Source: Swedish Transport Administration*

Figure 12 illustrates three different projections; the grey line illustrates the $CO_2$-emissions if no improvements would be made in the vehicle fleet and the transport demand increases. The yellow line illustrates the BAU-scenario; the transport demand increases by around 25% but with an improved vehicle fleet due to measures already decided today (the $CO_2$ regulation for new vehicles on EU-level is very important). The green line illustrates the path needed to meet the climate targets. The red arrow illustrates the gap between where we expect to be in 2045 if no additional measures are taken and where we need to be to reach the climate targets.

The GHG reduction obligation is an important measure in Sweden and currently the levels in the system are only set until 2020. The decision on reduction levels for the coming years will have a very large impact on the development of renewable fuels in Sweden (both the fuels included in the system and indirectly also the fuels outside).

There is also a lot of activity concerning electrification of the transport sector and one important measure is the Bonus-Malus system. The idea of the bonus malus system is to reward vehicles that emit relatively small amounts (up to 60 grams per kilometer) of carbon dioxide ($CO_2$), with a maximum bonus of 60,000 SEK[30], while burdening vehicles that emit relatively large amounts of $CO_2$ with higher vehicle tax for the first three years: malus. This way, the bonus malus system can serve as a complement to the more general fuel tax, and contribute to reducing the transport sector's oil dependence and climate impact. The Bonus-Malus system has significant impact on the sales of new cars. There is also a new climate premium introduced in 2020 in the form of state aid for certain environmental vehicles. The premium will promote the introduction of environmental trucks and electric non-road mobile machinery on the market and contribute to reduced greenhouse gas emissions. The Swedish Transport Administration has been given a Governmental assignment to develop deployment strategies for an electric road system.

[30] 1 SEK is around 0.12 USD

## Germany

**Key facts for Germany**

Total fuel consumption of the road transport sector:
54,120 ktoe, of which 2,850 ktoe are renewable in 2017

Number of vehicles in use:
About 50 million in road application, of which 1.6% are alternative fuel vehicles (incl. electric vehicles)

Current GHG emissions from the road transport sector:
162 million- $t_{CO2eq}$ in 2017

The energy consumption of the road transport sector is projected to likely increase until 2030 due to different prognoses.

The target is to reduce GHG emissions from the transport sector by 42% compared to 1990 by 2030.

Measures to achieve this target include the transposition process of the RED- II and ESR into national laws and regulations. Moreover, the Climate protection Law will be the base allowing to reach the targets until 2030 or not. It is very likely that the GHG quota will be continued from 2021 onwards and further $CO_2$-related instruments will come into effect.

### Energy supply and demand

#### Introduction

The primary energy demand of Germany in the year 2017 was 325 Mtoe (13,594 PJ) and the corresponding final energy consumption was 223 Mtoe (9,329 PJ). Almost 30% of final energy consumption (66 Mtoe – 2,755 PJ) was used in the transport sector. After a steady growth phase in the 1990s, from 2000 on the total demand for energy in transport declined slightly. Since 2010, it has been increasing steadily again. Compared to 1990, the energy demand increased by 16% in the transport sector, while the total energy demand of Germany decreased by 9% in the same period. Above all, the demand for diesel and jet fuel is rising, while the consumption of gasoline has fallen sharply in the last 20 years. In 2017, 82% of the 66 Mtoe (2.755 PJ) in transport were used in road transport, 15% in aviation and only 2% and 1% in rail transport and inland shipping, respectively. Figure 13: shows the development of the final energy consumption.

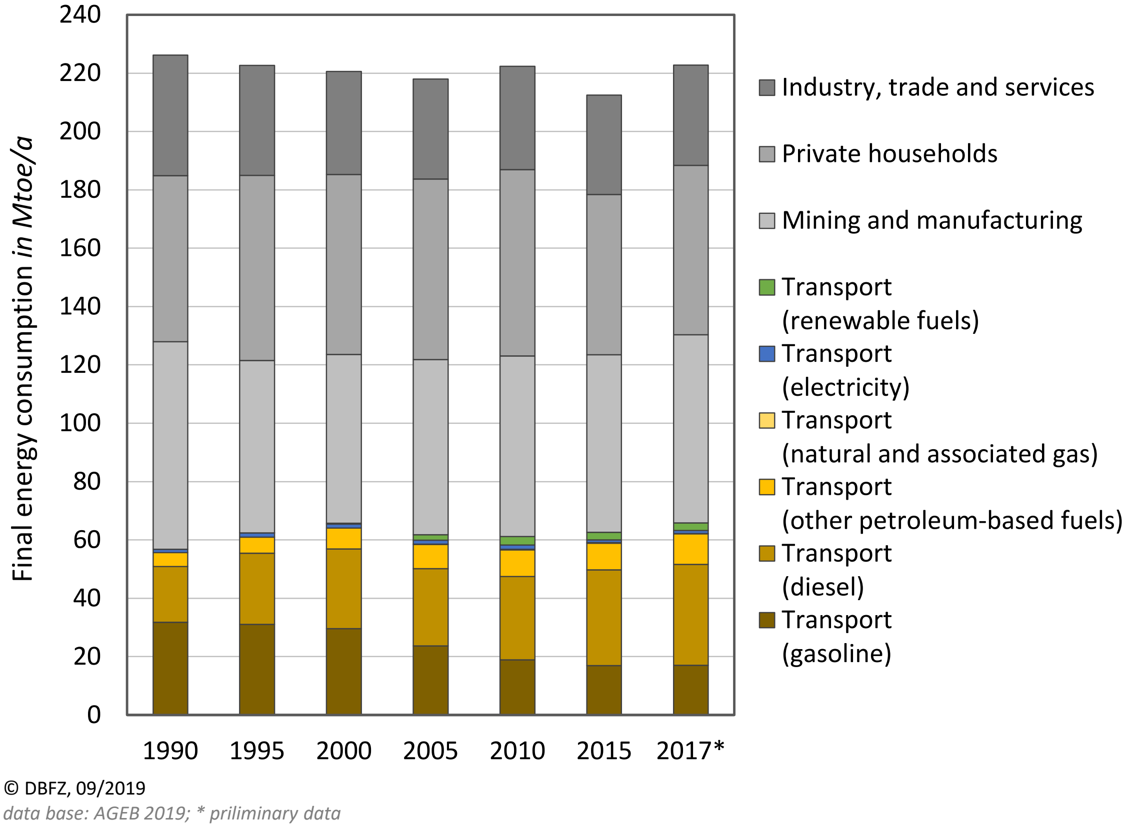


*Figure 13: Development of the energy demand of different sectors (DBFZ based on AGEB 2018)[31]*

## Transport sector

In 2017, the German energy consumption in the transport sector (64.8 Mtoe w/o electricity) was 96% fossil (53% diesel, 26% gasoline, 16% jet fuel, 0.2% CNG/LNG, and 0.5% LPG) and only 4% were renewable fuels. The renewable share includes biofuels such as biodiesel (FAME) with 1.9 Mtoe (80 PJ) and bioethanol with 0.7 Mtoe (31 PJ). Other renewable fuels like vegetable oils, HVO/HEFA and biomethane are less than 0.1 Mtoe (3.1 PJ).

The German biofuel sector has been heavily influenced by changing political conditions (abolition of tax breaks for biofuels in 2011 and switch from energy-based to GHG based biofuel-quota in 2015). As a result, biofuels were mainly used as blends and the total amount of biofuels brought onto the market decreased slightly despite the steadily increasing energy demand. Figure 14 shows the production and use of biofuels in Germany as well as the achieved GHG mitigation. While the fraction of pure biofuels was still around 60% (2.7 million tonnes) of total renewable fuels in Germany in 2007, due to changed policies it

[31] AG Energiebilanzen e.V., Auswertungstabellen zur Energiebilanz Deutschland 1990-2017, Stand: Juli 2018 (online: https://ag-energiebilanzen.de/index.php?article_id=29&fileName=ausw_30jul2018_ov.xls)

has meanwhile dropped to well below 1% in 2017. HVO/HEFA is not produced in Germany, it is completely imported. The production volumes of biodiesel (FAME) were at about the level of domestic use until 2011. Since 2012, production volumes have been rising slightly despite decreasing biodiesel use. Germany is currently a net exporter of biodiesel (0.8 million tonnes). The biofuel market for gasoline substitutes has developed rather steadily. Since 2011, it has accounted for up to 23% (1.2 million tonnes) of the total biofuel used (by energy content). The remaining demand is imported. Biomethane has been established on the market at a rather low level. The amount of biomethane used as fuel was around 0.04 Mtoe (1.6 PJ) in 2017. This is equivalent to about one third of the CNG fuel used in transport. The total amount of biomethane produced and fed into the natural gas grid is significantly larger at around 0.8 Mtoe (33.2 PJ) per year and is mainly used in the electricity and heating market.

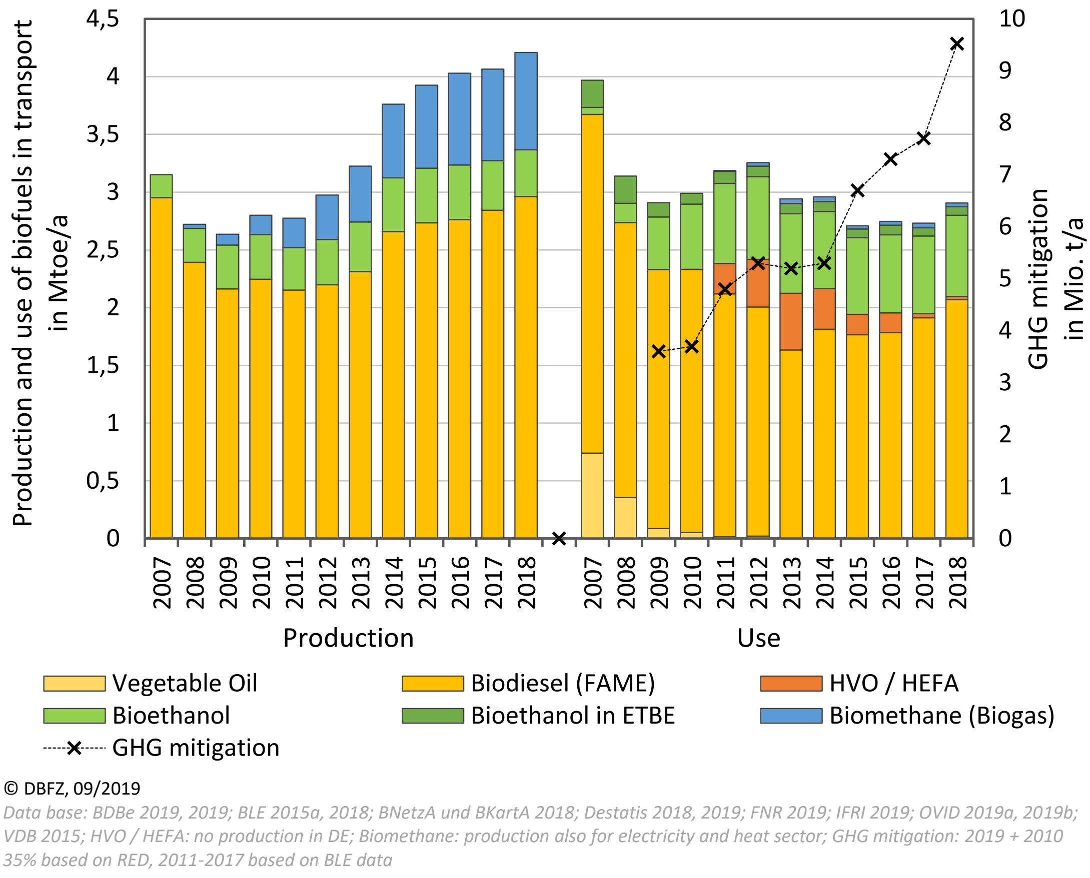


*Figure 14: Development of biofuel production and use (adopted from DBFZ 2019)* [32]

[32] Naumann, Karin: Monitoring Biokraftstoffsektor. 4. überarbeitete und erweiterte Auflage. Leipzig: DBFZ

The biofuels used avoided 7.7 million tonnes of greenhouse gases (GHG) in 2017. The average specific GHG mitigation potential of biofuels within GHG quota is 81% for biodiesel (FAME), 65% for HVO/HEFA, 83% for bioethanol and 91% for biomethane.

### Vehicle fleet

The stock of registered vehicles has been very volatile in Germany in recent years. While the stock of road vehicles is steadily rising, other segments like rail vehicles and vessels show significant declines. Table 4 shows the German vehicle stock in 2010 and in 2017. The number of passenger cars has increased by almost 10%. This is essentially driven by a massive increase (35%) in diesel-powered passenger cars. The stock of gasoline-powered passenger cars (incl. LPG and CNG/LNG) has remained virtually unchanged since 2010. Although there is an impressive increase in hybrid electric vehicles (HEVs) and battery-electric vehicles (BEVs,) the absolute number of vehicles, in particular for battery electric vehicles, continues to be very low, only 79,000 registered vehicles are clearly off the (now discontinued) target of one million electric vehicles (incl. Plug-in hybrid vehicles, PHEV) on the German market by 2020.

*Table 4: German vehicle stock – comparison of amounts in 2010 and 2017*[33]

| | 2010 | 2017 | Change |
|---|---|---|---|
| **Passenger cars** | 42.3 million | 46.5 million | **+9.9%** |
| *Gasoline* | *30.5 million* | *30.5 million* | *-0.1%* |
| *Diesel* | *11.3 million* | *15.2 million* | *+35.1%* |
| *Autogas* | *419 thousand* | *421 thousand* | *+0.6%* |
| *Natural gas (CNG/LNG)* | *72 thousand* | *75 thousand* | *+5.5%* |
| *HEV (incl. PHEV)* | *37 thousand* | *237 thousand* | *+535%* |
| *BEV* | *2 thousand* | *54 thousand* | *+2,235%* |
| **Light and heavy duty vehicles** | 2.4 million | 3.0 million | **+24.2%** |
| **Semi-trailer trucks** | 178 thousand | 211 thousand | **+18.5%** |
| **Buses and coaches** | 76 thousand | 79 thousand | **+3.9%** |
| **Rail vehicles** | 14.3 thousand | 9.9 thousand (in 2015) | **- 0.8%** |
| **Airplanes** | 1.3 thousand | 1.2 thousand | **-8.7%** |
| **Vessels** | 4.7 thousand | 4.1 thousand | **-12.2%** |

(DBFZ-Report Nr. 11). 2019. ISBN 978-3-946629-36-8. (online: https://www.dbfz.de/fileadmin/user_upload/Referenzen/DBFZ_Reports/DBFZ_Report_11_4.pdf)

[33] Radke, Sabine: Verkehr in Zahlen 2018/2019. 47th year. Federal Ministry of Transport and digital Infrastructure Germany, ISBN 978-3-00-061294-7

The sharp increase in the number of road vehicles is also reflected in the resulting mileage. Between 2010 and 2016, the mileage increased by 9% and corresponded to the increase of vehicle fleet. The annual mileage of a vehicle significantly influences the type of vehicle propulsion system used. Passenger cars have shown that diesel-powered vehicles are more commonly used for longer journeys. They make up 33% of the vehicle stock and account for 47% of the mileage of passenger cars. Alternative propulsion systems such as natural gas, LPG and electric propulsion are only responsible for less than 2% of the mileage. Trucks are almost exclusively diesel driven. Only subordinate mileage of 2% and 0.5%, respectively, can be attributed to gasoline and alternative propulsion systems.

### Targets and measures

An overview on existing transport fuel policy measures on EU level and their national transposition in Germany is shown in Figure 15:. A more detailed overview on measures is given in (DBFZ 2019)[34] and (IEA T39 2019) [35].

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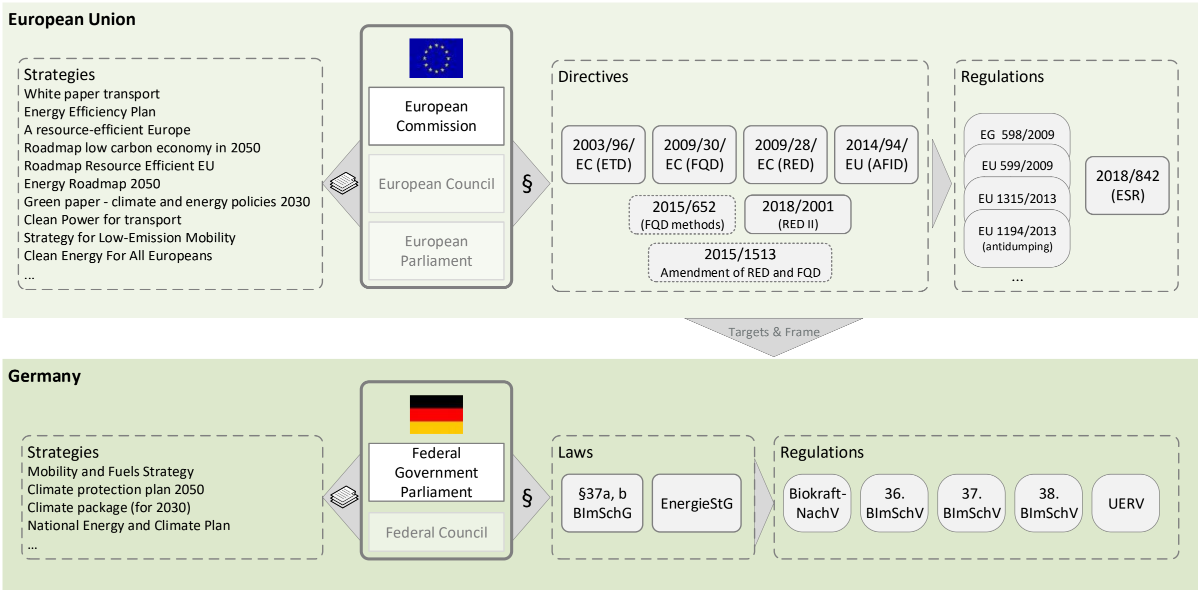
[34] Naumann, Karin: Monitoring Biokraftstoffsektor. 4. überarbeitete und erweiterte Auflage. Leipzig: DBFZ (DBFZ-Report Nr. 11). 2019. ISBN 978-3-946629-36-8. (online: https://www.dbfz.de/fileadmin/user_upload/Referenzen/DBFZ_Reports/DBFZ_Report_11_4.pdf)

[35] IEA TCP Bioenergy T39 (2019) Implementation Agendas- 2018 Update: A review of key biofuel producing countries- May 2019 (to be published by 12/2019 at http://task39.ieabioenergy.com/publications/)




© DBFZ 09/2019 | without claiming to be exhaustive
2009/30/EG (98/70/EC) – FQD Fuel Quality Directive | 2009/28/EC – RED Renewable Energy Directive | 2003/96/EC – ETD Energy Tax Directive | 2014/94/EU – AFID Directive on the deployment of alternative fuels infrastructure | 2018/842 (ESR) – Effort sharing regulation 2021-2030 | BImSchG: Federal Immission Control Act (§37a – Minimum shares of biofuels related to the total fuel amount in transport) | EnergieStG: Energy Tax Law | Biokraft-NachV – Biofuels sustainability regulation | 36. BImSchV – Regulation for implementation of biofuels quota | 37. BImSchV – Regulation for counting of electricity based fuels and coprocessing of biooils on the GHG quota | 38. BImSchV – Regulation for the determination of further terms regarding the GHG mitigation of fuels

*Figure 15: Policy frame in the EU and their transposition in Germany (adapted from DBFZ 2019)36*

Key to fulfil the RED and FQD targets is the GHG-based quota system, which was been implemented in 2015. It obligates fuel supplier companies to sell the respective biofuel together with its fossil counterparts' gasoline or diesel (which is usually done through blending), in order to produce a fuel mix with 3.5%, 4% and 6% GHG mitigation (compared to fossil gasoline and diesel mix) for the entire fuel sector from 2015, 2017 and 2020 onwards. The target continues after 2020 at the level of 6% a year. In case of non-fulfilment of these obligations, penalties will apply of about 47 EURct/kg $CO_2$ equivalent. Biofuels that are counted within the quota are fully energy taxed. Moreover, the German BImSchV regulations provide for instance the frame for a maximum limit of conventional biofuels and minimum quotas for advanced biofuels as well as counting of electricity for transport.

According to the German Climate protection plan in transport, the GHG mitigation has to be about 40-42% until 2030 (c.t. 1990, i.e. reduction about 65-68 million tonnes). The framework conditions for renewables in transport until 2030 is set with the Renewable Energy Directive II (RED-II, 2018/2001/EU, set of 14% renewable fuels in transport by 2030

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[36] Naumann, Karin: Monitoring Biokraftstoffsektor. 4. überarbeitete und erweiterte Auflage. Leipzig: DBFZ (DBFZ-Report Nr. 11). 2019. ISBN 978-3-946629-36-8. (online: https://www.dbfz.de/fileadmin/user_upload/Referenzen/DBFZ_Reports/DBFZ_Report_11_4.pdf)

and frame for dedicated fuels and sustainability criteria). In addition, the Effort sharing regulation (ESR 2018/842), which sets binding annual emission reductions by Member States from 2021 to 2030, is important. Recently, Germany has started the transposition process of the RED-II and ESR into national laws and regulations. Moreover, the Climate action program 2030 as well as the Climate protection law will be the base allowing to reach the targets until 2030 or not.

It is very likely that the GHG quota will be continued from 2021 onwards combined with $CO_2$-related instruments.

## Projections

In the following section several scenarios are summarized, and an analysis of pathways to achieve the German targets for the transport sector is presented.

### Summary of scenarios until 2030/2050

A summary of different scenarios of developments in Germany based on Wietschel[37] et al is presented in Table 5.

[37] Wietschel, Martin et al.: Überblicksstudie. Auswertung von Studien und Szenarien der Energiesystemanalyse mit Schwerpunkt „Mobilität“ (online: https://um.baden-wuerttemberg.de/fileadmin/redaktion/m-um/intern/Dateien/Dokumente/5_Energie/SDA/Studie_Energiesystemanalyse_Mobilitaet.pdf)

*Table 5: Brief summary of exemplary scenarios*

*(RS – Reference scenario; FS – Future scenario, [a] RS and national solo efforts; [b] global climate protection)*

| Premise | (Öko 2016)[38] | (BDI 2018)[39] | (dena 2018)[40] | (Öko/ISI 2015)[41] |
|---|---|---|---|---|
| Base assumption | | | | |
| Population (million) in 2030 / 2050 | 78 / 74 | 81 / 77 | 81 / 76 | 78 / 74 |
| GDP CAGR until 2050 | 0. % p.a. | +5% | 1.1% p.a. | 0. % p.a. |
| Oil (USD/bbl) in 2030 / 2050 | 120 / 195 | 111[a], 80[b] / 115[a], 50[b] | 77 / 65 | 128 / 195 |
| $CO_2$ (EUR/$t_{CO2}$) in 2030 / 2050 | – | 26 / 45 | – | 30 / *50* |
| Scenario target | | | | |
| Reference scenario (RS) | Current measures will be continued | Current measures will be continued | Current measures will be continued | Current measures will be continued |
| Future scenario 1 (FS1) | Decarbonization of transport sector and maximum vehicle efficiency | 80% GHG-reduction in 2050 | Strong variation of technologies used | 80% GHG-reduction in 2050 |
| Future scenario 2 (FS2) | FS1 + Quality of life in inner cities and | 95% THG-reduction in | Strong electrification | 95% GHG-reduction in |

38 Zimmer, Wiebke et al.: RENEWBILITY III - Optionen einer Dekarbonisierung des Verkehrssektors. Endbericht zum Vorhaben FKZ 2013/S 142-247681 (online: http://www.renewbility.de/wp-content/uploads/Renewbility_III_Endbericht.pdf)

39 Gerbert, Philipp et al.: Klimapfade für Deutschland, Boston Consulting Group, prognos, Januar 2018 (online: https://bdi.eu/publikation/news/klimapfade-fuer-deutschland/)

40 Bründlinger, Thomas et al.: dena-Leitstudie Integrierte Energiewende, Juli 2018 (online: https://www.dena.de/fileadmin/dena/Dokumente/Pdf/9261_dena-Leitstudie_Integrierte_Energiewende_lang.pdf)

41 Repenning, Julia et al.: Klimaschutzszenario 2050, 2. Endbericht, Studie im Auftrag des Bundesministeriums für Umwelt, Naturschutz, Bau und Reaktorsicherheit, Dezember 2015 (online: https://www.oeko.de/oekodoc/2451/2015-608-de.pdf)

| Premise | (Öko 2016)[38] | (BDI 2018)[39] | (dena 2018)[40] | (Öko/ISI 2015)[41] |
|---|---|---|---|---|
| | shifting of freight traffic to the rails | 2050 | in all sectors | 2050 |
| Biomass assumption | RS: until 2020 7% cap and after 2020 phase-out for fuels from cultivated biomass.<br><br>FS: Blending quota for Bioethanol (lignocellulose) of 5%, biodiesel (BTL, HVO palm oil, UCOME) of 10% and biomethane of 4%; total potential biofuels of maximum 90 PJ | RS: maximum sustainable amount available for energy use is 29 Mtoe (1,200 PJ) to 31 Mtoe (1,300 PJ) in Germany.<br><br>FS: available sustainable amount increase from 26 Mtoe (1,076 PJ) in 2015 to 29 Mtoe (1,200 PJ) in 2050; therefrom 9% for transport sector | Domestic potential for bioenergy is 23 Mtoe (950 PJ/a); imported potential for bioenergy is 4 Mtoe/a (173 PJ/a); the assumed potential limit of 24 Mtoe/a (1023 PJ/a) is achieved for all scenarios | Domestic biomass potential is 29 Mtoe/a (1,211 PJ) (RS), 29 Mtoe/a (1,223 PJ) (FS1) and 27 Mtoe/a (1,131 PJ) (FS2); raw materials mainly waste and residues; imported biomass necessary |
| PTX assumption (Power to X, PTG – to gas,<br>PTL – to liquids) | FS: 5% in 2030; 95% in 2050; 100% imported | FS2: demand for PTX fuels is 29 Mtoe/a (1,224 PJ) for all sectors, 21 Mtoe (878 PJ) for transport sector; significant import demand for Germany | Domestic PTX is 11 to 14 Mtoe/a (468 to 590 PJ/a )in 2050.<br><br>FS2: PTG hydrogen mainly produced in Germany and PTG methane imported from EU | FS2: PTL after 2030; 2040: 25% PTL of total liquid fuels; 2050: 50% PTL of total liquid fuels; domestic or imported PTL is used. |

Based on the studies investigated in Wietschel et al[42], Figure 16 shows exemplary vehicle fleet scenarios until 2050 and Figure 17 shows scenarios for the final energy demand in the German transport sector by 2050 split into the most important energy carriers.

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[42] Wietschel, Martin et al.: Überblicksstudie. Auswertung von Studien und Szenarien der Energiesystemanalyse mit Schwerpunkt „Mobilität“ (online: https://um.baden-wuerttemberg.de/fileadmin/redaktion/m-um/intern/Dateien/Dokumente/5_Energie/SDA/Studie_Energiesystemanalyse_Mobilitaet.pdf)

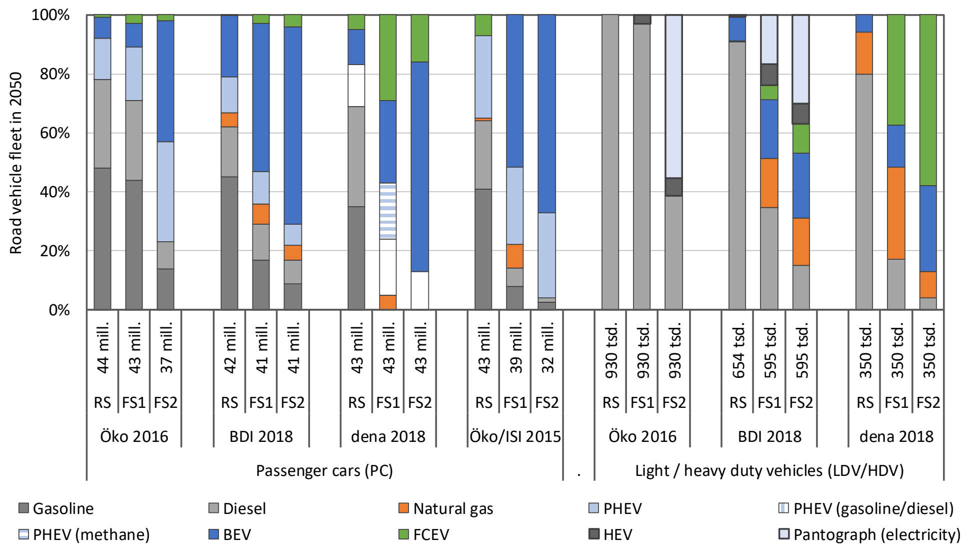


*Figure 16: Vehicle fleet scenario Germany in 2050 (DBFZ based on Wietschel et al)[43]*

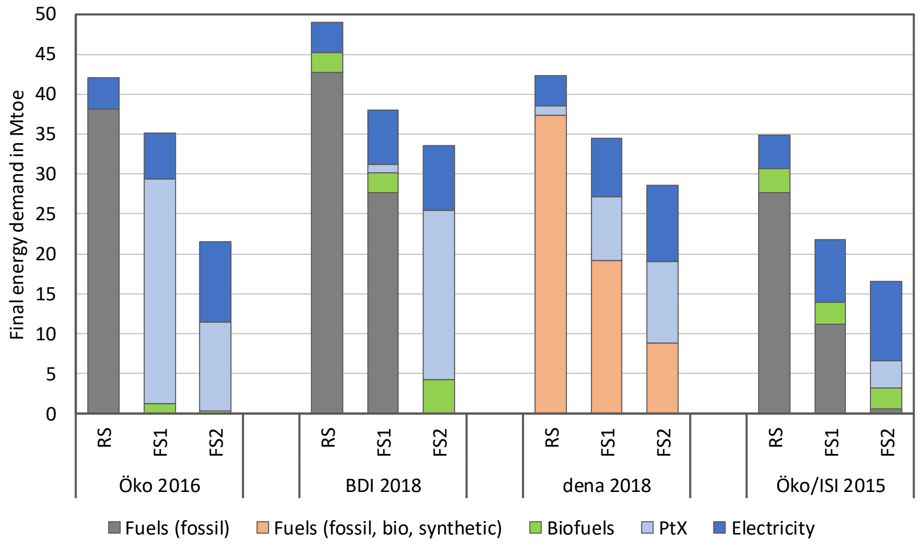


*Figure 17: Final energy demand of German transport sector in 2050 (DBFZ based on Wietschel et al )[43]*

Although different methods, assumptions and data bases were used for these scenarios, the following statements can be made:

- The national target for 2030 will not be reached in most of the studies
- Avoiding traffic or shifting traffic is relevant in all scenarios but to a different extent

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[43] Wietschel, Martin et al.: Überblicksstudie. Auswertung von Studien und Szenarien der Energiesystemanalyse mit Schwerpunkt „Mobilität" (online: https://um.baden-wuerttemberg.de/fileadmin/redaktion/m-um/intern/Dateien/Dokumente/5_Energie/SDA/Studie_Energiesystemanalyse_Mobilitaet.pdf)

- Direct or indirect use of electricity is dominant for all transport modes
- Combustion engines remain relevant, but with alternative fuels
- There is demand for synthetic fuels (especially e-fuels or PTX-fuels) that will be mainly imported
- Passenger cars show direct electrification in all scenarios (BEV with market shares of 10-30% until 2030 and 30-70% until 2050), while other powertrains and related fuels (e.g. PHEV, fuel cell, synthetic fuels, CNG) and their shares greatly vary between the different assessments
- LDV and HDV become increasingly more relevant due to high estimated growth; battery-based powertrains are seen for LDV up to 12 t and HDV short-radius distribution; other solutions vary between the different assessments (e.g. trolley HDV with hybrid-diesel and battery, hydrogen-HDV, and HDV with synthetic fuels)

### Scenarios for biofuels and other renewable fuels until 2030

In order to analyze the impacts of the European and national targets and frames on the design of the GHG quota in Germany, nine different scenarios for the development of the energy supply until 2030 have been investigated using the BENOPT model[44,45] . More details on objectives, frame assumptions, data base and results can be found in the working paper of Meisel et al[46].

In each scenario the optimal fuel mix has been modeled based on input parameters such as:

- political frame,
- biomass feedstock potentials,
- international feedstock and fuel imports,
- blending walls based on the existing fuel standards,
- existing fuel capacities and their meaningful increase,

[44] Millinger, Markus: Greenhouse gas abatement optimal deployment of biofuels from crops in Germany Transport. Res. Part D-Transport. Environ. 69, 265 – 275: https://doi.org/10.1016/j.trd.2019.02.005

[45] Millinger, Markus: BioENergyOPTimisation model (Version 1.0). http://doi.org/10.5281/zenodo.2812986

[46] Meisel, Kathleen et al.: Future Renewable Fuel Mixes in Transport in Germany under RED II and Climate Protection Targets: Untersuchungen zur Ausgestaltung der Biokraftstoffgesetzgebung in Deutschland - Arbeitspapier (04.07.2019), Energies 2020-13(7)-1712: https://doi.org/10.3390/en13071712 Results of the BMEL/FNR project FZK 22401416 (online: https://www.dbfz.de/fileadmin/user_upload/Referenzen/Studien/Ausgestaltung_Biokraftstoffgesetzgebung.pdf)

- specific efficiencies for fuel production,
- increase of renewable electricity within the German electricity mix,
- increase of gaseous fuels in transport and
- fuel specific GHG emissions and production costs.

Moreover, electro mobility for road transport has been taken into account as well. The relative advantage of different fuel options in fulfilling the overall energy demand within the GHG quota system is mainly based on the fuel specific GHG mitigation costs. These are used as an indicator for competitiveness of fuel options on the market[47].

The results of the two most important scenarios are briefly explained as follows.

**Base case scenario – direct transposition of RED-II**

If the RED-II frame is directly implemented to reach 14% renewables in transport while the final energy demand in road and rail transport is about 52Mtoe (2,178 PJ) in 2030 (56 Mtoe - 2,350 PJ in 2017), the corresponding GHG quota is just 5.7% (w/o upstream emission reduction and electricity in rail transport). This would be less than the 6% target already set for 2020 onwards and of course far away from reaching the target on GHG reduction until 2030 (40-42% ct. 1990). This is even the case with about 6 million BEV, that have been taken into account and an increase of the gas share in transport towards 3% until 2030.

To fulfill RED-II minimum targets about 3,8 Mtoe (160 PJ) are required (Figure 18:). To reach this, important options are biomethane from biowaste, which will fulfill the advanced fuel quota set in RED-II, as well as sugar cane ethanol and/or domestic ethanol (mainly based on starch, in the case that sugar cane ethanol imports do not increase), which will provide the renewable fuel share in 2030. Moreover, there will be decreasing shares on used cooking oil (UCO) methyl ester as well as on rape seed based methyl ester and palm based methyl ester. Options that show increasing markets globally such as HVO/HEFA will not play a role.

[47] Müller-Langer, Franziska: Importance of biofuels within the Renewable Energy Directive (RED II) as a contribution to climate protection in transport. 16th International Conference on Renewable Mobility. Berlin (Germany). 21.01.2019

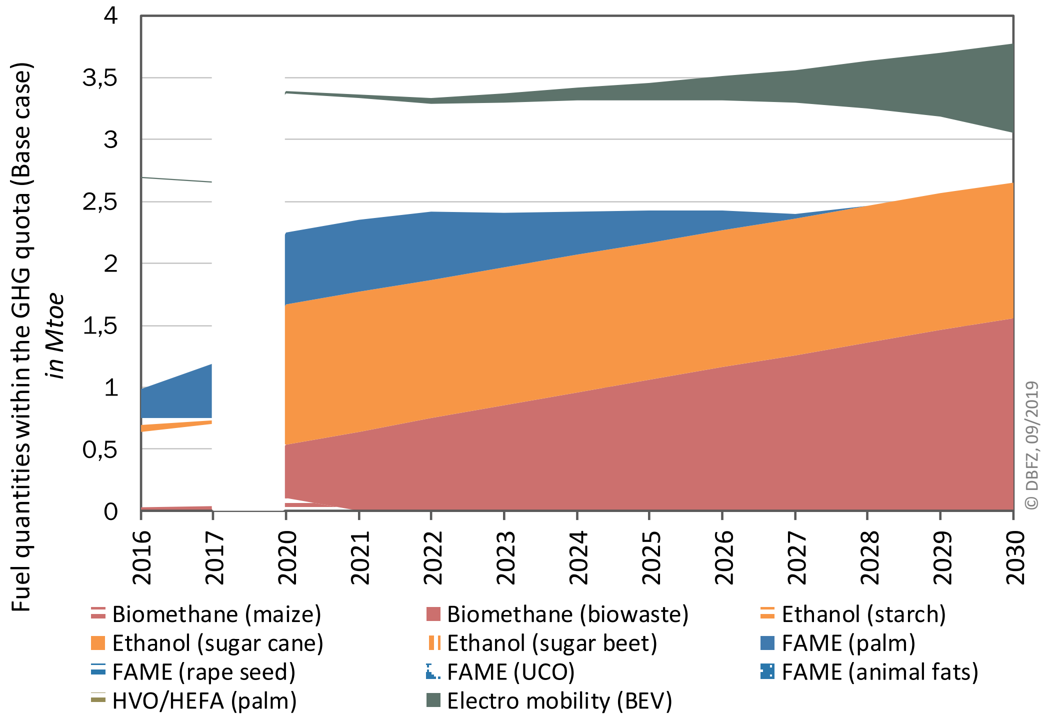


*Figure 18: Base case scenario – fuel quantities within the GHG quota until 2030*

### Climate scenario – 40% GHG reduction

To achieve the target of -40% GHG until 2030, a significant reduction on final energy demand in road and rail transport is required (39 Mtoe – 1,620 PJ compared to 50 Mtoe - 2,110 PJ in 1990) and at the same time a comparably high GHG quota of about 34.5% which corresponds to about 41% renewables.

To reach this, in addition to about 10 million BEV and an increasing gas market shares, approximately 14 Mtoe (690 PJ) from almost all considered fuel options would be required (Figure 19). To ensure this, commercial fuel production capacities for advanced biofuels (mainly straw based ethanol and synthetic BTL fuels) and PTX (mainly PTL) need to be installed and come into operation already in the early 2020s.

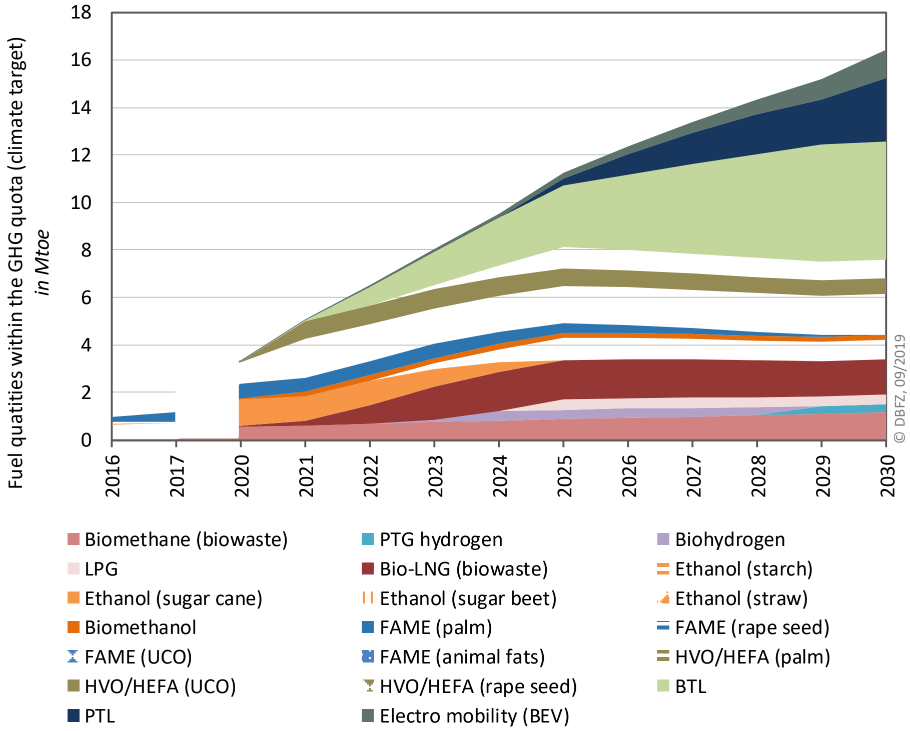


*Figure 19: Climate scenario – fuel quantities within the GHG quota until 2030*

## USA

**Key facts for the USA**

Total fuel consumption of the road transport sector:
708 Mtoe, of which 36.1 Mtoe are renewable

Number of vehicles in use:
260 million, of which 1.08 million are alternative fuel vehicles (incl. electric vehicles)

Current GHG emissions from the road transport sector:
1,871 $Mt_{CO2eq}$ in 2017

The energy consumption of the road transport sector in the US is projected to decrease due to fuel efficiency standards, vehicle electrification, and biofuels.

The Renewable Fuel Standard is aimed at reducing GHG emissions from the transportation sector. State regulations will reduce GHG emissions in certain areas such as California.

Measures to lower GHG emissions include Renewable Fuel Standard and California Low-Carbon Fuel Standard. Scenarios show that it is possible to reduce GHG emissions from the transportation sector.

### Energy supply and demand

While renewable energy capacity continues to grow, current U.S. energy production and consumption is largely reliant on fossil fuels. The United States is currently a net exporter of coal and natural gas, and is expected to become a net exporter of petroleum liquids after 2020.[48] Much of this increased production of fossil fuels is tied to continued development of tight oil and shale gas resources. However, renewable transportation fuel production has also been increasing, with an average annual percentage change of 15.3% for ethanol production (1981-2018) and 10.4% for biodiesel (2008-2018).[49]

In 2018, the U.S. produced 95.722 quadrillion BTU of energy (100.987 EJ), a combination of fossil fuels, nuclear electric power and renewable energy.[50] Renewable energy production

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48 https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf

49 https://tedb.ornl.gov/wp-content/uploads/2019/03/TEDB_37-2.pdf

50 https://www.eia.gov/totalenergy/data/monthly/pdf/sec1_3.pdf

accounted for 12% of total energy production in the U.S. (11.617 quadrillion BTU, i.e. 12.256 EJ). In addition, the U.S.'s net imports of energy amounted to 3.625 quadrillion BTUs (3.824 EJ).[51] Ultimately, the U.S. consumed 101.093 quadrillion BTUs (106.653 EJ) of energy in 2018.[52] Of this total, 80% was in the form of fossil fuels (coal, coal coke imports, natural gas and petroleum).[53] Domestic petroleum accounted for 89% of U.S. petroleum consumption.[54] Figure 20 shows the U.S. primary energy consumption by sector in 2018.

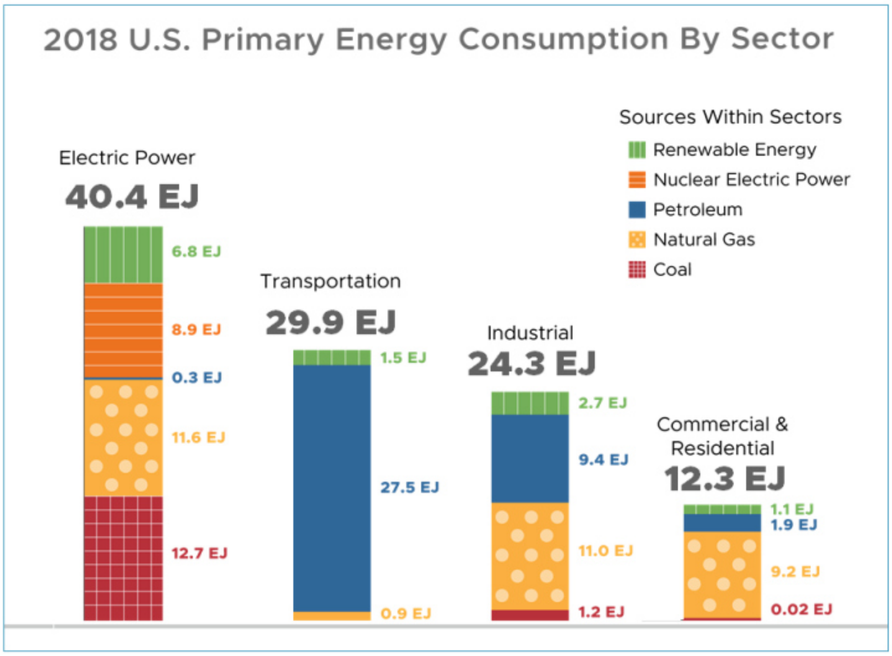


*Figure 20: 2018 U.S. primary energy consumption by sector[55]*

The U.S. transportation sector accounted for 28% of the country's energy use in 2018.[56] Of this energy, 91.7% of it was comprised of petroleum, with transportation petroleum accounting for 93% of total U.S. petroleum production and 69% of U.S. petroleum use.[57] According to 2016 figures, 59% of U.S. transportation energy use was in cars and light

[51] Ibid.

[52] Ibid.

[53] Ibid.

[54] https://tedb.ornl.gov/wp-content/uploads/2019/03/TEDB_37-2.pdf

[55] U.S. Energy Information Administration, Monthly Energy Review, July 2019

[56] Ibid.

[57] Ibid.

trucks.[58] 5% was used for medium trucks, and 19% for heavy trucks and buses, with around 18% being used by non-highway modes of transportation.[59]

In 2018, of the fuel consumed for transportation in the U.S., 3.1% (880.19 tBTU, i.e. 928.7 PJ) was from natural gas, 5% (1,419.67 tBTU, i.e. 1,497.8 PJ) from renewables (including ethanol and biodiesel) and 0.3% (24,964 GWh)[60] from electricity.[61] Ethanol is typically blended with gasoline, while biodiesel can be used in diesel engines or blended with petroleum diesel. In 2018, U.S. production of ethanol surpassed 16 billion gallons (31,000 ktoe), with 90% of it being consumed domestically.[62] Biodiesel production in 2018 hit 1.8 billion gallons, with close to 1.9 billion gallons (5,6000 ktoe) being consumed domestically, including imports.[63] U.S. biofuels production by RFS category is summarized in Table 6.

*Table 6: U.S. biofuels production in 2018[64]*

| U.S. fuel production by type | Million Gallons [Million Liters] | % |
|---|---|---|
| Renewable fuel (-20% GHG) | 14,955 [56,605] | 86% |
| Ethanol (corn) | 14,955 [56,605] | |
| Advanced (-50% GHG) | 2,212 [8,372] | 12.5% |
| Biodiesel | 1,855 [7,021] | |
| Renewable diesel | 305 [1,154] | |
| Other | 52 [197] | |
| Cellulosic (-60% GHG) | 275 [1,041] | 1.5% |
| Ethanol | 6.5 [25] | |
| Renewable natural gas (LNG/CNG) | 268 [1,014] | |
| Other | 0.5 [2] | |

[58] Ibid.

[59] Ibid.

[60] 85.18 tBTU equivalent

[61] https://tedb.ornl.gov/wp-content/uploads/2019/03/TEDB_37-2.pdf

[62] Ibid.

[63] Ibid.

[64] EPA RIN production data

## Targets and measures

There are a number of measures in place that are driving transportation sector greenhouse gas (GHG) emissions reductions in the United States including several policies and initiatives aimed at increasing biofuel use and vehicle efficiency. While there is no current national target for GHG emissions reduction, 24 states plus the territory of Puerto Rico have adopted state-level GHG targets, as depicted in Figure 21 below.[65]

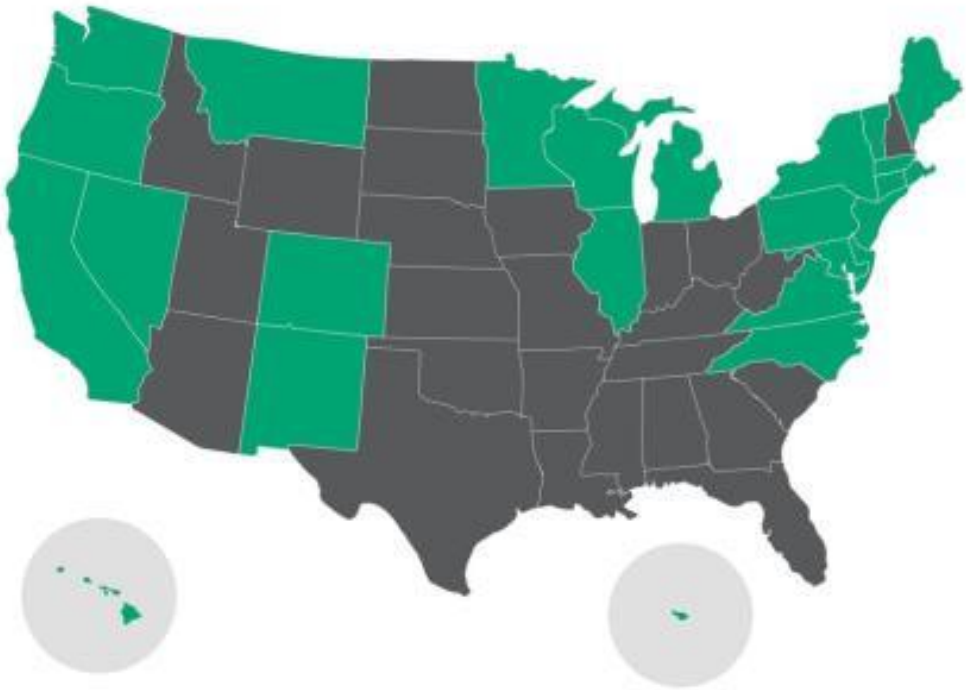

*Figure 21: States (in green) that have adopted state-level GHG targets in line with the Paris Agreement*

## Corporate Average Fuel Economy (CAFE) and GHG Emission Standards

Corporate Average Fuel Economy (CAFE) standards, regulated by the U.S. Department of Transportation's (DOT's) National Highway Traffic and Safety Administration (NHTSA), set annual targets for average fuel economy that automakers are required to meet for light-, medium- and heavy-duty vehicle fleets. In parallel, the U.S. Environmental Protection Agency (EPA) has developed vehicle tailpipe GHG emission standards. Under the current standards, cars and light trucks of model year 2017-2021 must meet a combined fleet-wide fuel economy of 40.3-41 mpg (5.74 – 5.84 liters/100 km) on average, and require to not exceed 163 grams/mile of carbon dioxide ($CO_2$) (101 g $CO_2$/km).

[65] https://www.usclimatealliance.org/

CAFE standards were first enacted in 1975 in order to reduce energy consumption in the transportation sector by increasing the fuel economy of cars and light trucks (now expanded into medium and heavy duty vehicle fleets). The CAFE standards set a fleet-wide average fuel economy that must be achieved by each automaker for each category of vehicle. When CAFE standards are raised it drives automakers to create a more fuel-efficient fleet, strategically reducing GHG emissions on a per mile basis for each fleet[66].

### Renewable Fuel Standard (RFS)

Adopted in 2005 and expanded in 2007 under the Energy Independence and Security Act, the Renewable Fuel Standard (RFS) established volume requirements for renewable fuel based on life-cycle GHG emission reduction thresholds across several fuel categories. Annual volume targets in the initial legislation culminate at 36 billion gallons (136.25 M liters) of total renewable fuels per year in 2022, with a 15 billion gallon (56.78 M liters) per year cap on conventional biofuels (e.g. corn ethanol).[67] The volume targets are depicted in Figure 22.

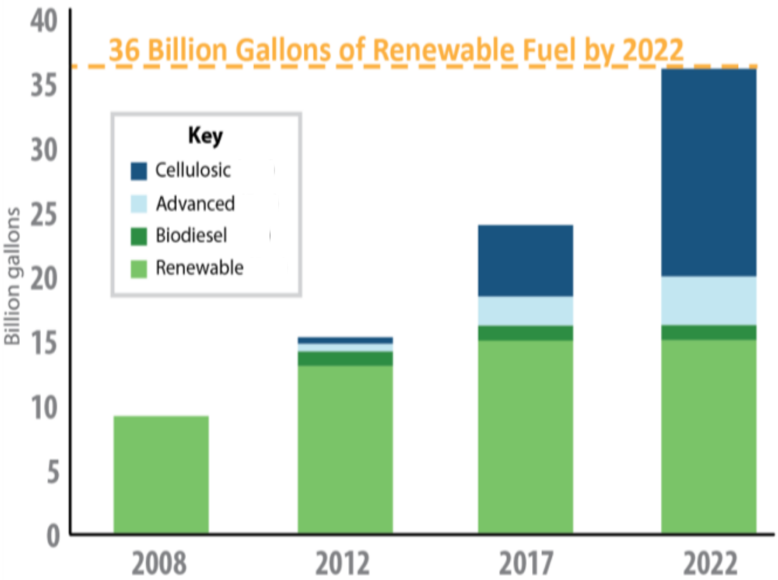


*Figure 22: Volume targets for renewable fuel under RFS[68]*

The Environmental Protection Agency (EPA) is tasked with annually adjusting volume targets for the four categories of renewable fuel specified in the legislation: cellulosic biofuels, advanced biofuels, biomass-based diesel and total renewable fuels. Fuels in each

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66 https://www.transportation.gov/mission/sustainability/corporate-average-fuel-economy-cafe-standards

67 https://www.epa.gov/renewable-fuel-standard-program/overview-renewable-fuel-standard

68 Conversion factor from billion gallons to billion liters is 3.785

of these categories must meet the corresponding lifecycle GHG emissions reduction threshold relative to a petroleum baseline: cellulosic biofuels - 60% reduction, advanced biofuel - 50% reduction, biomass based diesel - 50% reduction, and conventional renewable fuels - 20% reduction.

*Table 7: GHG emission reduction thresholds for renewable fuels in RFS*

| **Renewable Fuel Category** | **Lifecycle GHG Emissions Reduction Threshold** |
|---|---|
| Cellulosic | 60% |
| Advanced | 50% |
| Biomass Based Diesel | 50% |
| Conventional Renewable Fuel | 20% |

The RFS is implemented through the EPA administered program via a Renewable Identification Number (RIN), which assigns a RIN to each gallon of renewable fuel. Each regulated entity is required to meet the set volumes based on the percentage of its petroleum product sales, these set volumes are known as renewable volume obligations (RVOs). Entities can meet their RVOs by either selling biofuel volumes or purchasing RINs from other entities that have exceeded their requirement in the RIN market[69].

While there has been significant growth in total renewable fuel since the RFS was adopted, throughout the life of this program, the growth of cellulosic biofuel production has been lower than anticipated. The reduced volume targets have been largely satisfied by renewable natural gas, with cellulosic ethanol making up only 2% of the cellulosic biofuel volume.

### California's Low-Carbon Fuel Standard (LCFS)

The State of California adopted the Low-Carbon Fuel Standard (LCFS) in 2009 to incentivize the production of renewable fuels. This fuel agnostic program aims to reduce transportation GHG emissions, setting annually decreasing carbon intensity benchmarks for gasoline, diesel, and their replacement fuels. The LCFS has a goal of reducing the carbon intensity of its transportation fuel pool by 20% by 2030 (relative to a 2011 baseline).[70] California's Global Warming Solutions Act of 2006 has a GHG emission reduction goal of 80% below 1990

[69] https://afdc.energy.gov/laws/RFS.html

[70] https://ww3.arb.ca.gov/fuels/lcfs/background/basics-notes.pdf

levels by 2050.[71] The program has succeeded in increasing renewable fuel use (see Figure 23), and has established a market for credit transactions exceeding $2 billion in 2018.[72] The State of Oregon has a program similar to the LCFS requiring reduction of carbon intensity of its transport fuels. Other states in the USA are exploring similar clean fuel programs to reduce transport fuel GHG emissions.

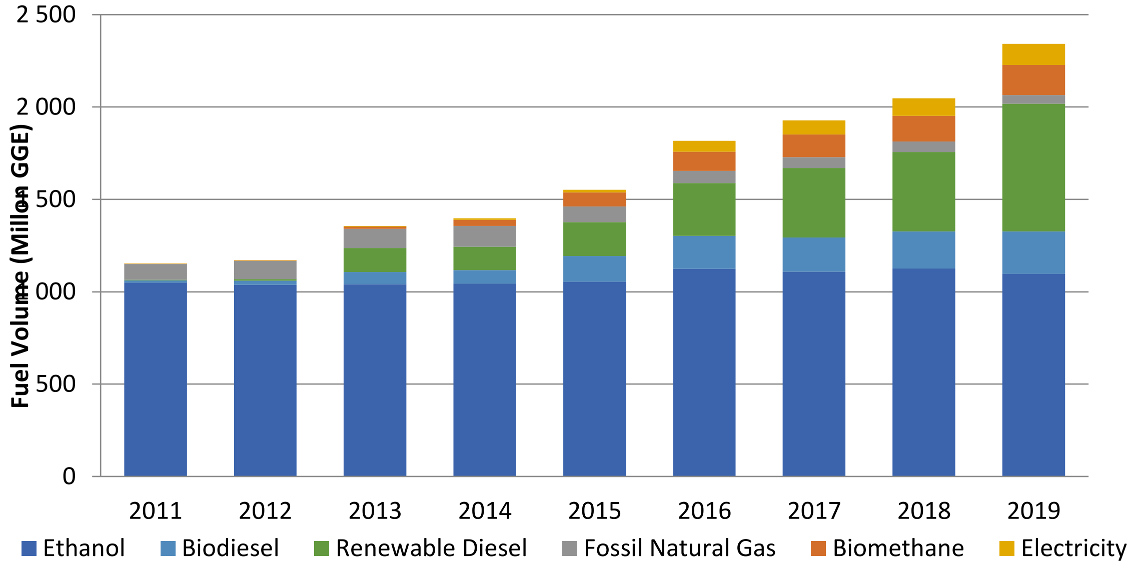


*Figure 23: Renewable fuel growth resulting from California's LCFS (2011-2019)*

## The Bioeconomy Initiative

The Bioeconomy Initiative seeks to enable the sustainable production and utilization of biomass for affordable domestic biofuels, bioproducts, and biopower.[73] This initiative was created by the Biomass Research and Development (BR&D) Board, an interagency collaborative, co-chaired by the U.S. Department of Agriculture (USDA) and U.S. Department of Energy. The initiative seeks to align the member agencies' goals and activities, to address technology uncertainty, leverage resources and capabilities, and accelerate bioeconomy growth.

[71] Ibid.

[72] https://ww3.arb.ca.gov/fuels/lcfs/background/basics-notes.pdf

[73] https://biomassboard.gov/pdfs/Bioeconomy_Initiative_Implementation_Framework_FINAL.pdf

## Projections

According to projections by the U.S. Energy Information Administration's (EIA's) Annual Energy Outlook 2019 report, overall U.S. transportation energy consumption is projected to grow between 2018 to 2050.[74] However, increases in efficiency will partially offset this growth. The transportation sector is set to see the steepest decline in energy intensity among all sectors, calculated as "the amount of energy consumed per unit of potential demand."[75] Light and heavy duty vehicles are projected to see a 32% decline in level of energy used per mile between 2018 and 2050, despite an increase of 20% in miles traveled, due to fuel economy and energy efficiency standards. Heavy duty vehicle energy consumption and diesel use is expected to be at 2018 levels in 2050, again due to fuel economy standards, despite a 52% increase in truck vehicle miles traveled. However, transportation is projected to remain the sector with the highest $CO_2$ intensity, as petroleum remains the dominant fuel used in vehicles.

The EIA's projections as depicted in Figure 24 show alternative fuels increasing their share of total transportation energy consumption, as the motor gasoline and distillate fuel oil shares drop from 84% in 2018 to 74% in 2050. Growth is projected in sales of battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV) and hybrid electric vehicles. Second to electricity, jet fuel consumption is projected to increase by 35% between 2018 and 2050, as aircraft fuel efficiency is outpaced by increased demand for air transportation. Natural gas use in medium- and heavy-duty vehicles is also projected to increase in terms of total sale share.[76]

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[74] https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf

[75] Ibid.

[76] https://www.iea-amf.org/app/webroot/files/file/Annual%20Reports/AMF_Annual_Report_2018_FINAL.pdf

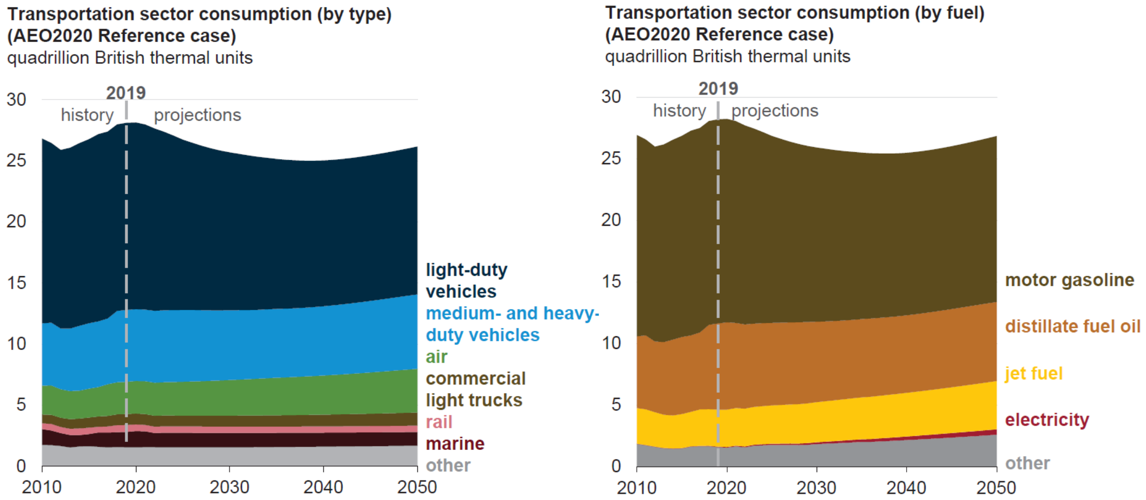


*Figure 24: Projections of annual LDV sales and of transport sector fuels consumption in the USA*[77][78]

[77] EIA 2019 Annual Energy Outlook

[78] The Conversion factor for quadrillion BTUs to Mtoe which is 25.1997

## Brazil

**Key facts for Brazil**

Total fuel consumption of the road transport sector:
84.3 Mtoe in 2017, of which 16.9 Mtoe are renewable [(a)]

Number of vehicles in use:
39 million in 2017, of which 27.7 million are alternative fuel vehicles (incl. flex fuel + ethanol + hybrid vehicles)[(b)]

Current GHG emissions from the road transport sector:
187 $Mt_{CO2eq}$ in 2017[(a)(c)]

The energy consumption of the road transport sector in Brazil is projected to increase due to the car fleet raise driven by the economic growth[(b)].

The target is to reduce GHG emissions by 37% compared to 2005 by 2025 and indicated a 43% reduction by 2030, economy-wide, which includes the transport sector[(d)].

Measures to achieve this target include RenovaBio Policy, which will gradually reduce the average GHG intensity in the Brazilian transport sector[(e)].

Scenarios show that it seems possible to achieve this target.

(a)79 (b)80 (c)81 (d)82 (e)83

## Energy supply and demand

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79 EPE (2019) *Brazilian Energy Balance*. Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br

80 EPE (2018). *Demanda de Energia dos Veículos Leves: 2018 – 2030.* Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br

81 IPCC (2006) Intergovernmental Panel on Climate Change – *IPCC Guidelines for National Greenhouse Gas Inventories*, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T., and Tanabe K. (eds). Published: IGES, Japan. Source: www.ipcc.ch

82 BRASIL (2015) *intended Nationally Determined Contribution towards Achieving the objective of the United Nations Framework Convention On Climate Change*. September 2015. Source: http://www.itamaraty.gov.br/images/ed_desenvsust/BRAZIL-iNDC-english.pdf

83 BRASIL (2017) *Law 13,576/2017*, December 26th. Brasília: Diário Oficial da União. Fonte: www.planalto.gov.br

## Introduction

The Brazilian energy matrix is quite varied and stands out worldwide for its high degree of renewability, an attribute observed in few countries in the world. As a result, GHG emissions per unit of energy consumed in the country are small compared to other nations. However, energy consumption *per capita* is currently well below standards in developed countries. Reducing the level of poverty tends to increase energy demand, even when prioritizing less energy-intensive processes, decoupling the increase in energy consumption from economic growth.

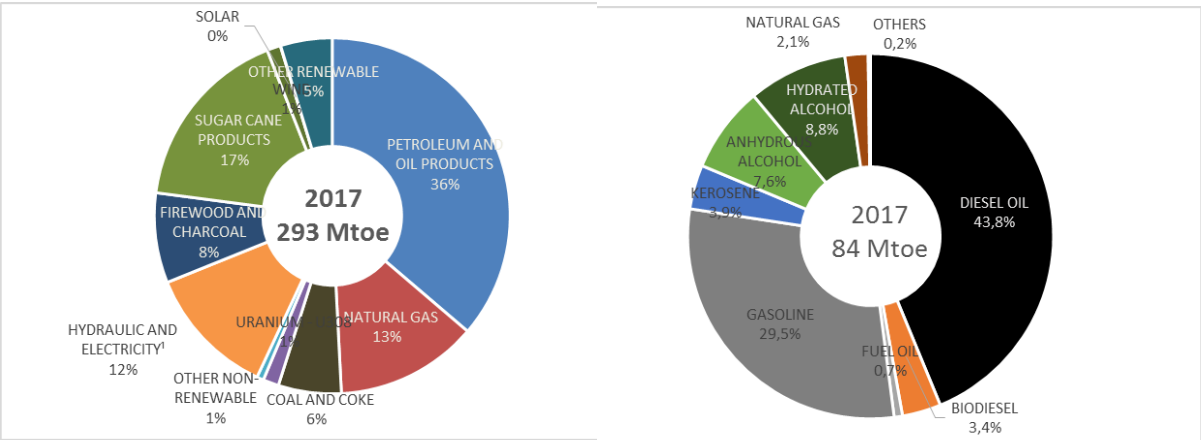
Thus, the great challenge of the Brazilian energy sector is to adapt to provide an increasing national energy demand, while ensuring a high share of renewable sources in its matrix, and guaranteeing competitiveness and reliability. According to EPE's medium and long term studies, this will imply expansion and production of liquid biofuels such as ethanol and biodiesel, as well as the significant upscaling of installed capacity of wind, solar, biomass thermoelectric plants, the construction of new hydroelectric plants, and also investments in energy efficiency. In short, there are several actions and policies to be taken with the ultimate goal of keeping GHG emission indicators among the smallest in the world, without compromising socioeconomic progress and the commitment made by Brazil to combat climate change.

## Current situation

The present energy situation of Brazil is summarized in Figure 25. Brazil has already a higher contribution of renewable energy, 43% of the domestic energy supply, compared to most countries. Fossil fuels still represent 54.9% of the total domestic energy supply, and 77.8% of transport sector, while biofuels are already 19.7% of the transport sector in 2017 (21.1% for road transport)[84], and are going to rise to 27.9% by 2029 (31.8% for road transport)[85].

[84] EPE (2019) Brazilian Energy Balance. Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br

[85] EPE (2019) Ten-Year Energy Expansion Plan 2029. Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br




Brazilian Primary Energy Supply Transport Sector

*Figure 25: The Brazilian primary energy supply and Final consumption energy for transports in 2017*

The main renewable fuel in transport is hydrous ethanol, used as E100, followed by anhydrous ethanol and biodiesel, which are blended into gasoline and diesel, respectively, by mandate.

The use of biofuel in the transport sector in 2017 was 26.6 billion liters of ethanol (hydrous and anhydrous), the majority is from sugar cane, 0.4 billion liters come from corn ethanol, and 3.6 billion liters of biodiesel. The total energy consumption of biodiesel was 4.2 billion liters[85]. Almost 70% of the biodiesel production has been made from soy-bean oil[86].

The use of electricity in the transport sector is quite insignificant, since it is used only in trains and the presence of hybrid and electric vehicles in the fleet is inferior of 0.5%.

Since passenger cars are not licensed for the use of diesel as a fuel, the ethanol and gasoline consumption are related to this class of vehicles, whereas diesel and biodiesel are used by trucks, buses, various types of machinery and some light-duty vehicle models. In Brazil, approximately half of the work related to the transport of goods is based on heavy-duty vehicles.

Concerning the main oil products used in transport sector in 2017, there was a net import in gasoline[86] of 4.0 billion liters[87] and diesel of 12.3 billion liters[88]. Net imports of ethanol were

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[86] Gasoline A and diesel A: fuels without the addition of hydrous ethanol and biodiesel, respectively.

[87] EPE (2019) Brazilian Energy Balance. Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br

[88] ANP (2018) *Resolution* ANP nº 719, 22 de fevereiro de 2018. Agência Nacional de Petróleo, Gás Natural e Biocombustíveis. Brasília: Diário Oficial da União. Source: www.anp.gov.br

small (0.4 billion liters)[88].

### Ethanol

The use of biofuels, notably ethanol, has a long tradition in Brazil. In 1975, the Brazilian government started the National Alcohol Program (Proalcool), aiming to reduce dependence on oil imports by promoting the production of fuel ethanol (anhydrous as an additive to gasoline and hydrous to dedicated fleet– E100).

Ethanol has remained an important part of the Brazilian transport fuel system, with an E100 distribution network and a mainly locally produced car fleet. In 2003 flex vehicles were launched that could operate on gasoline or E100 according to the preferences of the consumer (mainly based on fuel prices ratio). The market share quickly increased to more than 90% of new car sales. In 2017, 74% of Otto cycle fleet was flex fuel. This development was also supported by tax-breaks both regarding the vehicle sales taxes and the fuel taxation.

The blending mandates for anhydrous ethanol in gasoline have been varied over time for different reasons. In early 2015, it was raised to 27% and has been kept at this level since. Fuel distributors are annually obliged to provide evidence to the regulatory entity (ANP - Brazilian Agency of Petroleum, Natural Gas and Biofuels) of the requirement to meet their anhydrous blending mandate, based on the sales of gasoline of the year before. Similar rules are applied to ethanol producers and importers[88].

There were roughly 370 sugar mills in Brazil by the end of 2017, and two industrial scale cellulosic ethanol plants using bagasse, and six operating plants of corn ethanol, most co-located with sugarcane mills and operating also in the off-season and some stand-alone plants. The installed capacity was around 40 billion liters of hydrous ethanol and 20 billion liters of anhydrous ethanol. The actual split between sugar and ethanol is typically 40/60, but this ratio is adjusted each season by the mill owners to take account of the expectations for the harvest as well as for the sugar and ethanol markets[89]. In addition to the 26.6 billion liters directed in 2017 for transport purposes, some 1.0 billion liters were consumed for chemical and other non-fuel purposes and a practically neutral import/export balance. So, the Brazilian internal production was 27.7 billion liters[87].

### Biodiesel

The National Biodiesel Production Program (PNPB) has been instituted in 2004 to promote

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[89] EPE (2019b) *Ten-Year Energy Expansion Plan 2029*. Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br

domestic biodiesel production and reduce the diesel import dependency. It has a social element to alleviate and reduce regional economic differences by supporting family-operated farms[90]. There are some 50 licensed biodiesel plants, predominantly based on soy-bean oil (some 70%), followed by tallow (17%). Through an auctioning system, the fuel distributors are obliged to buy the biodiesel to accomplish their blending mandate. The overall production was 4.3 billion liters in 2017[88]. Federal Law 11,097/2005[90] established biodiesel as a fuel and set a compulsory 2% blending mandate in 2008, which was increased to 3% later the same year, to 4% in 2009, 5% in 2010. The Federal Law 13,303 /2014[91] enforced a blending mandate to 6%, and 7% later in the same year. In 2016, Federal Law 13,263[92] established new legal mandate with a compulsory blending to 8% in 2017, rising to 10% in 2018, reaching 11% in September 2019. The legal framework enables an increase of biodiesel in the blend up to reach 15% at the earliest in 2023. Fleets of trucks, buses, agricultural machinery etc. can go beyond the mandate to 20-30%, if so desired.

## Targets and measures

### The Paris Agreement

Brazil is a party to the UNFCCC and has instituted National Policy on Climate Change[93]. Following the Paris Agreement, the Nationally Determined Contribution (NDC) of Brazil has been formalized to the commitment to a target to reduce the GHG emissions by 37% by 2025 and an indicative contribution of a reduction of 43% of the GHG emissions by 2030, both relative to 2005[94]. Such tasks include the agriculture, forest, industrial processes and waste sectors, adopting a nationwide coverage for the economy-wide, including $CO_2$, $CH_4$, $N_2O$, perfluorocarbons, hydrofluorocarbons and $SF_6$.

Brazil intends to adopt further actions that are consistent with the 2°C temperature goal, in

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[90] BRASIL (2005) Law 11,097/2005, January 13th 2005. Brasília: Diário Oficial da União. Fonte: www.planalto.gov.br

[91] BRASIL (2014) Law 13,303 /2014, September 24th 2014. Brasília: Diário Oficial da União. Fonte: www.planalto.gov.br

[92] BRASIL (2016) Law 13,263/2016, March 23rd 2016. Brasília: Diário Oficial da União. Fonte: www.planalto.gov.br

[93] BRASIL (2009) *Law 12,187/2009*, December 29th 2005. Brasília: Diário Oficial da União. Fonte: www.planalto.gov.br

[94] BRASIL (2015) *intended Nationally Determined Contribution towards Achieving the objective of the United Nations Framework Convention On Climate Change*. September 2015. Source: http://www.itamaraty.gov.br/images/ed_desenvsust/BRAZIL-iNDC-english.pdf

particular:

- strengthening the share of sustainable bioenergy in the Brazilian energy mix to approximately 18% by 2030, by expanding biofuel consumption, amplifying ethanol supply, including by heightening the share of advanced biofuels (second generation), and increasing the share of biodiesel in the diesel mix
- achieving 45% of renewables in the energy mix by 2030

It is important to highlight that Brazil's NDC applies to the economy as a whole and is therefore based on flexible paths to achieve the 2025 and 2030 objectives. This means that the Brazilian approach considers that technological innovations, market conditions, public policies, among others, may affect the GHG emission allowance cost hierarchy of specific actions and therefore the NDC of the country does not set sectoral targets.

### RenovaBio

The Brazilian Biofuel Policy[95], RenovaBio, has the main purpose of expanding biofuel production in Brazil (including ethanol, biodiesel, biogas and aviation biokerosene), based on the principles of predictability, environmental, economic and social sustainability as well as being compatible with market growth. Notwithstanding, RenovaBio aims to internalize the positive environmental impacts due to the use of biofuels and to contribute to meeting the Brazilian commitments under the Climate Agreements, such as Paris Agreement.

RenovaBio includes a Carbon Certificate (CBIO) trading system (1 CBIO = 1 tonne $CO_{2(eq)}$). It links producers of biofuels (generators of CBIO) with the fuel distributors (obligated buyers of CBIO) via a market trading system. The producers will have their production certified by an LCA methodology to ascertain the GHG emission of the production, expressed as g $CO_2$/MJ, which multiplied with the production placed on the fuel market results in the number of CBIO generated.

Each distributor has a reduction goal expressed as g $CO_2$/MJ (allowing for both reduction in specific GHG emissions and in energy efficiency improvements), which multiplied by the energy of the fuels sold in MJs gives the number of CBIO to be acquired within the national GHG reduction target. The means of equating this is by the trading of CBIO certificates in a dedicated and supervised marketplace.

The quantitative goal of the RenovaBio system is to gradually reduce the average GHG intensity in the Brazilian transport system, which are equivalent, in 2030, to 90.7 million

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[95] BRASIL (2017) *Law 13,576/2017*, December 26th. Brasília: Diário Oficial da União. Fonte: www.planalto.gov.br

CBIO that shall be acquired by the distributors. In this way, savings on the emission intensity in production and use of advanced biofuels is promoted [96]. The expected impact is to reduce the increase in GHG emission from transports.

### Others Policies

In light of the public policies adopted for biofuels, Proalcool and PNPB were precursors for the insertion of ethanol and biodiesel, respectively, in the Brazilian fuel market. In addition, other policies, including financial and tax incentives, have enabled the development of new industrial, agricultural and automotive technologies that generate employment and income.

Moreover to the blending mandate, BNDES (Brazilian Bank for Economic and Social Development) has developed specific financing tools for the sugar and ethanol sector, whose objective is to encourage the production of biofuel. Biodiesel was boosted by legal mandates, which successfully introduced biodiesel in the energy sector. Furthermore, state and federal tax differences on ethanol and biodiesel are policies for promoting greater participation of biofuels in the fuel market[97].

In addition, more recently, the Rota 2030 - Mobility and Logistics Program, is part of the Federal Government's strategy for developing the country's automotive sector, by raising the vehicle energy efficiency and hereby impact the final energy demand of the transport sector. For mid and long term, Rota 2030 will contribute to harmonizing biofuels and alternative vehicles technology.

PROCONVE, the Motor Vehicle Air Pollution Control Program, was created in 1986, by the National Council of the Environment (Conama / Brazilian Ministry of Environment), and aimed at mitigating local pollutant emission levels from light and heavy duty vehicles. It contributed to the technological development of fuel, engine and auto parts manufacturing, as well for the fuel and engine efficiency. Throughout its more than 3 decades of implementation, PROCONVE has been allowing ever-smaller levels of pollutants to be emitted by the engines. Although initially this program was not directly aimed at climate change, it enables the creation of mechanisms to address GHG /fuel economy regulation.

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[96] CNPE. (2018). Resolução CNPE n° 05, de 15 de março de 2018. Conselho Nacional de Política Energética. Brasília: Diário Oficial da União. Source: http://www.mme.gov.br/documents/10584/71068545/Resolu%C3%A7%C3%A3o+n%C2%BA+5_2018_CNPE.PDF/a46326ab-df5d-4d3f-ad52-b9f1ffc7ab1d.

[97] EPE (2016) *Analysis of Biofuels' Current Outlook*. Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br

### Barriers and Policy Gaps

As could be seen, Brazil is already a major protagonist in the renewable fuels consumption in the transport sector. Several public policies contributed to the promotion of biofuels, including actions by government, sector agents and civil society. Among the regulatory and economic instruments that structure public policies, EPE (2016) highlighted the mandates to add biofuels to oil products, the mechanisms of tax differentiation between renewables and fossils, and financing tools.

In order to reach the main national objectives and to ensure the impressive presence of advanced transport biofuels, there are some challenges that Brazil may consider.

- Improve the convergence between RenovaBio, Proconve and Rota 2030. All these three instruments work towards a more efficient, cleaner, more reliable and economically sustainable transport market growth.
- Consider new emerging technological trends in future policies. The synergy between artificial intelligence, internet of Things (IoT), robotics, drones, blockchain, augmented reality, virtual reality and 3D printing shall improve biofuels production and, consequently, its consumption.

Besides that, there are a number of themes that require attention:

- Technical barriers from sugar cane lignocellulosic ethanol production need to be solved. Despite some issues, in the last years, Brazil has built a productive capacity of 100 million liters of this biofuel, with two plants (GranBio and Raízen) in operation, while other plants worldwide have failed in the same period.
- It is key to stimulate the voluntary use of biodiesel beyond the mandatory blend, in specific fleets (trucks, buses, agricultural machinery etc. - as topic 1.2), in line with the legal framework.

In addition to these internal challenges, there are global issues affecting biofuels production and use that may contribute to their expansion, not only in Brazil, but around the world as well.

- Ethanol production is limited to a few countries (note that USA and Brazil respond for more than 80% of global production). The growth of global production is a necessary condition to improve international markets and to strengthen Brazil internal production and use.
- Envisaging the creation of a more expanded global ethanol market, Brazil crafted agreements that seek to contribute to improve income, employment and living

conditions, reducing poverty, illnesses and isolation in the countries involved, especially in Africa.

- Brazil signed the technical and technological cooperation bilateral agreements towards promoting production and use of biofuels in Africa, focusing on 2003–2010. Brazil also entered into trilateral cooperation, involving Mozambique and Kenya plus a Northern donor (EU), to develop bioenergy projects, between 2008 and 2010.
- In 2007, a Memorandum of Understanding (MoU) on biofuels cooperation was signed between Brazil and the US, stimulating private-sector biofuels investment in Central American, Caribbean and African countries.
- Biofuels cultivation worldwide should occur in areas that protect the native forest, with legal framework respecting the environment, natural resources and local communities, likewise as in Brazil. It should also ensure that agriculture produces safe, nutritious and sufficient food, seeking to reach the Sustainable Development Goals (SDG 2), which is Zero Hunger by 2030.

Notwithstanding, it is worth saying that a more successful way to go beyond these challenges is to create an environment where all these challenges are discussed and the solutions could be interconnected. To achieve this goal, it is important to have a strategy based on clear targets and analysis of local potential pathways.

## Projections

EPE has made and published several projections for the future, e.g. Ten-Year Energy Expansion Plan 2029[98] and others up to 2030 and to 2050, each with somewhat different scope. Below is a selection of the data to give some details on the forecasts for the period to 2050.

The projected energy usage in the transport sector to 2050 is shown in Figure 26 for a lower and higher scenario, respectively. It is clear that there will be a growth over time in the overall energy consumption, most notably in the diesel consumption[49,99,100].

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[98] EPE (2019) *Ten-Year Energy Expansion Plan 2029*. Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br

[99] EPE (2018). *Cenários de oferta de etanol e demanda Ciclo Otto 2020 – 2030.* Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br

[100] EPE(2018) *Cenários de Demanda para o PNE 2050*. Documento de Apoio ao PNE 2050. Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br

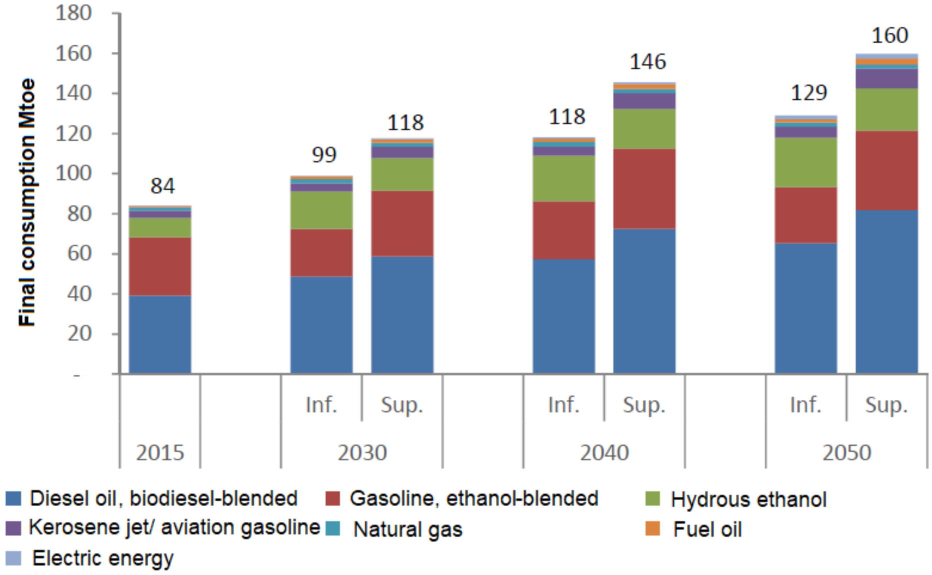


*Figure 26: Transport energy demand projections over time in two scenarios*[101]

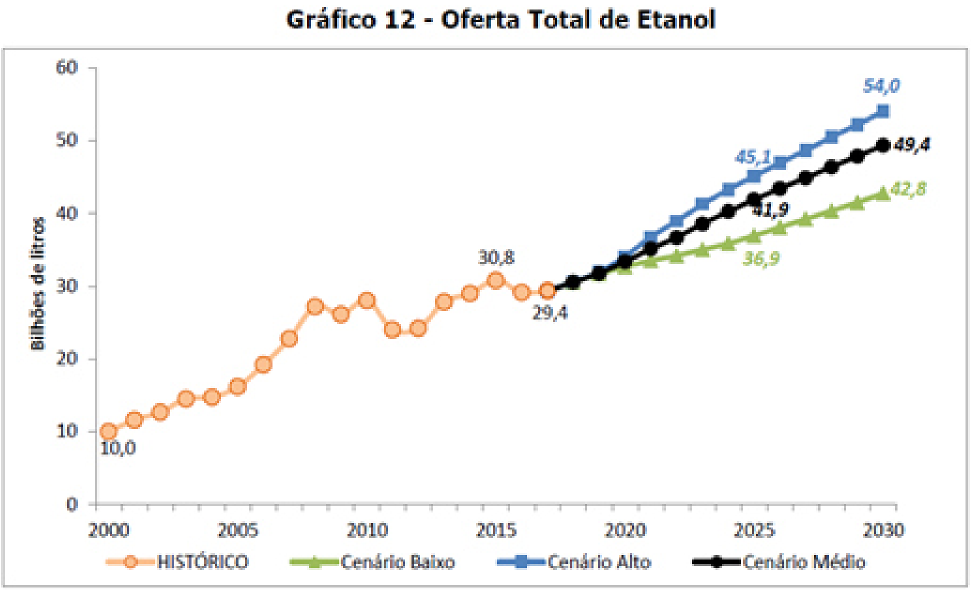


*Figure 27: Historic and projected ethanol supply for three scenarios* [102]

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[101] EPE(2018) *Cenários de Demanda para o PNE 2050*. Documento de Apoio ao PNE 2050. Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br

102 EPE (2019) Cenários de oferta de etanol e demanda Ciclo Otto: 2020 – 2030. Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br

With regard to the ethanol supply to 2030, Figure 27 shows the expected growth in the production to somewhere in the range of 43 to 54 billion liters by 2030, of which some 1 billion liters are cellulosic ethanol and 4-5 billion liters are corn-based. From this production, 1-2 billion liters are used for other purposes and another +/-1-3 billion liters are exported (or imported, if necessary), the remainder is used for domestic transport fuel purposes. The split between use of E100 and anhydrous ethanol in gasoline will vary depending on the scenarios from 1/3 for low annual production to 50% for the high production scenario.

Regarding biodiesel, the forecasted production, related to the demand generated by the blending mandate, is shown in Figure 28. The use is expected to more than double up to 2029 relative to 2017[103].

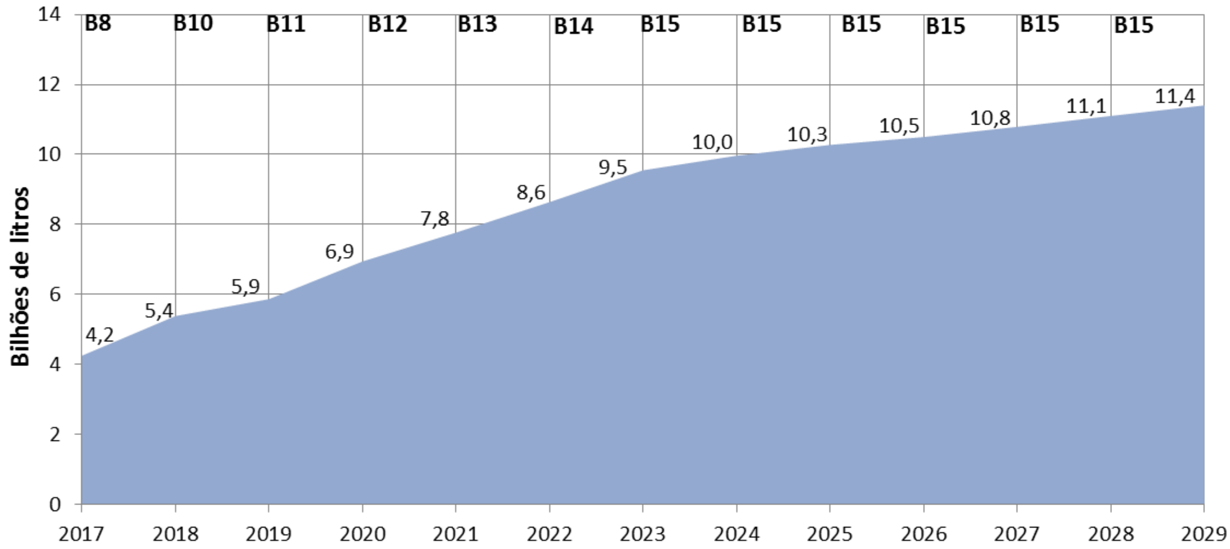


*Figure 28: Projected biodiesel production to 2029*

Regarding electrification, a report (EPE, 2018d) has made two scenarios for the introduction of electromobility, for light duty vehicles of which the less rapid transition scenario is shown in Figure 29 (the more rapid scenario was considered less likely when weighing in Brazilian context).

103 EPE (2019) Ten-Year Energy Expansion Plan 2029. Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br

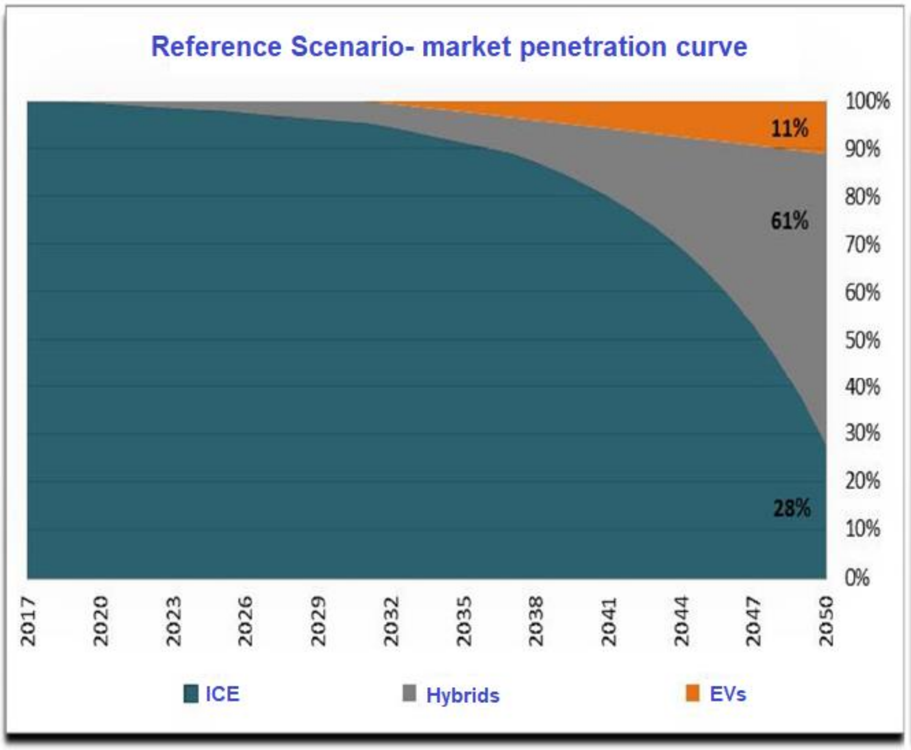


*Figure 29: Market penetration of hybrid and EV light duty vehicles on the Brazilian market[104]*

The report concludes that the public policies for accelerating the entry of HEV and EV in the country will entail significant incentives and investments to off-set the barriers and challenges that such technologies still need to overcome and that it is necessary to evaluate in detail the cost effectiveness of these alternatives, since Brazil already has a competitive technology to reduce GHG emissions in the light duty transport sector and that its Nationally Determined Contribution is in line with the adoption of this available solution.

Regarding heavy-duty vehicles, it also concludes that up to 2050, electromobility needs to be developed and industrialized elsewhere before it can be imported for implementation in Brazil. Changes in motor/fuel technology for heavy vehicles, such as electrification, will only be implemented in the country in niche markets and will only marginally be present in the fleet of heavy duty vehicles in Brazil. The entry of electromobility in the market of heavy vehicles is not trivial and has not been proposed as a priority policy for reducing GHG emissions in this segment.

As stated in the EPE (2018d): "regarding the transport sector, internal combustion engines should continue to be present in the Brazilian matrix in the next decades, and their

[104] EPE (2018) *Eletromobilidade e Biocombustíveis*. Documento de Apoio ao PNE 2050. Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br

replacement by technologies using other forms of propulsion, such as hybrid and electric vehicles, is expected to be slower than the growing presence of liquid biofuels". In addition, in the document "Electromobility and Biofuels", we consider that hybrid flex fuel vehicles will be manufactured in Brazil, using electricity and/or ethanol as well; and BEV will be mostly fuel cell based on ethanol and gas (biogas/biomethane or natural gas).

## Final Remarks

It might be worth to consider that Brazil already presents a degree of renewables content in its energy matrix that is equivalent to almost the triple of the reality of many countries spread across the planet. In our Ten-Year Energy Expansion Plan 2029[105], the Total Primary Energy Supply is expected to grow 2.6% (2019-2029), reaching 380 Mtoe, with the renewable sources achieving 48.0% in 2029. The majority of the countries will still be distant from the current Brazilian renewables position in the energy matrix, according to different medium term studies[106][107][108]. Within this framework, the clean sources growth will happen in tandem with both the Brazilian economy and energy sector, connected to the debottlenecking of the restrained demand. It is worth to mention that all targets concerning the increase of biofuels production and use will be driven by sustainability criteria.

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[105] EPE (2019) *Ten-Year Energy Expansion Plan 2029*. Empresa de Pesquisa Energética, Rio de Janeiro. Source: www.epe.gov.br

[106] IEA (2018) World Energy Outlook. International Energy Agency. Source: www.iea.org

[107] SHELL (2018) Energy Transition Report. Source: https://www.shell.com/energy-and-innovation/the-energy-future/shell-energy-transition-report.html

[108] EXXON MOBIL (2018) Outlook for Energy: a view to 2040. Source: https://corporate.exxonmobil.com/

## China

**Key facts for China**

Total fuel consumption of the road transport sector in 2017:
nearly 300,000 ktoe, of which approximately 3,000 ktoe are biofuel

Number of vehicles in use:
217 million (excluding motorcycles and rural vehicles), of which 1.53 million are electric vehicles

Current GHG emissions from the road transport sector:
881 million $t_{CO2eq}$ in 2017

The energy consumption of the road transport sector in the China is projected to increase due to continuous motorization and industrial development.

The target is to reduce China's carbon intensity (measured by tonnes of $CO_2$ emissions per unit gross domestic product) by 60% to 65% compared to 2005 by 2030. No specific target is announced for the transportation sector in China.

Measures to achieve this target include improved energy efficiency (e.g., stringent fuel consumption regulations) and rapid diffuse of electric vehicles.

### Energy supply and demand

In 2017, the total primary energy consumption in China was reported as 3,143 million toe (131.6 EJ), representing an annual increase of 3.0%. Coal remained as the major primary fuel to drive China's economic development, accounting for 60.4% of the total energy consumption, followed by petroleum (18.8%), natural gas (7.0%) and non-fossil fuels (13.8%).

China is abundant in coal resources. More than 99% of coal consumed in China was produced domestically. For petroleum energy, China has a high reliance on global supply that up to 68% of petroleum consumption was imported. In 2017, the domestically produced, imported and exported petroleum were 191.5 million tonnes (Mt), 420.0 Mt, and 4.9 Mt, respectively. For natural gas, the domestically produced, imported and exported natural gas were 147.4 billion cubic meter, (bcm), 95.5 bcm, 3.6 bcm, respectively. The reliance rate of imported nature gas for China was 38%.

In 2017, China generated 6.42 million GWh of electricity, including coal power (64.5%), natural gas power (3.2%), other thermal power (3.2%), hydropower (18.6%), nuclear power

(3.9%), wind power (4.8%), and solar power (1.8%), suggesting a declined share of coal-based electricity,

For final energy consumption, 2227 million toe was consumed in 2017 according to China Renewable Energy Outlook. Industrial sector (57.9%) led in the amount of final energy consumption among all sectors in China, followed by building sector (21.4%), transport sector (16.3%), agriculture sector (6.9%), and construction sector (2.2%), respectively.

China consumes 0.589 billion tonnes petroleum. The transportation sector is the main user of petroleum products and was responsible for the use of 57.7% of the total final petroleum products, while other sectors accounts for 27.4% (industrial sector), 6.9% (living consumption sector), 5.2% (building sector), 1.1% (agricultural sector) and 1.7% (other sectors). Within the transport sector, road transportation consumed 83% of petroleum products, followed by aviation (8%), shipping (8%), pipeline & railway (1%).

In 2017, China produced 2.147 million tonnes of biofuel, about 2.6% of global production. Although the Chinese government has promoted ethanol gasoline in 6 provinces and 31 cities and its consumption accounted for 20% of total Chinese gasoline consumption, the total biofuel consumption was only about 3 million tonnes.

## Targets and measures

### China's climate commitments

In the Paris climate conference (COP21) in 2015, China pledged in the Intended Nationally Determined Contributions (INDC) to peak its carbon emissions by about 2030 or earlier. Furthermore, China has committed to lower its carbon intensity (measured by tonnes of $CO_2$ emissions per unit gross domestic product) by 60%–65% compared to 2005, to increase the share of non-fossil energy in the total primary energy to around 20%, and to increase the forest stock volume by 4.5 bcm above the 2005 level. It should be noted that China previously set a governmental goal of reducing the carbon intensity by 40%-45% compared to 2005. This target has been achieved in 2017, prior to the initial time plan, as China's carbon intensity has declined by 46% from 2005 to 2017.

For the transport sector, China has set a near-term goal to reduce the carbon intensity during the period of the 13th Five Year Plan (2016-2020) for energy conservation and environmental protection for transport sector, which was administrated by the Ministry of Transport and local governmental agencies. Buses, freight trucks and ships are involved in this plan. The $CO_2$ emissions per transport unit (units in passenger-km for coaches, and tonne-km for trucks) should decrease by 2.6% and 8%, respectively in 2020 compared with the 2015 level. For urban buses, the $CO_2$ emissions per passenger are required to decrease by 12.5% during this period.

### National energy security and energy supply

The 13th FYP has included an official target to cap total energy consumption at 5 billion tce (tonne standard coal equivalent, equal to 1.43 toe) by 2020. In particular, China will control the coal consumption to be capped below 4.1 billion actual tonnes. Enhancing energy security supports maintaining more than 80% of total energy consumption supplied by domestic sources. To fulfill the overall target, the energy structure will be adjusted by utilizing renewable and clean energy. Domestic energy production will be allocated to about 4 billion tce of coal, including 3.9 billion tonnes of coal, 200 million tonnes of crude oil, 220 bcm of natural gas, and 750 million tce equivalent energy from non-fossil energy (e.g., wind and solar power). Thus, the proportion of coal consumption in total energy consumption will be less than 58%, while the proportions of non-fossil energy and natural gas consumption will be more than 15% and 10%, respectively. The installed capacity of power generation units will reach approximately 2 million MW. The average coal consumption of power supply will decrease to 310 gram per kWh or even lower levels, and the loss rate of electricity transmission and distribution should be controlled within 6.5%.

The National Development and Reform Commission has released a national strategy of reforming energy production and consumption, which set a target of capping total energy consumption below 6 tce by 2030. Non-fossil energy and natural gas will account for about 20% and 15% of total energy consumption, respectively. New energy demand will be primarily fulfilled by clean energy sources.

### Action plans on air pollution prevention and control

China has launched a long-term national strategy of developing a beautiful China and promoting ecological civilization. This indicates an overall target that the entire country will basically reach the national ambient air quality standards (NAAQS), and better working targets are now under development. In the near-term, China has released two rounds of action plans on air pollution prevention and control since 2013 (2013-2017, and 2018-2020). In 2018, the central government released the three-year action plan (2018-2020), primarily focusing on $PM_{2.5}$ pollution and three major polluted regions (e.g., the Beijing-Tianjin-Hebei region, the Fen-Wei Plain region, and the Yangtze River Delta region). The three-year action plan highlights four fundamental, long-term strategies to improve the energy structure, industrial structure, transport structure, and land use structure. According to the three-year action plan, the annual $PM_{2.5}$ concentrations for polluted cities exceeding the $PM_{2.5}$ national ambient air quality standards (NAAQS) should decrease by more than 18% compared to their 2015 levels. The ratio of good days (definition of a good day: Air Quality Index

(AQI)<100, meaning daily $PM_{2.5}$ concentration is below 75 µg/$m^3$), and the ratio of severe pollution days will decrease by more than 25% compared to 2015 (definition of a severe pollution day: AQI>200, meaning daily $PM_{2.5}$ concentration is above 150 µg/$m^3$). Furthermore, the total emissions of $SO_2$ and $NO_X$ will be reduced by more than 15% compared to 2015.

Diesel freight trucks are one of most important emission sources according to the three-year action plan. It is required to substantially increase the proportion of railway freight. By 2020, China's railway freight volume will increase by 30% compared with that in 2017, and regional increases are required as 40% for the BTH region, 25% for the Fen-Wei Plain region, and 10% for the YRD region. For coastal cities with large container ports, China is promoting multi-modal transport systems to reduce road freight transport by developing dedicated railway systems. The volume of such rail-port multi-modal transport activity is planned to increase more than 10% annually across key port cities in China.

### Fuel consumption regulations

China has set a series of increasingly stringent standards limiting distance-based volumetric fuel consumption for new LDPVs. The 4th phase of fuel consumption standards set a national goal to reduce the overall average fuel consumption to 5.0 L/100 km in 2020, compared with 7.0 L/100 km in 2015. The 5th phase of fuel consumption standards has been just released in 2019, which set a more stringent goal of national average fuel consumption at 4.0 L/100 km in 2025 (NEDC). To improve the representativeness of real-world driving conditions, the Worldwide harmonized Light vehicles Test Cycle Procedure (WLTP) will replace the former NEDC by using a conversion factor of 1.15 (i.e., 4.6 L/100 km under the WTLC as the national average fuel consumption target). The upgrade of the fuel consumption standard plus the dual credit system, a special mandate on new energy vehicle, will be an important driver for manufacturers to produce more energy-efficient vehicles and deploy electric vehicles. The further fuel consumption limit through 2030 is still under development. According to an advisory report by the Chinese Academy of Engineering, the average fuel consumption of new passenger vehicles will decrease to 3.2 L/100 km.

China has also developed the fuel consumption standards for medium-and heavy-duty commercial vehicles (HDVs), which limit volumetric fuel consumption according to vehicle category and weight class. China’s average fuel consumption for HDVs is targeted to decrease by more than 10% during 2015-2020, aiming to narrow the gap with developed countries.

### Emissions and fuel quality regulations for vehicles

China has adopted a series of emissions standards for light-duty vehicles, heavy-duty vehicles and motorcycles since the late 1990s. Each upgrade of emission standard, typically every four or five years on the average, requires more advanced emission control technologies. The first stage of the most stringent China 6/VI standards (i.e., China 6a/VIa) have been implemented in several regions since July 2019. It is scheduled that the second stage of China 6/VI (i.e., China 6b/China VIb) will fully take effect from 2023 nationwide.

Historically, the previous emissions standards (China 1 to China 5) were developed based on the European regulation architypes (i.e., equivalent to Euro 1 to Euro 5). Compared with the Euro 6 standards, the China 6 standard (GB 18352.6-2016) includes several progressive features. First, the emission standards of China 6b are stricter than the Euro 6 emission limits by 33% to 50% under the WLTP. Second, fuel-neutral and technology-neutral principles are reflected by the unified limits of $NO_X$ and particle number (PN) applicable to both gasoline and diesel vehicles, and to both multi-port fuel injection and direct injection engines. Third, a 48-h evaporation testing procedure including diurnal and hot soak emissions has been specified in the China 6 standard, requiring more efficient control technologies (e.g., on-board vapor recovery) for evaporative emissions. Similar to the European practice, a real driving emissions (RDE) testing protocol has been required since the China 6, however, which has not regulated the cold-start emissions.

For heavy-duty vehicles, the China VI emission standard (GB 17691-2018) has been developed greatly based on the Euro VI. The on-road testing by using portable emissions measurement system (PEMS) will become fully mandatory since China VI b for ensuring conformity through type-approval, zero-mileage and in-service stages. The China VI has regulated the application of on-board sensor-based emission monitoring (OBM) of $NO_X$ concentrations. Heavy-duty engine manufacturers are required to collect instantaneous OBM data and transmit the data to Chinese environmental authorities. Such OBM programs have been pioneered in several large cities (e.g., Beijing) to monitor $NO_X$ emissions for in-use China IV and China V heavy-duty vehicles. For natural gas vehicles, many local measurements have found high $NO_X$ emissions due to lean-burn combustion without any $NO_X$ control after-treatment device. The China VI standard will only allow stoichiometric combustion plus three-way catalytic converter for natural gas-powered vehicles.

To assure sufficient control efficacy for the China 6/VI standards, China has improved the fuel quality standards for both on-road and non-road transport sectors (GB 19147-2016). Since 2019, on-road China 6 gasoline and China VI diesel fuels have been fully supplied nationwide. The sulfur contents of the new gasoline and diesel fuels should not exceed 10 part per million (ppm). For the China 6 gasoline, more stringent limits are specified for the contents of olefins, aromatics and benzene. The upper volumetric limits for olefins and aromatics are reduced to 18% (v/v) (15% for China 6b) and 35% (v/v). For China VI diesel, the upper mass limit for polycyclic aromatics is reduced to 7% (m/m).

The non-road diesel fuels for all machineries and partial vessels are required to comply with the China VI diesel fuel quality standard. China has introduced emission control areas in three coastal regions where the low sulphur fuels (e.g., sulfur content below 0.5% m/m) should be used for ocean-going ships; the Pearl River Delta, the Yangtze River Delta and Bohai-rim waters. In December 2018, the Ministry of Transport released an upgraded action plan for establishing a national domestic emission control area (DECA). The DECA confirms the early adoption of the Internationals Maritime Organization (IMO)'s sulfur cap of 0.5% m/m and pilots a 0.1% m/m sulfur requirement for all ships in the Yangtze and Pearl Rivers and for 12 nm around Hainan Island. Very recently the Chinese government has scheduled the fuel sulphur limit, which should be reduced to 0.10% m/m from 2020 onwards in its domestic ECAs.

### New energy vehicles and automotive biofuels

Electric vehicles, also categorized as new energy vehicles in China, have been vigorously promoted in the past decade as important strategy to reduce petroleum consumption and to mitigate GHGs and pollutant emissions. In 2012, the State Council of China released the final version of "Energy-saving and New-energy Vehicle Development Plan (2012–2020)". It proposed that the total stock of plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) in China would exceed 5 million by 2020. The annual production volume of PHEVs and BEVs in 2020 should reach 2 million.

To fulfill this target, substantial subsidies have been offered by both central and local governments. The purchase subsidies are determined according to vehicle category (BEV vs. PHEV) and all-electric range (AER). For example, a BEV with 300 to 400 km-AER can receive 44 thousand RMB (approximately 6,300 USD) subsidies from the central government. Local governments will provide additional subsidies alongside the central subsidies. In several cities with strict license control policies (e.g., Beijing, Shanghai), favorable license management policies have been developed to stimulate personal EV purchases. Consequently, China has become the most important driver in the global EV market and has accounted for half of the global sales volume since 2017. According to the latest statistics, the total sales of EVs increased to 1.26 million by 2018. For passenger vehicle sector, the total sales volume has climbed to 1.05 million by 2018, including 0.79 million light-duty BEVs and 0.26 million light-duty PHEVs. 0.20 million medium-duty and heavy-duty commercial EVs have been sold in China, almost dominating the total global sales of commercial EV market. In Shenzhen, almost all the taxis and public transit buses have been electrified, while urban logistics trucks have been also considerably electrified. In Beijing, where licenses for conventional fuel vehicles are stringently controlled, the share of EVs in total vehicle stock is expected to increase to 6% by 2020. It is worth noting that China is also the largest market of two-wheel electric vehicles. It is estimated that the total number of electric bikes and electric motorcycles is about 250 million in China.

China has developed a few future technological targets for the new energy vehicle industry. In 2019, The Ministry of Industry and Information Technology released a draft version of the New-energy Vehicle Industry Development Plan (2021–2035). According to this plan, by 2025, the fuel economy of new energy vehicles will be at the leading international level, accounting for more than 15% of total sales. The average fuel economy of new energy passenger vehicles will be improved to 11 kWh/100 km. The electricity consumption per unit mass of the electric buses will be 3.2 kWh/100km·t. By 2030, new energy vehicles will account for more than 40% of total auto sales in China. The electricity consumption per unit mass of the electric buses will be 3.0 kWh/100km·t.

The purchase subsidy programs for new energy vehicles are scheduled to be substantially adjusted after 2020. The current subsidies for personal EV purchases are scheduled to be reduced since 2017 and be completely cancelled after 2020. Meanwhile, China finalized its new energy vehicle mandate in September 2017 (also called dual credit policy), which aimed to provide additional compliance flexibility to the fuel consumption regulation. The rule establishes dual credit targets of 10% of the conventional passenger vehicle market in 2019 and 12% in 2020. Each NEV sold generates a certain number of credits, depending on characteristics such as electric range, energy efficiency, and rated power of fuel cell systems. For subsidy programs, public heavy-duty EVs (i.e., electric urban buses), charging infrastructure and hydrogen fuel cell vehicles (FCEVs) will remain as major concentrations of incentive designs. 10 provinces and cities including Shanghai have launched policies to accelerate the development of the FCEV industry. Domestic investment plans for hydrogen energy industrial parks, FCEVs, and related material projects have exceeded 200 billion RMB.

China launched several pilot programs to use ethanol as automotive fuel around the early 2000s. The total production has increased to approximately 2 million tonnes by 2012, which became stable in the recent years. In September 2017, 17 central ministries, including the National Development and Reform Commission and the National Energy Department, jointly issued the “Implementation Plan for Expanding the Production of Biofuel Ethanol and Promoting the Use of Ethanol Gasoline for Vehicles”. The Plan required that all relevant units should develop grain fuel ethanol appropriately, control the total production scientifically, and develop cellulosic fuel ethanol greatly to meet the growing market demand. The promotion of ethanol blended gasoline fuels (E10) would begin with 11 trial provinces and then roll out to the entire country. In the polluted North China Plain region, E10 gasoline fuels have already penetrated the market in 2018. It is expected that E10 gasoline fuels will be fully available nationwide around 2020. The market operation mechanism and the advanced bio-liquid fuel innovation system have yet to be constructed. The 50,000-tonne plant of cellulosic fuel ethanol will be demonstrated and operated. The advanced bio-liquid fuel technology, equipment and industry will reach the leading international level and a more complete market operation mechanism will be formed by 2025.

China still needs to overcome several challenges to further promote bio-ethanol fuels in the future. First, the pricing mechanism was adjusted in 2018 by canceling the previous linkage between ethanol and gasoline prices (0.9111 based on the gasoline price). After this adjustment, the pricing of automotive ethanol is now greatly influenced by the oil refinery industry. Second, the market supervision system should be improved. Otherwise, low-price coal-based ethanol products may enter the market. Furthermore, some consumers have concerns regarding the fuel economy and power performance of E10 fuels. More education and engagement programs are required to encourage more consumers to choose ethanol blended fuels.

## Projections

The historical trends suggest a strong relationship between economic development and passenger vehicle ownership density. The Gompertz function is applied to predict the future stock of passenger car fleet in China using a fitting analysis based on its historical data (vehicle ownership density vs. GDP per capita). It is noted that China's vehicle sales numbers in 2018 and 2019 have not maintained high increases.

In the future low scenario, lower increase rates are proposed for the three developed regions (i.e., BTH, YRD and PRD) in eastern China. For vehicle categories other than passenger cars, the vehicle population trends are predicted based on the average increases of historical data. Thus, as Figure 30 indicates, the total vehicle population in China is expected to increase to 307 million by 2030. For passenger vehicles, the ownership density is estimated to be 190 vehicles per 1000 persons. To comply with stricter fuel consumption standards and new energy vehicle mandates, the proportion of MPFI, GDI, HEV, BEV, and PHEV are estimated to be 26%, 31%, 12%, 11%, and 9%, respectively. EVs (BEV and PHEV) will account for about 20% of the total passenger car stock. Thus, by considering real-world fuel consumption (i.e., the road to lab gaps), it is estimated that the fleet-average fuel consumption will decrease by more than 40% according to the fleet composition in 2030. The total gasoline consumption for passenger vehicles in China is estimated to peak around 2027. The estimated total gasoline consumption in 2030 could be lower by 5% to 10% compared with the 2017 level.

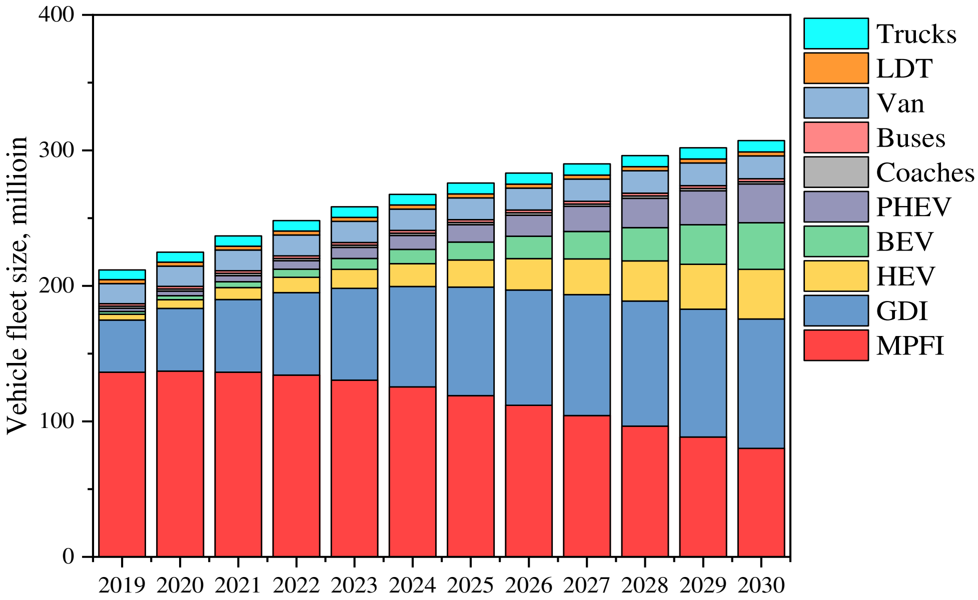


*Figure 30: The prediction of future vehicle stock in China (low scenario)*

Another scenario, the high scenario, presumes that the developed regions will maintain higher increases in passenger vehicle fleet. This high scenario predicts that the total vehicle population will increase to 376 million by 2030 (see Figure 31). Among them, passenger vehicles would account for approximately 340 million, representing a national ownership density of 230 vehicle per 1000 persons. In addition to these four-wheel vehicles, approximately 120 million gasoline-powered motorcycles are registered in China. The future population of motorcycles will be estimated stable compared to the current fleet size, as they are being prohibited in many urban areas of China and have been replaced by electric two-wheel vehicles.

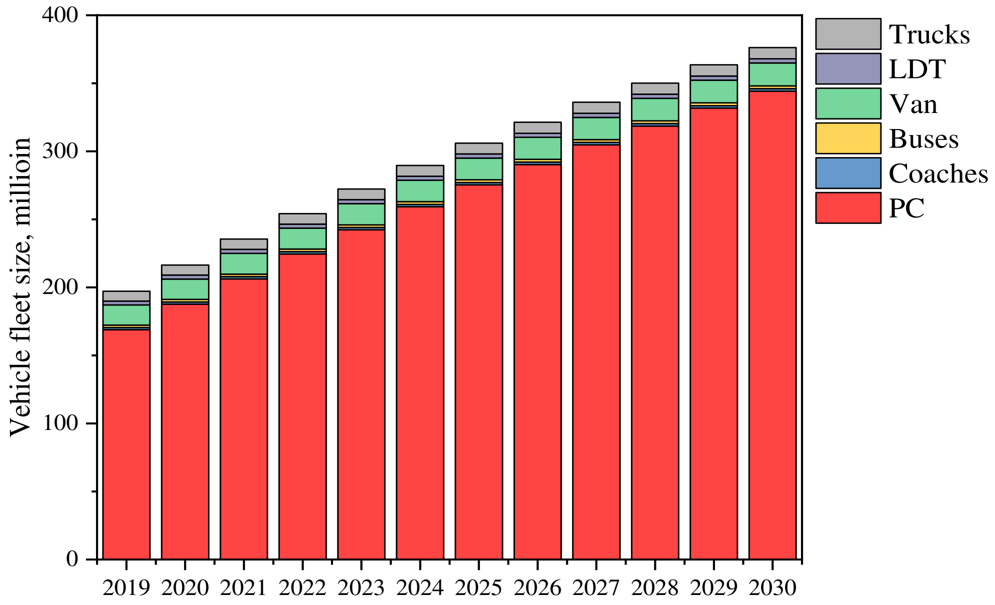


*Figure 31: The prediction of future vehicle stock in China (high scenario)*

LDT: Light-duty trucks (gross vehicle weight below 4.5 tonne); Trucks: medium and heavy-duty trucks (gross vehicle weight above 4.5 tonnes)

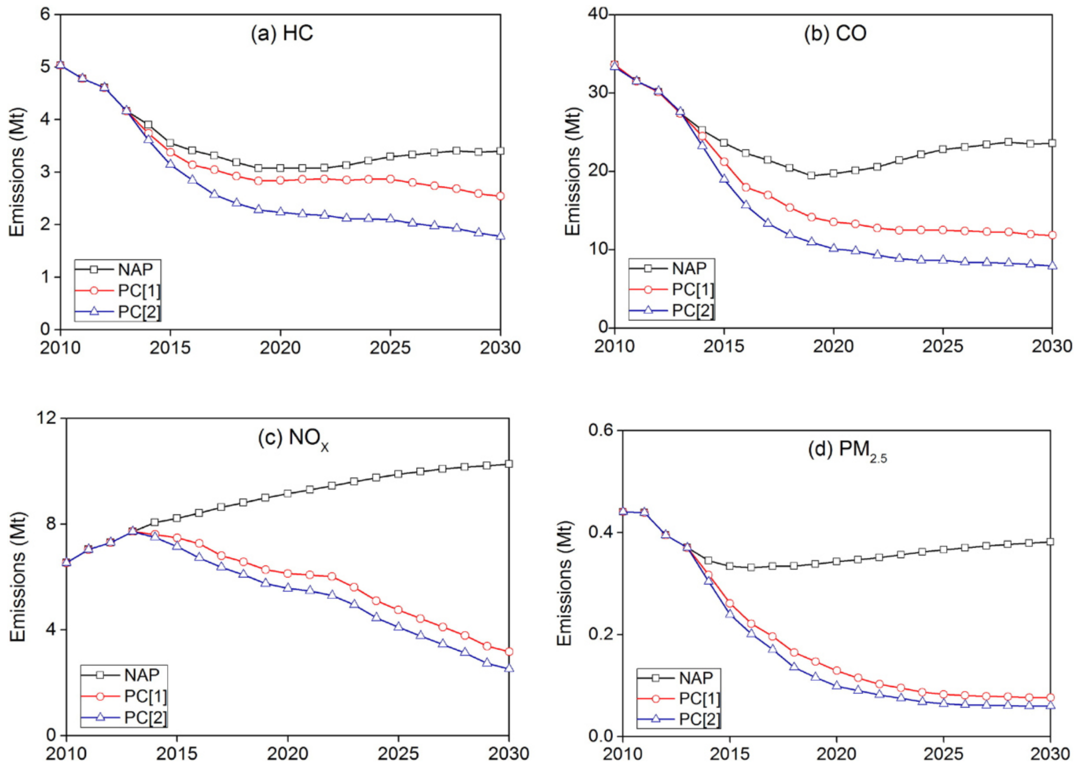


*Figure 32: The future emission trends for on-road vehicles in China under three designed policy cases (note: emissions of gasoline-powered motorcycles included)*

The future emission trends of major air pollutants are projected according to the two population scenarios and by using Tsinghua University's EMBEV model (see Figure 32). The EMBEV model was developed based on thousands of light-duty vehicles tested using dynamometers and hundreds of light-duty vehicles, buses, trucks, and alternative fuel vehicles tested on road using PEMS. The Ministry of Ecological Environment released its first version of national emission inventory guidebook for on-road vehicles, which is substantially based on the archetype EMBEV model. The NAP case indicates that future vehicle population will follow the high scenario trend, and no additional control policies will be implemented after 2017. The PC[1] case indicates that stringent emission standards will be implemented but no electric vehicles will penetrate under the high scenario population trend. The PC[2] case indicates that both stringent emission standards and fleet electrification will take effect for the low scenario population scenario, which could be regarded as the most plausible case among the three cases. The results of PC[2] case show that the total on-road emissions HC, CO, $NO_X$ and $PM_{2.5}$ in 2030 could be reduced by approximately 57%, 71%, 67% and 84%, respectively, (the PC[2] scenario) relative to 2013. In the PC[2] scenario the total vehicle emissions of HC and CO are further reduced compared with those under the PC[1] scenario due to lower population of passenger vehicles and substantial penetration of new energy vehicles. The vehicle emissions of HC would decrease to 1.78 Mt by 2030, representing an overall emission density of 0.18 t/km$^2$, which is lower than the United States level at 2011. Although the decrease during 2020 to 2030 is less rapid than that during 2010 to 2020, the further emission controls contained by the PC[2] scenario can continuously achieve HC emission mitigations with no stagnancy. Although the marginal benefits of tightening the PC[1] to the PC[2] in mitigating $NO_X$ and $PM_{2.5}$ emissions are not as significant as HC emissions, however, a considerable amount of $NO_X$ and diesel particulate matter will be eliminated in urban areas.

## Japan

**Key facts for Japan**

Total fuel consumption of the road transport sector:
646,030 ktoe, of which 13,067 ktoe are renewable in FY 2018*

Number of vehicles in use:
77,767,606, of which 117,822 are alternative fuel vehicles (incl. electric vehicles) in FY 2017**

Current GHG emissions from the road transport sector:
213,184 kt$CO_{2eq}$ in FY 2017***

The energy consumption of the road transport sector in Japan is projected to decrease due to measures to promote the introduction of next-generation vehicles and improve traffic systems.

The target is to reduce GHG emissions from the transport sector by 32.1% compared to 2005 by 2030****.

Measures to achieve this target include mainly GHG emissions will be reduced by approximately 80% per vehicle compared to 2010. Furthermore, as the ultimate goal, with innovations in how vehicles are used (autonomous drive, connected, etc.) and in collaboration with the global efforts to achieve zero emissions from energy supply, Japan will aim to realize Well-to-Wheel Zero Emission****.

*Total fuel consumption[109], **Number of vehicles[110], ***Current GHG emissions[111], ****Target GHG emissions and Measures[112]

[109] Source: Portal Site of Official Statistics of Japan, https://www.e-stat.go.jp/stat-search/files?page=1&layout=dataset&toukei=00600370&kikan=00600&metadata=1&data=1 (in Japanese)

[110] Source: Automobile Inspection & Registration Information Association, https://www.airia.or.jp/index.html (in Japanese), Next Generation Vehicle Promotion Center, http://www.cev-pc.or.jp/tokei/hanbai.html (in Japanese)

[111] Source: Greenhouse Gas Inventory Office of Japan, http://www-gio.nies.go.jp/aboutghg/nir/nir.html

[112] Source: Submission of Japan's Intended Nationally Determind Contribution, https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Japan%20First/20150717_Japan%27s%20INDC.pdf

## Energy supply and demand

Japan´s energy supply almost entirely depends on imported energy carriers. In fiscal year (FY) 2018, the country imported 99.7% of its coal use, 97.5% of its LNG use and 99.3% of its crude oil use.

As Figure 33 shows, total primary energy supply has peaked in 2005 at 22.90 EJ, and was at 20.03 EJ in FY 2017. Of these, 87.7% were from fossil sources such as oil, coal and natural gas, 1.2% was nuclear energy, 3.4% hydro and 7.7% other renewable energy.

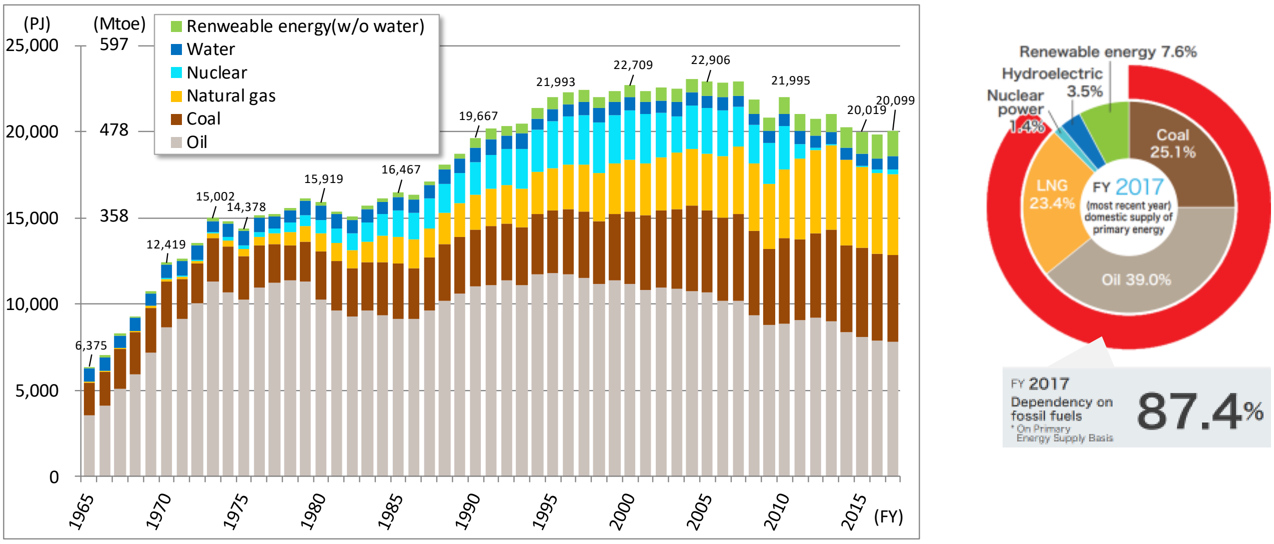


*Figure 33: Trends in composition of primary energy supply[113].*

Energy demand in the transport sector has already peaked in FY 2001 (see Figure 34), and was at 3,099 PJ in FY 2017. Gasoline provides 54.4% of transport energy, followed by diesel with 31.7%. There is a small share of electricity of 2.0%, and only 1.5% biofuels (countable number as ETBE mixed into gasoline from the public statistical data.

ETBE derived from bioethanol is included in gasoline though it is not described on the picture. Bio-diesel such as FAME is not included in this source because it's statistically very small.

[113] Converted from Japanese into English by LEVO, units added (toe). Source: METI (Ministry of Economy, Trade and Industry), https://www.enecho.meti.go.jp/en/category/whitepaper/, https://www.enecho.meti.go.jp/about/whitepaper/2019pdf/ (Japanese), https://www.enecho.meti.go.jp/en/category/brochures/pdf/japan_energy_2018.pdf

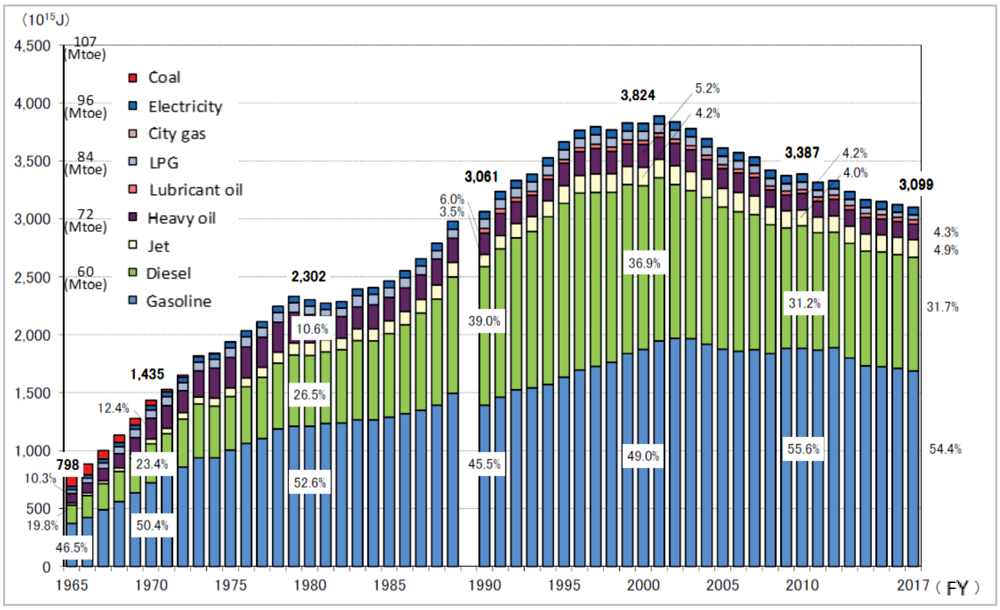


*Figure 34: Trends in energy consumption in the transport sector[114].*

Installed biofuel production capacities are listed in Table 8.

*Table 8: Biofuel installed production capacity (ML/year)[115].*

| Year | FAME Biodiesel | Ethanol | Cellulosic ethanol | Biogas as transportation fuel | Renewable diesel (from lipids) |
|---|---|---|---|---|---|
| **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 | 1.4 | - | - |
| **2017** | - | 2 | 1.6 | - | - |

114 Converted from Japanese into English by LEVO, units added (toe). Source: METI, https://www.enecho.meti.go.jp/en/category/whitepaper/, https://www.enecho.meti.go.jp/about/whitepaper/2019pdf/ (Japanese)

115 Source: Implementation Agendas - 2018 Update: A review of key biofuel producing countries, IEA Bioenergy Task 39

Raw materials for ethanol are mainly wood, lumber waste and molasses. Ethanol decreased from 2016, as some ethanol developments and demonstrations were terminated by 2015.

*Table 9: Summary of the transport fuel consumption (ML)[116]*

| Year | Gasoline | Diesel fuels | Aviation fuel | Biodiesel * | Ethanol ** | Market share(%) of biofuels *** |
|---|---|---|---|---|---|---|
| **2010** | 52,964 | 27,186 | 7,925 | 9 | 386 | 0.7 |
| **2011** | 53,266 | 25,990 | 7,623 | 9 | 359 | 0.7 |
| **2012** | 54,439 | 25,904 | 8,040 | 8 | 365 | 0.7 |
| **2013** | 53,689 | 25,681 | 8,572 | 10 | 440 | 0.8 |
| **2014** | 52,192 | 25,685 | 9,150 | 15 | 539 | 1.0 |
| **2015** | 51,502 | 25,679 | 9,494 | 15 | 700 | 1.4 |
| **2016** | 51,354 | 25,455 | 9,909 | - | 786 | 1.5 |

* Based on an inquiring survey replied, thus it could be practically 20-25ML/year

** Based on 1G bioethanol.

*** Market share of biofuels in the total transport fuel consumption. Bioethanol in Gasoline (Biodiesel in Diesel: <0.1%)

Most of the “ethanol” is imported ethanol. Raw materials for biodiesel are mainly surplus rice, wheat and waste vegetable oil. In Japan, the concentration of ethanol that can be mixed with gasoline is 3% (E3), and the concentration of biodiesel that can be mixed with diesel is 5% (B5) or 100% (B100).

## Targets for emission reductions in road transport

Japan has committed to reduce its GHG emissions from energy provision from 1,219 million tonnes of $CO_2$ equivalent in 2005 to 927 in 2030. The transport sector currently produces 225 million $t_{CO2eq}$ (FY 2013), and this number shall be reduced to 163 by 2030. This is a reduction of 27%.

[116] Source: Implementation Agendas - 2018 Update: A review of key biofuel producing countries, IEA Bioenergy Task 39

*Table 10: Estimated emissions of energy-originated $CO_2$ in each sector (Japan´s Intended Nationally Determined Contribution (INDC))[117]*

| $CO_2$ from energy provision [million t $CO_2$] | FY 2005 | FY 2013 | FY 2030 (estimated) |
|---|---|---|---|
| **Industry** | 457 | 429 | 401 |
| **Commercial and other** | 239 | 279 | 168 |
| **Residential** | 180 | 201 | 122 |
| **Transport** | 240 | 225 | 163 |
| **Energy conversion** | 104 | 101 | 73 |
| **Total** | **1,219** | **1,235** | **927** |

## Measures to promote reduced $CO_2$ emissions from road transport

As stated in the document Submission of Japan´s Intended Nationally Determined Contribution towards post-2020[118], the following main policies and measures in the transport sector are expected to be implemented for the reduction of GHG emissions:

- Improvement of fuel efficiency
- Promotion of next-generation automobiles
- Other measures in the transport sector (traffic flow improvement, promotion of public transport, modal shift to railway, comprehensive measure for eco-friendly ship transportation, reduction of land transportation distance by selecting nearest port, comprehensive low-carbonization at ports, optimization of truck transport, energy consumption efficiency improvement of railways, energy consumption efficiency improvement of aviation, accelerated promotion of energy saving ships, making vehicle transport business more eco-friendly by eco-driving, promotion of collective shipment, promotion of Intelligent Transport Systems ITS (centralized control of traffic signals), development of traffic safety facilities (improvement of traffic signals, and promotion of the use of LED traffic lights), promotion of automatic driving, eco-driving and car sharing)

One of government's policy measures is new fuel efficiency standards formulated in 2019. The targets for each passenger car and truck will apply from 2025 and 2030. The

[117] Source: MOFA (Ministry of Foreign Affairs of Japan), https://www.mofa.go.jp/mofaj/files/000090898.pdf

[118] MOFA, https://www.mofa.go.jp/mofaj/files/000090898.pdf

government has also carried out some subsidy measures. For example, to promote next-generation vehicles, the government subsidies half of the price difference between conventional and next-generation vehicles.

*Table 11: Major examples of government policy measures[119]*

| Policy measures | 2018 subsidy(M$) |
|---|---|
| New fuel efficiency standards were formulated in 2019<br><br>(FY 2030 target for passenger car was raised by 32.4% (25.4km/L) compared to FY 2016 sales performance. FY 2025 target for trucks was raised by approximately 13.4% compared to FY 2015 target.) | - |
| The tax exemption program for the low emission or fuel efficiency vehicles | - |
| Subsidy measures to promote the dissemination of clean energy vehicles | 125 |
| Subsidy measures to promote the dissemination of clean diesel trucks | 28.6 |
| Subsidy measures to promote the dissemination of energy saving system for trucks and ships | 58.2 |

## Projections

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has committed to a wide array of policy development initiatives for achieving the mid-term objective based on this plan, including making housing and buildings more energy efficient, measures for individual vehicles, and the promotion of low-carbon urban development. In addition, MLIT partially amended our Environmental Action Plan in March 2017, and set out long-term roles for the MLIT in mitigation policies and other environmental policies.

[119] Created by LEVO based on information from METI, https://www.enecho.meti.go.jp/en/, https://www.enecho.meti.go.jp/about/whitepaper/2019pdf/ (Japanese)

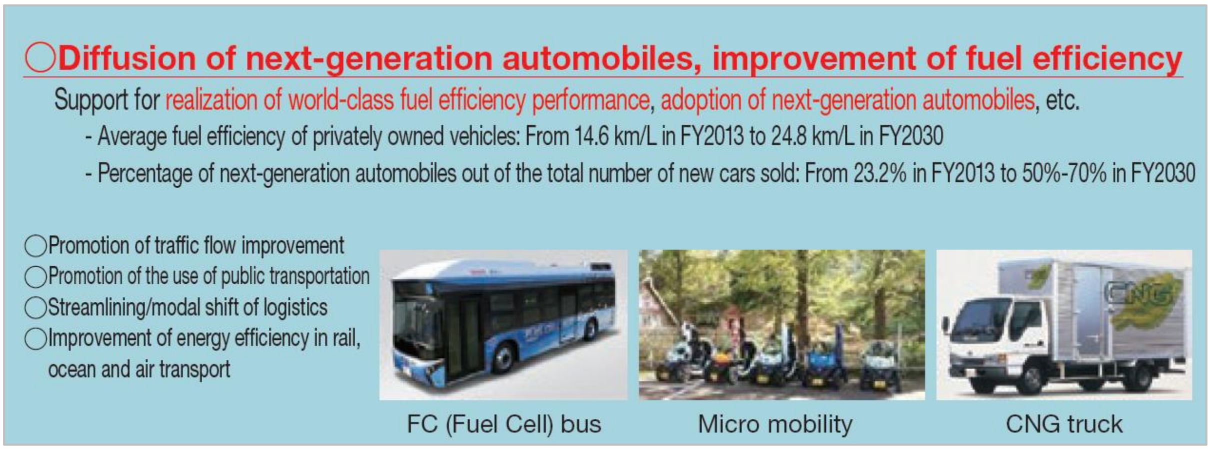


*Figure 35: Examples of MLIT efforts in the plan for global warming countermeasures[120]*

*Table 12: Dissemination targets for the next-generation passenger vehicles in 2030 sales and results in 2017[121]*

| | 2017 Results | | 2030 Targets |
|---|---|---|---|
| | % | # × $10^3$ | % |
| Conventional vehicles | 63.6 | 2,791 | 30～50 |
| Next-generation vehicles | 36.4 | 1,595 | 50～70 |
| HEV | 31.6 | 1,385 | 30～40 |
| EV/PHV | 0.41/0.82 | 18/36 | 20～30 |
| FCV | 0.02 | 0.85 | ～3 |
| Clean Diesel | 3.5 | 155 | 5~10 |

Table 12 shows a target for passenger cars in the dissemination of next-generation vehicles. Commercial vehicles are not listed in the table. However, promotion of FCEV buses, CNG trucks and so on are described in policy statements.

### Planned further policy measures

On June 11, 2019, the government approved the “The Long-term Strategy as a growth strategy based on the Paris Agreement”[122]. It is a long-term vision for the direction of policies

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[120] Source: MLIT, http://www.mlit.go.jp/common/001269888.pdf

[121] Created by LEVO based on information from METI, https://www.meti.go.jp/english/press/2018/0831_003.html, https://www.meti.go.jp/press/2018/08/20180831007/20180831007-3.pdf (Japanese)

[122] MOE (Ministry of the environment), https://www.env.go.jp/en/headline/2406.html, https://www.env.go.jp/press/802.pdf

and measures in the transport sector, and includes the main following main points:

- Challenging “Well-to-Wheel Zero Emission”
- Achieving the world’s highest level of environmental performance of Japanese cars supplied worldwide by 2050
- Development and early utilization of biofuels and alternative fuels that can be commercialized and have the capacity for significant $CO_2$ reduction.
- Road/transport systems using big data and IoT

Currently, Japan is discussing the 6th basic energy plan for the summer of 2021. On October 26, 2020, the Japanese prime minister declared that "Japan aims to realize a carbon-neutral society by 2050". It is expected that further measures will be considered for the realization of a carbon-neutral society by 2050.

## Abbreviations

| | |
|---|---|
| AER | all-electric range |
| ALIISA | Model used by VTT to calculate the future composition of vehicle fleets in this study |
| AMF | Advanced Motor Fuels |
| AQI | Air Quality Index |
| B5, B7,… | Diesel blends with x% FAME |
| BAU | Business as usual |
| bbl | barrel |
| BEV | Battery electric vehicle |
| BTL | Biomass to Liquid |
| BTU | British thermal unit |
| CAFE | Corporate Average Fuel Economy, US regulation |
| CAGR | Compound annual growth rate |
| CBIO | Carbon Certificate, used in Brazilian regulation |
| CNG | Compressed natural gas |
| ct | cent |
| DBFZ | Deutsches Biomasseforschungszentrum gemeinnützige GmbH |
| DECA | Domestic emission control area |
| E5, E10,… | Gasoline blends with x% ethanol |
| ECA | Emission control area |
| EPA | US Environmental Protection Agency |
| EPE | Brazilian Energy Research Office |
| ESR | Effort Sharing Regulation |
| ETBE | Ethyl tert-butyl ether, ethanol-containing gasoline additive |
| EU | European Union |
| EUR | Euro |
| EV | Electric vehicle |
| FAME | Fatty acid methyl ester |
| FCEV | Fuel cell electric vehicle |
| FFV | Flex-fuel vehicle, capable of using either gasoline or high-blend ethanol (or pure hydrous ethanol in the case of Brazil) |
| FQD | Fuel Quality Directive |
| FS | Future scenario |
| FYP | Five Year Plan, strategy document in China |

| | |
|---|---|
| FY | Fiscal Year |
| GDI | Gasoline direct injection |
| GDP | Gross domestic product |
| GHG | greenhouse gases |
| HC | Hydrocarbon emissions |
| HDT | Heavy duty truck |
| HDV | Heavy duty vehicles |
| HEFA | Hydrotreated esters and fatty acids |
| HEV | Hybrid electric vehicle |
| HVO | Hydrotreated vegetable oils |
| IEA | International Energy Agency |
| ILUC | Indirect land-use change |
| ILUC Directive | EU Directive including provisions on indirect land-use change |
| IMO | International Maritime Organization |
| INDC | Intended National Determined Contribution, refers to the Paris Agreement |
| ITS | Intelligent Transport System |
| JRC | Joint Research Centre, linked to the European Comission |
| LCA | Life-cycle assessment |
| LCFS | Low-carbon Fuel Standard, Californian regulation |
| LDPV | Light duty passenger vehicles |
| LDT | Light duty truck |
| LDV | Light duty vehicles |
| LNG | Liquefied natural gas |
| LPG | Liquefied petroleum gas (auto gas) |
| MDT | Medium duty truck |
| mill | million |
| MPFI | Multi-point fuel injection |
| MTBE | Methyl tert-butyl ether, methanol-containing gasoline additive |
| Mtoe | million tonnes of oil equivalent |
| MY | Model Year |
| NAAQS | National ambient air quality standards, used in China |
| NDC | National Determined Contribution, refers to the Paris Agreement |
| NEDC | New European Driving Cycle, a standard for measuring vehicles' emissions of pollutants |

| | |
|---|---|
| NEV | New energy vehicle |
| OBM | On-board sensor-based emission monitoring |
| PC | Passenger cars |
| PEMS | Portable emissions measurement system |
| PFAD | Palm fatty acid distillate |
| PHEV | Plug-in hybrid electric vehicle |
| PN | Particle Number |
| PNPB | National Biodiesel Production Program, Brazilian regulation |
| PROCONVE | Motor Vehicle Air Pollution Control Program, Brazilian regulation |
| PTG | Power to Gas |
| PTL | Power to Liquids |
| PTX | Power to X (X for different products), usual German definition for e-fuels |
| RED | Renewable Energy Directive, EU regulation |
| RED-II | Recast of the Renewable Energy Directive, EU regulation |
| RFS | Renewable Fuel Standard, US regulation |
| RIN | Renewable Identification Number, used in US regulation |
| RMB | Renminbi, Chinese currency |
| Rota 2030 | Mobility and Logistics Program, Brazilian regulation |
| RS | Reference scenario |
| RVO | Renewable Volume Obligation, used in US regulation |
| SDG | Sustainable Development Goal |
| TCP | Technology Collaboration Programme (of the IEA) |
| tsd | thousand |
| TTW $CO_2$ emissions | Tank-to-wheel $CO_2$ emissions, i.e. tailpipe emissions |
| UCO | used cooking oil |
| UCOME | used cooking oil methyl ester |
| UER | Upstream emission reduction |
| UFZ | Umweltforschungszentrum e.V. |
| USD | United States (of America) Dollar |
| WLTP | Worldwide Harmonised Light Vehicles Test Procedure, a standard for measuring vehicles' emissions of pollutants |
| WTT $CO_2$ emissions | Well-to-tank $CO_2$ emissions, i.e. upstream emissions from fuel or electricity production |
| WTW $CO_2$ emissions | Well-to-wheel $CO_2$ emissions, i.e. WTT and TTW combined |

# Appendix

# Translation of the Biofuels 2030 study

Nils-Olof Nylund

## Introduction

The Finnish strategies for emission reductions in transport and the Finnish biofuels policy are described in the chapter on Finland. The country assessment for biofuels in Finland is based on a study initiated by the Prime Minister's Office in 2018, eventually leading to setting a new biofuels mandate for Finland for the period 2021 - 2030.

Over the years, VTT Technical Research Centre of Finland Ltd and other actors have provided information and policy support regarding energy, climate and biofuels in transport. In 2015[1] and 2017[2], VTT published reports on how to reach a 40 % $CO_2$ emission reduction in road transport by 2030. In these reports, also the implications on the national economy of alternative strategies to reduce $CO_2$ from transport were assessed. One of the key findings was that in the case of Finland, biofuels is a cost effective way to reduce emissions. It was pointed out that drop-in type biofuels do not require new vehicles or modifications to the fuel supply system.

In Finland, the first biofuels obligation was set in 2008. The obligation was revised in 2010, with a target of 20 % biofuels (taking into account double counting) in 2020[3]. The 2016 national energy and climate strategy sets a target of a 50 % $CO_2$ emission reduction in transport by 2030, compared to 2005. Increasing the physical share of biofuels (energy content) in road transport fuels to 30 % by 2030 is also mentioned in the strategy.

In 2018, in preparation for the update of the biofuels mandate for 2021 to 2030, the Prime Minister's Office (PM Juha Sipilä) launched a tender for a study with the title "Cost effective pathways of biofuels until 2030". A consortium led by Pöyry Management Consulting Ltd won the tender. The other partners were VATT Institute for Economic Research and TEC TransEnergy Consulting Ltd. The final report of the study was published in early October 2018[4] ("Biofuels 2030"). The study confirmed the definition of policy set in the 2016 national energy and climate strategy; Finland will need some 30 % liquid biofuels in 2030 to meet a 50 % emission reduction target in road transport.

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[1]http://www.transsmart.fi/files/297/Tieliikenteen_40_hiilidioksidipaastojen_vahentaminen_vuoteen_2030_Kayttovoimavaihtoehdot_ja_niiden_kansantaloudelliset_vaikutukset._VTT-R-00752-15.pdf

[2]http://www.transsmart.fi/files/430/Tieliikenteen_40_hiilidioksidipaastojen_vahentaminen_vuoteen_2030_Vuoden_2016_paivitys_VTT-R-00741-17.pdf

[3] Saarinen, J. (2013). The Finnish Biofuel Policy. CEN/TC 19 Conference. Helsinki, 27 May 2013.

[4] http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161074/63-2018-Biopolttoaineiden_kustannustehokkaat_toteutuspolut_vuoteen_2030_.pdf?sequence=1&isAllowed=y

The study resulted in a proposition by the Government to the Parliament on the update of the biofuels mandate already within the month of October. The new biofuels obligation law was finally approved in March 2019[5].

Key points are:

- total 30 % share (energy) of biofuels in road transport in 2029and onwards
    - increasing linearly from 18 % (physical) in 2021 to 30 % in 2029
- sub target of 10 % advanced biofuels in road transport in 2030 and onwards
    - starting at 2 % in 2021 - 2023
    - feedstocks according to Annex IX A of the RED II Directive[6]

The new 10 % biocomponent obligation for light fuel oil in 2030 is written in a separate law[7].

[5] Saarinen, J. (2013). The Finnish Biofuel Policy. CEN/TC 19 Conference. Helsinki, 27 May 2013.

[6] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN

[7] https://www.finlex.fi/fi/laki/alkup/2019/20190418

## The assessment

### General

The 2018 study on biofuels launched by the Prime Minister's (Juha Sipilä) Office and executed by the consortium led by Pöyry Management Consulting basically followed the directions set up in the 2016 national energy and climate strategy. The study, preparing for the update of the Finnish biofuels obligation demonstrated what amounts of biofuels would be needed in alternative 2030 scenarios to reach the overall $CO_2$ reduction target in road transport, -50 % compared to the year 2005. The study also assessed future availability and costs of biofuels. It was concluded that the current and expected Finnish biofuels production capacity would be sufficient for a 30 % share of biofuels in road transport by 2030, but that the production would be primarily based on imported feedstocks. The 30 % share of biofuels, in combination with improvements in energy efficiency and introduction of electric vehicles, would deliver the targeted 50 % reduction in $CO_2$ emissions. The cost impacts were estimated to be moderate, mainly in the range of 0.3 to 1 %, depending on the sector of the economy.

Figure 1 shows the basic elements of the study. The assessment at hand concentrates on determining the amounts of biofuels needed in road transport.

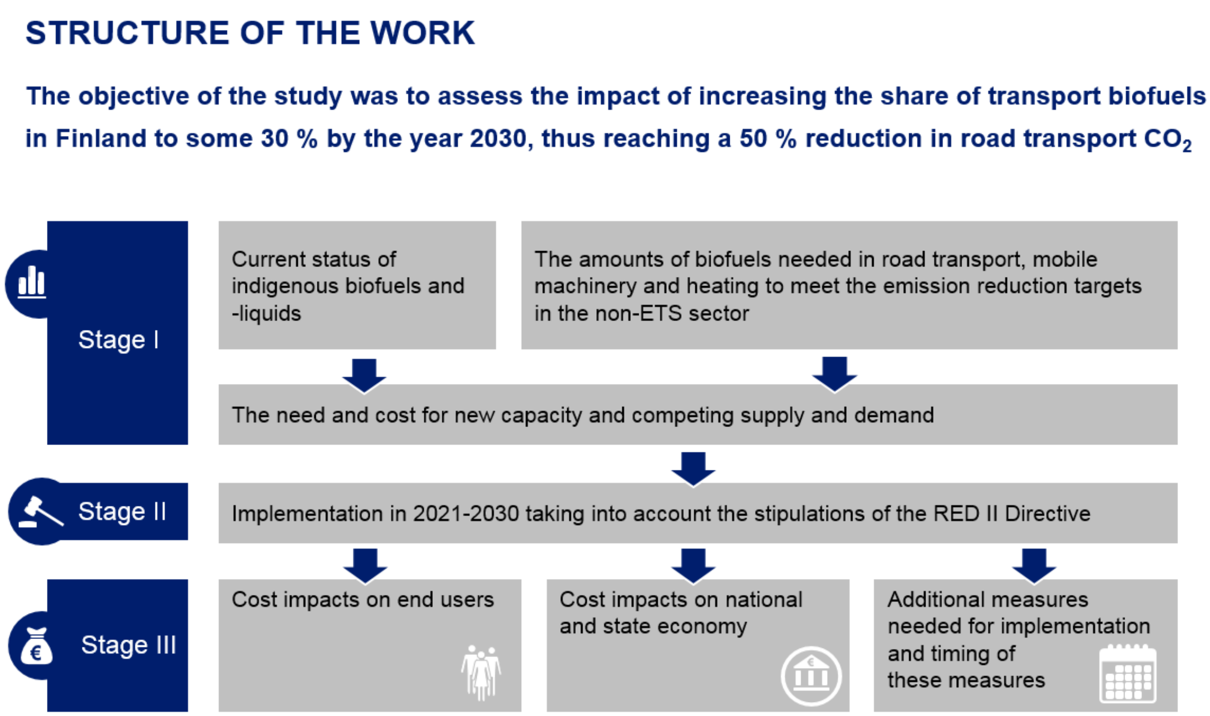



*Figure 1. The basic elements of the "Biofuels 2030" study.*

## Starting values

LIPASTO is a calculation system developed and maintained by VTT[8]. It is used to calculate transport emissions and energy consumption in Finland, covering road, rail, waterborne and air transport as well as working machines. The official Finnish transport emission inventories are based on the LIPASTO system. The sub models for road transport are called LIISA (emission inventory) and ALIISA. ALIISA is the vehicle fleet sub model producing vehicle fleet data for the LIISA model. The models are also used to produce energy and emission into the future.

The starting point for the calculations of biofuel volumes in 2030 was the so-called ALIISA 2016 "business as usual" baseline[9], sanctioned by the Ministry of Transport and Communications. The main assumptions for road transport in 2030 are (see also "Country report - Finland):

- total energy use: 3,420 ktoe
    - fossil liquid fuels 2,904 ktoe (84.9 %)
    - liquid biofuels 462 ktoe (13.5 %)
    - natural gas 8 ktoe (0.2 %)
    - biogas 8 ktoe (0.2 %)
    - electricity 37 ktoe/427 GWh (1.1 %)
- passenger car stock: ~3 million units
    - electric passenger car stock (PHEVs + BEVs): 120,000 units

[8] http://lipasto.vtt.fi/en/index.htm

[9] http://lipasto.vtt.fi/aliisa/aliisa_tulokset.htm

## The projections for 2030

**Key modelling assumptions for the Biofuels 2030 Study**

- The 2030 baseline scenario created earlier for the Ministry of Transport and Communications was used as a starting point, a scenario which encompasses moderate improvements in vehicle energy efficiency, 13.5 % liquid biofuels and a moderate penetration of EVs, but no additional policy measures.
- For the “Biofuels 2030” study, a slightly modified 2030 reference case was formed by removing all biofuels and all electric vehicles (a zero renewables baseline).
- Based on this zero renewables reference, two different pathways were created, one with no additional improvements in energy efficiency and one with successful energy efficiency measures throughout the system.
- For both pathways, EVs were then added (0, 120,000, 250,000, 600,000 by 2030).
- Then for each combination, biofuels were added to reach the required $CO_2$ reductions.

For the “Biofuels 2030” study, a slightly modified 2030 reference was created (including intermediate points for 2020 and 2025). This was done by eliminating all biofuels and electricity, to demonstrate the situation without any renewable or carbon neutral energy carriers. With this arrangement, adding either biofuels or electricity became a more straight forward procedure basically starting from a clean table.

For energy efficiency, two separate scenarios were evaluated, one according to the ALIISA baseline scenario without any dramatic improvements in energy efficiency, and one scenario with improvements throughout the whole transport system, according to the 2016 energy and climate strategy, and resulting in a 1.6 Mt reduction in $CO_2$ emissions in 2030. The emission reductions stem from improved vehicle efficiency (other than energy efficiency improvements through electrification) but also from improved logistics and increased use of public transport.

It should be noted that economic growth normally increases transport work. Therefore, progress in energy efficiency could easily be mitigated by increased transport work in 2030.

Table 1 presents total energy use and $CO_2$ emissions for road transport without any biofuels or electricity in 2005 (reference year) and in 2030 (two different cases for energy efficiency). Without significant improvements in energy efficiency, carbon neutral energy has to bring about an additional reduction of 42 % to reach an overall reduction of 50 %, in the case of improved efficiency the figure is 28 %. In calculating the $CO_2$ inventory of transport, the end use of biofuels, electricity and hydrogen is considered carbon neutral.

*Table 1. Total energy use and $CO_2$ emissions for road transport with no renewable or carbon neutral energy.*

| | 2005 | 2030 baseline | 2030 energy efficiency |
|---|---|---|---|
| Road transport energy (ktoe) | 3780 | 3485 | 2963 |
| Road transport $CO_2$ (Mt) | 11.7 | 10.7 | 9.1 |
| $CO_2$ relative to 2005 (%) | | -8 | -22 |

Figure 2 describes the setup of the different scenarios, the variables being:

- $CO_2$ emission reduction target for transport
  - -50 % as set by the 2016 national energy and climate strategy
  - -39 % being the overall emission reduction target for Finland in the non-emission trading sector (European effort sharing)
- two different pathways for energy efficiency
  - baseline pathway with no significant improvements in energy efficiency
  - positive development in energy efficiency in line with the 2016 energy and climate strategy
- number of EVs in the fleet in 2030
  - 0…600,000 units (mainly passenger cars but also some commercial vehicles)
  - ALIISA baseline projection 120,000
  - number according to the 2016 energy and climate strategy 250,000
  - 600,000 representing a “high scenario” meaning a 20 % of the passenger car fleet in 2030

AMOUNT OF BIOFUELS NEEDED IN THE NON-ETS SECTOR

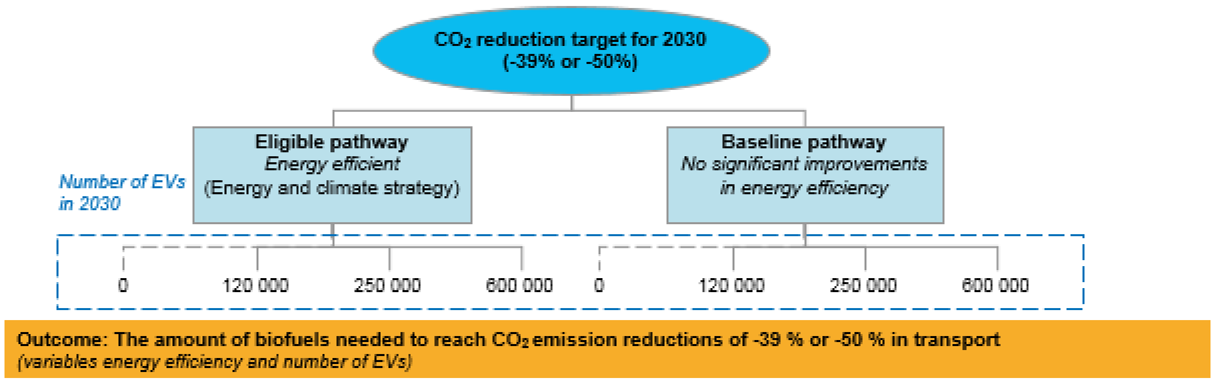



*Figure 2. Evaluated scenarios, main variables are $CO_2$ reduction target, energy efficiency and number of electric vehicles.*

The following parameters were treated as fixed:

- the number or vehicles in 2030 (ALIISA 2016)
- the transport work in 2030 (ALIISA 2016)
- the number of gas fuelled vehicles (50,000 passenger cars and some commercial vehicles)
    - 2016 national energy and climate strategy
- the amount of biogas used in road transport in 2030 (44 ktoe)
    - 2016 national energy and climate strategy

## Impact of electric vehicles

As electric vehicles are more energy efficient than internal combustion engines equipped vehicles, total energy demand goes down as the number of electric vehicles goes up. In the calculations, it is assumed that one energy unit of electricity replaces 2.8 units of fuels.

The calculations of total energy use are based on the Finnish average annual driving distance of 17,000 km for passenger cars, which is some 45 km/day. This can be reached both with battery electric vehicles and plug-in hybrids running on electricity only, so to streamline the calculations, these vehicle categories are grouped together as “electric vehicles”.

Figure 3 shows the different trajectories for the growth of the EV passenger car fleet towards

2030. The market shares of EVs start at very low levels. To reach 600,000 EVs in 2030, the market share of EVs would have to be some 70 % in 2030, whereas the 120,000 units mentioned in the ALIISA baseline scenario would require a modest market share of 13 % in 2030.

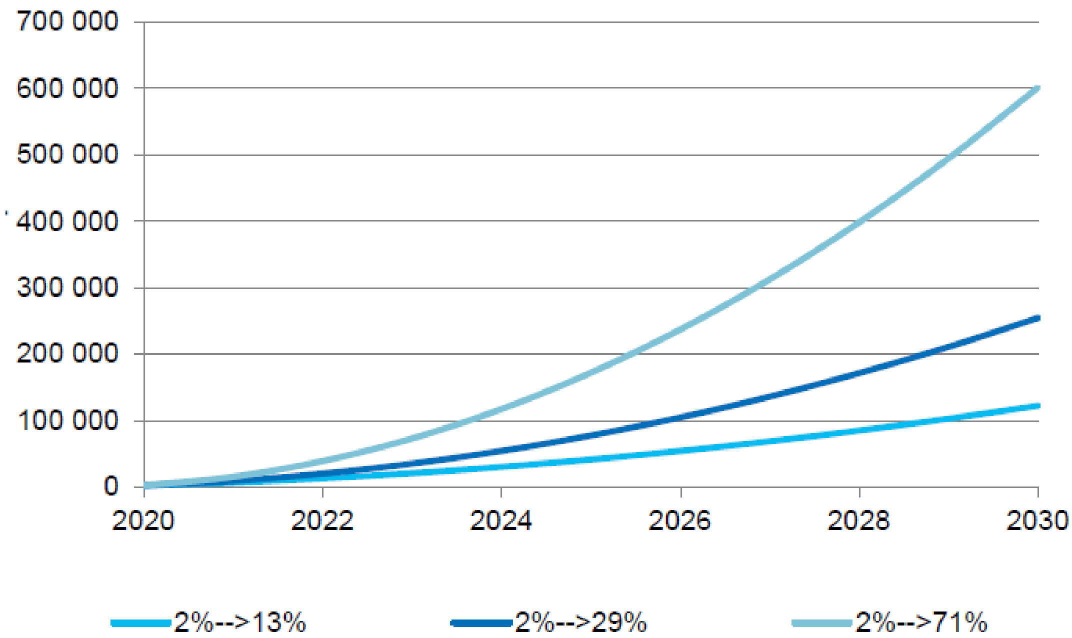



*Figure 3. Trajectories for EV fleet growth with market shares in 2020 and 2030.*

The calculations assume use of electricity also in other vehicle categories than just passenger cars, that is e.g., delivery vehicles and city buses. For the scenario of 600,000 electric passenger cars, it is assumed that the passenger cars use some 185 ktoe of electricity and the other vehicle categories 20 ktoe, totalling 205 ktoe of electricity and some 90 % of the electricity used in passenger cars.

Figure 4 shows the effects of electrification on total energy demand and fuel replacement in the case of the energy efficient transport system.

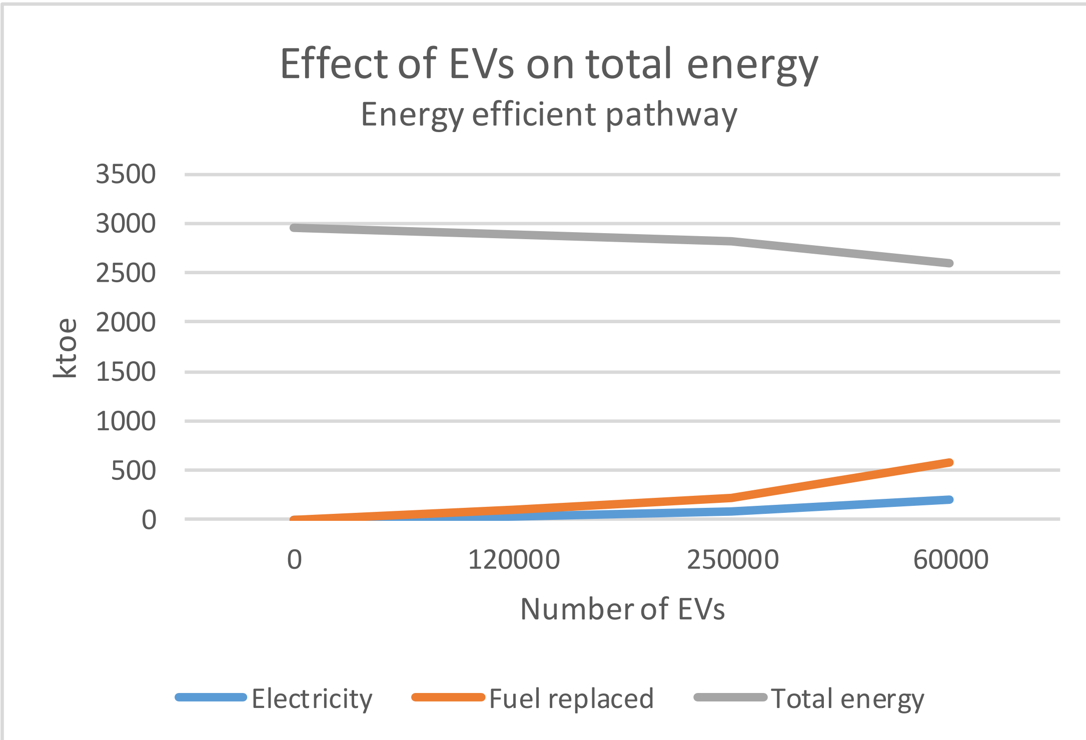



*Figure 4. The effects of electrification on total energy demand and fuel replaced, calculated for the energy efficient transport system pathway.*

Figure 5 shows the levels of $CO_2$ reductions (relative to 2005) that can be reached with electrification only. Values are presented for the "baseline" efficiency case and the case of improved transport system efficiency.

The combination of a highly efficient transport system and a high number of EVs could according to this calculation delivers a $CO_2$ reduction of 37 % relative to the year 2005, close to the non-ETS effort sharing for Finland (-39 %) but still less than the 50 % reduction called for in the 2016 national energy and climate strategy. This, however, on condition that transport work does not increase significantly.

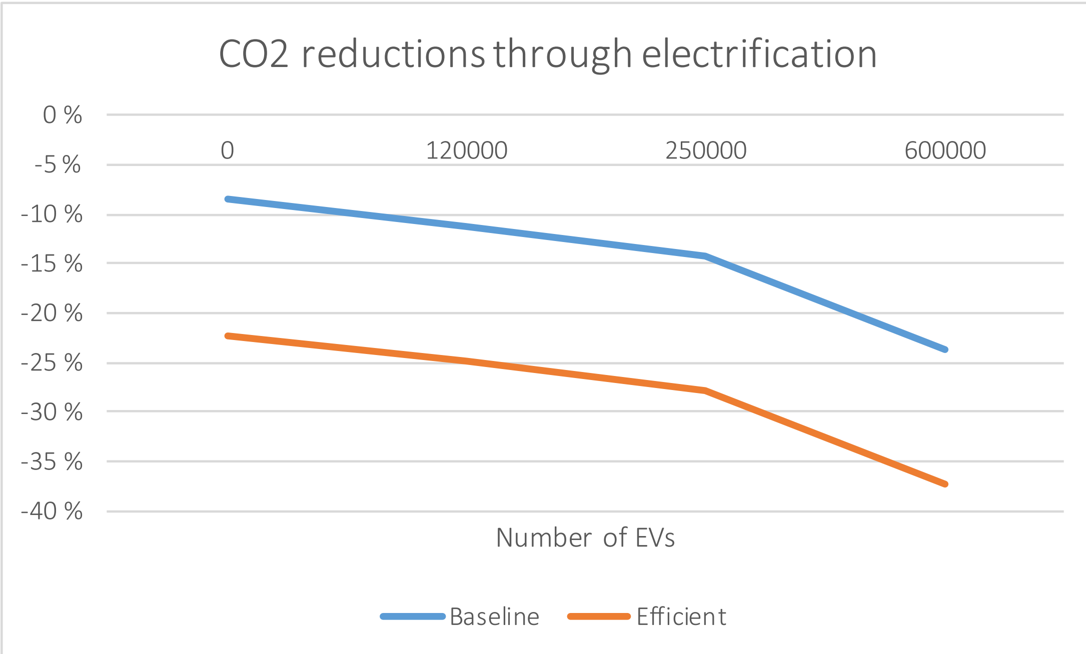



*Figure 5. Levels of $CO_2$ reductions (relative to 2005) that can be reached with electrification only.*

## The need for biofuels

As stated in Figure 2, the basic outcome of the calculations is the amount of biofuels needed to reach a 39 or 50 % reduction in road transport $CO_2$ emissions as a function of energy efficiency and the number of electric vehicles.

The calculations were carried out for three different years, 2020, 2025 and 2030, presuming that the $CO_2$ emission reductions should be linear between 2005 (reference year) and 2030 (target year).

Results are presented in Figures 6 (2020), 7 (2025) and 8 (2030). Figure 9 summarises the need for liquid biofuels aiming for a 50 % $CO_2$ reduction in an energy efficient transport system, as defined by the 2016 national energy and climate strategy.  For this case the number of EVs is varied between 120,000 (ALIISA projection) and 600,000.

In all cases, the amount of biogas is fixed at a modest 44 ktoe in 2030. In Finland, biogas is exempted from energy taxes, and can therefore not be included in the biofuels mandate, which consequently only covers liquid biofuels. Anyhow, for the $CO_2$ inventories, it is insignificant whether the biofuel is in liquid or gaseous form. Higher amounts of biogas would lower the need for liquid biocomponents and vice versa. However, the division between liquid and gaseous biofuels has an impact on costs, as the use of gas (methane) requires dedicated vehicles as well as dedicated refuelling facilities.

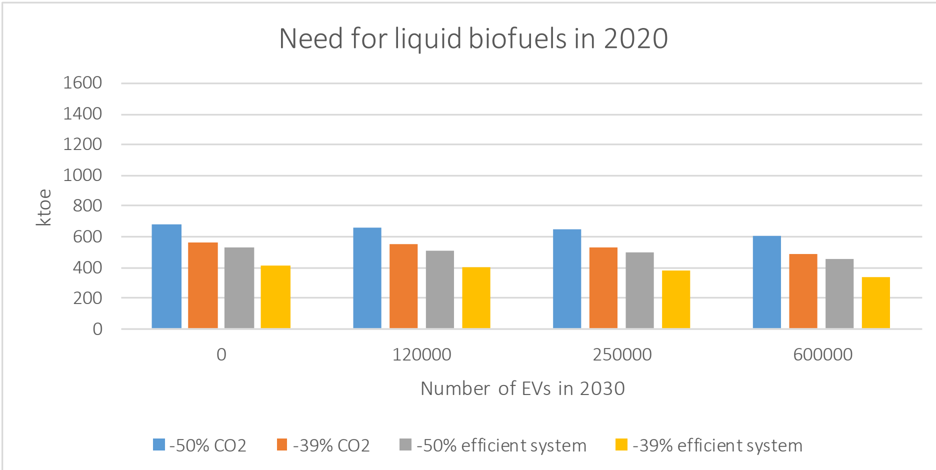



*Figure 6. The need for liquid biofuels in 2020.*

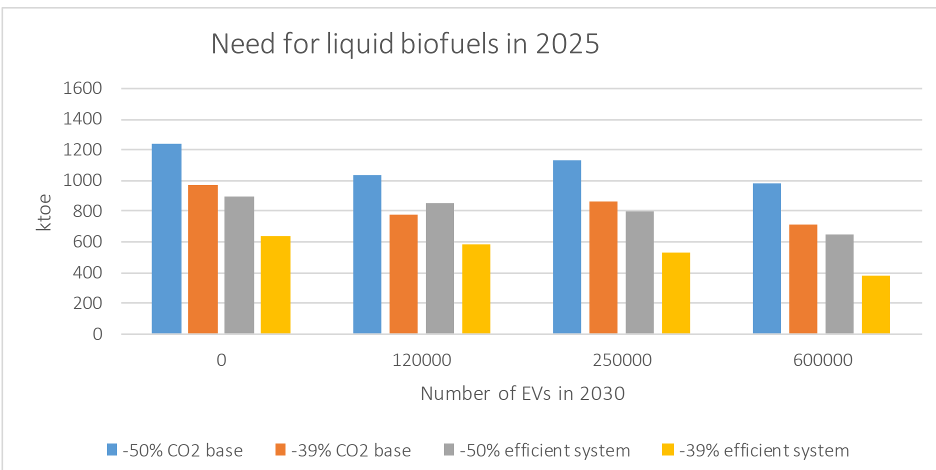



*Figure 7. The need for liquid biofuels in 2025.*

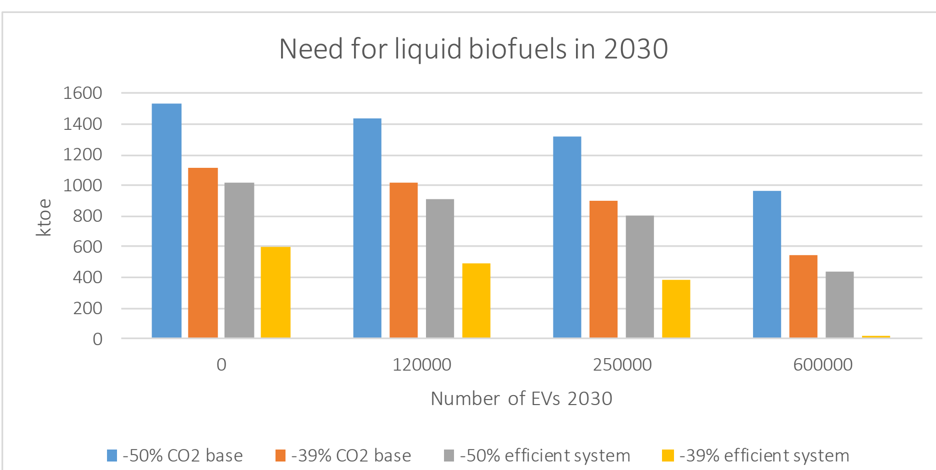



*Figure 8. The need for liquid biofuels in 2030.*

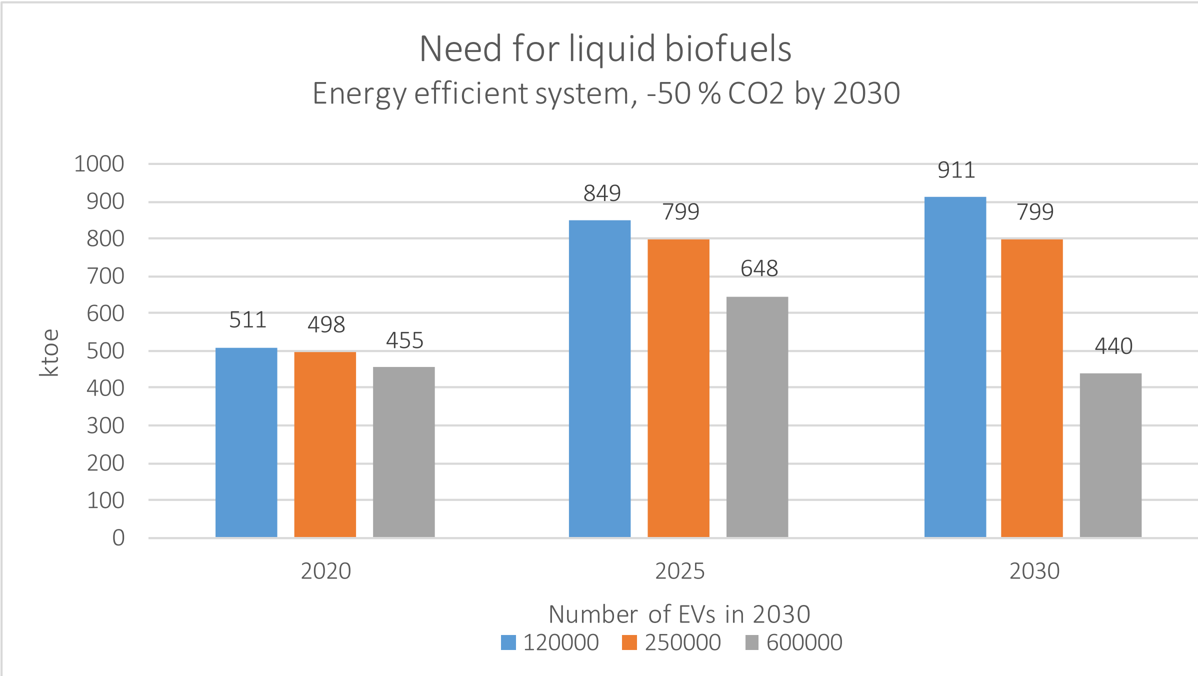



*Figure 9. The need for liquid biofuels in an energy efficient transport system.*

In 2030, the need for liquid biofuels varies between some 1500 ktoe (50 % $CO_2$ reduction, baseline energy efficiency, zero EVs) and 20 ktoe (39 % $CO_2$ reduction, energy efficient system, 600,000 EVs).

If a 50 % reduction in $CO_2$ emissions by 2030 is required, and the energy efficiency measures are successful, the amount of liquid biofuels in the time period 2020 to 2030 varies between some 450 and 900 ktoe/a.

In line with the 2016 national energy and climate strategy, with successful energy efficiency measures and with the trajectory to 250,000 EVs in 2030 (some 8 % of the total passenger car population and some 30 % of new car sales in 2030) the need for liquid biofuels is 800 ktoe/a both in 2025 and 2030. The reason for this is that sales of EVs are expected to really pick up after 2025 and that the impact of EVs is still rather small in 2025. For this pathway, the share of liquid biofuels of the total amount of actual fuels is 14 % in 2020, 25 % in 2025 and 29 % in 2030.

In 2030, with success in energy efficiency and 250,000 EVs, the fuel mix would be as follows:

- fossil petrol 666 ktoe
- fossil diesel 1,238 ktoe
- ethanol 80 ktoe (assumption all petrol E15)
- renewable diesel 719 ktoe
- biogas 44 ktoe
- electricity 77 ktoe
- total 2825 ktoe

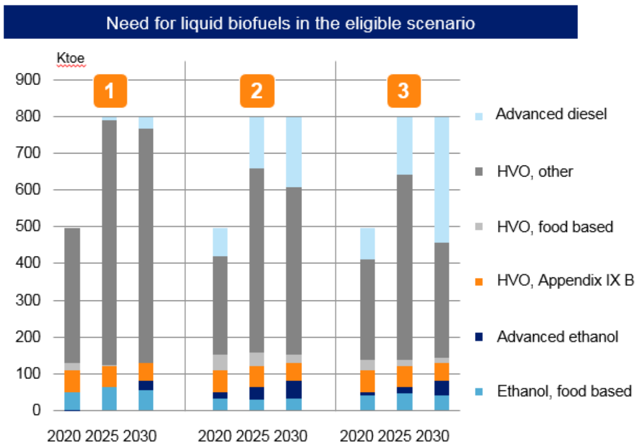
Electrification will mainly replace petrol. As there is a blending wall for adding ethanol to petrol (the assumption is that all petrol is E15) and as FFV vehicles have practically disappeared from the market, the sink for ethanol in 2030 will be low, only some 80 ktoe, if no new technologies to utilise ethanol are introduced. This means that the major part of the biofuels in 2030, some 90 %, has to be drop-in type renewable diesel, unless new ethanol sinks or new renewable components for petrol can be found. The use of FAME (conventional biodiesel) as a blending component is considered challenging in the Finnish climate with severe winter conditions. Increasing the use of biogas significantly both in passenger cars and in heavy-duty vehicles would reduce the need and pressure for renewable diesel.

## Advanced biofuels

In preparation for the upcoming mandate, three different options for advanced biofuels within the mandate were evaluated, namely 3.5 % (minimum RED II subtarget), 10 % and 15 % (Figure 10). The thinking was that the higher the subtarget for advanced biofuels is, the higher the contribution from indigenous biofuels will be.

## FUELS IN ALTERNATIVE OPTIONS FOR THE MANDATE

**Three different options for advanced biofuels within the mandate were created, all based on actual energy without double-counting (all resulting in a 50 % reduction in road transport $CO_2$)**




**1** ***The first option*** is based on the RED II sub-target for advanced biofuels and biogas, going with moderate pace towards 3.5 % in 2030.

**2** ***The second option*** is a linear path towards 10 % advanced biofuels and biogas in 2030, with the aims to increase the share of indigenous biofuels within the overall mandate and to speed up the deployment of advanced biofuels.

**3** ***The third option*** sets the target for advanced biofuels as high as 15 %, with the pace increasing towards 2030, targeting a 50 % share of indigenous feedstock.

*Figure 10. Alternative subtargets for advanced biofuels.*

## Main conclusions of the "Biofuels 2030" study

The main conclusions of the study can be summarised as follows (with comments):

- *Finland can reach a 50 % emission reduction by 2030 with a combination of improved energy efficiency, 30 % liquid biofuels (800 ktoe), 25, 000 EVs and 50,000 biogas vehicles*
    - confirmation of the definition of policy set in the 2016 national energy and climate strategy
    - mandate set at 30 % (actual) for 2030
- *The current and planned indigenous production capacity would be sufficient for a 30 % share of liquid biofuels, but the production would for the greater part be based on imported feedstock*
    - a separate subtarget of 10 % advanced biofuels to speed up development of indigenous biofuels based on, e.g., lignocellulosic feedstocks
- *The effect of the new biofuel mandate on pump prices (with tax) is estimated to be +5 % on an average (-3…+14 %), which with current prices and taxation system would mean +7 cnt/l (relative to the current mandate of 20 % with double counting)*
    - fluctuations in current daily pump prices of fuels can easily be ±5 cnt/l, so the impact can be considered to be relatively marginal
- *The cost increase for the various business sectors and the end-users induced by the new mandate would, on an average, be moderate*
- *The effects of the new mandate on the state economy is limited as well, as the effect on tax revenues is estimated to be less than 0.3 %, while increase in VAT compensates for reduced fuel taxes*
    - with the current tax system (energy and vehicle taxes) a drop in tax revenues will be an issue when moving towards electrification of vehicles