Deutsches Biomasseforschungszentrum
gemeinnützige GmbH

Background paper

FURTHER DEVELOPMENT OF THE GERMAN GREENHOUSE GAS REDUCTION QUOTA

February 2021

Deutsches Biomasseforschungszentrum gemeinnützige GmbH
Torgauer Str. 116
D-04347 Leipzig

Karin Naumann
+49 (0) 341/2434-711
karin.naumann@dbfz.de

Dr.-Ing. Franziska Müller-Langer
+49 (0) 341/2434-423
franziska.mueller-langer@dbfz.de

Dr. rer. nat. Kathleen Meisel
+49 (0) 341/2434-472
kathleen.meisel@dbfz.de

Stefan Majer
+49 (0) 341/2434-411
stefan.majer@dbfz.de

Jörg Schröder
+49 (0) 341/2434-522
joerg.schroeder@dbfz.de

Uta Schmieder
+49 (0) 341/2434-556
uta.schmieder@dbfz.de

Citation:

Naumann K, Müller-Langer F, Meisel K, Majer S, Schröder J, Schmieder U (2021): Further development of the German greenhouse gas reduction quota, Background paper. Leipzig: DBFZ. 02/2021.

Content

1. The greenhouse gas quota as a tool for reducing greenhouse gases in the transport sector

The Intergovernmental Panel on Climate Change (IPCC) is again calling for decisive action to be taken in the energy, transport and agriculture sectors to achieve the goals of the Paris Agreement of an 80-95% reduction in greenhouse gases (over 2010 levels) by 2050. Key is to drastically reduce energy consumption while significantly increasing the proportion of sustainable renewable energy sources.

The transport sector faces particular challenges in creating sustainable and climate-friendly mobility. Here, the development of the final energy consumption and the power trains and energy sources used in the various modes of transport play a decisive role. In addition to measures to avoid and shift transport, approaches focus on the use of alternative engines and renewable energy sources.

The Renewable Energy Directive (2009/28/EC, or RED) is one of the primary tools for promoting the use of renewable energy sources in transport. It was adopted at the European level in 2009 and was revised in 2018 (2018/2001/EC, or RED II). At the heart of both directives are the minimum percentages of alternative and renewable energy sources that EU member states are expected to achieve in the transport sector (RED: 10% by 2020, RED II: 14% by 2030). Also, framework conditions have been established to demonstrate the sustainability and minimum greenhouse gas reduction of these energy sources. (European Union 23.04.2009a, 11.12.2018)

A second tool relevant for transport-related energy sources is the Fuel Quality Directive (2009/30/EC, or FQD), which was also adopted in 2009. The FQD aims to gradually reduce the lifecycle greenhouse gas emissions of fuels. The FQD defines the greenhouse gas reduction targets that need to be implemented by EU member states for fuels placed on the market (by 2020: 6% through alternative and renewable fuels including the crediting of up to 1.2% upstream emission reductions). Fuel suppliers fall under the obligated parties who must report the greenhouse gas emissions for the fuels they place on the market. (European Union 23.04.2009b)

European directives are to be transposed into the national legislation of the respective EU member states. In Germany, the RED and FQD are implemented through the Greenhouse Gas Quota (GHG quota) (specifically, Section 37a-d of the Federal Immission Control Act (BImSchG) and subsequent ordinances). The basic principle of the GHG quota is simple: since 2015, fuel distributors (so-called obligated parties) have been required to monitor and gradually reduce the GHG emissions of the fuels they place on the market. This is usually achieved by blending fossil fuels with renewable fuels that have a low greenhouse gas balance (GHG balance).

The national transposition of RED II and, hence, adjustments to the 2030 GHG quota, must be completed by June 2021. Currently, various proposals for the implementation of RED II and thus for the continuation and further development of the 2030 GHG quota are under discussion.

The sections below describe how the GHG quota works, outline the possible consequences of the discussed proposals, and detail how they fit into Germany's climate protection goals.

2. Development and impact of the GHG quota up to 2020

Germany began using the quota instrument in 2006 as an energetic biofuel quota. This required fuel distributors to use a specified minimum amount of biofuels for energy purposes. As a result of these and other subsidy measures (e.g., temporary energy tax relief on pure biogenic fuels), the proportion of biofuels rose in Germany until 2007. In addition to comparatively lower shares of pure fuels, the quota was largely achieved by blending biofuels with gasoline and diesel fuels.

The GHG quota was introduced in 2015 and replaced the biofuels quota; now the emphasis was placed on the reduction of greenhouse gases. Obligated parties, i.e., the distributors of gasoline and diesel fuels for road transport, must now ensure that the GHG emissions of the fossil fuels they place on the market, as well as the GHG emissions of the alternative fuels and biofuels they place on the market, are lower than a defined reference value (3.5% starting in 2015, 4% starting in 2017 and 6% from 2020 onwards; the reference value can be found in the Appendix | Description of method). In case of non-fulfillment, penalties must be paid on the shortfall. It is possible to transfer one's obligations to third parties as part of a contractual agreement (Section 37a (6) BImSchG) and quota trading has now become an established practice. The main customs office in Frankfurt/Oder is responsible for calculating and monitoring the greenhouse gas quota.

The requirements outlined in in the RED (European Union 23.04.2009a) on sustainability and balancing GHG emissions are transposed into national law by the Biofuel Sustainability Ordinance (Biokraft-NachV), adopted in 2009. It applies to all entities along the production and supply chain, i.e., from the cultivator to those in the biofuel sector obliged to provide proof. The Federal Office for Agriculture and Food (BLE) is the competent authority for implementing the sustainability criteria. Biofuels (and all other renewable fuels) can only be counted against the quota if the above requirements are met and the proof is provided through a certificate. Requirements have become more stringent in recent years, e.g., specific minimum GHG reductions for renewable fuels compared to the fossil reference (50% reduction for existing plants, 60% reduction for new plants), as well as stipulations on the feedstocks that can be used and the land that can be utilized for biomass cultivation.

Fig. 1 shows the development of biofuels used in Germany since 2007 and the GHG reductions achieved through their use since 2009. The market incentive brought about by the GHG quota to specifically use biofuels that contribute to a high GHG reduction, has increased the total annual GHG reduction while decreasing or leveling off biofuel quantities. In 2019, 124 PJ (equivalent to about 3.6 million tonnes) of certified biofuels were used (Federal Office for Agriculture and Food (BLE) 2020), saving a total of about 9.7 million tonnes of CO_2 equivalents (GHG) with an average GHG reduction of 83% compared to the fossil reference. Until 2019, FAME (fatty acid methyl esters) and ethanol fuels were the primary contributors to fulfilling the quota, while HVO (hydrotreated vegetable oils) and vegetable oils have played only a minor role, especially in recent years.

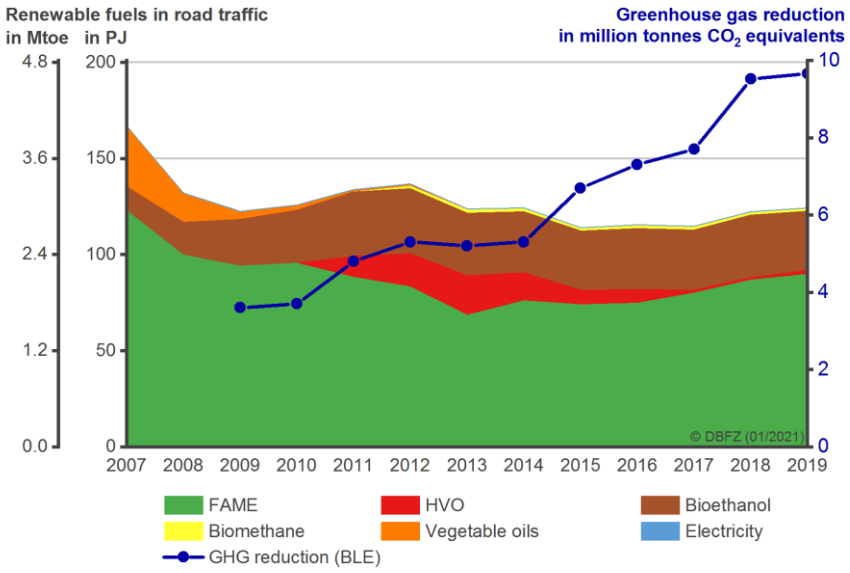


Fig. 1 Development of proportion of biofuels in the transport sector from 2007 to 2019

In addition to biofuels, other fulfillment options can now be applied to the GHG quota. This means that other, partially fossil-based fuels can also be used, provided their GHG balance shows a comparative advantage over the previous average value. Other fulfillment options include:

- fossil gas fuels such as liquefied petroleum gas (LPG) and natural gas (as compressed natural gas - CNG or liquefied natural gas - LNG),
- electricity and electricity-based fuels,
- the co-refining of vegetable oils in mineral oil refineries, limited until 2020
- measures to reduce emissions from crude oil production, known as upstream emission reductions (see the UERV), which, with a share of up to 1.2%, can contribute to GHG reductions from 2020 onwards.

Fossil gas fuels contribute to about 0.15% of the required 6% in 2020. Based on current estimates, it is assumed that the GHG reduction of 1.2% from UER will not yet be fully utilized for 2020 and will remain below 1%. Fuels produced through co-refining were not included in the quota in 2019 (Zoll 2020). Despite a rise in newly registered electric vehicles in recent years, electricity utilized as a part of the GHG quota has so far contributed only marginally to fulfilling the quota.

Currently, only an estimation can be made about whether the quota will be fulfilled in 2020 (Fig. 2). Based on various influencing factors and assumptions (see Appendix | Description of method), it can be assumed that about 150 to 160 PJ of biofuels will be required to meet the quota.

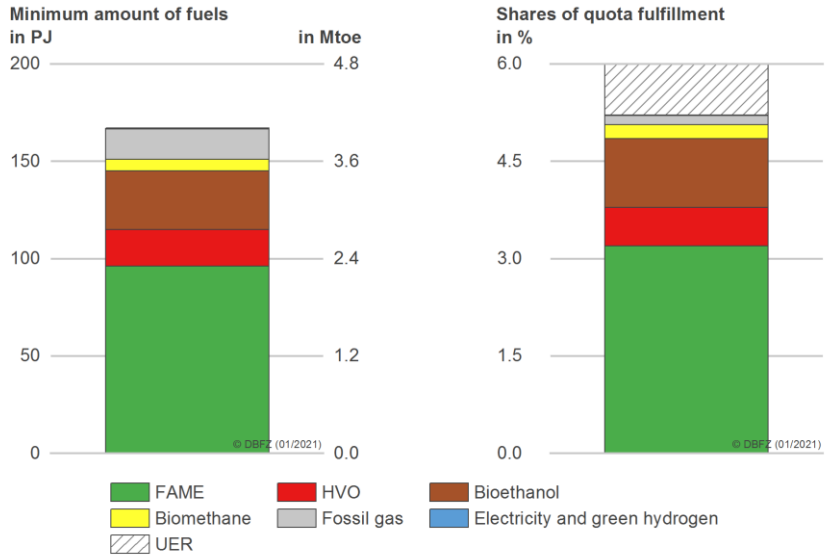


Fig. 2 Estimate for fulfilling the GHG quota in 2020 with UER at 65% of 2.5 million tonnes of CO_2-eq.

3. Prospects for the GHG quote up to 2030

The deadline for national implementation of the RED II requirements is June 30, 2021. In Germany, it will be transposed by continuing and redesigning the GHG quota in accordance with the current draft. The initial draft act was published in September 2020 (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) 2020). An inter-ministerial agreement was subsequently reached on a cabinet draft, which has been resolved on Feb 2, 2021. The key points that have been published to date are summarized in Table 1.

Table 1 Key points for the national transposition of RED II in Germany (if no information is given for a specific year, there are no specifications regarding the minimum/maximum quotas) (Falk Heinen 2021)

Total quota & option	Explanation	2022	2023	2024	2025	2026/ 2027	2028/ 2029	2030
Total GHG quota	*Minimum GHG reduction*	*6.5%*	*7%*	*8%*	*8%*	*10%*	*14.5%*	*22%*
Fulfillment options								
Advanced biofuels (RED II Annex IX Part A)	Minimum for energy purposes, double credit for amounts over the minimum	0.2%	0.3%	0.4%	0.7%	1.0%	1.7%	2.6%
Biofuels from used cooking oils (UCO) and animal fats (RED II Annex IX Part B)	Maximum for energy purposes	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%
Conventional biofuels from feedstocks that also serve the food and feed sector	Maximum for energy purposes, excluding palm oil until 2026	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%
Green hydrogen and downstream products (PTx fuels/e-fuels)	Double credit for quantities used in refineries and road transport							

Total quota & option	Explanation	2022	2023	2024	2025	2026/ 2027	2028/ 2029	2030
PTL kerosene	Minimum percentage of kerosene					0.5%	1.0%	2.0%
Electricity	Triple credit (electricity from public charging stations, private electric vehicles, fleets)							

Another fulfilment option is the continuation of a maximum 1.2% GHG reduction quota through UER measures. Outstanding delegated acts, which must also be implemented on a national level once they have been defined by the European Commission, include:

- by Jan 2021 the establishment of appropriate minimum GHG reductions through recycled carbon fuels (RCF),
- by Dec 2021 the establishment of a method for determining the proportion of biofuels as well as biogas for the transport sector produced by processing biomass with fossil fuels in a single process,
- by Dec 2021 the establishment of a method for balancing GHG for PTx fuels and RCFs while ensuring that avoided emissions are not credited if credit has already been given for capturing that CO_2 under other legislation.

Studies show that, in a limited market and within the framework of a GHG quota, renewable fuels initially compete primarily over their GHG abatement costs (e.g., (Meisel et al. 2020). The possibility of earning multiple credits through specific fulfillment options for reaching minimum energy targets and the GHG quota promotes technology and fuel options that are particularly desired by the legislator. At the same time, these options increase the uncertainty for all other fulfillment options and, in fact, lead to a competitive advantage for fulfillment options that receive multiple credits compared to fulfillment options that only receive a single credit. At the same time, these multiple credit options only contribute to half (for double credit) or to one-third (for triple credit) of the real GHG reductions in the transport sector since the obligated parties only need to place a correspondingly smaller amount of the fuel or electricity onto the market in each case. Moreover, a efficiency factor is foreseen for alternative powertrains when hydrogen is used in fuel cell vehicles and electricity in electric vehicles (a factor of 0.4 respectively) (for these factors, see Appendix | Description of method).

As part of the cabinet resolution for redesigning the GHG quota, a mechanism is to be established in the GHG quota that raises the quota as soon as the electricity for electromobility in the quota calculation exceeds the value expected for that year. In addition, a review and, if necessary, revision of the law is planned for 2023/24 (Falk Heinen 2021). This will be necessary not least because of the expected amendment of the RED II in the wake of the Green Deal and the European Union's stricter climate goals for 2030.

Based on the key points mentioned above, there are many possible scenarios for the shares of the respective fulfillment options in the overall GHG quota. The sample scenario presented in Fig. 3 is primarily based on the assumption that electromobility and hydrogen (for fuel cells and in mineral oil refineries) achieve the goals set by the German government and that a significant expansion of capacities in these areas primarily occurs in the second half of the decade.

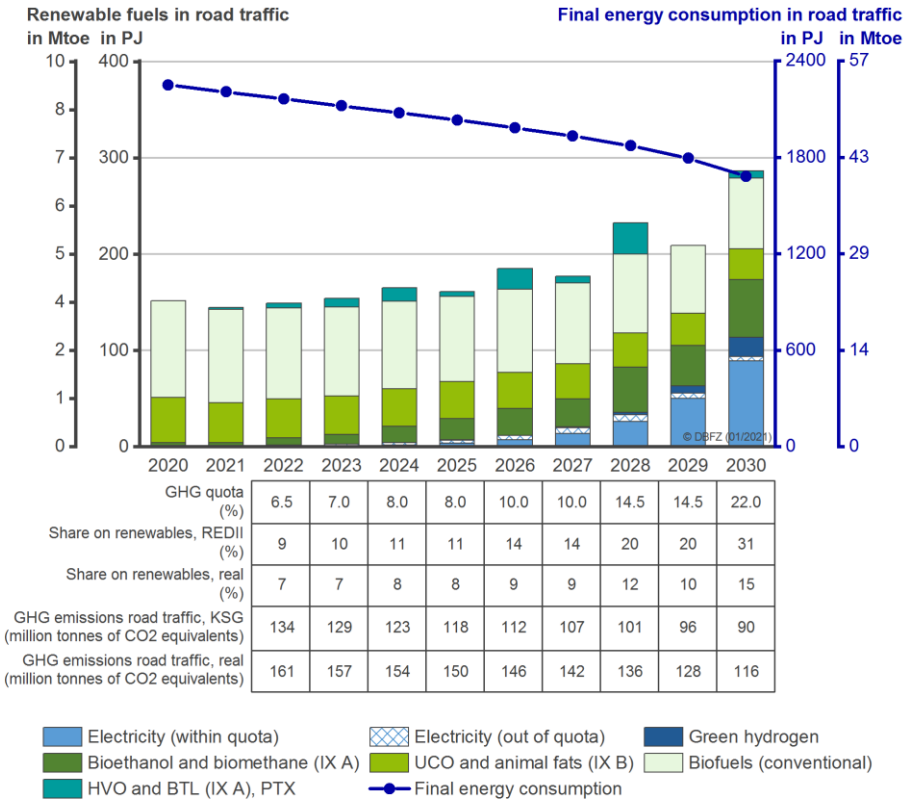


Fig. 3 Calculation example for possible quota fulfilment from 2020 to 2030

Interpretation aid Fig. 3*:* In contrast to the significant increase in the overall quota, the absolute volume of biofuels shown in the calculation example will only increase moderately between 2022 and 2030. This results from a cap on conventional biofuels and biofuels based on used cooking oils and animal fats (Annex IX Part B), and from the slowly increasing sub-quota for advanced biofuels (Annex IX Part A). Larger biofuel volumes are expected in the even calendar years, especially in the second half of the decade up to 2030. The calculation example also shows a strong increase in electromobility during the same period. Accordingly, in 2030, about one third (without taking into account multiple credits) of the energy volume accounted for in the GHG quota will be covered by electricity. Hydrogen use will also play a discernible, albeit still subordinate, role in the second half of the decade. It is difficult to estimate what proportion of hydrogen is used directly as a fuel in transport and what is used in mineral oil refineries for fuel production. The volumes of the paraffinic renewable fuels HVO/HEFA and BTL (IX A), as well as PTG (methane) and PTL, shown in turquoise, vary greatly. These fuel options are not preferred due to their perceived lower competitiveness (in terms of GHG abatement costs). Thus, up until 2030, they only play a subordinate role as a fulfillment option in the GHG quota. The chart in Fig. 3 also shows that the RED II target of 14% renewable energies in transport in 2030 is significantly exceeded at 31%. However, it is also clear that real emissions nevertheless significantly exceed the emissions permitted in road transport under the Climate Change Act every year up to 2030.

The formula on which the calculation of the GHG quota is based is provided in the Appendix | Description of method.

4. Contribution of the GHG quota to the goals of the Climate Change Act

The 2030 Climate Protection Program and the Climate Change Act (KSG, (the Federal Government 12.12.2019)) adopted by the Federal Government through the Climate Cabinet in 2019 are a direct result of the GHG reduction commitment made by the EU as part of the Paris Agreement of 2015 and implemented through the European Effort Sharing Regulation (2018/842 EC, or ESR) (European Union 30.05.2018). For the transport sector, the Climate Change Act calls for an incremental 42% reduction from 1990 GHG emission levels to 95 million metric tonnes by 2030. If the annual targets are not met by 2030 (Table 2) emergency measures must be taken within 90 days.

Table 2 Annual permissible emissions in the transport sector as per Germany's Climate Change Act

Annual permissible emissions in million tonnes of CO_2 equivalent	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Transport	150	145	139	134	128	123	117	112	106	101	95

Based on different levels of ambition and corresponding measures in the area of avoiding, shifting and improving transport, a wide range of scenarios emerge for the transport sector in 2030. The scenarios shown in Fig. 4 are based on third-party studies (see Appendix | Description of method). To varying degrees, they already include measures for transforming transportation and for changes in engine technology and are intended here as a starting point for further discussion on the contribution of the GHG quota in meeting the climate target.

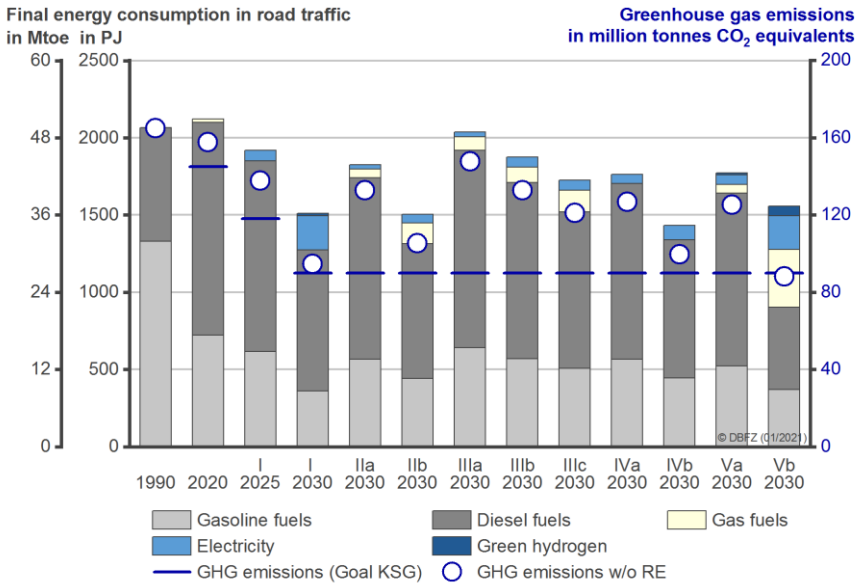


Fig. 4 Final energy consumption, types of fuel and direct transport emissions of Scenarios I to Vb in 2030

The 2030 climate target represents an important intermediate step on the way to climate-neutral transport in 2050. At the same time, the path leading to this goal must also provide the greatest possible reduction in greenhouse gases to reduce the burden on the CO_2 budget as much as possible.

In addition to the implementation and increased establishment of alternative engine technology, the next ten years will also be crucial for initiating the development and launch of advanced fuels and energy sources. Comprehensive electrification in all transport sectors is difficult at the current stage of development, which also results in a long-term need for sustainable fuels.

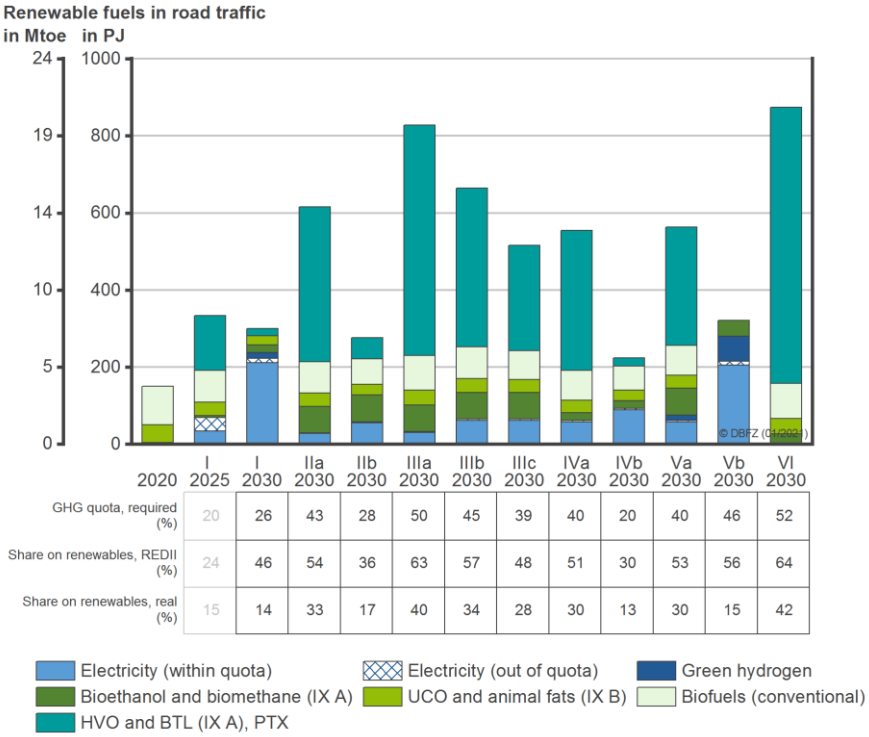


Fig. 5 Required volume of fuels from renewable sources and their possible distribution in 2030 in Scenarios I to VI.

Interpretation aid (Fig. 5): In terms of the annual volume of emissions permissible in the transport sector as per the Climate Change Act, the demand for renewable fuels varies greatly depending on the development of electromobility and, among other things, the associated development of total energy consumption in the transport sector. Assuming there is a fundamental system change with regard to mobility and engine technology, as in scenarios I, IVb or Vb, there would only be a very small demand for renewable fuels for internal combustion engines. However, if these points experience little to no change, the only option is to directly substitute fossil fuels with renewable sources if the climate target is to be achieved. However, these scenarios, such as IIIa or VI, are likely to significantly exceed the volumes that can be sustainably realized by 2030. If these volumes are, in turn, used to calculate the GHG quota, this would result in the GHG quotas for the year 2030 as listed in the figure above. These are compared to the share of renewable energies according to the methodology of RED II (both with different factors for individual fulfillment options) and the real share of renewable energies. The GHG quota required to meet the target of the Climate Change Act ranges throughout the scenarios from 20% to 50%, and 52% for the status quo (VI).

5. Conclusions

Up to now GHG reduction for the transport sector is realized almost exclusively by conventional biofuels. The GHG quota, in place since 2015, with the incentive to specifically use biofuels that contribute to a high GHG reduction, has increased the total annual GHG reduction while decreasing or leveling off biofuel quantities.

With regard to the total GHG quota in the years up to 2030 the following can be concluded

- Except for the very ambitious scenario IVb, all GHG quotas required to achieve the target of the Climate Change Act are well above the 22% currently defined for 2030. Even with the implementation of very ambitious and successful measures to reduce overall energy consumption in road transport, it can be assumed that a GHG quota of at least 30 to 40% would be required in order to achieve the target (taking all current factors into account).
- Multiple credit for specific fulfillment options of the GHG quota not only promotes it, but also increases the uncertainty for all other fulfillment options. This effect should be adequately taken into account, e.g., by adjusting the overall quota based on the development of all fulfillment options. An important milestone here is the review scheduled for 2023/24.

The calculations essentially show:

- To achieve the climate goals, it is critical to significantly reduce final energy consumption. Scenarios with higher final energy consumption tend to have a very high need for advanced biofuels and renewable non-biogenic PTx fuels. In order to achieve feasible quantities of fuels from renewable sources, Scenario IIb, at 1,500 PJ, appears, for example, to be expedient.
  The climate protection program for the transport sector includes the following action points:

  (i) shifting passenger and freight transport to climate-friendly options,

  (ii) the use of alternative fuels,

  (iii) a move towards alternative engine technologies for private and commercial vehicles,

  (iv) various possibilities for reducing CO_2 through digital networking.

  (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) 2019)
  The extent to which each of these measures will be implemented sufficiently in order to contribute to the necessary, ambitious reduction of final energy consumption in the transport sector will become clear in the coming years. At least for the first few years of the new decade, it is likely that the goals will not be met.
- A high share of gas fuels in road transport supports the cost-effective use of renewable sources and accordingly reduces the need for advanced and mostly more costly renewable liquid fuels. This applies to both biogenic and non-biogenic fuels. For areas of transport in which electrification poses a challenge, gas fuel (CNG/LNG) is also a sustainable option in the long term since biomethane is an established technology option that efficiently uses waste and residual materials. At the same time, PTG (methane) is second only to hydrogen as the most energy-efficient option for electricity-based energy sources.
  Without a sufficient percentage of gas fuel in the transport sector until 2028 or 2030, it is likely to be difficult to introduce into the fuel market the required volumes of advanced fuels, such as ethanol and HVO as per Annex IX A.

- As a possible fulfillment option, a reasonable level of conventional biofuel use continues to be essential and is an important component of climate protection in the transport sector.
- Due to the relative limitation of conventional biofuels (4.4%) and biofuels from used cooking oils and animal fats (1.9%, both for energy), the permissible volume in the quota decreases as the energy demand in road transport decreases. This should be addressed accordingly in the review.

Appendix | Description of method

A | Assessment of quota fulfillment in 2020

The assessment of the total volume of fuels is based on the following assumptions:

- The BAFA data available at this time for Jan through Oct 2020 are projected for all of 2020 based on a (fossil and renewable) diesel and gasoline consumption in Nov and Dec that is 5% and 10% (m/m) below the same respective months of the previous year.
- The total volume relevant for meeting the quota obligation is based on (fossil and renewable) diesel volumes analogous to the projection based on the BAFA data, and (fossil and renewable) gasoline volumes of plus 5% (analogous to the year 2018).

The assessment of the GHG quota fulfillment options is based on the following assumptions:

- Biodiesel as a blend (FAME+HVO) is achieved through around 2.6 million tonnes of FAME and 0.4 million tonnes of HVO, based on the assumption that the proportion of biodiesel (FAME) in blends is 7% (v/v) for diesel fuel (B7) and the total amount of biodiesel (FAME+HVO) is about 3 million tonnes,
- Ethanol in gasoline amounts to around 1.1 million tonnes (E5 and E10, incl. ETBE) resulting from a blend of 6.5% (v/v) on average,
- Natural gas (CNG) increases slightly to 6 PJ and is supplied entirely in the form of biomethane,
- Liquified petroleum gas (LPG) continues to decline slightly to approx. 15 PJ,
- Liquefied natural gas (LNG) increases but remains < 1 PJ,
- Electricity and hydrogen also increase but cannot yet contribute significantly to fulfilling the quota (< 0.1%),
- UER measures are unlikely to reach their maximum volume of around 2.5 million tonnes of CO_2-eq. in 2020, instead achieving only about 30% and/or 65% of this level.

Unlike in previous years, quotas cannot be carried over from 2019. The quantities exceeded in the 2019 GHG quota will be added to the year 2021 in accordance with Section 4a of the 38th BImSchV.

At this point in time, it is not yet possible to conclusively assess the extent to which the highest possible 1.2% GHG reduction in the transport sector from 2020 onwards can be met by the projects published to date (German Emissions Trading Authority). The estimate based on BAFA data (Jan - Oct 2020) results in a continued need for a GHG reduction of 1.8 million tonnes CO_2-eq. (0.9% instead of the maximum possible 1.2%), cf. Fig. 6.

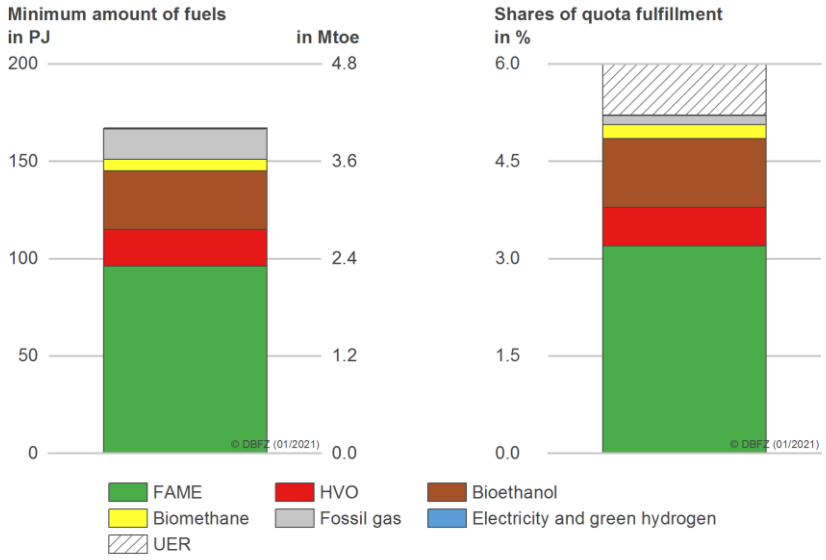


Fig. 6 Estimate (min.) to fulfil the GHG quota in 2020 with a UER at 65% of 2.5 million tonnes CO_2 eq.

Should the UER measures, contrary to expectations, contribute to a smaller degree to fulfilling the quota in 2020, correspondingly higher volumes of HVO must be assumed for the months of Nov and Dec. The calculation example in Fig. 7 assumes UER measures totaling around 0.8 million tonnes of CO_2-eq. (0.4% instead of 1.2%). This would result in an overall demand for about 31 PJ of biodiesel (HVO). According to the DIN EN 590 fuel standard, this quantity would be feasible as a blend. Assuming that no further biogenic gas fuels can be included, this would result in a failure to meet the GHG quota in 2020.

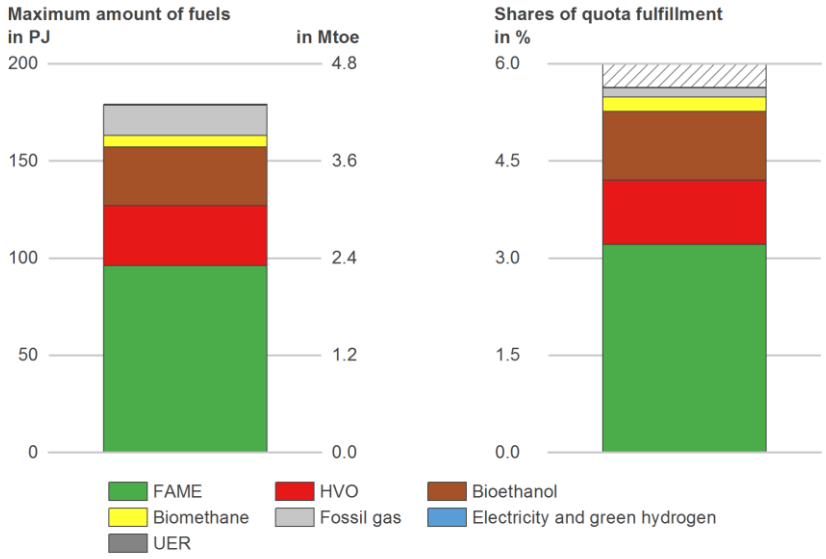


Fig. 7 Estimate (max.) for fulfilling the GHG quota in 2020 with a UER at 30% of 2.5 million tonnes of CO_2 eq.

Remarks: As a result of the emission factors for fossil-based diesel and gasoline (95.1 and 93.9 kg of CO_2-eq./GJ respectively), the emissions of the fossil fuel component (of which approx. 35% is gasoline, 65% diesel with respect to the energy content) are above the reference value and its emission factor of 94.1 kg of CO_2-eq./GJ (base value according to Section 3 of the 38th BImSchV). Starting from the

reference value, the 6% GHG abatement as per the quota is again achievable. Due to this difference, a GHG reduction of 6.5% is required in real terms in 2020 instead of the officially required 6%.

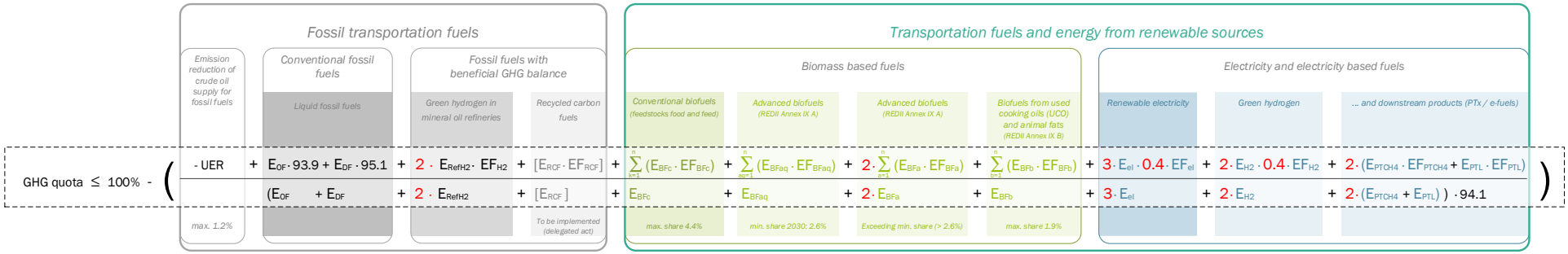
(Please note: the percentages for quota fulfillment are normalized to 6% in Fig. 6 and Fig. 7 for better illustration.)

B | Calculation example of the GHG quota from 2022 onwards

The GHG ratio is basically calculated from the ratio of (real) emissions in the transport sector (the numerator in the formula) over a reference value (the denominator), as simplified as follows.

$$\text{GHG quota} \leq 100\% - \frac{\sum(\text{energy quantity of used fuel option } [E \text{ in GJ}] \times \text{factor for emission } [EF \text{ in kg } CO_2\text{-eq/GJ}] \times \text{factor for efficiency powertrain } [-] \times \text{factor for multi counting } [-]) - \text{UER}}{\sum(\text{energy quantity of used fuel option } [E \text{ in GJ}] \times \text{factor for multi counting } [-] \times \text{basic value } [kg\ CO_2\text{-eq/GJ}]}$$

In addition to the primary factors such as amount of energy (of a fuel) and emission factor (of a fuel), various other factors as well as boundary conditions (minimum and maximum amounts) must also be taken into account for the different fulfillment options as shown in the formula as follows.



The current draft to adjust the GHG quota up to 2030 eliminates the fulfillment option of fossil-based gas fuels (starting from when it enters into force, i.e., probably in quota year 2022). At the same time, it introduces a fulfillment option for green hydrogen in petroleum refineries. The national implementation of recycled carbon fuels, as a fulfillment option of RED II, depends on the delegated acts.

Please note that this formula is developed by DBFZ based on their understanding of the calculation method related to the GHG quota without claiming to be exhaustive and/or correct; an official formula has not been published yet. Furthermore, a verification must still take place as soon as outstanding adjustments to the related Federal Immission Control Ordinances are available.

Other assumptions on which the calculation example for quota fulfillment for 2022 – 2030 is based:

- 7.5 million e-vehicles (government target 7 to 10 million) and a proportion of e-trucks (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) 2019),
- Overall final energy consumption in road transport is based on the BMWi reference scenario (reduced accordingly by higher volumes of electromobility and hydrogen and their engine efficiency),
- Gas fuelsbased on BMWi reference scenario (Fraunhofer ISI, consentec, ifeu (BMWi) 2017),
- 40 PJ of green hydrogen (from electricity via electrolysis) will be used as a fuel or in refineries in 2030, corresponding to 2 GW of electrolyzer capacity according to the National Hydrogen Strategy (Federal Ministry for Economic Affairs and Energy (BMWi) 2020),
- Percentage of renewables in the electricity mix increases from 50% in 2020 (emission factor 153 kg of CO_2-eq./GJ) to 65% in 2030 (emission factor of 82 kg of CO_2 eq./GJ) in line with the German government's target,
- The proportion of electricity in the quota is steadily increasing. It is assumed that only part of the electricity used in the transport sector can be separately measured and thus traded and credited within the quota because charging will initially take place predominantly in the private sector. It is assumed here that as electromobility increases, private charging that is not separately measured will also decrease. It was assumed here that in 2022, 20% of the used electricity will be included in the quota; this percentage will increase by 10% each year until it reaches 90% in 2029 and 95% in 2030,
- The quota carryover from 2019 is not included in the assessment. It amounts to 0.99 million tonnes of CO_2-eq. (Customs 2020); in accordance with Section 4a of the 38th BImSchV, this is not carried over to the following year as is usually the case, but instead to 2021.

Table 3 summarizes the assumptions about the total final energy consumption per annum and, of this, the energy volumes for gas fuels, electricity (included in the quota), and green hydrogen in the area of road transport.

Table 3 Assumption of the total final energy consumption per annum and, of this, gas fuels, electricity and green hydrogen in road transport in PJ (2022 - 2030)

in PJ	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total final energy consumption in road transport	2,182	2,138	2,094	2,049	2,002	1,950	1,889	1,811	1,698
CNG/LNG	20	23	26	29	33	37	42	48	54
Electricity (in quota)	1	2	4	7	12	20	33	55	94
Green hydrogen	-	-	1	2	3	8	13	23	40

C | GHG quota 2030 scenarios for achieving the climate goals in the transport sector

Definition of total energy consumption in road transport and distribution of fuel types

In order to determine total final energy consumption in the transport sector and its distribution among different engine systems and thus fuel types/energy sources, studies were used which show possible developments in the transport sector by means of assumption-based scenarios (Table 4).

Table 4 Types and amounts of fuels in the 2030 scenarios

in PJ	2025	2030										
Scenario	I	I	IIa	IIb	IIIa	IIIb	IIIc	IVa	IVb	Va	Vb	VI
Energy (sources) in road transport, total	1,919	1,510	1,825	1,505	2,038	1,875	1,725	1,764	1,433	1,773	1,559	2,085
Gasoline	611	360	565	443	640	570	507	568	446	521	371	713
Diesel	1,222	913	1,177	871	1,279	1,139	1,013	1,135	893	1,119	533	1,365
Gas fuels	18	0	54	133	86	101	140	-	-	58	374	21
Electricity	68	223	29	58	32	65	65	61	94	61	216	>1
Hydrogen	0	14	0	0	0	0	0	0	0	14	65	>1

Table 5 References for the types and amounts of fuel in the 2030 scenarios

Abbrev.	Name	Reference
I		(Agora Energiewende, Agora Verkehrswende, Stiftung Klimaneutralität (prognos, Öko-Institut e.V., Wuppertal Institut) 2020)
IIa	Reference scenario	(Fraunhofer ISI, consentec, ifeu (BMWi) 2017)
IIb	Basis scenario	
IIIa	Reference	(Boston Consulting Group (BCG), Prognos 2018)
IIIb	80% pathway	
IIIc	95% pathway	
IVa	GreenLate	(UBA 2019)
IVb	GreenEe2	
Va	Reference scenario (RF)	(Deutsche Energie-Agentur (Dena) 2018)
Vb	Technology mix scenario (TM80/95)	
VI	Status quo	No change in the distribution of consumed fuels in terms of type and quantity compared to 2020

If the data in Table 5 was not explicitly included in the above references, the following simplified assumptions were made:

- In rail transport: electricity consumption of 42 PJ and diesel consumption of 10 PJ in 2030 (analog to 2018 according to the (Federal Ministry of Transport and Digital Infrastructure (BMVI) 2020)),

- 1:2 ratio for gasoline and diesel,
- Unless gas fuel volumes are specified for 2030, these fuel types were also not considered here.

Calculation of the GHG emissions excluding renewable fuels

Assuming that the supplied fuels are exclusively fossil-based (as the reference), the GHG emissions associated with fuel use can be determined using the IPCC methodology, which is also used for the National Inventory Report (Federal Environment Agency 2020). When used, renewable liquid and gaseous fuels, as well as hydrogen and electricity, result in an entry of zero emissions in the GHG balance of the transport sector. The emission factors of the fossil fuels only depict the direct CO_2 emissions when the vehicle is in use (so-called tailpipe emissions, which result from the combustion of the fuels in the vehicle). These are summarized in Table 6.

Table 6 Emission values for fossil fuels in 2018 according to (Federal Environment Agency 2020)

Type of fuel	Unit	Emission factor
Gasoline, fossil	kg CO_2/GJ	75
Diesel, fossil	kg CO_2/GJ	74
Natural gas (CNG, LNG)	kg CO_2/GJ	56
Liquefied petroleum gas (LPG)	kg CO_2/GJ	66

The direct (fossil) transport emissions determined in this way now provide a foundation for further calculations. In conjunction with the goals of the Climate Change Act, this results in a more or less large delta between “GHG emissions without RE (renewable energies)” and the Climate Change Act target for GHG emissions, which has to be achieved through fuels from renewable sources.

Defining the target value

The targets for the transport sector, as set forth in the Climate Change Act, are only based on civilian domestic air transport, road transport, rail transport and domestic shipping. They do not include pipeline transports, or international and non-civilian transports.

The permitted annual emission levels in the transport sector are 150 million tonnes of CO_2-eq. in 2020, 123 million tonnes of CO_2-eq. in 2025, and 95 million tonnes of CO_2-eq. in 2030 (Table 2). In 2018, 6 of the 164 million tonnes of CO_2-eq. in domestic transport were not attributable to road transport (Federal Environment Agency 2020). This distribution was extrapolated for 2030 and a road transport target of 90 million tonnes of CO_2-eq. was defined (2025: 118 million tonnes). This is also labeled in Fig. 4 as GHG emissions, Climate Change Act target.

Substituting fossil fuels

Below, the calculated delta between “GHG emissions without RE (renewable energies)” and “Climate Protection Act target for GHG emissions”) is filled in by fuels from renewable sources.

First, the constraints for the year 2030 mentioned in the following sections into account in order to ultimately replace the required amount of fuel with fuel from renewable sources in a specific order.

Quotas, limits and credits

The current draft to amend the GHG quota essentially comprises the following key points for the year 2030:

1. Quotas and limits for fuels in road transport:

– Minimum quota of 2.6% for advanced biofuels (for energy),

– Cap on biofuels as per Annex IX B at 1.9% (for energy)

– Cap on conventional biofuels at 4.4% (for energy; from feedstocks that also serve the food and feed industry)

2. Subsidy through multiple counting for selected fulfillment options for the GHG quota:

– Double counting on all amounts of advanced biofuels over the minimum target,

– Triple counting on electricity used directly for transport,

– Double counting on all downstream products made with renewable electricity. This includes hydrogen (as a fuel in transport and as a feedstock in conventional petroleum refineries) and all other PTx options (especially methane, liquid fuels),

– Adjustment factor for the power train efficiency of 0.4 for battery-powered electric motors and hydrogen cell-based electric motors (continuation of previous regulation in line with Annex 3 of the 38th BImSchV).

(Falk Heinen 2021).

The reference value used for the quotas and limits (100%) is aligned with the calculation of the GHG quota and is as follows: Amount of fuel including all renewable substitutes and electric power counted toward the quota and excluding fossil gas fuels. However, multiple credit is not taken into account.

Admixture limits

Based on the current fuel standards, it is assumed here that, with respect to energy content, a maximum of 6.5% biodiesel (FAME, as per DIN EN 590), a maximum of 6.8% bioethanol (as per DIN EN 228) and a maximum of 20% biodiesel (HVO, as per DIN EN 590) can be added.

Assignment of renewable fuel substitutes

The fuel types are replaced by renewable fuel substitutes in a specific order (Table 7). In each case, the fuel is substituted up to a predefined maximum level. This order is based on the greenhouse gas abatement costs determined in projects (Meisel et al. 2020). Due to the uncertainties caused by the multiple crediting of some fuel options for the GHG quota, a simplified approach was chosen here and this influence was not explicitly included in the analysis. In all scenarios, it is assumed that the hydrogen used as a fuel is supplied entirely from renewable sources and that an additional 20 PJ of this green hydrogen (equivalent to 1 GW of electrolyzer capacity) is used in refineries to produce conventional fossil fuels.

The fossil fuels will gradually be replaced in the following order until the above-mentioned target of 90 million tonnes of CO_2-eq. is achieved in road transport:

1. Achievement of the sub-quota for advanced fuels through biomethane and bioethanol and, where applicable, HVO (Annex IX A feedstocks).

2. Achievement of the maximum amount of biofuels listed in Annex IX B feedstocks (UCO, animal fats)
3. Achievement of the cap for conventional biofuels
4. Exceeding the quota for advanced fuels up to a physical (admixture) or other limit (Table 4)
5. Supply of PTG (methane) for remaining gas fuel quantities
6. Supply of residual amount in equal parts in the form of PTL and BTL (diesel and gasoline)

The limits set for advanced fuels in Table 7 are not the explicit result of a feasibility or potential study. Instead, they only serve to provide a plausible technical limit for the individual options. They are based on current and scheduled production capacities or those that may be feasible (Germany, EU and worldwide). A change in the limits would essentially lead to shifts between advanced biofuels and electricity-based (non-biogenic renewable) fuels. The total amount of renewable fuels required to reach the climate goal, remains the same. Lower limits mean the proportion of electricity-based fuels would increase accordingly in the respective scenarios. These are backed by very low specific GHG emissions, which is why the GHG quota that would then be necessary would increase accordingly.

Table 7 Renewable fuel options by group (relevant for quota, limit, and credit), type (order based on GHG abatement costs according to (Meisel et al. 2020))

Group	Type of fuel	Limit in 2030
Advanced biofuels (Annex IX A)	Biomethane (IX A) Ethanol (IX A) HVO (IX A) Biomethane (SNG, IX A) BTL diesel, BTL gasoline (IX A)	max. 50 PJ max. 20 PJ max. 50 PJ
Biofuels (Annex IX B)	FAME (IX B) HVO (IX B)	
Biofuels, conventional	Ethanol conv. FAME conv. Biomethane conv. HVO conv.	
Other	PTG methane PTL diesel, PTL gasoline	

Determining the resulting GHG quota required

Based on the determined renewable fuels and energies and in combination with emission factors (Table 8), a GHG quota is determined using the formula (cf. above, Annex B), on which the amounts to be achieved are based. Recycled carbon fuels were not taken into account due to the lack of national implementation to date. UER (1.2% GHG reduction) and hydrogen in refineries (20 PJ) are included in the quota to the appropriate extent. However, as part of the upstream emissions from the fuel supply, they are not taken into account in the balance as per the Climate Change Act (according to IPCC) and therefore do not reduce the amount of renewable transport fuels required to meet the target under the Climate Change Act.

The share of hydrogen used as a fuel in each of the scenarios is considered in the calculations as being fully renewable and, in turn, is included in the quota as green hydrogen.

Table 8 Applied emissions factors in kg CO_2-eq. /GJ

Option	Emission factor	Reference
Electricity (65% RE)	82	Own calculations
Green hydrogen	9.1	37th BImSchV, Annex 1
Ethanol conv.	11.0	(Average for 2019 according to the BLE)
Ethanol (IX A)	15.7	Default value RED II
BTL gasoline (SRP, IX A)	16.7	Default value RED II
PTL gasoline	2	Disaggregated standard value for transport and distribution of FT diesel (BTL) in accordance with 2009/28/EG (RED I)
FAME conv.	32.4	(BLE for 2019, RME)
FAME X (UCO/AF, IX B)	6.9	(Average for 2019 according to the BLE)
HVO conv.	19.4	(Average for 2019 according to the BLE)
HVO (UCO/AF, IX B)	16.0	Default value RED II
HVO (IX A)	16.0	(Analog to HVO IX B, UCO)
BTL diesel (SRP, IX A)	16.7	Default value RED II
PTL diesel	1.2	See PTL gasoline
Biomethane (IX A)	9.4	(Average for 2018 according to BLE)
Biomethane conv.	34.8	Default value for maize, optimal (RED II)
PTG (methane)	3.3	37th BImSchV, Annex 1
Diesel fossil	95.1	Default value as per the 38th BImSchV
Gasoline fossil	93.9	Default value as per the 38th BImSchV

conv. = conventional biofuels from feedstocks that also serve the food and feed sector | IX B = biofuels produced from used cooking oil (UCO) or animal fats (AF), according to Annex IX B of RED II | IX A = advanced biofuels produced from feedstocks according to Annex IX A of RED II (an extension to the list in Annex IX A is currently in progress) | SRP = wood from short-rotation plantations;
BLE: (German Federal Office for Agriculture and Food (BLE) 2020)

The results are particularly sensitive with regard to the following two parameters: (i) total final energy consumption and (ii) the amount of electricity in transport and/or the percentage of it considered in the quota. To illustrate the sensitivity of this assumption, the GHG quota required for all scenarios is compared in Table 9 based on two assumptions: 20% and 95% of electricity in the transport sector are included in the quota (i.e., they are recorded, traded, and credited).

Table 9 GHG quota required to achieve the target of the Climate Change Act in 2030 with different percentages of electricity

Total GHG quota in 2030 required when considering	I	IIa	**IIb**	IIIa	IIIb	IIIc	IVa	IVb	Va	Vb	VI
20% of electricity	13%	42%	**25%**	40%	43%	37%	38%	13%	39%	40%	52%
95% of electricity	26%	43%	**28%**	50%	45%	39%	40%	20%	40%	46%	52%

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List of abbreviations

Abbreviation	Explanation
BAFA	Federal Office for Economic Affairs and Export Control
BImSchG	Federal Immission Control Act
BImSchV	Ordinance on the Implementation of the Federal Immission Control Act
BioKraft-NachV	Biofuel Sustainability Ordinance
BLE	Federal Office for Agriculture and Food
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BTL	Biomass-to-liquid, biomass-based liquid fuels
CNG	Compressed natural gas
CO_2-eq.	CO_2 equivalent
ESR	Effort Sharing Regulation
FAME	Fatty acid methyl ester
FQD	Fuel Quality Directive,
GHG	Greenhouse gas
GJ	Gigajoule
GW	Gigawatt
HEFA	Hydrotreated esters and fatty acids
HVO	Hydrotreated vegetable oil
IPCC	Intergovernmental Panel on Climate Change
KSG	German Climate Change Act of 2019
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas, that is generated in the processing of crude oil
Mtoe	Million tonnes oil equivalent
ÖPNV	Public transit
PJ	Petajoule
PTG	Power-to-gas, electricity-based gaseous fuels
PTL	Power-to-liquid, electricity-based liquid fuels
PTx	Power-to-X, generic term for all electricity-based products, whether liquid or gaseous
RCF	Recycled carbon fuels
RED	Renewable Energy Directive 2009,
RED II	Renewable Energy Directive 2018,
UERV	Upstream Emission Reduction Ordinance