Low-carbon mobility with renewable fuels

Affordability and accessibility of passenger cars for EU-consumers

Final Report

studio gear up

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Executive Summary

The European Commission considers the CO_2 emission performance standards for passenger cars and vans as the main instrument to reduce GHG emissions in the passenger road transport. This makes progress in GHG reduction to a large extent depending on the pace of electrification of the passenger road segment.

The main outcome of the study is that the GHG impact is relatively modest of the approximately 30 million zero emission vehicles in Europe for 2030, that is the number considered by the Sustainable and Smart Mobility Strategy. The combined results of the increased efficiency of new ICEVs (Euro 6-engines) and renewable fuels in the mix (Figure Ex.Sum. 1) will have a larger impact. With the instruments set in place the projected GHG reduction in the road transport sector falls short from the minus 55% target in 2030.

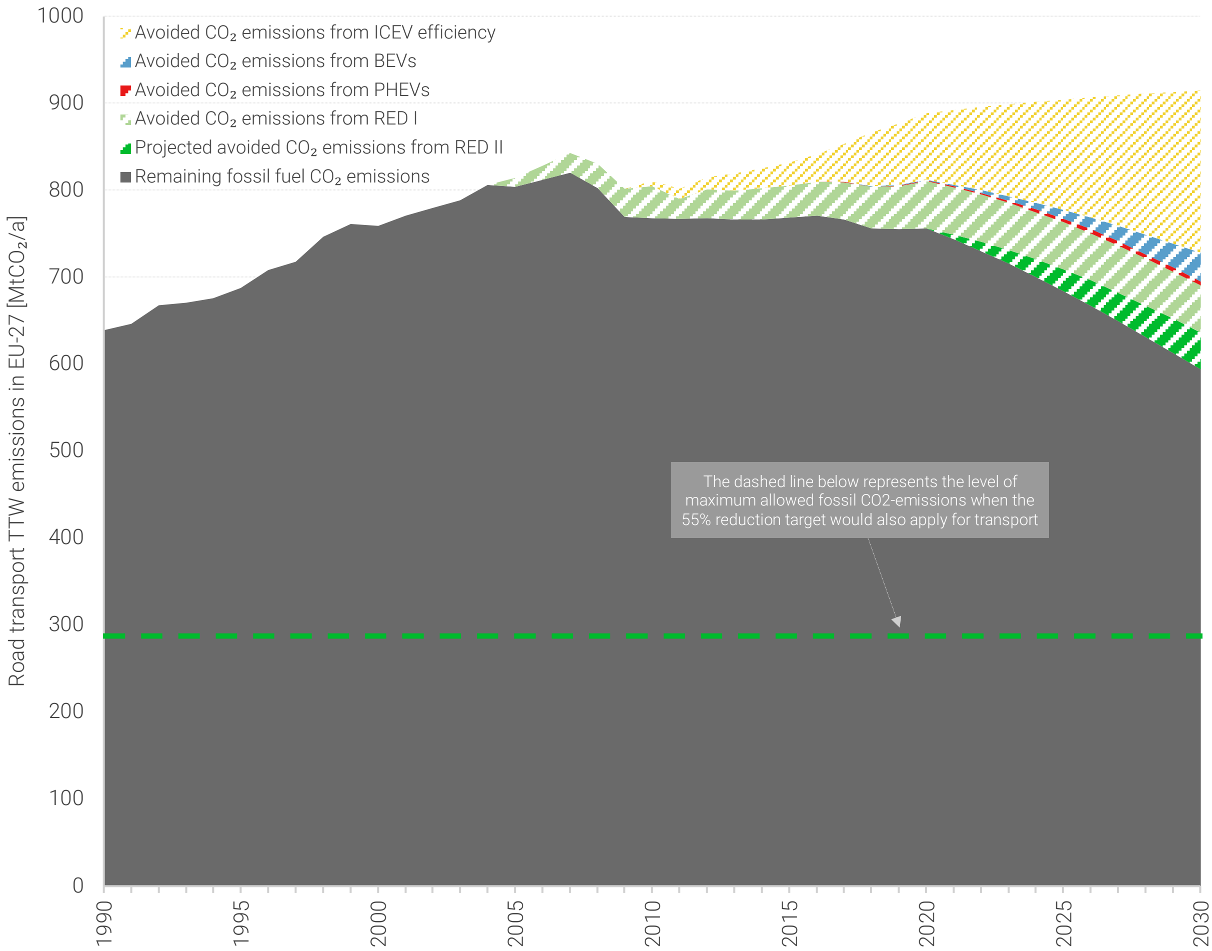

Figure Ex.Sum. 1 Effect of EU road transport measures on TTW emissions (light and heavy-duty). Source: Eurostat, data analysis and projections by studio Gear Up.
Note: The green dotted line represents the maximally allowed emissions by road transport if the road transport sector were to achieve the 55% CO_2 emissions reduction target set by the European Green Deal. In this graph transport demand, number of cars and share of passenger cars in road transport are assumed constant from 2019. But in all EC scenarios, passenger transport still rises from 2015 18-20% by 2030, and 32- 34% by 2050. Also TTW emissions from renewable fuels are set to zero, this is in line with the RED (II) policy.

Concerning the demand for renewable fuels, the sector has been operating in the context of the mandated volumes, set by the European Renewable Energy Directive (RED). However, studio Gear Up has shown in this research project that the proposed Fit-For-55-package will diversify the regulatory landscape, with implications on renewable fuel demand in the market. With the increased ambition in the Effort Sharing Regulation and the introduction of transport in the European Emission Trading Scheme (ETS), the sector needs to seriously consider a higher demand for renewable fuels in the passenger road sector than currently mandated in the proposed amendment of RED II[1]. The option of electrification of the light duty vehicle segment alone will not bring enough emission reduction in the sector up to 2030.

Therefore, a more resilient policy strategy is recommended that stimulates both the use of battery-electric vehicles and the ramp up of renewable fuels, not only in the heavy-duty road segment, but particularly also in the passenger road segment to get GHG-reductions down faster in the mobility sector. These volumes will shift from light-duty and heavy-duty, to aviation and maritime over time. Deployment of higher volumes of renewable fuels will create more policy space to act in reaching climate targets in a) the mobility sector and also for b) the 2030 -55% overall reduction targets and beyond. The CO_2-emission standard is the central instrument to make sure the passenger car park will shift from an internal combustion engine to battery electric drive trains. Scaling up renewable fuels is complementary to electrifying passenger road transport.

Similar GHG-performance

This report contains an analysis of the uptake of battery-electric vehicles in the passenger car market from a consumer perspective. Our analysis on basis of total cost of ownership shows that, under equal conditions, both a battery-electric vehicle and a vehicle with an internal combustion engine driving on 100% renewable fuels deliver the same equivalent GHG reduction performance, at similar costs (see Figure 18, page 36). It does not matter whether new vehicles or second-hand models are mutually compared: this equal performance occurs when both options receive equal subsidy support, or when both are operating without an incentive scheme. In a technology-neutral and climate-driven policy setting, either option would deliver the same climate benefit at comparable costs. While both options have a similar GHG reduction potential.

Societal impacts

Considering the societal impacts and consequences of light duty fleet electrification on access to passenger vehicles for EU-consumers studio Gear Up's analysis finds the following outcomes:

1. The analysis on total cost of ownership has shown that new battery-electric vehicles have reached cost parity with a comparable combustion engine model in all the investigated European Member States that provide a battery electric purchase subsidy. Only in a few Member States cost parity was reached without the existence of purchase subsidies or tax incentives for battery-electric vehicles. Due to for example, comparatively low purchase prices of the VW ID.3 and high petrol to electricity cost ratio.
2. However, for the majority of private consumers in the EU-27 market, the initial purchase costs of a new battery-electric vehicle are beyond their financial capabilities (see Figure 19 and Figure 20, page 40).

[1] European Commission, 2021, COM (2021) 557 final

3. In a number of Member States the incentives to stimulate the uptake of battery-electric vehicles in the market result in a loss of income for government. It is estimated that it will not be affordable to prolong this amount of support in the long run (Figure 17, page 35)

4. The historic numbers and the projections towards 30 million battery-electric vehicles by 2030 show that so far the uptake of new battery-electric vehicles is low and will have to see a significant acceleration on the coming nine-years to reach the policy targets (Figure 4, page 17) in Europe.

5. Most transactions in the passenger cars sales market occur in the used-car market and out-number the new car registrations. To take Germany as an example, the German used passenger car market has shown that only 0.3% of the total second-hand car registrations concerned battery-electric vehicles in 2020 (see Figure 22, page 41).

6. In general, the rate of growth of the European fleet surpasses the number of BEV sales until 2035. Total numbers of passenger vehicles and vans, in 2020 about 260 million, are expected to grow to a total of about 280 million of these light duty vehicles in 2030[2]. So, the penetration of new battery electric vehicles results in additions to the total fleet, rather than replacing ICEVs in the fleet. After 2035, zero emission vehicles will start replacing ICEVs. However, the average age of cars is increasing. This could further result in ZEVs be additions to the total fleet, rather than replacing ICEVs even beyond 2035.

7. Our analysis has also shown that a battery-electric vehicle potentially is more cost-effective for suburban drivers who have a higher annual mileage and access to a charging point at home, compared to urban consumers that drive less kilometres and depend on public charging (which is often more expensive). The case of the city of Amsterdam furthermore exemplifies how the current capacity of the electricity grid limits the expansion of new charging infrastructure.

Policy implication: Reconsider the renewable fuel option into the policy options portfolio

The European policy scenarios count only on a 21-23% GHG emission reduction by 2030 in transport, relative to 2005, as stated in the EC's Sustainable and Smart Mobility strategy. Compared to 1990 levels (the reference year for the -55% emission reduction target), this is equivalent to reducing transport emissions by 1-3% by 2030. Increased emission reduction is according to the policy scenarios taking place after 2030 with raised ambition in the CO_2 emission performance standards. The European Commission expects that a fully electrified passenger car fleet is required to efficiently achieve climate-neutrality by 2050. However, in the underlying scenario developments renewable fuel have not been taken into account as the main driver to reach climate neutrality. The Commission takes the assumption that Low-Carbon Liquid Fuels (LCLFs) are only used for transitional purposes and limited to the hard-to-abate transport sectors such as the maritime and aviation sectors. As a logical consequence, the contribution of renewable fuel options to decrease GHG emissions do not appear in the model outcomes either, from which subsequently policy options have been designed. This means that current policy option choices are based on an

[2] European Commission (2021) EU Reference scenario 2020, page 79, Figure 42

incomplete portfolio of options. Given the results from our analysis that the 100% renewable fuel option, having similar costs to the consumer, would have the same GHG reduction impact, it would be worthwhile to reconsider the renewable fuel option and integrate this into the policy options portfolio and execute new assessments.

It can be argued that the ETS extension to road transport (and buildings) might be the missing instrument that has the potential to stimulate the ramp up of renewable fuels. According to Figure 11, page 29, the current proposed pathway to limit fossil fuels in the ETS for transport and building, could be steep and, depending on the pace of electrification in road transport, will require high volumes of renewable fuels also in the passenger car segment next to heavy-duty road, aviation and maritime sectors. The CO_2 pricing instrument is however an incremental instrument, and the refining system needs a supportive policy framework to transform away from fossil feedstocks to renewable and recycled carbon feedstocks. This has several economic and societal advantages:

- **Economic value of the renewable and synthetic fuels**

  Renewable synthetic fuels and many advanced biofuel pathways make use of carbon and hydrogen. It is often pointed out that synthetic fuels reach a low energy efficiency compared to the electric drivetrains. However these fuels show benefits at the energy system level. Hydrocarbon storage creates flexibility at the European energy system level and provides other services such as easy and long-term storage characteristics of high energy dense fuels necessary for high-power and high-range applications. The best climate performance of synthetic fuels is achieved by using renewable electricity in combination with carbon from biofeedstocks or from the natural carbon cycle. Eventually carbon from direct air capture could be used, when cost effectiveness, less material and renewable energy input has been reached. On the short term, biofeedstock supply-chains will be required for the refining system and carbon capture to design a circular carbon system.

- **Exclusion of bio-feedstocks from the options increases mitigation costs**

  It has been shown that excluding the use of biofeedstocks from integral mitigation strategies increases mitigation costs substantially and, in many cases, makes achieving a 1.5 °C pathway impossible. Also, the industry can be supported to create negative emissions options (through Bio-Energy with Carbon Capture Storage (BECCS)) which are of major importance to compensate for very difficult remaining GHG emissions and add to lower overall mitigation costs for society.

- **Opportunities for the EU industrial system**

  Major opportunities for European low carbon chemical/fuel industry are ahead with the proper policy vision. It is however important to notice that existing and planned regulations and mandates do not reward defossilisation of liquid fuels, petrochemicals or materials. studio Gear Up recommends starting a policy dialogue to enable the transformation of the refining system to substitute fossil carbon with bio- and waste-based carbon at scale.

Key-recommendations

Recommendations for the European Commission are:

- To include 100% (drop-in) renewable fuels as a main driver in the policy modelling activities in order to explicitly see their impact and contribution in the resulting policy option results.
- To carry out an assessment to determine the cost-effectiveness of various options from the perspective of:
  - final consumers in the market, and
  - on the level of the transformation of the energy system as a whole, including the infrastructure section, and supply chain challenges such as constrained availability of rare earth metals.

Recommendations for FuelsEurope are:

- To monitor the actual developments of electrification in the European consumer passenger market, including the used-car market. This monitoring helps to determine at an early stage the required volumes of renewable fuels. This is also required to understand the dynamics of the extended ETS on potential renewable fuel demand in the road sector and implications for renewable fuel demand resulting from the national Effort Sharing Regulation targets,
- To open a policy dialogue both at EU and Member States levels about the required additional instruments to secure long-term stability of the capital service conditions to build the green, circular refining system. The central supporting arguments for this are:
  - scale-up the GHG emission savings to reach 2030 GHG-reduction goals in the mobility sector
  - social-economic benefits on the energy-system level
  - circular refining systems, currently under-represented in policy visions and instrumentation
- This would entail for the European refining sector to develop scenario's that explore how to further scale-up renewable fuels volumes above what is required for meeting the amended and former RED 2-targets in 2030 and to prepare for a steep reduction pathway in the ETS immediately beyond 2030.

1 Introduction

In the context of the energy transition of the European refining sector towards climate neutrality, FuelsEurope has asked studio Gear Up to study the societal impacts and the consequences of light duty fleet electrification on access to passenger vehicles for the EU citizens. studio Gear Up has been asked to compare the option of low carbon liquid fuels in the mix of options for passenger cars and assess the broader economic impacts of the uptake of the Low Carbon Liquid Fuels (LCLFs).

In this research we have looked at how a battery electric vehicle (BEV) compares with an internal combustion engine vehicle (ICEV) in 16 selected European Member States on basis of total cost of ownership (TCO).[3] The current status of battery electric vehicle adoption in the European passenger consumer market will be discussed. Analysis of the European Commission's policy framework and other references will be used for an assessment to what extent Low Carbon Liquid Fuels can be considered a cost-effective option.

1.1 Scope

The European Commission considers full electrification for passenger road transport as the principal solution for reaching zero-emission mobility by 2050. Therefore, the question is **if and how low carbon liquid fuels can be a complementing solution to reach the climate targets in the passenger car segment**.

The Commission takes the assumption LCLFs have a transitional purpose and will be limited to the hard-to-abate transport sectors such as maritime and aviation. This approach poses several problems including how to scale-up LCLFs production in the absence of the leverage of the passenger road transport segment.

Compared with the 1.5 TECH scenario used by the Commission in the 2018 "Clean Planet for All" [4]and subsequently in its 2020 Communication "Stepping up Europe's 2030 climate ambition – Investing in a climate-neutral future for the benefit of our people"[5], the Clean Fuels for All (CF4A) strategy[6], developed by FuelsEurope, aims to provide an alternative inclusive proposal where, along with the electrification, a gradual uptake of the LCLFs in the passenger road segment is also envisaged.

studio Gear Up has been asked to comment on this strategy.[7]

1.2 Approach

In Europe, in the total energy consumption for all transport segments, road transport has the largest share in energy demand, with passenger vehicles taking up

[3] The total cost of ownership (TCO) looks at the total cost of a product or service throughout its life cycle, and thus is the purchase price of an asset plus the costs of maintenance/operation. This research included 13 parameters to assess the TCO of ICE and BE vehicles: fixed and variable depreciation, vehicle VAT, fixed and variable maintenance, maintenance VAT, insurance costs, insurance VAT, ownership and registration tax, purchase and manufacturing subsidies, fuel/electricity costs, fuel/electricity excise and fuel/electricity VAT. An elaborate explanation of the methodology can be found in section 5 of the Annex TCO report.
[4] COM (2018) 773 A clean planet for all – A European strategic long-term vision for a prosperous, modern competitive and climate neutral economy.
[5] COM(2020) 562 , 17.09.2020
[6] https://www.cleanfuelsforall.eu/wp-content/uploads/2021/02/2021_DEF_EN_CFFA_Narrative_digital.pdf
[7] While FuelsEurope in the "Clean Fuels for All" uses the term 'Low-carbon Liquid Fuels', in this report studio Gear Up will also use the term 'renewable fuels' to represent the whole spectrum for low-carbon options.

approximately a two third share of the road energy demand. It makes therefore sense to include the passenger car segment in any climate mitigation analysis (Figure 1).

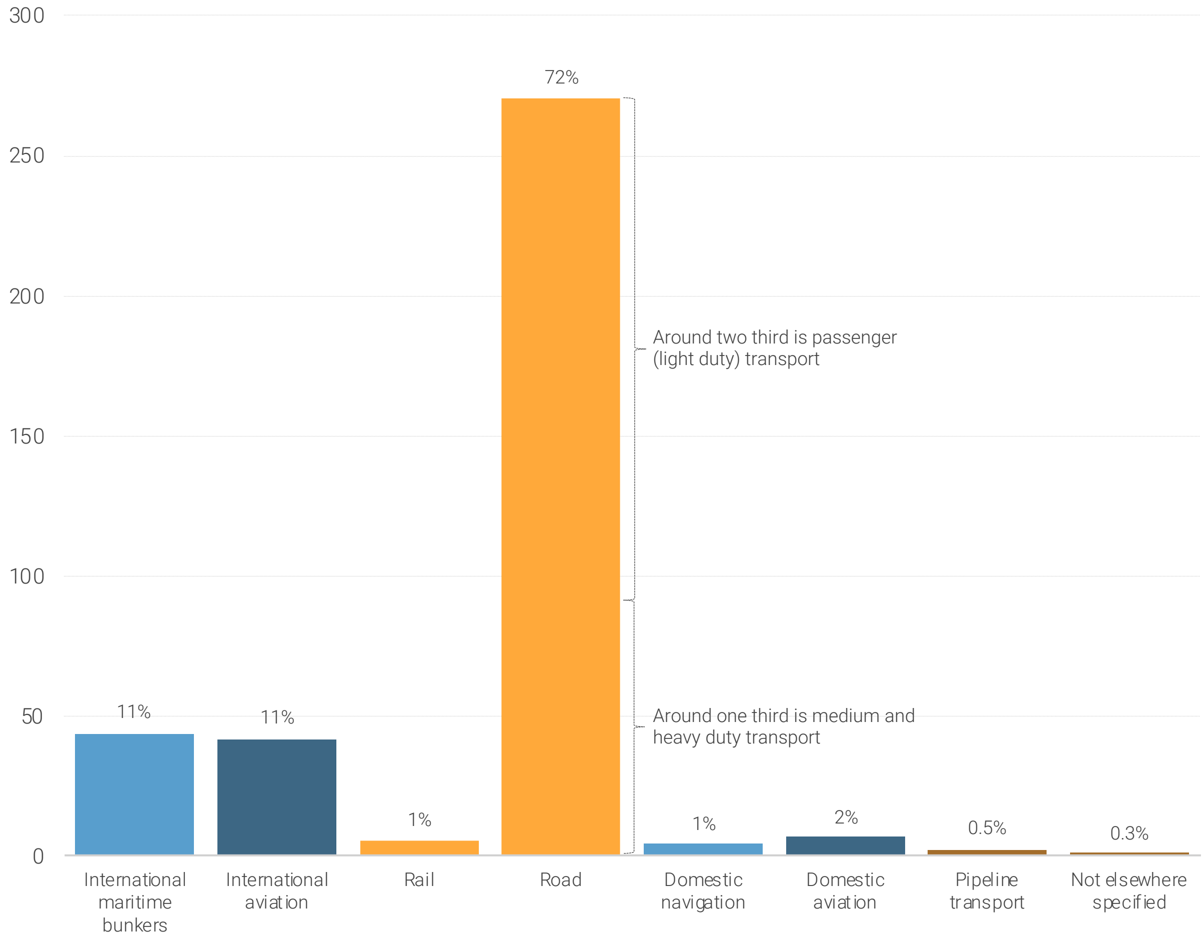

Figure 1. Energy consumption (2019, in million tonnes of oil equivalent - Mtoe) of the EU transport sector.
Source: Eurostat, 2021, Complete energy balance

In this study we analyse the option of 100% renewable fuels as an option for low-carbon mobility in the road passenger segment. We have analysed what can be expected of renewable fuels for road transport for reaching GHG-reductions in European policy developments[8] and have compared this with FuelsEurope "Clean Fuels for All" Strategy.

The proposed introduction of a separate emission trading system for road transport and buildings will require that consumers have green options in the market. In this study, studio Gear Up provides a bottom-up analysis of the GHG emissions reduction options for passenger vehicles from a consumer perspective.

For this analysis a model was developed to compare total cost of ownership (TCO) for a passenger vehicle with an internal combustion engine with a comparable model on a battery.

This analysis is complemented with assessing the market uptake of battery-electric vehicles and a discussion of the policy framework.

[8] "Stepping up Europe's 2030 climate ambition – Investing in a climate-neutral future for the benefit of our people COM (2020) 562 , 17.09.2020

1.3 Structure of the study

First, the position of low-carbon liquid fuels has been analysed in European policy developments, starting with the 1.5 Tech Scenario published by the European Commission[9] and in the recently published 'Fit-for-55'-proposals.[10]

In the following chapter we have compared the proposed extension of the Emission Trading Scheme (ETS) to road transport and building with the volumes foreseen across the whole transport sector (demand scenario 1) in the "Transition towards Low-carbon Fuels by 2050", elaborated by Concawe.[11]

The proposed introduction of an ETS for road transport will mean that consumers in the market increasingly will look for green options. How will a battery electric vehicle compare with an internal combustion engine vehicle using renewable fuels on basis of total costs of ownership? This will be analysed in Chapter 4.

Chapter 5 has looked at the affordability of battery electric vehicles.

In Chapter 6 we wil discuss the broader economic impacts of ramping up low carbon liquid fuels

The last chapter summarises the main conclusions and recommendations

A Total Cost of Ownership (TCO) analysis for 16 European Member States has been included in a separate TCO Annex Report, including an explanation of the methodology.

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[9] European Commission, 2018, A clean planet for all, a European long term strategic vision for prosperous, modern, competitive and climate neutral economy - In-depth analysis in support of the Commission communication, COM(2018)773

[10] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en

[11] https://www.concawe.eu/publication/transition-towards-low-carbon-fuels-by-2050-scenario-analysis-for-the-european-refining-sector-2/

2 The policy context

2.1 A blind spot for low-carbon liquid fuels

With adopting the European Climate Law[12], the European Member States have agreed that Europe operates climate neutral by 2050. So, the entire European economy cannot emit net GHG-emissions. Some sectors might still have emissions but those should be compensated for by negative emissions. Such a goal calls for an industrial system transition that will span several decades, but which has already started today.

A ramp up of low-carbon liquid fuels is linked to a transition away from fossil crude oil as a feedstock to making use of renewable and sustainable or recycled carbon base. This industry transformation will require "a policy framework that can facilitate investments, support innovation and incentivise all the necessary changes".[13]

The Clean Planet for All vision acknowledges that it is important to ensure that proper incentives are given for low-carbon fuels starting as early as today. However, concrete policy measures have not been proposed and therefore these may have not been considered in the modelling. This may have contributed to the lack of visibility of the low-carbon fuel option. The policy gap for a net-zero industry has been pointed out as "not well recognised in today's climate policies and discussions".[14]

Furthermore, the background analysis of the "Clean Planet for All" vision takes the assumption of limited availability of feedstocks for renewable fuels and therefore sees deployment especially in maritime and aviation.[15] The study assessed eight scenarios, where there were several main drivers to reach climate neutrality (e.g., electrification, hydrogen, power-to-X fuels or a combination). However, no scenario looked into upscaling current available technologies, and thus, have renewable fuels as the main driver to reach climate neutrality. This implies that a possible contributor to climate mitigation in the mobility sector has been overlooked in the policy option impact assessment. In this way the scenario development has not shown the full potential to what low-carbon fuels could bring as a climate solution for internal combustion engine passenger vehicles on the shorter and longer term.

The European Commission's Sustainable and Smart Mobility Strategy focuses on the effects of measures such as CO_2 emission standards or carbon pricing on reduction pathways for 2030 and 2050.[16] We have assessed the impact of the proposed CO_2-emission standards for cars and vans on the electrification of the passenger car park (see Figure 5, page 10) and, in Chapter 4, we have looked at the possible impact of the proposed ETS reduction pathway on renewable fuels.

The scenarios of the Sustainable and Smart Mobility Strategy all show a maximum of 12.5% share of ZEVs in the passenger car fleet in 2030, this translates in a technical maximum of 30 million zero emission passenger vehicles, or less, in Europe in 2030[17]. It does not provide an explanation why exactly the Commission is counting on

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[12] https://www.consilium.europa.eu/en/press/press-releases/2021/06/28/council-adopts-european-climate-law/
[13] European Commission (2018), A Clean Planet for all - In depth analysis, p 158
[14] University of Cambridge Institute for Sustainability Leadership (CISL) (2019), Material Economics. Industrial Trans- formation 2050 - Pathways to Net-Zero Emissions from EU Heavy Industry.
[15] European Commission (2018) A Clean Planet for all - In depth analysis, p. 108, 112
[16] European Commission (2020) Sustainable and Smart Mobility Strategy – putting European transport on track for the future {SWD(2020) 331 final}
[17] The Sustainable and Smart Mobility Strategy was published in late 2020. Fit for 55 is built upon the modelling done for the Sustainable and Smart Mobility Strategy.

approximately 30 million zero-emission vehicles (ZEVs)[18] , but that is likely based on the effect of the policy incentives. However, as these are projections, we could see a variation in the number of ZEVs in 2030.

For renewable fuels a maximum of a 10-11% share is considered in the fuel mix in 2030. That is only a 5%-point growth from 2020 and the 13% GHG-reduction target of the amended RED II remains mostly at the same volumes.[19] [20] This low ambition for renewable fuels will keep the position of fossil fuel use in the mobility system largely unchanged until electrification will take over.

High shares of renewable fuels in the fuel mix on the short term have not been considered. Also, the cost-effectiveness of measures has not been looked at for the Sustainable and Smart Mobility Strategy (EC, 2020).[21] The Staff Working Document (SWD(2020) 331) accompanying the Communication has shown how the impact of CO_2 emissions standards for 2030 and beyond[22] will be very significant, albeit with a time delay for reaching GHG-emission reduction in the mobility sector.[23]

Does society get the best deal in terms of GHG-reductions in transport and cost-effectiveness with the current proposed policy measures? The European Commission has explored the maximum contribution of electric vehicles on reducing climate emissions, the maximum contribution of renewable fuels has not been explored. The EC scenarios have not looked at the ramp up of renewable fuels at scale on the short and medium term. Furthermore, the European scenarios focus on GHG-reduction and did not explore the cost-effectiveness of measures. The CO_2 emission standard instrument or a ban on new sales of combustion engines will set the pace towards reaching climate neutrality in the mobility sector in the passenger road segment. The policy scenarios developed for the European Commission's long-term strategic vision 'A Clean Planet for all' and subsequently the ones used for the Sustainable and Smart Mobility Strategy show a blind spot for the role of low-carbon fuels to reduce the climate impact of mobility, especially in the passenger road segment.[24]

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[18] The EU Commission considers battery electric vehicles and fuel cell vehicles to be zero-emission vehicles.

[19] The amended RED II has proposed a 13 % GHG-reduction target, instead of a minimum share of renewable energy from transport. The transition to the GHG-reduction target is not a more ambitious target, as both goals imply around the same low-carbon fuels. However, in the amended RED II double counting is not allowed, which probably leads to an increase in low-carbon fuels. Depending on the WTW CO2 reduction savings (70% or 80%) this will translate into 16% - 18 % of renewable fuels. This would imply a double volume in 2030 compared with 2020 volumes but is about 8-10% percentage point growth.

[20] The European Commission researched multiple policy intensifications to reach the -55% goal in 2030. Researched policy measures were for example including the transport segments in an ETS and intensify the RES policies. The share of renewable fuel volumes are roughly the same for all scenario's (around 10-11%). So, it implies that the revision of the RED II does not lead to higher shares of renewable fuels.

[21] EC, COM (2020) 789, Sustainable and Smart Mobility Strategy – putting European transport on track for the future.

[22] After 2035, all newly bought vehicles need to be zero emission (BEVs or fuel cell vehicles)

[23] SWD(2020) 331 final, The European Commission sees climate neutrality target for mobility sector in 2050 only attainable if by 2050, almost all passenger cars (between 88-99% of the vehicle stock) are low or zero emission (which is BEV, FCEV and a share of plug-ins). In the long run (by 2050), electricity would represent 30 to 42% of the energy use in road transport, while hydrogen would provide an additional 31 to 40%. Biofuels and biomethane are projected to contribute a lower share (6 to 15%), while e-fuels would represent 10 to 17% of the energy mix, according to the staff working document.

[24] COM/2018/773

The European Green Deal, the impact assessments in the context of the European Climate Law, the impact assessment for the Sustainable and Smart Mobility Strategy and the proposed instruments in the 'Fit-For-55' package as published in July 2021 all built on the scenario's developed for the European Commission's long-term strategic vision 'A Clean Planet for all'

2.2 In 2030, only 1-3% projected greenhouse gas (GHG) reduction for the transport sector relative to 1990

The European Commission considers electrification or zero-emission vehicles to be the most important instrument to act on still increasing emissions in the European mobility sector.[25] The aimed 30 million zero emission vehicles (ZEVs), on the European roads by 2030 will represent around 13% of the passenger car fleet in Europe in 2030. In 2019, 975.000 zero and low-emission vehicles were on the European roads (including plug-in hybrid vehicles - PHEVs).

This projected share of zero-emission vehicles is only having a modest impact on reducing tank-to-wheel greenhouse gas emission reduction in the road transport sector in 2030, as is shown in Figure 2 (see next page). This is due to the relatively small share of electric vehicles in the market compared with the remaining ICEVs and the heavy-duty Tank-to-Wheel (TTW) emissions[26], Projected efficiency gains from new internal combustion engines in the market will in fact contribute more to TTW CO_2 emission reductions than the battery electric vehicles and the plug-in-hybrids, because of the higher number of ICEVs from now to 2030. As mentioned before the amount of 30 million zero emission vehicles seems to be considered a maximum for 2030[27], we therefore notice a gap due to a mismatch between climate goals and instruments. The amount of ZEVs should be significantly higher than 30 million to bridge the gap in 2030.

The European Commission is aware of the limited contribution of battery electric vehicles in reducing climate emissions in the passenger's road segment in the timeframe towards 2030. The dependency of fossil fuels and high GHG emissions in the mobility sector by 2030 seems accepted. Electrification of passenger road transport will reduce emissions substantially in the period after 2030. According to the Commission, active policies to reduce mobility such as more use of public transportation or mobility-as-a-service concepts should put a brake on the expansion of passenger cars.

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[25] European Commission (2020) Sustainable and Smart Mobility Strategy – putting European transport on track for the future. Staff Working Document {COM(2020) 789 final}, p.249 (point 1092) The EC holds the basic assumption that: "By 2050, almost all cars (between 88-99% of the vehicle stock) need to be low or zero emission in order for the climate neutrality target to be attainable.

[26] All five policy intensification scenarios researched by the European Commission show a maximum electrification share of 4% by 2030 over all modes of transport and 12% share in light duty road transport (SWD (2020) 331 final). It is not explicitly mentioned why they do not expect higher shares of electric vehicles with new policy measures, it could be caused by technical feasibility. As the goal of 30 million zero emission vehicles is 30 times more than the 2019 level (1 million BEVs in Europe).

[27] "Stepping up Europe's 2030 climate ambition - Investing in a climate-neutral future for the benefit of our people", SWD(2020) 176 final.

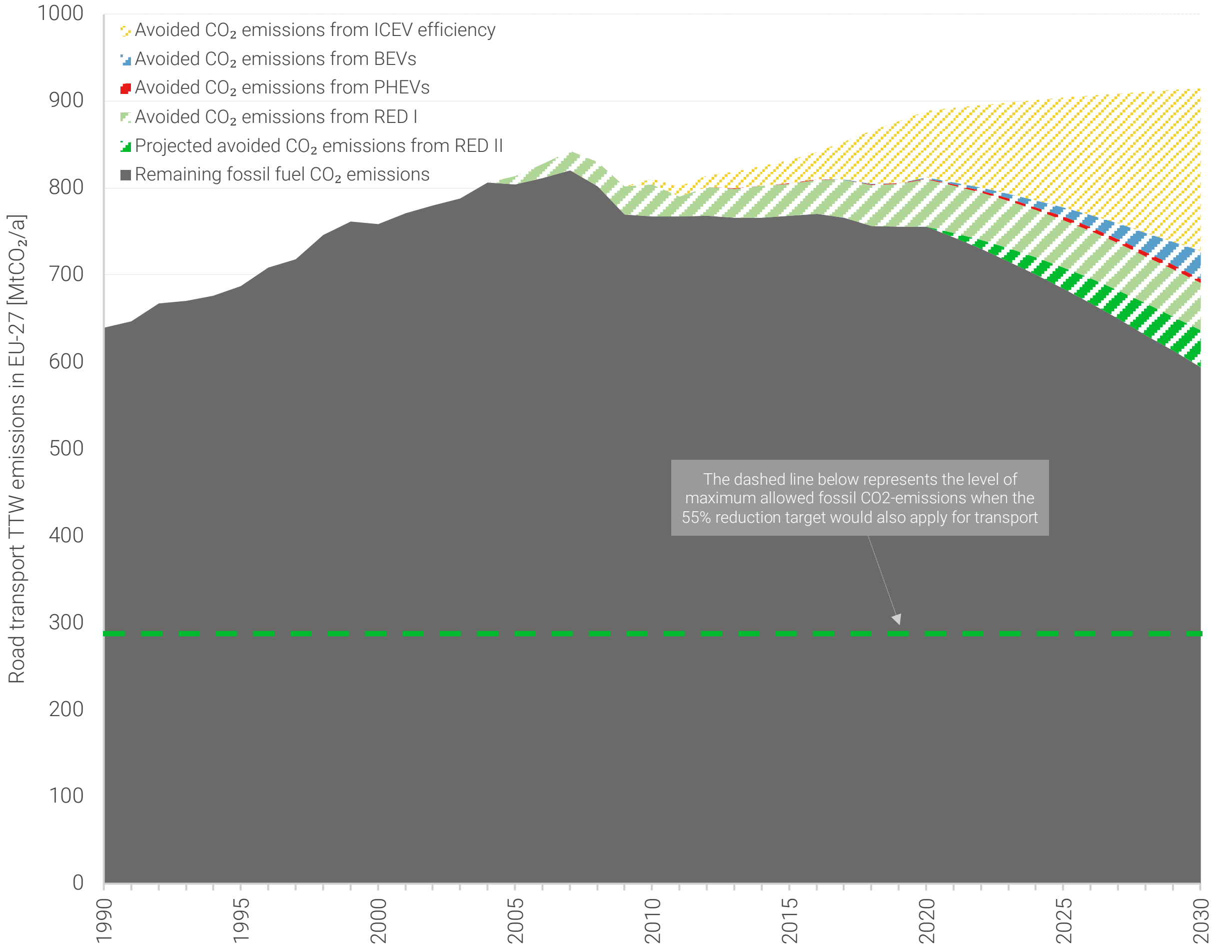

Figure 2. Effect of EU road transport measures on TTW emissions (light and heavy-duty). Source: Eurostat, data analysis and projections by studio Gear Up.
Note: The green dotted line represents the maximally allowed emissions by road transport if the road transport sector were to achieve the 55% CO_2 emissions reduction target set by the European Green Deal. In this graph transport demand, number of cars and share of passenger cars in road transport are assumed constant from 2019. But in all EC scenarios, passenger transport still rises from 2015 18-20% by 2030, and 32- 34% by 2050. Also TTW emissions from renewable fuels are set to zero, this is in line with the RED (II) policy.

The scenarios explored in the impact assessment "Stepping up Europe's 2030 climate ambition"[28] all achieve climate neutrality by 2050. For achieving economy-wide emissions reductions of at least 55% by 2030, scenarios show that transport emissions (including intra-EU aviation and intra-EU maritime) would need to decrease by 21-23% by 2030 relative to 2005. This is equivalent to reduce transport emissions by 1 to 3% in 2030, compared to 1990. In this way, reduction levels of the European mobility sector in 2030 will only be marginally better than the situation in 1990, when the transport sector emitted 673 million tonnes (Mton) CO_2 per year. In other words, the efforts to reduce emissions in the mobility sector up to 2030 only compensate for the still growing emissions of the sector up to today.[29]

[28] "Stepping up Europe's 2030 climate ambition - Investing in a climate-neutral future for the benefit of our people", SWD(2020) 176 final.
[29] European Commission (2020) Sustainable and Smart Mobility Strategy – putting European transport on track for the future_SWD_2020_331, p.9-10, (1-3% by 2030 compared to 1990 emission levels in mobility sector).

2.3 Assessing the implications of (intensified) CO_2 emission standard for cars and vans

The climate neutrality target for mobility sector in 2050 is according to the Commission only attainable if by 2050 almost all passenger cars (between 88-99% of the vehicle stock) are low or zero emission.[30] To this purpose, the proposal for a regulation to strengthen the CO_2 emissions performance standards for new passenger cars and new light commercial vehicles is expected to play a key role, not only in the emissions reductions, but also in the market uptake of the EVs.[31] The intensification of the standards will especially reduce emissions substantially in the period after 2030. We have assessed the impact of the proposed CO_2-emission standards for cars and vans on the electrification of the passenger car park.

Figure 3 shows around 30 million zero emission vehicles on a total park of approximately 250 million passenger vehicles in the 27 Member States by 2030. Until 2030 ZEVs will predominantly be battery electric vehicles. The figure shows how the share of electric vehicles on the total passenger car fleet will still be small in 2030[32]. It also shows how the GHG-reduction in mobility is depending on the pace of electrification.

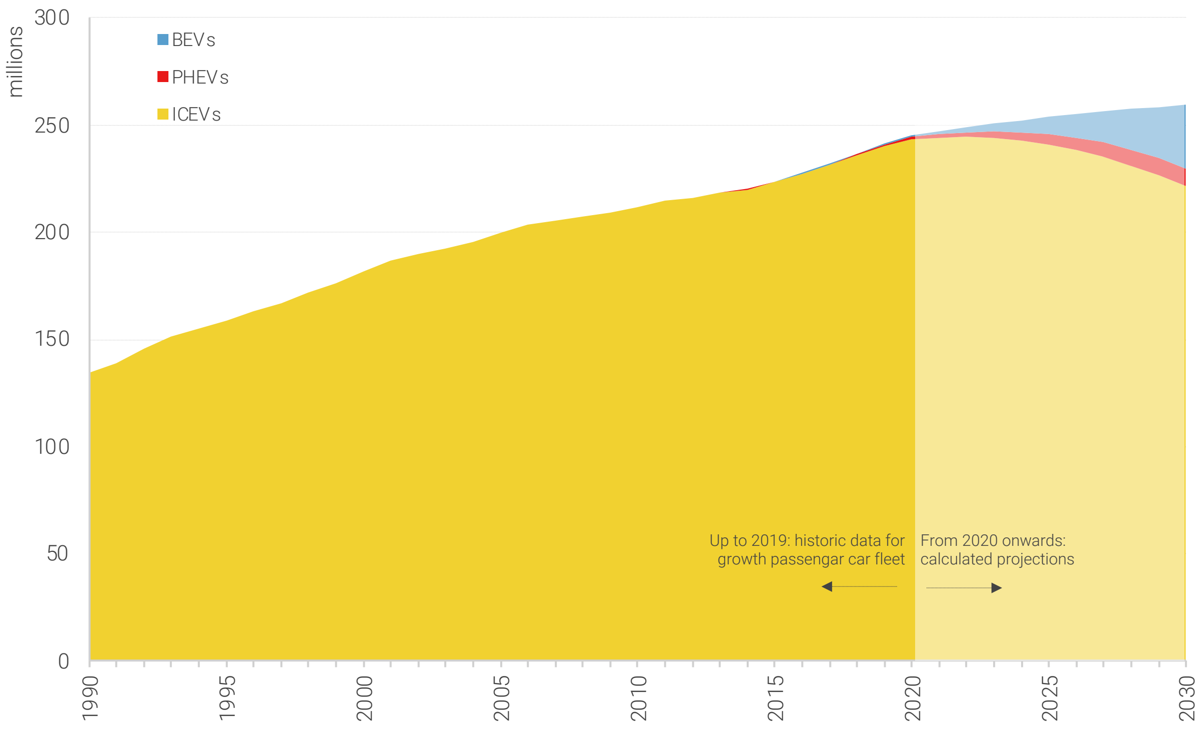

Figure 3. Development of the share of EV in the total car fleet in EU 27. Actual numbers for 2000-2018 (ACEA, 2021, Vehicles in use) and projection towards 2030 (various EC document)

When the intensified CO_2 emission performance standard for cars and vans will be adopted, all new car sales will be zero-emission from 2035 onward. It can be expected that will significantly increase the share of electric vehicles beyond 2035. The current

[30] Ibidem, 1092 p. 249
[31] Ibidem, 1088, p. 248
[32] The European Commission does not provide argumentation for the 4% maximum share of electrification in 2030.

CO_2 emission standards would lead to 6 million newly sold battery electric vehicles as from 2030. After 2035 this number will approximately double and will lead to 13 million ZEVs sold annually. The historic numbers and the projections towards 30 million zero emission vehicles by 2030 show that so far the uptake of new battery-electric vehicles is low and will have to see a significant acceleration on the coming nine-years to reach the policy targets (Figure 4) in Europe.

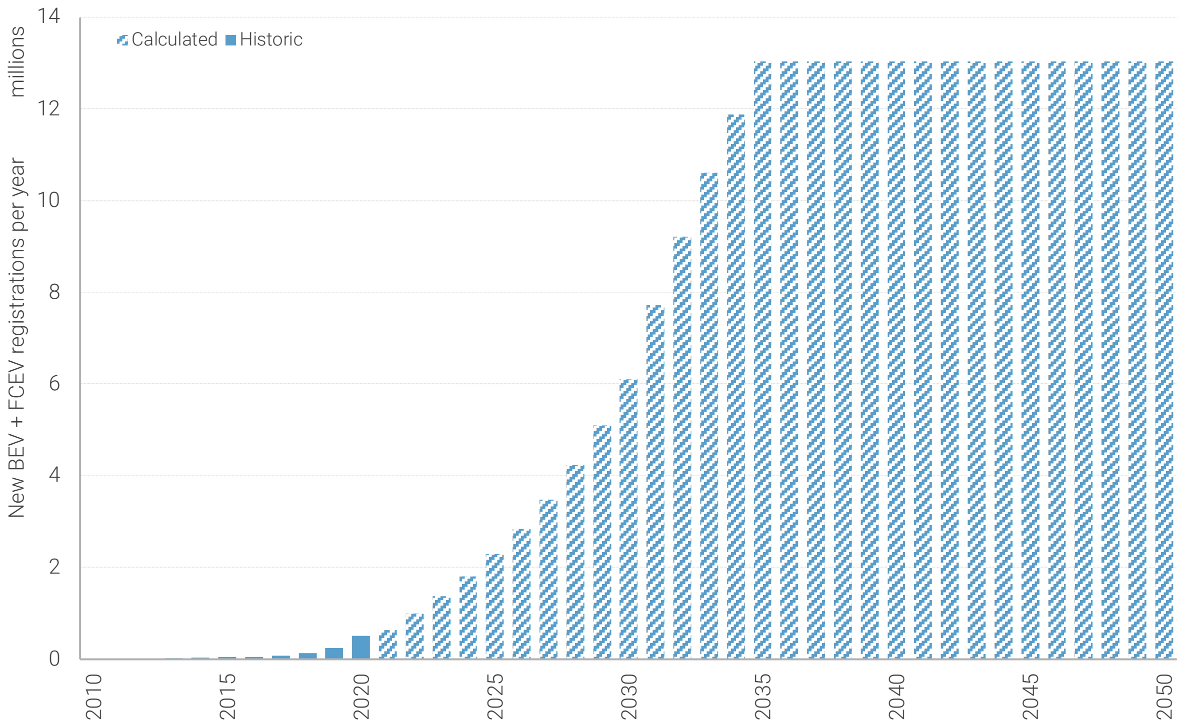

Figure 4. Historic and calculated projections for BEV reaching an accumulated volume of 30 million by 2030. 100% BEV sales as of 2035, assuming stable total fleet and annual sales of 13 million vehicles

Figure 5 shows the projected impact of the intensified CO_2 emission performance standard on the share of ZEVs in the total car fleet. The rate of growth of the fleet surpasses the number of BEV sales until 2035. In his way, the penetration of new zero emission vehicles result in additions to the total fleet, rather than replacing ICEVs. It is after 2035, that the influx of zero emission vehicles will cause a reduction of total numbers of ICEVs in the passenger car fleet. In this analysis the average age of cars in use of 10 years was based on ACEA[33], but a recently published ACEA study shows that the average lifespan of a car is increasing[34]. This could further result in ZEVs be additions to the total fleet, rather than replacing ICEVs even beyond 2035.

[33] Sources: ACEA - Vehicles in Use (2017 - 2021) & ACEA - Automobile Pocket Guide 2015 - 2016 (p.45). It is unclear which average age the European Commission uses in their analysis, however

[34] See Van den Heuvel (2021) Analysis of car sales in 2020 in the Netherlands: sales of small and cheap cars are under pressure. ACEA has used the 10 year average in the past. This could potentially change as an increase has been reported for 2020. The reported age becomes closer to 11 years

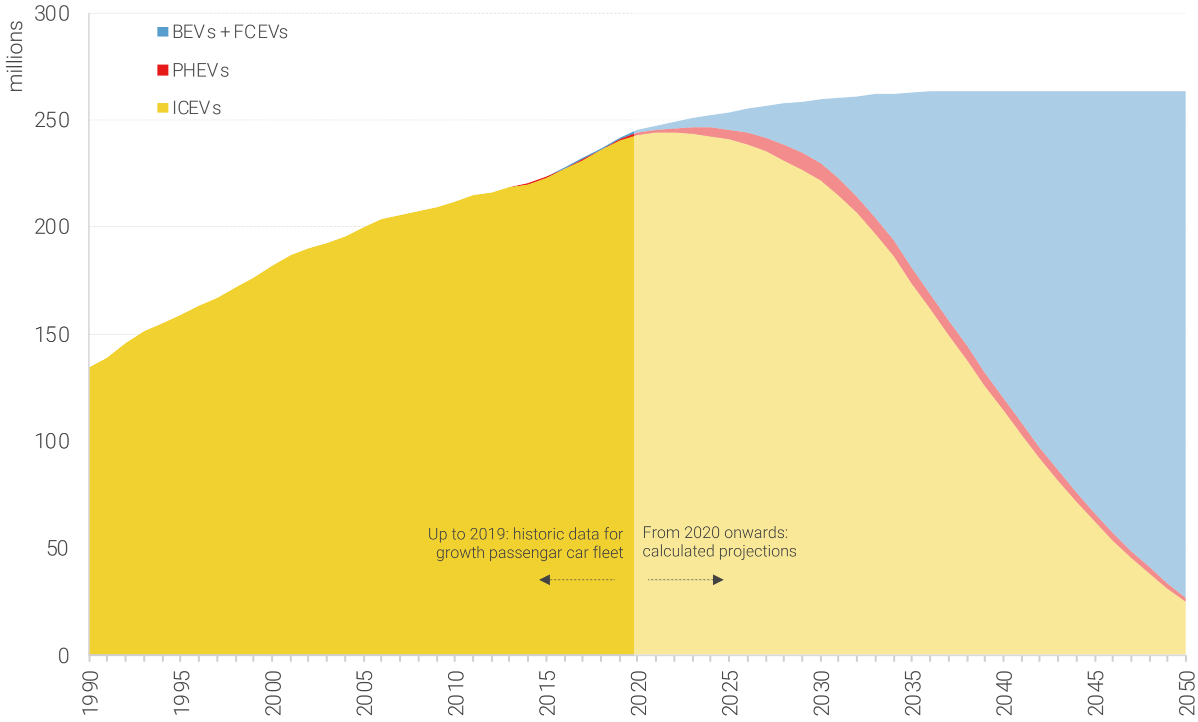

Figure 5. Development of the share of EV in the total passenger car fleet in EU 27. Actual numbers for 2000-2018 (ACEA, 2021, Vehicles in use) and projection towards 2050 (tentative analysis studio Gear Up)

The new proposed CO_2 emission standards has the objective to stimulate the uptake of BEVs and thus, TTW emissions will further decrease after 2030. Since this measure focuses on the sales of new vehicles, the new CO_2 standards do not consider the remaining share of ICEVs in the transport fleet until 2050 (as seen in Figure 5). This analysis shows a fuel demand of 420 PJ/a (around 10 Mtoe) for passenger cars. This is in line with Concawe's alternative 1.5°C scenario[35], that, is exploring the role of low carbon liquid fuels in the passenger road segment by 2050

2.4 Renewable fuels are indispensable for raised GHG-emission reduction

Suppose the 55% emission reduction target would also apply as a climate target for the mobility sector in 2030 then extra volume of renewable fuels would be required to achieve enough emission reduction by 2030.[36] Figure 6, next page, shows options how a hypothetical emission reduction target of 55% by 2030, compared to 1990, could be achieved in the transport sector[37]. The message is that scaling other GHG reduction options for mobility, such as increased efficiency, optimized logistics or modal shifts are limited. So, when assuming a similar mobility demand in 2030, there will be a significant gap to be bridged for which higher volumes of renewable fuels are required. Especially if mobility demand is not radically reduced, by for example car-free weekends all across Europe.

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[35] https://www.concawe.eu/publication/transition-towards-low-carbon-fuels-by-2050-scenario-analysis-for-the-european-refining-sector-2/
[36] studio Gear Up (2020), CO_2 reductions in the transport sector in the EU28.
[37] Figure 6 is the product of sGU by reverse engineering analysis of the -55% goal in 2030.

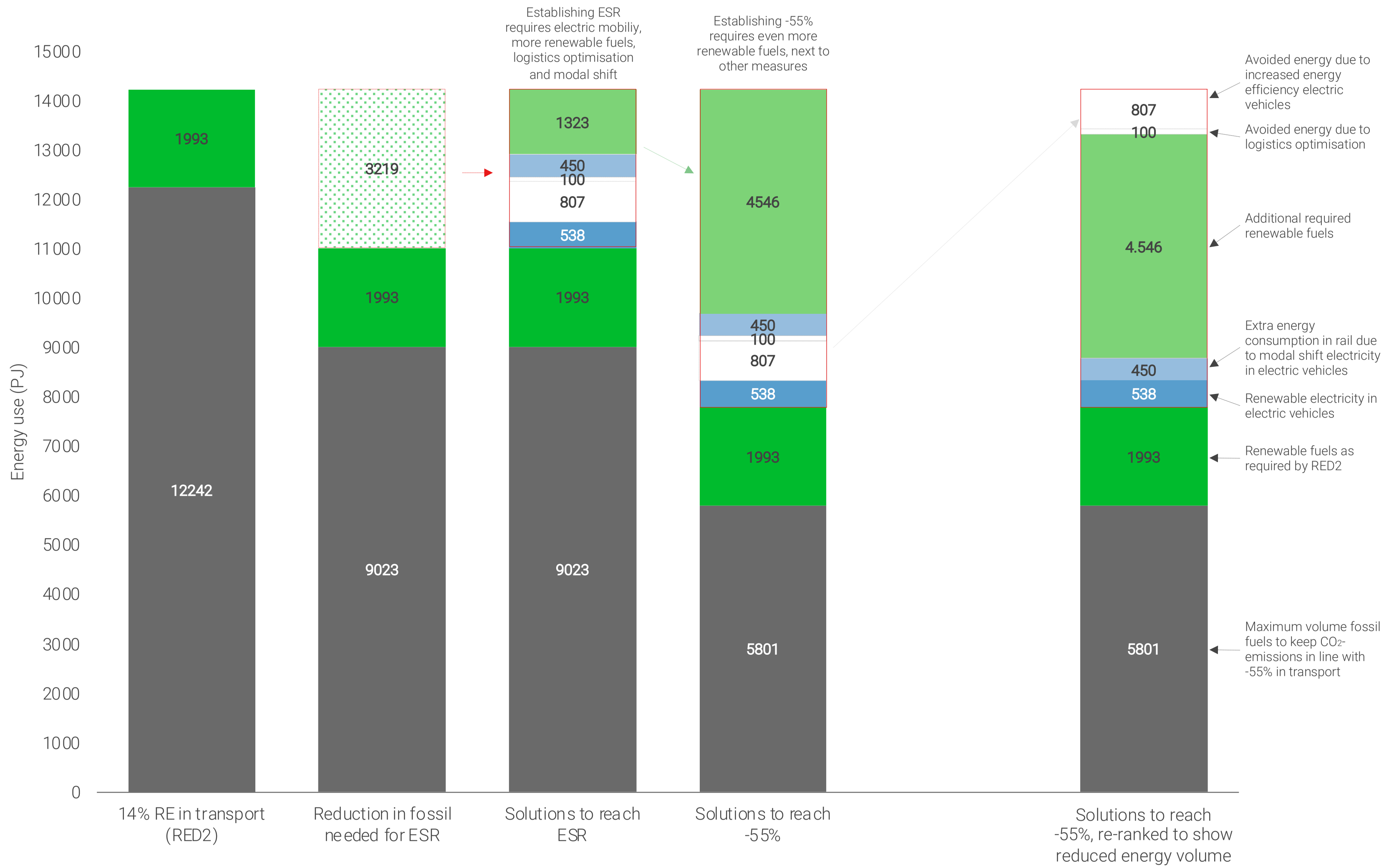

Figure 6. Policy targets for the road transport sector in 2030 don't bridge the gap: extra volume of renewable fuels is required to reach the -55% target. Source: studio Gear Up, 2020, CO_2 emission reductions in the transport sector in the EU28. [1]: the targets for RED (II) equal approx. 14% physical volume of renewable fuels

Would a minus 55% target for the total mobility sector be in place, this would translate into a maximum of 5,801 PJ of fossil fuels to be used in 2030 under the assumption of unchanged mobility demand. The RED II, renewable energy for transport targets will result in 1,993 PJ of renewable energy carriers. If, in a hypothetical case, there would be 60 million electric vehicles on the European Roads (following IEA[38])[39], that is double the amount of the European Smart and Sustainable Mobility policy goal, this would avoid 807 PJ of energy by the higher efficiency of the electric drive train and would need 538 PJ of renewable electricity. It is expected that the efficiency gains, due to the uptake of electric vehicles, will be materialised in the light-duty segment. Additional considerations to reach -55% are more efficiency due to modal shifts (450 PJ), and 100 PJ by optimising logistics in the transport sector

Figure 6 implies that if the targets for greenhouse gas emission reduction in the total road transport sector are raised for 2030 to also meet a goal of minus 55%, the volumes of renewable fuels will have to increase. Even with including the 60 million battery electric vehicles as shown in Figure 6 there will still be a significant gap to reach a goal of minus 55% in 2030 in the transport sector. This is because the other instruments for transport meet limits to scale up on the short term. In other words, the extent to which more greenhouse gas reduction on the short terms will be reached, will depend on the ability of renewable fuel production to scale up. This is an important insight to further discuss between policymakers and FuelsEurope.

The (amended) RED 2 targets and the proposes CO_2 emission standards will together not create enough emission reduction in line with the minus 55% reduction. If the measures and incentives for the transport sector cannot realise the calculated contribution for meeting the 2030-targets, other sectors, such as the built environment, will need to raise ambition to compensate for missing reduction in the transport sector. This in order to reach the agreed -55 overall reduction target. Moreover, if other sectors are unable to meet their greenhouse gas reduction targets for 2030 (think for instance of the Effort Sharing Regulation targets for individual Member States), it is important to convey the message to policy makers that higher levels of renewable fuel volumes can scale up fast to deliver extra CO_2-emission reductions.

2.5 The EC ‘Fit-For-55’ package

With the publication of the ‘Fit-For-55’ package the European Commission has presented a set of instruments to support the energy transition and to reach the reduction targets set for 2030. The impacts on the demand for renewable fuels will have to be analysed and understood in more depth. As mentioned before, the Commission expects an acceleration of the electrification of road transport after 2030.

A reduction of the CO_2-intensity of energy carriers of 13% for transport in 2030, in the revision of the Renewable Energy Directive is certainly not in line with the EU- wide reduction target of at least -55% net emission reduction by 2030 compared to 1990 as established in the European Climate Law.[40] Also the proposed CO_2 standards for cars

[38] IEA analysis the global uptake of BEVs. The global outlook was recalculated for the European context and equals 60 million BEVs in 2030. However, this is not the policy target set by the European Commission.
[39] IEA (2018) Global EV Outlook
[40] In the impact assessment “Stepping up Europe’s 2030 climate ambition – Investing in a climate-neutral future for the benefit of our people”, the EC considers 21-23% reduction necessary by 2030, p. 9

and vans will not bridge the gap. The European Commission expects to further close the gap with the introduction of the ETS for road transport.[41] This will further be discussed in the section below.

The ambition is also modest for the other mobility sectors, aviation and shipping. Aviation is growing to a mandatory admixture of 5% by 2030. Shipping only needs to achieve a 2% CO_2 intensity reduction up to 2030 and a 6% CO_2 intensity reduction up to and including 2035 compared to emissions in 2020. But volumes in these segments will increase substantially from respectively 2035 and 2040 onward.

The proposed changes of the Energy Tax Directive are supportive to the uptake of renewable fuels. The base of taxation will shift to energy content and renewable options are supported with differentiated tariffs and in case of the maritime sector exemption from duties for the renewable fuels deployed.

Unclear is how the raised ambition in the Effort Sharing Regulation (ESR) will work out for the Member States. Will other ESR-sectors reach limits, and knowing the uptake of electric vehicles will take time, and would raising the bar mean that more renewable fuels in transport will be required to meet the national ESR targets?

2.6 Extension of ETS for road transport

The most important instrument to ensure a cap on GHG-emissions is the emission trading system. **Placing fossil CO_2 emissions from the transport sector in an emissions trading system could lead to new dynamics**. Although it has been pointed out that carbon pricing is an important instrument for incremental changes, it is not an effective instrument for the high-capital investments required for industry.[42]

In the case of the road transport (and built environment sector) the ETS does not place the responsibility on the end users (namely, the emitter in the road transport), but considers the fuel suppliers as the obligated party. The principle remains the same as the one set on in the 2003/87 EC Directive: to buy allowances or to use alternative options instead. For the fuel supplier it will be an important question whether providing renewable fuel options to the market could be a cost-effective proposition compared to other options.

The introduction of an emissions trading system gives room for developing alternatives for the customer that do not emit fossil CO_2. This can lead to more demand for cost-effective options. Customers in the market benefit from this.

In the following chapters the impact of a decreasing ceiling for emitting fossil CO_2 and the choices for end users in the passenger vehicle market will be further analysed.

[41] As mentioned before, the European Commission researched five different scenarios, where policy intensifications led to the -55% goal in 2030. Inter alia, the intensification of RES policies (such as the RED) and the ETS (source: SWD (2020) 311 final)

[42] Heleen de Coninck e.a. 'What are sources of carbon lock-in in energy-intensive industry? A case study into Dutch chemicals production in Energy Research & Social ScienceVolume 60, February 2020 https://www.sciencedirect.com/science/article/pii/S2214629618312234?via%3Dihub#sec0006

3 Analysing the ETS Transport proposal in relation to the Concawe' scenarios on the "transition towards low-carbon fuels by 2050"

The European Commission proposes to introduce emissions trading for the road transport and the buildings sector. This proposal will have a goal of a 43% greenhouse gas emission (CO_2 equivalent) reduction in 2030 for these sectors, compared to 2005. In 2024 there will be 1,109 Mtonne CO_2 allowances for the building sector and road transport (this is based on the average amount of emissions for the year 2016-2018 in combination with a certain assumed emission reduction until 2024).

The linear reduction factor is set to 5.15% from 2024 onwards according to the Commission's proposal. This means a constant absolute reduction between 2024 and 2030 of 57.1 Mtonne CO_2 per year. If there are no corrections along the way, this will lead to zero emissions in 2045, in the buildings and road transport sector combined.

The 57.1 Mtonne CO_2 per year will lead to a total required reduction of approximately 343 Mtonne CO_2 between 2024-2030 for the buildings and road transport sector. As the two sectors fall under one ETS, it does not matter in which sector the reductions are met: together they need to be under the maximum number of allowances. In both sector the responsibility lies with the energy supplier whilst action needs to be taken by the house owner and the car driver.

The total emissions of road transport and building sector were 1,246 Mtonne CO_2 between 2016-2018, of which 781 Mtonne was emitted by the road transport sector, equal to a 62.7% share.[43] The buildings sector accounted for 465 Mtonne CO_2, equal to a 37.3% share. It is currently unknown how the emissions reductions required by ETS will be distributed among the buildings and road transport sector.

Within an ETS there is the option to take measures to reduce carbon emissions or to buy allowances. In a combined ETS both sectors influence the price of allowances, if one sector could take elementary measures to reduce emissions the allowance price will remain low. According to the European Commission's impact assessment[44] this combined ETS would in the first instance lead to implementing energy efficiency and green energy options in the built environment, while the **car drivers will pay emission allowances**. Such a combined ETS will present a difficult base for the high capital investments required for transforming the refinery system away from using fossil feedstocks.

However, the questions remain how fast relatively elementary solutions can be implemented in the built environment and when a more difficult phase arrives where the measures are more complicated, for instance more capital intensive, than buying allowances. With a combined ETS the development in the built environment impacts the road sector. The fuel supplier would have to increasingly develop an understanding of the developments in the built environment to assess his position in this regard. In case energy efficiency and green energy options will be implemented at scale, less demand for additional volumes of renewable fuels can be expected. In

[43] European Commission (2021) Amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU)
[44] Ibidem

this way developments in the built environment impact the further upscaling (or not) of renewable fuels for the road sector. This is further explained below.

3.1 Scenarios elaborated by Concawe on the "transition towards Low-carbon Fuels by 2050"

Looking at the transport sector as a whole, the Concawe report defines and explores three 'alternative 1.5°C' scenarios, considering a different ramp-up and penetration of low-carbon fuels within each transport mode during the period 2030/2050[45]. Considering the scope of this research, studio Gear Up has further analysed scenario 1 as it includes passenger cars. The following chapter contains findings of studio Gear Up based on their analysis.

The scenarios are meant to provide an overall picture of the European refining system to meet the potential demand for liquid and gaseous fuels in a low GHG intensive manner and the related implications across the whole transport sector. Like other economic sectors by 2050, EU refineries are called to put into place the twin environmental & digital transformation, and circularity as a design parameter, as established by the EU Green Deal.

The scenarios look at the whole EU system and estimate the speed at how fast renewable fuels could be deployed according to the EU refining sector. The scenarios as such give an idea of volumes and range of potential investment cost rather than a specific assessment of feedstock or technology. It is an exploration of how different pathways could look like. Chosen pathways are illustrative examples based on high Technology Readiness Levels (TRL) and on the capacity to produce drop-in fuels. Besides this, advanced / waste-based biofuels are prioritised since biofuels based on food and feed are capped and include the present uncertainty around feedstocks for HVO.

[45] Concawe (2021) Transition towards Low Carbon fuels by 2050: Scenario analysis for the European refining sector.

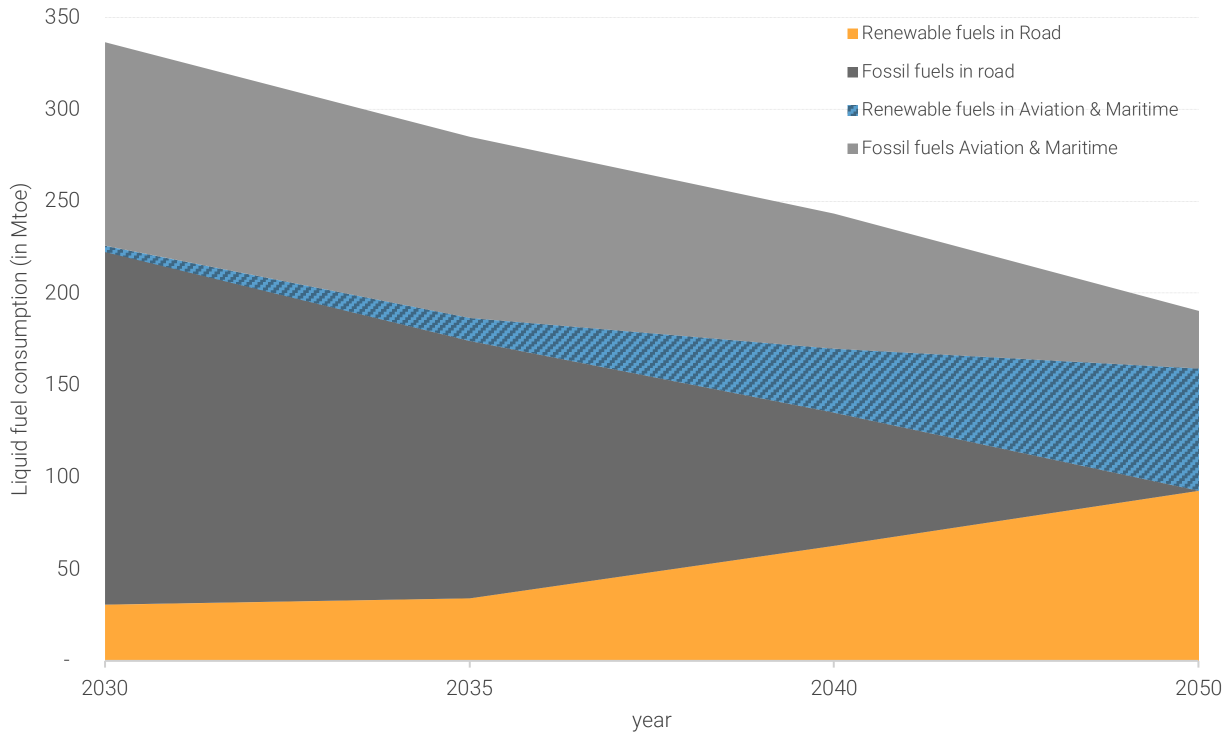

Figure 7. Summary of Concawe Scenario 1 (including passenger cars) presenting the volumes of low-carbon fuels and remaining fossil fuels in road transport, and in the aviation and maritime sector.

The European refining sector shows with these scenarios a ramp up of renewable fuels, especially from 2035 onwards. Scenario 1 replaces completely fossil fuels by low carbon ones in road and part of that goes to passenger cars. It is assumed that the demand for liquid fuels in the road segment over time decreases, due to increasing volumes of hydrogen and electrification. studio Gear Up supports the conclusion Concawe draws in this scenario and also sees the need for renewable fuels in light-duty in 2050.

Volumes of low-carbon fuels in the Concawe scenario increase from 19 Mtoe (795 PJ) in 2020 to a projected low-carbon liquid fuel use of 34 Mtoe (1,424 PJ) in 2030[46], which results in a 48 Mtonne additional CO_2 emission[47] reduction in 2030, on top of the 2020 CO_2 emission savings[48]. Concawe considers in its scenario analysis multiple sectors, namely aviation, maritime and road per category of low carbon fuels (first generation, advanced and e-fuels).

According to the "All transport" scenario, a share of 30.7 Mtoe of low-carbon liquid fuels are supplied to road transport. This would achieve an additional 36.7 Mtonne CO_2 (TTW) emission reduction in the road sector by low-carbon liquid fuels in 2030 on top of the already achieved reductions in 2020 by low-carbon liquid fuels.

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[46] The assumption was made that the total projected low-carbon fuel use would be in the road sector.
[47] Assuming every PJ of low-carbon fuel replaces one PJ of fossil fuel, where the TTW emissions of low-carbon fuels are counted as zero in the whole report, as the model focuses on renewable fuels. Compared to the baseline volume of low-carbon fuels in 2020 given by the Concawe. scenario (before the start of the ETS). Also, under the assumption that the whole volume of low-carbon fuels expected by Concawe are used in the road sector (not in aviation or maritime).
[48] In 2030, the total CO_2 emission savings by renewable fuels are 107 Mton. Of which 60 Mton was already achieved in 2020

Possible impact of ETS on renewable fuel volumes

The new ETS for road transport and buildings recently proposed by the EC, if adopted, starts from 2024 and aims for a 342 Mtonne CO_2 reduction for both sectors combined, in 2030 compared to 2024. In order to understand the potential impact on renewable fuel volumes considered in demand scenario 1 of Concawe, we have researched three potential distributions in the ETS:

1. Pro rata: The reduction effort is proportionally distributed over the two sectors.
2. Road transport only: All the reductions are met in the road transport sector.
3. Buildings mainly: We assume that emission reduction is cheaper in the buildings sector. Therefore, there are no additional measures taken to reduce CO2 emissions in the road transport sector beyond what is already achieved by RED II and the introduction of electric vehicles.

Current planned reductions

Multiple legislations are in place at EU level to support the transition to a more sustainable road sector and lower CO_2 emissions. First, the maximally allowed tailpipe emissions of average new ICEVs will lead to the biggest share of CO_2 emission reductions until 2030. Second, the introduction of BEVs and PHEVS will lead to (TTW) CO_2 emission reduction. Third, the RED II goals for the usage of renewable fuels are part of the CO_2 emissions reductions. These measures and their reductions are already planned and in the case of no additional measures the emissions of the road sector will therefore decrease from 700 to 594 Mtonne CO_2 between 2024 and 2030 (a 106 Mtonne CO_2 reduction).

ETS pro rata distribution 1 - Pro rata distribution between transport and buildings sector

In the pro rata distribution 1 the emission reduction required by the new ETS is proportionally divided between the buildings and road transport sector. On average, fuels burnt in road transport between 2016 and 2018 contributed to 781 Mtonne CO_2eq per year, while fuels used in buildings contributed to 465 Mtonne CO_2eq per year (Eurostat). This will mean that the road transport sector would be responsible for 62.7% of the required ETS CO_2 emission reductions in 2030. This would need additional measures on top of the RED II, ICEV efficiency and electrification. The pink area in Figure 8 shows this as an additional 110 Mtonne CO_2 reduction. 36 Mtonne CO_2 reduction is covered by the measures included in the Concawe scenarios (almost the whole dark green area). The additional emission reduction to achieve ETS in this Pro rata scenario would require an additional volume of 36 Mtoe (1,507 PJ) of renewable fuels in the road transport sector, on top of planned deployment of low-carbon fuels in the Concawe scenario.

On the other hand, these additional fuels may be increasingly expensive, and the dynamics of the ETS could at such a point drive the emission reduction efforts to the buildings sector mainly (i.e. following ETS distribution 3 below).

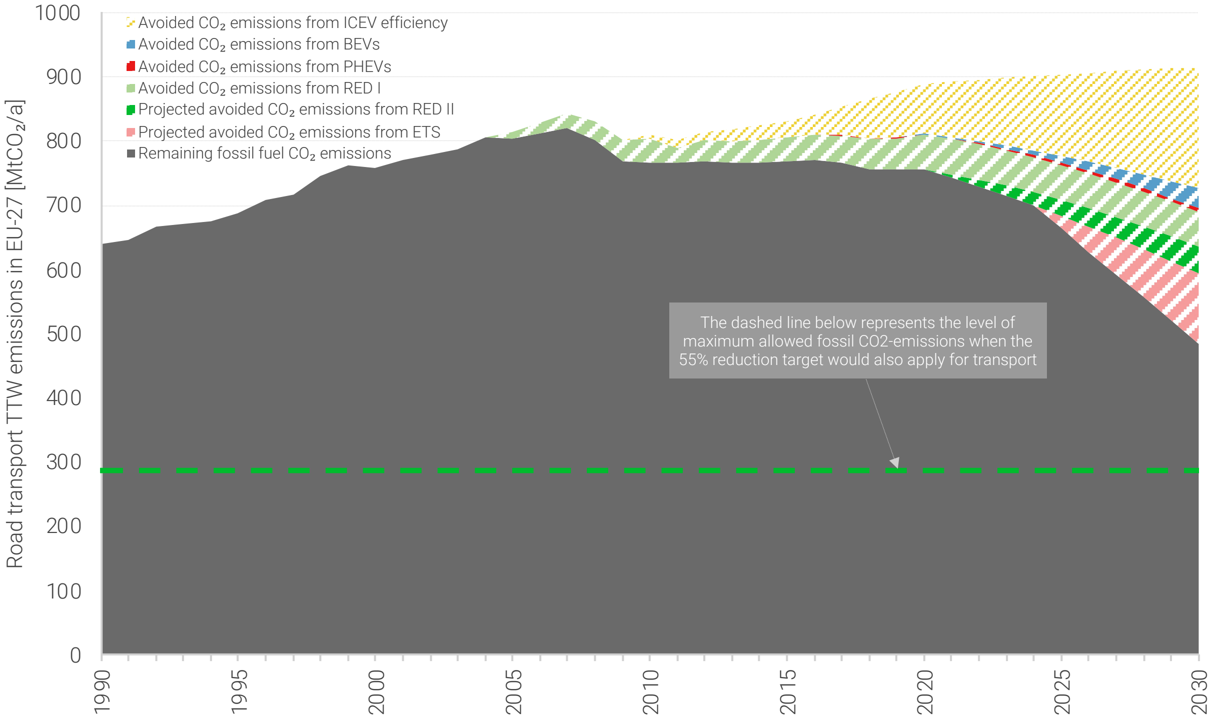

Figure 8. [ETS Pro rata distribution 1 Pro rata] TTW GHG emission reductions needed in the road transport sector, if required ETS reductions are pro rata divided. The pink area shows the additional required reductions needed between 2024-2030 (110 Mtonne CO_2eq).

ETS distribution 2 - Road transport only

In the extreme case that road transport will need to account for all the emission reductions of the ETS, it would need to reduce an additional 237 Mtonne CO_2 on top of the Concawe reduction. This additional required reduction is shown in pink in Figure 9, next page. Again, the deployment of low-carbon fuels in the Concawe scenario would cover most of the dark green area between 2020 and 2030. However, the whole pink area could not be covered by the measures and investment plans incorporated in the Concawe scenarios. This would mean an additional volume of 78 Mtoe (3,266 PJ) of renewable fuels by 2030 on top of volumes included the Concawe scenario.

ETS distribution 3 - Buildings mainly

The currently planned CO_2 reductions in road transport will account for 28-31% of the reductions in the ETS. The CO_2 reductions through the implementation of the RED II targets in 2030 are equal to 43 Mtonne (shown in dark green in

Figure 10, next page). If the other additional measures are taken in the built environment. The plans in the current Concawe scenario could cover 36 Mtonne of this 43 Mtonne CO_2 emission reduction. An additional 2 Mtoe is required on top of the planned 34 Mtoe (1,424 PJ) to cover the lacking 7 Mtonne CO_2 emission reduction. The building sector would need to take care of the remaining emission reduction to meet the targets of ETS, so around 244 Mtonne CO_2.

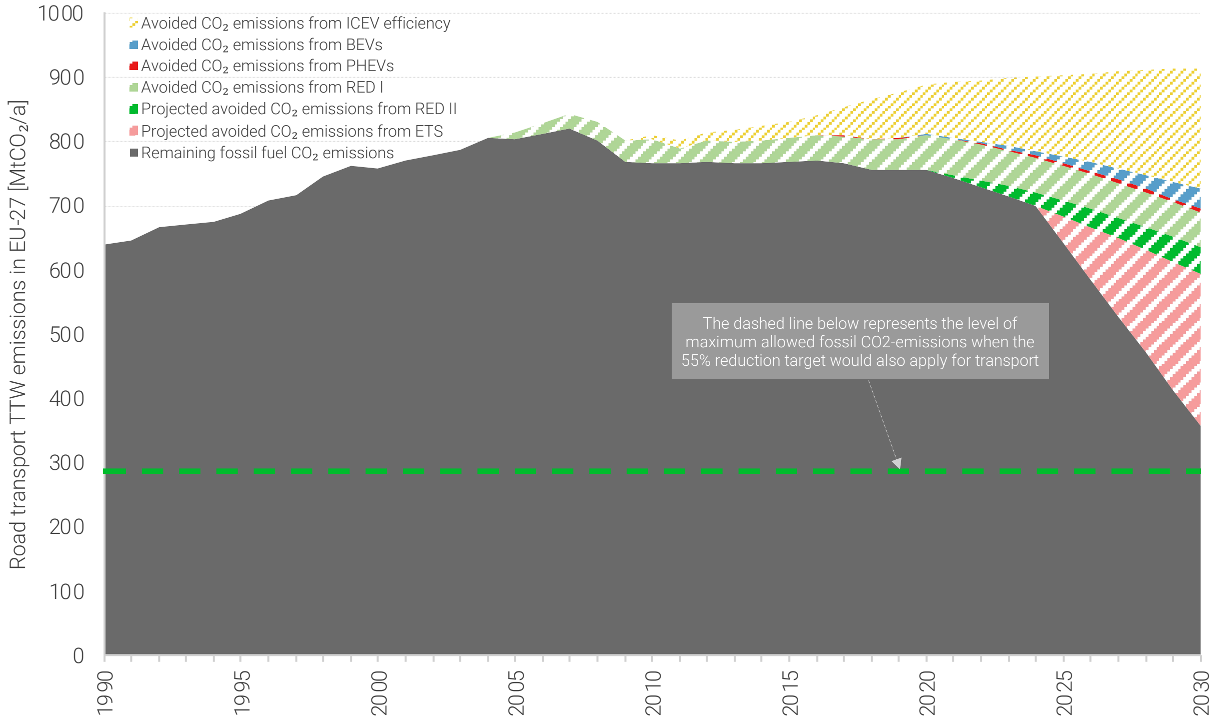

Figure 9. [Distribution 2 Road transport only] TTW emission reductions needed in the road transport sector if the building sector would not contribute. The pink area shows the additional required reductions needed between 2024-2030.

Figure 10. [Distribution 3 buildings mainly] TTW emission reductions between 1990 and 2030. If additional reductions would be required by the ETS it would have been shown in pink.

3.2 Discussion of Concawe-scenarios

If the buildings sector, following the EC's impact assessment, takes the lion share of the emission reduction within the ETS on the short term, it would follow the developments as discussed for distribution 3 until 2030. In this case the volumes of low-carbon fuels and their reduced emissions proposed by Concawe would follow the reduction path necessary to oblige to the ETS for the upcoming years. Although more needs to be done to meet the (and amended) RED II targets for 2030.[49]

As Figure 11 on the next page shows, the pathway for CO_2-reduction in transport after 2030 might turn out to be very steep in terms of emission reductions. EC policy expects an acceleration of the uptake of battery electric vehicles that - also due to high energy efficiency of the drive train - has the potential to contribute fast to GHG-savings. But it will have to be monitored to what extent and at what pace the legacy passenger car fleet will be replaced by electric vehicles. If this replacement will slow down[50], it can be expected that the volumes of renewable fuels will have to seriously ramp up to meet demand in the road segment in the context of an increasingly reduced ceiling on fossil CO_2-emissions.

In this regard, studio Gear Up confirms the likely demand for renewable fuels also in the road passenger segment by 2050, as elaborated on by Concawe in demand scenario 1 of "Transition towards Low-carbon Fuels by 2050". Both the current and revised RED II-target and possibly extra demand following the proposals to introduce an ETS to road transport and buildings will imply the need for higher renewable fuel volumes for the road sector by 2030, than what we believe is now foreseen in the Concawe scenarios. The proposal to include the road sector in the ETS could imply an increased demand of renewable fuels for road transport in the EU market. But with the uncertainty, you may wonder whether clarity can be derived in advance from the developments in the market. Also because policy interventions can take place continuously.

In theory, ETS could be a good instrument. But in this set up, an ETS for both road transport and buildings, does not provide a sufficient stable basis for the high capital investments that are required to scale up the volumes of renewable fuels. Rather, this would argue in favour of a separate ETS for road transport alone, which, however, should be thoroughly impact assessed in particular from a social perspective.

Considering these uncertainties, we believe that it would be a good idea that the refining industry starts exploring the plausibility how the European refining system can meet with substantial higher demand for low carbon liquid fuel, also on the short term. Our discussion of the policy has shown how the models of the European Commission do not incorporate the full potential of renewable fuels. This leads to low levels of GHG reductions in the transport sector by 2030. studio Gear Up recommends a more resilient policy strategy with incentives to accelerate the ramp up of renewable fuels to support GHG reductions in the transport sector by 2030 and beyond. Considering the share of energy demand in the road sector, deployment will need to first further increase in both in passenger cars and heavy duty modes, until

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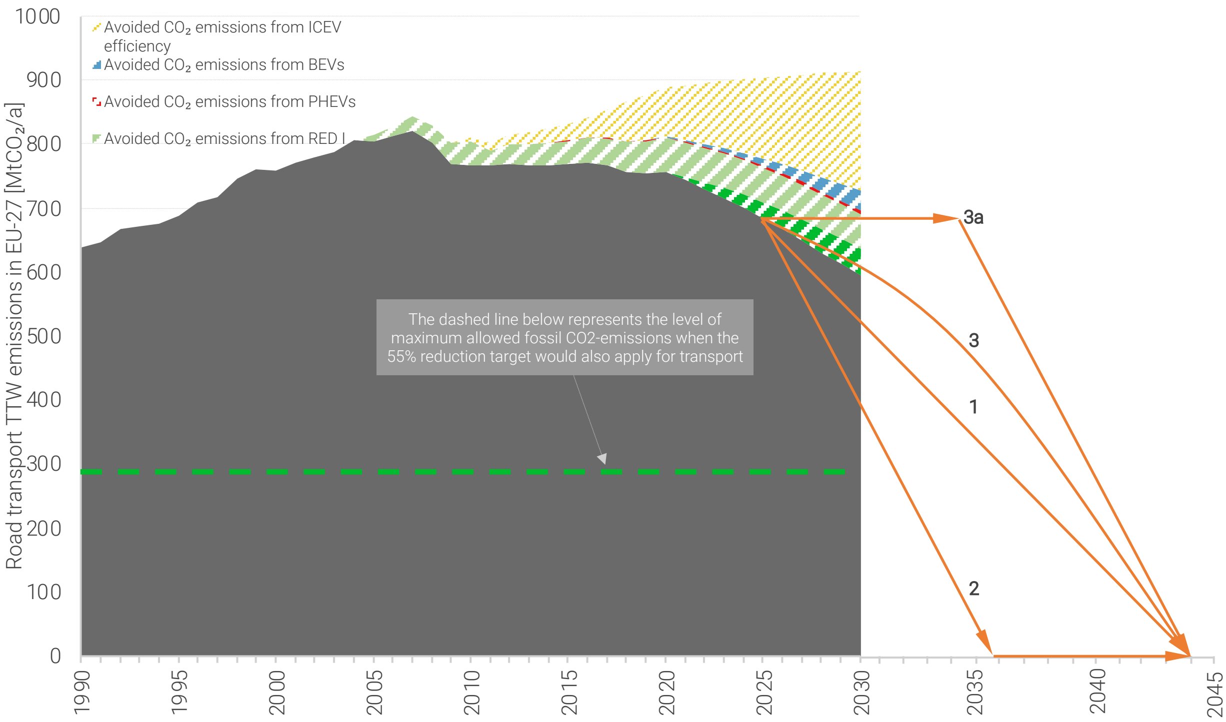
[49] Somewhat higher volumes of renewable fuels are expected for the revised RED II. Mainly due to not being able to double count anymore in the revised RED II. A theoretical maximum is a doubling of the volumes. RED II would imply a 10% physical renewable energy share (due to double counting), and when assuming an average of 70% GHG reduction this would lead to 7% GHG saving, the amendments target 13% savings.

[50] This could be caused by limited new EV sales due to their affordability, which in turn impacts the availability of BEVs in the second-hand market

electrification will take over. Application of these fuels will shift to the heavy duty transport sectors over time.



Scenario 1
Pro rata

- Emission reduction in both sectors is achieved at the same time and proportionally to their sized
- If the liner reduction rate is not changed zero emission for bot sectors is achieved around 2044

Scenario 2
Road transport only

- Emission reduction in road transport is continuously cheaper than in buildings
- Road transport achieves zero emission around 2036
- Only from the onwards buildings will reduce emissions

Scenario 3
Buildings mainly

- Transport does achieve some reduction through REDII
- The end point is the same in all scenarios: 2044 (if the linear reduction rate is not changed)
- The curve becomes ever steeper

[Scenario 3a]
Buildings only first

- If no emissions from transport, the orange line remains flat until building sector achieves zero emissions around 2032
- From then onwards transport has to reduce continuously

Figure 11. The development of the ETS emission ceiling after 2030

4 Low-carbon mobility options for consumers compared

When car owners want to decrease the climate impacts from driving their vehicle or choose not to pay for increasing energy costs due to emission allowances, they could opt for an electric car or a vehicle with an internal combustion engine (ICEV) driving on a low-carbon fuel. We evaluated the costs and carbon emission impacts of changing from a VW Golf driving on diesel or gasoline to an VW ID.3, and of driving the original vehicle, but on (a high blend of) low-carbon fuels. The calculations are based on 12 thousand km driven per year on basis of total Cost of Ownership (TCO). In this example case, France is chosen as reference EU Member State. At the end of this briefing, we also explore the impact in some other Member States.

In Figure 12 we have presented the results for France, in the case that the consumer who buys an electric vehicle is awarded a subsidy.

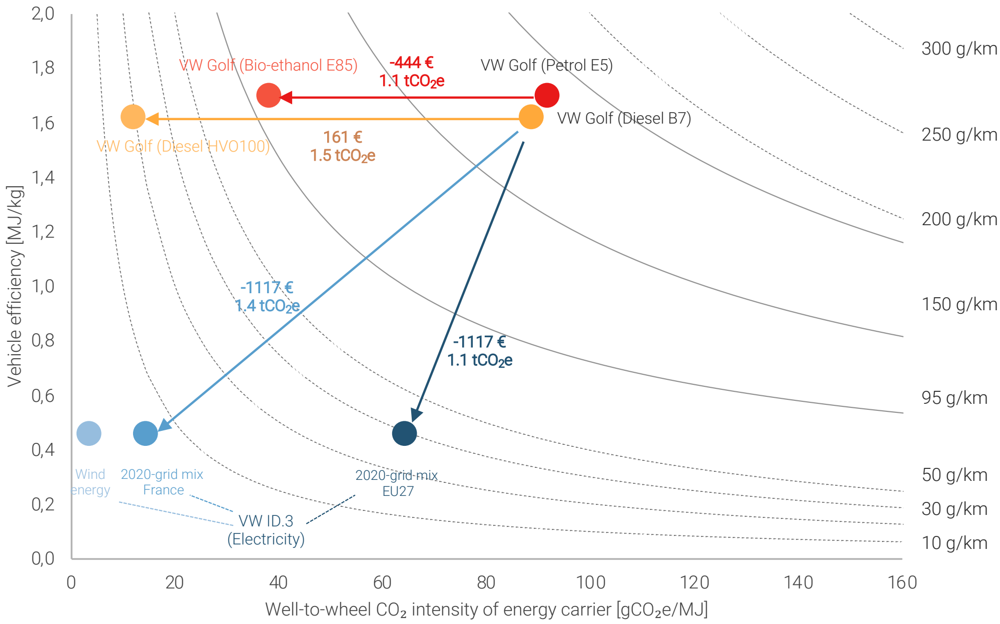


Figure 12. [situation for France] GHG abatement options for a consumer driving a VW Golf on E5 petrol. The ethanol fraction in E85 was assumed to deliver a GHG saving of 75% over petrol and HVO100 was assumed to deliver 88% GHG savings over diesel (e.g. via UCOs). E85 is bought for 0.60 €/ltr and HVO100 is bought for 1.58 €/ltr. The BEV owner is assumed to receive a purchase subsidy and to charge 50% at home and 50% in public. EU-27 average grid electricity was assumed for the GHG intensity of electricity (255 g CO_2/kWh). (to indicate the result of a 100% renewables based electricity grid the results are plotted)[51]

In France, a change from driving on petrol (E5) to driving on E85 (assuming 75% GHG emission savings over fossil for ethanol) can reduce the emissions of an ICEV by 1.1 t CO_2eq/year while reducing TCO by 444 €/year. This results in a negative abatement cost[52]. If the ethanol in E85 is exactly RED II compliant (60% GHG reduction over petrol), a shift to using E85 would still reduce 0.9 tCO_2eq/year, for the same amount of financial savings.

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[51] Particularly in France the electricity mix would result in a lower caron intensity. The total power sector in France emits 57.3 gr/kWh, thus 15.9 grCO2/MJ in 2020.But we do see that the European electricity grid is so much integrated. It is the overall European carbon intensity that is relevant.

[52] Please note that we only express negative abatement costs as 'below 0' and not in actual negative values. The reason for this is that the negative abatement costs are not providing insights and are not fit for comparison. In case of a change in TCO of e.g. -500 €/yr the abatement costs for 1.0 tCO_2eq/yr emission reduction is -500 €/tCO_2eq. when the reduction is only 0.5 tCO_2eq/yr the abatement cost becomes -1,000 €/tCO_2eq.

HVO100 can reduce GHG emissions even further (to 1.5 tCO_2eq/year if it is based on UCO, assuming 88% GHG emission saving over fossil). while increasing TCO by 161 €/year. This equals an abatement cost of 108 €/tCO_2eq. If the GHG performance of the HVO is equal to the RED II threshold value the GHG emission reduction amounts 1.0 tCO_2eq/year), at an additional cost of about 160 €/year compared to a regular car on Diesel B7 (an abatement cost of 160 €/tCO_2eq).

If the car owner shifts from a petrol car to an electric vehicle the GHG saving is 1.5 tCO_2eq/yr (assuming an EU average electricity mix).

If the car owner also receives a subsidy for buying an electric vehicle this will be reducing the TCO by 1,117 €/year. Due to the subsidy the option for shifting to an electric vehicle leads to the highest GHG-reduction in annual TCO costs.

The carbon intensity of the French electricity is much lower than the EU-average due to high shares of nuclear and renewable. The GHG saving in case of 100% renewables-based electricity the GHG saving for a BEV compared to a petrol car would be 1.9 tCO_2eq/yr.

If no subsidy is given and the consumer charges its electric vehicle primarily in public, then the results change significantly (see also Figure 13). For the shift from E5 to E85 and the shift from driving on HVO100 instead of B7 the situation remains the same, but the total cost of ownership for the BEV increase and are in this situation 228 €/year higher than for driving an ICEV on petrol (E5). Without the subsidy the option for a BEV becomes the least attractive abatement option and faces the highest change in annual TCO. This result is sensitive to the GHG intensity of the electricity and the choice where the vehicle is charges (at public or private charging poles, with different prices for electricity). Without subsidies for BEV but with 50% public charging the TCO increases by 83 €/yr (see also Figure, page 34).

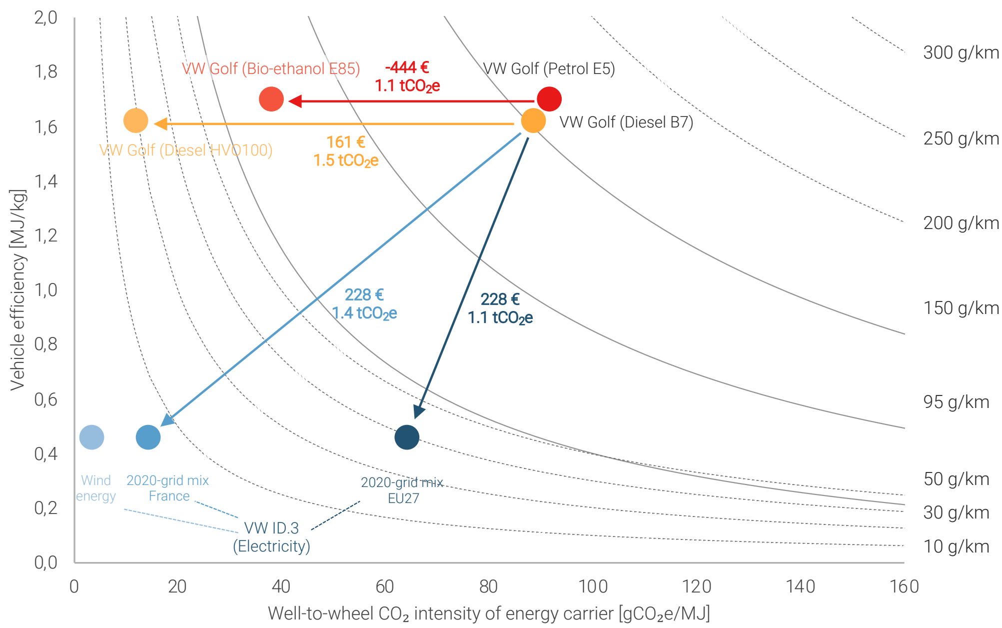

Figure 13. [situation for France] GHG abatement options for a consumer driving a VW Golf on E5 petrol. The ethanol fraction in E85 was assumed to deliver a GHG saving of 75% over petrol and HVO100 was assumed to deliver 88% GHG savings over diesel (e.g. via UCO). E85 is bought for 60 ct/L and HVO100 is bought for 1.58 €/ltr. The BEV owner is assumed to receive no subsidy and to charge 100% in public. EU-27 average grid electricity was assumed for the GHG intensity of electricity (255 gCO_2/kWh).

In Table 1 the information is summarised and in Figure 14 presented visually.

Table 1. Overview of GHG emisssion savings and changes in TCO when shifting from a fossil fuel based vehicle to low-carbon fuels and/or an electric vehicle

Shifting from:	Driving on petrol E5	Drivin on diesel B7	Driving on petrol E5	Driving on petrol E5
To:	Driving on E85	Driving on HVO100	Shifting to a VW ID3	Shifting to a VW ID3
			With subsidy for electric driving and 50% public charging	Without subsidy for electric driving and mainly public charging
GHG emission saving (in tCO_2eq/yr)	1.1	1.5	1.5	1.5
GHG emission saving (in tCO_2eq/yr) when GHG-saving is at REDII threshold value	0.9	1.0	n.a.	n.a.
Annual change in TCO costs (in €/yr)	-444	+161	-1.117	228
Abatement costs for GHG emission saving (in €/tCO_2eq)	below 0	+108	below 0	+152

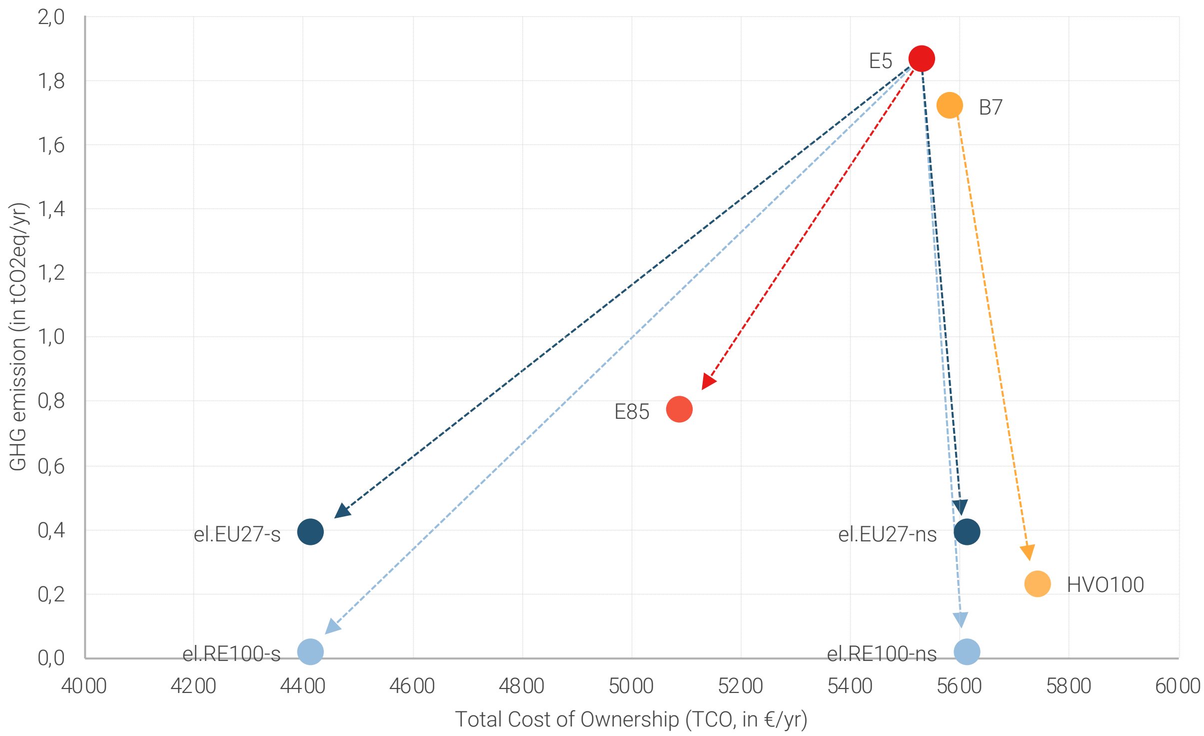

Figure 14. Visual overview of the changes in TCO and savings in GHG emissions when switching from petrol (E5) and diesel (B7) to alternative options. (Clarifications for the EV options: 'el.EU27' represents the average EU27 2020 grid carbon intensity. 'el.RE100' reflects a fully renewable based electricity grid. The extension '-s' shows the TCO-situation with subsidy for a BEV, and '-ns' the situation without such subsidy)

None of the above results take infrastructure costs into account because it is impossible to express infrastructure costs per kWh, especially because it remains unclear how infrastructure costs are or will be distributed between individual consumers and society on a whole.

Ricardo[53] estimated in an assessment of required infrastructure investments that a cumulative cost of about 38 billion euro is needed in Europe until 2030 for providing

[53] Ricardo Ltd. (2018) - "Impact Analysis of Mass EV Adoption and Low-carbon Intensity Fuels Scenarios". (Confidential to Concawe)

sufficient charging options (mainly home charging and limited public charging) for a high penetration of electric vehicles, rising to 500 billion euro until 2050.

Transport & Environment[54] estimated the required infrastructure costs to be considerably lower. In their analysis, the costs continuously reduce over time, and in the period from 2020 to 2025 are cumulatively 12 billion euro, which is small in comparison to what the EU spends annually on transport infrastructure (about 100 billion euro).

The difference between these two estimates shows that there is high uncertainty in the estimation of infrastructure costs and that underlying (and partially unknown) assumptions and methods highly influence the outcome. Consequently, no definite conclusions can be drawn on the investments required for infrastructure changes.

It is expected that there will be significant increases in local peak loads due to BEVs, leading to challenges when local transformers are pushed beyond their capacity. Not only spatial differences are occurring, but also extensive charging during certain time periods (e.g. peak hours after work when returning at home) will lead to peak loads and possible problems. This will probably require additional investments. In Amsterdam, local grid operator already have pointed out today that limits of grid capacity haven been reached in certain areas. The uncertainty if charging station for BEVs can be connected to the grid in the future shows that local grid capacity could be a serious threat for the adoption of BEVs in certain areas. Estimating the upcoming costs of the investments for grid capacity were out of the scope of this research.

Sensitivity analysis: impact of the greenhouse gas performance of low-carbon fuels:

A 100% renewable petrol was assumed as the recent Neste announcement brings the option of a renewable drop-in petrol fuel to the market.[55] This renewable petrol achieves a 90% GHG reduction over conventional petrol and is available for an additional 0.15 €/ltr before taxes.[56] Below, in Figure 15, next page, the plot is shown that assumes 50% public charging and no subsidies for the BEV.

A renewable petrol car can achieve the highest savings per year, but similarly to the HVO100 option and the BEV option when no subsidy is applied, it comes at an additional cost.

Renewable petrol in this case of Neste showcased a better GHG performance for petrol cars than E85. As a second sensitivity, the most pessimistic GHG intensities were assumed while the energy carrier prices were kept constant. The ethanol in E85 was assumed to exactly meet the RED II reduction of 60% compared to conventional petrol. This means the fuel just qualifies for acceptance in the EU market – in reality most renewable fuels outperform the required RED II GHG performances. For the electricity mix we assume the highest carbon intensity value found in Europe (grid electricity in Poland, mainly based on coal). The chart on the next page (Figure 16) presents the information under the assumptions of no subsidies for BEVs and 50% public charging.

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[54] Transport & Environment (2018) - "Roll-out of public EV charging infrastructure in the EU". https://www.transportenvironment.org/sites/te/files/Charging%20Infrastructure%20Report_September%202018_FINAL.pdf

[55] https://www.neste.nl/releases-and-news/renewable-solutions/neste-test-hernieuwbare-benzine-zweden-voor-mogelijkheden-van-internationale-commercialisering

[56] This is the average (0.10 – 0.20 €/ltr extra) for HVO100 before taxes, which was also assumed for HVO100.

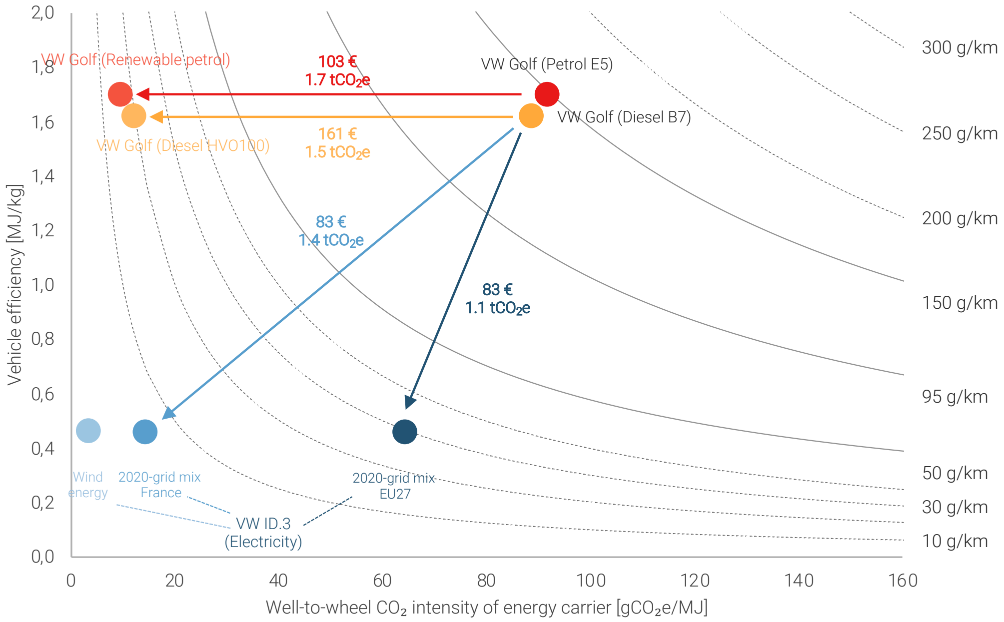

Figure 15. GHG abatement options for a consumer driving a VW Golf on E5 petrol. The renewable petrol was assumed to deliver a GHG saving of 90% over petrol and HVO100 was assumed to deliver 88% GHG savings over diesel (e.g., via UCO). Renewable petrol is bought for 1.70 €/ltr and HVO100 is bought for 1.58 €/ltr. The BEV owner is assumed to receive no subsidy and to charge 50% at home and 50% in public. EU-27 average grid electricity was assumed for the GHG intensity of electricity (255 gCO_2/kWh).

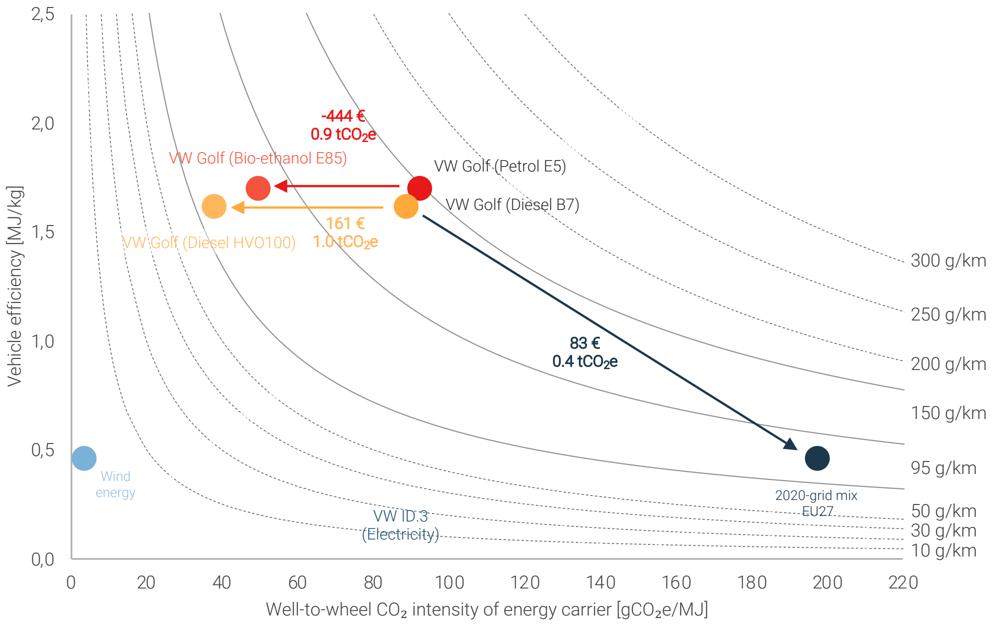

Figure 16. GHG abatement options for a consumer driving a VW Golf on E5 petrol. The ethanol fraction in E85 was assumed to deliver a GHG saving of 60% over petrol and HVO100 was assumed to deliver 60% GHG savings over diesel. E85 is bought for 0.60 €/ltr and HVO100 is bought for 1.58 €/ltr. The BEV owner is assumed to receive no subsidy and to charge 50% at home and 50% in public. Polish grid electricity was assumed for the GHG intensity of electricity (790 gCO_2/kWh).

Without subsidies and without access to low-carbon electricity, the electric vehicle is in this case the least favourable abatement option. It also saves the lowest amount of greenhouse gas emissions per year, even if the alternative fuels just meet the RED-II criterion of 60% GHG reduction.

In summary, this analysis shows that both the low-carbon fuels and electric drive trains realise Well-to-Wheel GHG emission reductions. By using 100% renewable electricity the shift to battery electric vehicle realised high GHG-reduction

(1.9 $MtCO_2eq$/yr). Based on the current European electricity mix, the GHG-reduction performance of renewable fuels could in some cases be better.

Without subsidies applied for EV, a shift from a fossil fuel to a low-carbon mobility option (renewable fuels or electric drivetrain) results in a comparable and moderate change in the annual total cost of ownership. In case of the electric drivetrain the annual TCO is to a large extent influenced by subsidies.

This is a relevant finding, also because the TCO-analysis shows how a purchase subsidy comes at a considerable cost for – certainly some - governments, see Figure 17. From these results, it follows that current subsidy schemes cannot be sustained for longer periods of time.

If a similar amount of subsidies granted for the purchase and use of a battery electric vehicle in France is used to stimulate driving on renewable fuels, then driving on low-carbon fuels would be possible at similar costs. A CO_2-reduction based subsidy for all low-carbon mobility options would therefore result in reaching similar GHG emission reductions at nearly the same annual total cost of ownerships, as can be seen in Figure 18. (next page). These findings imply that next to choosing a battery electric car, also driving an internal combustion engine vehicle fuelled with low-carbon fuels will reduce GHG-emissions at similar costs, assuming a level playing field.

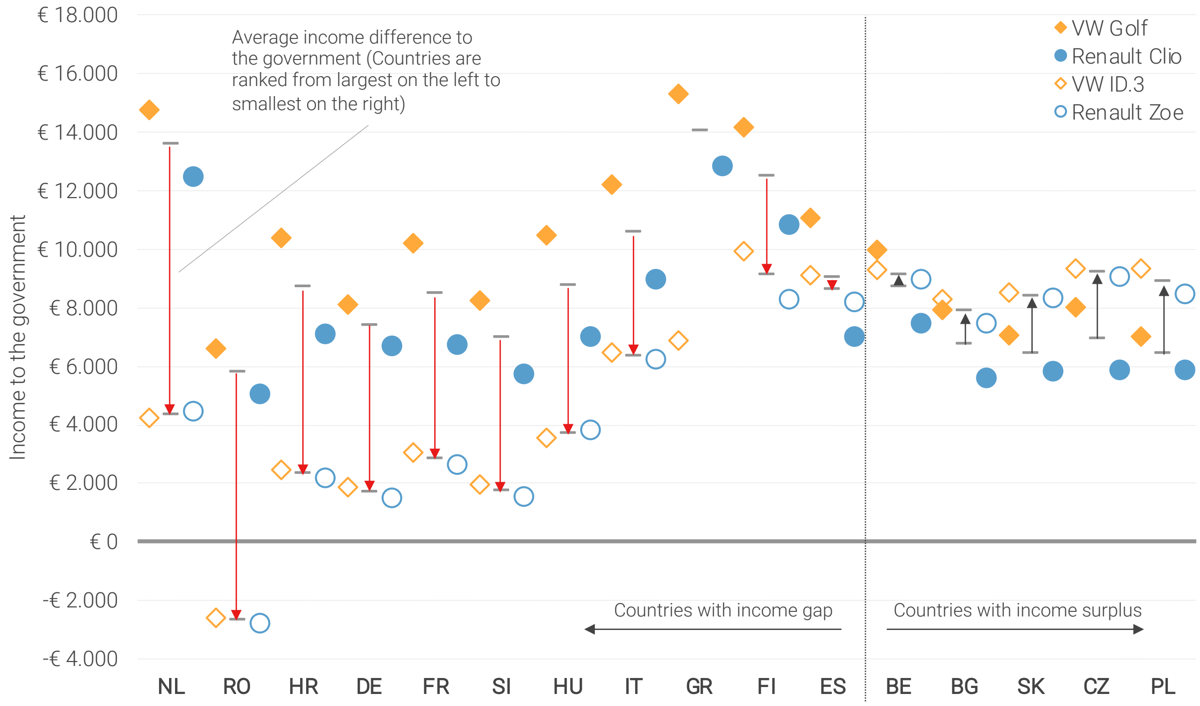

Figure 17 Revenues to the government from new cars over the first five years. All cars are assumed to drive 12,000 km/a. The ICEV (brown diamonds) is represented by the VW Golf and the Renault Clio, whereas the BEV (blue crosses) is represented by the VW ID.3 and the Renault Zoe. From left to right, the countries are ordered from the highest loss to the highest increase in income from BEVs compared to ICEVs.

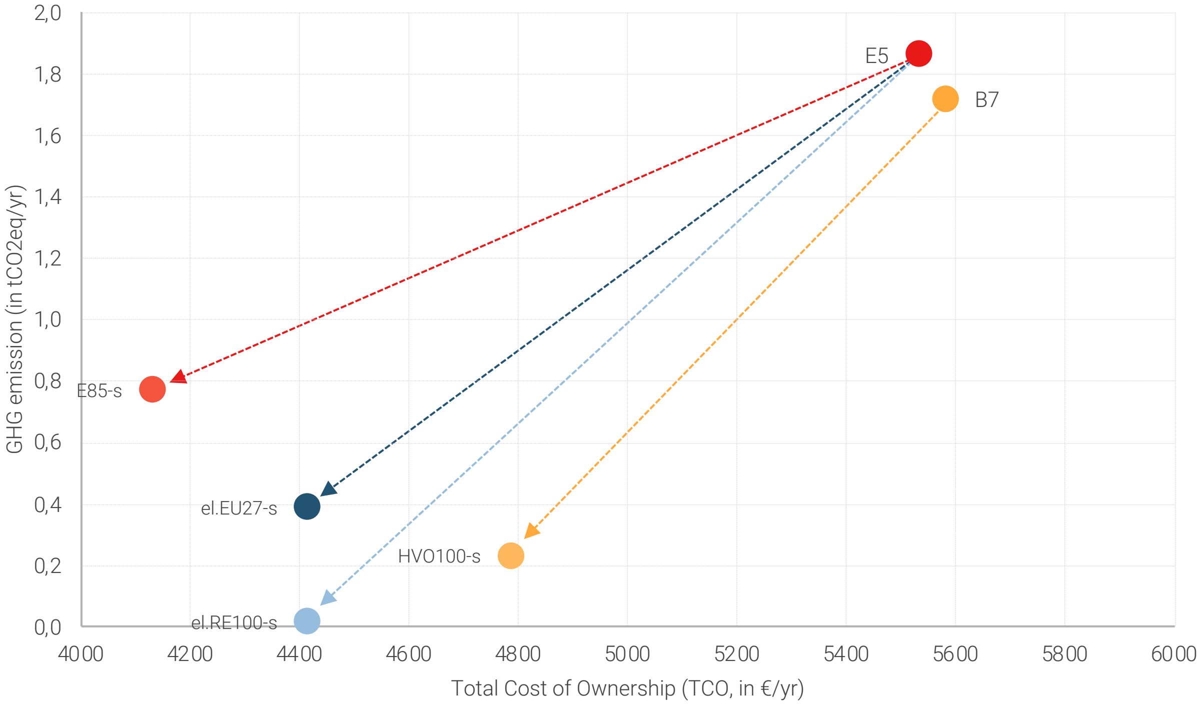

Figure 18. Visual overview of the changes in TCO and savings in GHG emissions when switching from petrol (E5) and diesel (B7) to alternative options. For all low-carbon options a subsidy based on the CO_2-reduction potential is applied.

5 Affordability of electric vehicles in the market

The full electrification of the passenger vehicle segment including (large shares of other road segments) can be considered a big innovation project that will have to overcome a number of challenges. These include **challenges on the energy system level, resource constraints of rare earth elements, social-economic inclusiveness, affordability, and consumer choices**. In this study project we have looked at the social-economic effects by looking at the affordability of electric vehicles in the market. As mentioned before, we have used an analysis on TCO of the vehicle costs and energy.

When a consumer decides on the purchase of a (next) car, both the purchase price and the total cost (per kilometre or per time-unit) matter.

The catalogue prices of battery-electric vehicles (BEVs) still largely exceed those of their internal-combustion-engine vehicles (ICEVs) counterparts. Sales are currently supported by subsidies and discounts, but this is costly to the government and subsidy allocations are often capped in size or limited in time. The total cost of ownership is the most important indicator to judge the affordability. It is necessary to understand how the total cost of ownership (TCO) of BEVs performs in comparison to the TCO of ICEVs and which parameters impact these TCOs.

Furthermore, it is necessary to analyse the impact of the support schemes to the state income, which also has consequences for the citizens (increasing taxes or cuttings in other services). Understanding these relations is particularly crucial since financial support is slowly phased out in many European Union (EU) Member States.

Finally, the obligation to car manufacturers to sell electric vehicles and in some countries to give additional discounts, is compensated by higher prices for ICEVs. Effectively, the purchase of (any) new car is increasingly costly and this will impact the mobility of the lower income segment.

To gain insight into these matters, studio Gear Up developed a TCO model with a bottom-up approach, the full analysis and description of the methodology is available as a separate annex report.

Three main conclusions can be drawn:

1. **New BEVs are becoming competitive to new ICEVs in all Member States where subsidies are applied.**

   Specifically, in the Netherlands, Germany, and Romania, the analysed BEVs are already cheaper than their ICEV counterparts. In eight other Member States, subsidy schemes bring the total cost of ownership of BEVs within the range of ICEVs. This is the case in Croatia, Greece, Hungary, France, Italy, Finland, Slovenia and Spain. Under certain conditions, new BEVs may become competitive to new ICEVs, even if subsidies and tax exemptions were discontinued. In five countries (the Netherlands, Spain, Greece, Finland and France) BEVs remain roughly on par with ICEVs if subsidies are removed.

2. **New BEVs with a purchase subsidy and incentives compete with second-hand ICEVs since new ICEVs become more expensive and the market for second hand BEVs is small.**

The majority of the European population cannot afford a new vehicle, and thus relies on the second-hand car market. However, the penetration of BEVs in the second-hand car market is currently limited. For quick adoption, new BEVs need to compete with used ICEVs. In Member States with high subsidy schemes, new BEVs can already compete with four-year-old second hand ICEVs, such as in Germany. In countries without support schemes, such as Poland, the premium for owning a new BEV over a used ICEV may amount to about 11 thousand Euro over a 5-year ownership period. The differences in affordability across Europe may negatively impact the inclusiveness of the transition to a zero-emission transport sector.

3. **The costs and the loss of tax revenues for European governments due to the support of BEVs over ICEVs are considerable.**

   Current support translates to around 2,000 – 8,000 € losses for European governments per car over its first 5-year ownership. If subsidies were discontinued, BEVs still can only generate a similar revenue to the government if their purchase prices remain higher than those of ICEVs, because their current main contribution to government income is the purchase value added tax (VAT) for new vehicles. Governments earn less on the energy consumed in electric vehicles compared to fuels in ICEVs due to the lower energy consumption and the significantly lower taxation. When used cars are compared, the government revenues from a second-hand BEV are roughly half of the government revenues from an equivalent ICEV. These observations imply that the introduction of BEVs is costly for the society. This could restrict the durability of current benefit schemes for BEVs.

Among the sixteen analysed Member States of the European Union, the countries with the highest subsidy schemes for electric vehicles were The Netherlands, Romania and Germany. Czech Republic, Hungary and Poland offer the lowest level of subsidies, see also Figure 17, page 35).

Considering the investigated car models (Volkswagen Golf, Volkswagen ID.3, Renault Clio, Renault Zoe), it can be concluded that the VW ID.3 is more competitively priced than the Renault Zoe in comparison to their respective ICEV counterpart. The business case of the Zoe still largely depends on subsidies, while in a few cases the ID.3 can reach total cost parity with the Golf even without purchase subsidies, namely where cheaper energy costs for the EV more than compensates the higher purchase and depreciation costs (Netherlands, Spain).

The TCO analysis also shows that a battery-electric vehicle potentially is more cost-effective for suburban drivers who generally have a higher annual mileage and access to a charging point at home, compared to urban consumers that drive less kilometres and, in many cases, may depend on public charging (which is often more expensive).

The full TCO-analysis is available as a separate annex report.

5.1 Affordability of BEVs differs across Europe

The country's economy may influence the ability to provide subsidy schemes for BEVs and the affordability of BEVs for its citizens. This means that some countries have limited means to incentivise the purchase of electric vehicles, and most of the citizens are dependent on the second-hand market for their next car.

Also including subsidies, we have found that new (battery-electric) vehicles are largely out of reach for most consumers in the market. In the case of Belgium only the top tier income class will be able to finance a new car (see Figure 19). A new Renault Clio would be in reach from income classes of the third quintile. A country like Bulgaria is in all income classes largely driving used cars (Figure 20). The separate detailed TCO annex report includes country profiles of 16 Member States including car budget ranges.

Car dealers increasingly respond to the issue of high initial purchase costs for EVs by developing private lease concepts that allow consumers to drive a car at a fixed monthly rate. In general, company cars dominate new car registrations. With respect to car sales by private car owners, most transactions take place in the used-car market.

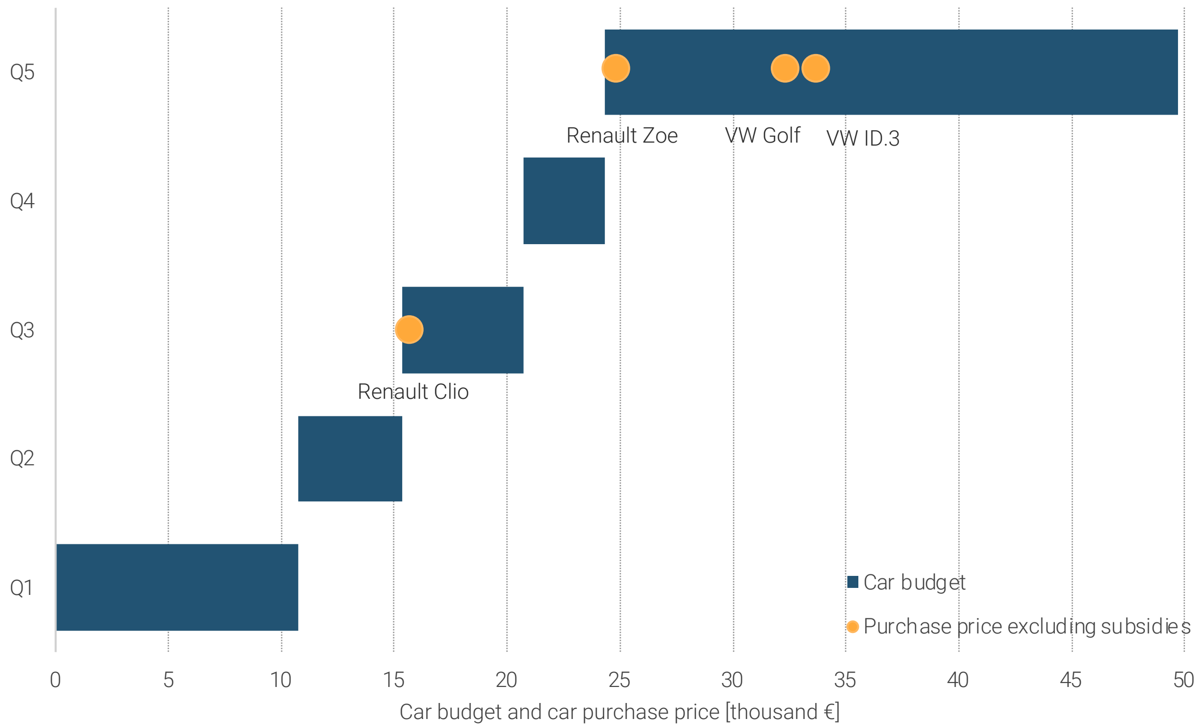

Figure 19. Available budget ranges for new car purchases for all income quintiles in Belgium and the catalogue prices of new ICEVs (Renault Clio, VW Golf) and new BEVs (Renault Zoe, VW ID.3).

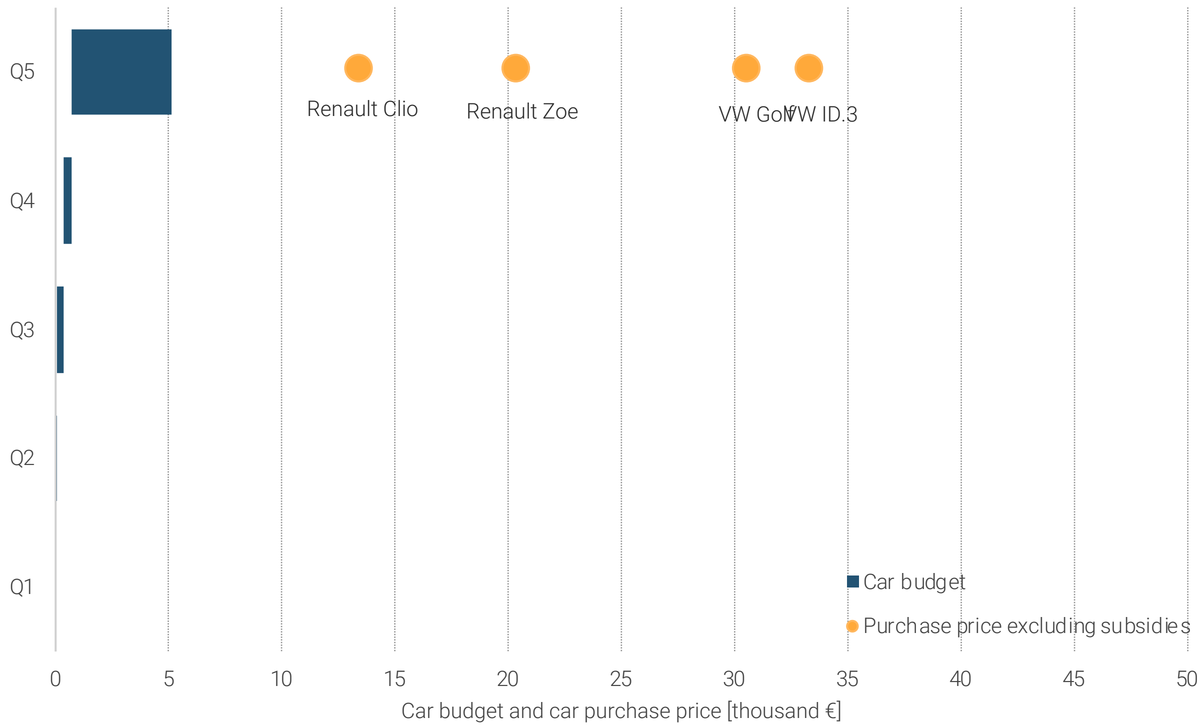

Figure 20. Available budget ranges for new car purchases for all income quintiles in Bulgaria and the catalogue prices of new ICEVs (Renault Clio, VW Golf) and new BEVs (Renault Zoe, VW ID.3).

5.2 Share of battery-electric vehicles in the used car market

In its 2021 'Vehicles in Use' report, ACEA states that at the end of 2019, a total of 970 thousand BEVs were registered in the EU 27. In less than 10 year's time, the total BEV passenger car fleet will have to increase 30-fold. The year 2020 was a record year for newly registered BEVs. Nevertheless, if we look at the numbers, it is visible that the share of BEVs in total new car registrations in the EU remains small with a 5.4% share (see Figure 21).

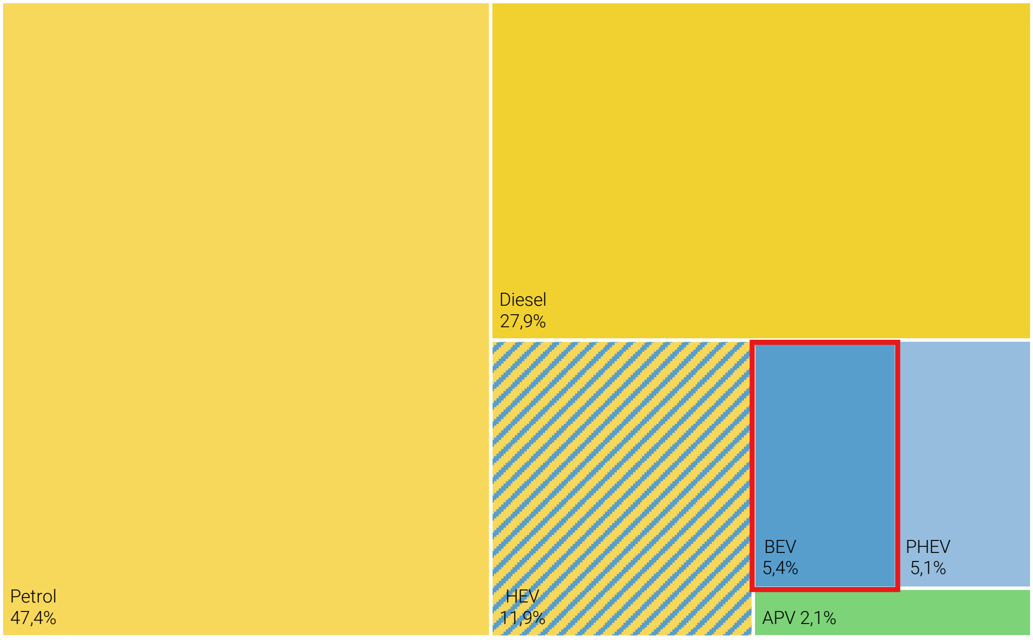

Figure 21. New car registrations by fuel type/drivetrain (Source ACEA, 2021; EC Transport in Figures)

Analysing the introduction of BEVs on the used car market is difficult as data on second hand BEVs sales are difficult to find in European countries. Germany however does publish annual data on used car sales, specifying second-hand car sales by fuel type (see Figure 22).

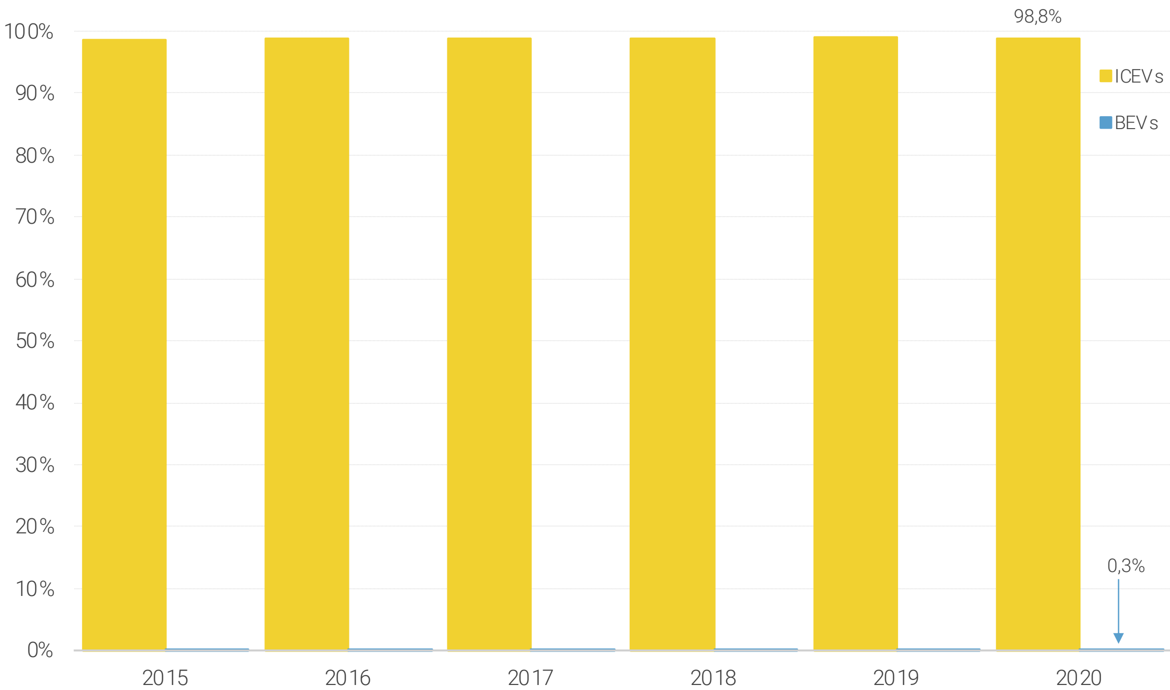

Figure 22. The share of battery electric vehicles in the German used car market is still very low. In 2020 the share was equal to 0.3%, which is in the scale of the graph not clearly visible.
Source data: KBA, 2021, Besitzumschreibungen von Kraftfahrzeugen und Kraftfahrzeuganhängern, 2015-2020

In 2020, Germany recorded a 6.7% share of new BEVs in the total new passenger car registrations. This reflects an upward trend of BEV registrations over the last four years. However, 92.8% of the newly registered cars in 2020 still have an ICE.[57] The most popular BEVs that were registered in 2020 in Germany are[58,59]:

- Renault Zoe (€29,990)
- VW e-Golf (€31,900) (now out of production)
- Tesla Model 3 (€39,990)
- VW ID.3 (€31,960)
- Hyundai Kona (€37,750)

Due to the high purchase prices (even with financial incentives included), BEVs are mainly purchased by companies or households with a high-income level. Households with a lower income look to the second-hand car market for vehicle purchases. To stimulate BEV uptake in society, policy makers are increasingly aware of the importance of the second-hand market for BEVs. However, as Figure 22 shows, the amount of sold second hand BEVs still lags behind as only 0.3% of the total second-hand car registrations was battery electric.

The low sales numbers of BEVs in the second-hand market can have two reasons:

- Second-hand car sales are linked with the new car market. As BEV sales have still a low share in the new car market, it will take some years before these cars will come into the second hand car market.[60]
- Prices of new electric car models are too high for a large part of the passenger car consumers in the market.

[57] PHEVs are included in the ICEV section
[58] https://www.best-selling-cars.com/germany/2020-full-year-germany-best-selling-electric-cars-by-brand-and-model/
[59] Prices for BEVs: https://www.renault.de/elektromodelle/zoe/preis-versionen.html?gradeCode=ENS_MDL2PSL1SERIESPE2
https://www1.hyundai.news/de/modell-news/sportlicher-neuzugang-im-suv-portfolio-der-hyundai-kona-n/
https://www.volkswagen.de/de/modelle/id3.html
https://insideevs.com/news/367887/vw-lower-e-golf-price-europe/
https://www.tesla.com/de_de/model3/design#overview
[60] Second-hand cars are on average 6-7 years old when bought (Source: GfK (2014): Consumer market study second hand cars)

6 Broader economic impacts of the uptake of the LCLFs.

6.1 Renewable fuels are complementary option

studio Gear Up has shown that from a consumer perspective a battery electric vehicle and a comparable model with a combustion engine that drives on 100% renewable fuels reach comparable results in terms of GHG-emission reduction at similar costs. Since renewable fuels in the passenger road segment make use of existing fuel infrastructure and current vehicle engines on the market, this climate mitigation can be scaled up with no additional cost for new infrastructure or vehicle technology. Obviously, there are costs to scale-up technology for production of drop-in fuels. Deployment of renewable fuels does not compete with the increasing electrification of this segment. The increased ambition in the CO_2-emission standard to (as proposed) 100% in 2035 is the central instrument to make sure the passenger car park will shift from an internal combustion engine to battery electric drive trains. Scaling up renewable fuels is complementary to electrifying passenger road transport. The volumes will shift from the light-duty and heavy-duty, to aviation and maritime sectors over time. The essential advantage of making use of renewable fuel option, also in the passenger road segment, is to scale-up the GHG emission savings to reach 2030 GHG-reduction goals in the mobility sector and also for the overall -55% reduction targets that European Member States are aiming for.

As discussed previously the lack of visibility of the renewable option in light-duty segment may have been due to the fact that renewable fuels for the transport sector were not considered as a potential main driver to reach climate neutrality in the Clean Planet for All strategic study. And as a consequence, the option is also not considered in many studies that take the scenario development as a reference base. Moreover, the central target of the European scenario development has been how to reach net-zero emissions in the sector in 2050. The cost-effectiveness of the various options or pathways have not been compared assssing the accompanying staff working documents.

6.2 Cost-effectiveness of renewable fuels at system level

Energy system transition

It has been pointed out that scenarios including a broader mix of technologies by 2050 cost significantly less and are more robust in the face of implementation challenges, such as constraints of raw materials and public acceptance.[61][62] State of the art insights[63] show that the use of sustainable biomass is a highly attractive mitigation option for deep GHG mitigation and energy system transitions. Over time, the optimal biomass-use shifts from heat and power to advanced fuels and feedstock for industry. Creating negative emissions through for instance bioenergy capture and storage will compensate for the very difficult to decrease remaining GHG emissions in some sectors and will lower overall mitigation costs. Additional benefits come from

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[61] Deutsche Energie-Agentur (dena) (2018), Dena Study, Integrated Energy Transition. Impulses to shape the energy system up to 2050. Report of the results and recommended course of action

[62] EC 2020, Critical raw materials for strategic technologies and sectors in the EU. A Foresight study

[63] Prof. A. Faaij, presentation for round table dicussion: transition in CO_2-sources - KIVI, Den Haag, 27 August 2021

increased carbon-storage combined with good land use practices in the supply-chains for biofeedstocks. If these benefits are well integrated in the green refining system supply-chains, the sector will deliver an important impact on the societal need for negative emission. According to Faaij (2021) "Excluding biomass from integral mitigation strategies increases mitigation costs substantially and in many cases makes achieving a 1.5°C pathway impossible"[64].

A net-zero economy will see a demand for CO_2 as a feedstock and convert it into value-added products such as fuels, chemicals or building materials. Withdrawal of fossil feedstocks from the energy system and feedstock production is the top priority. A cyclic utilisation of carbon and hence a circular carbon economy will be needed. Biomass as feedstocks, eventually Direct Air Capture of CO_2 or carbon capture and usage could be considered to let no new fossil carbon enter the supply-chains. Biomass use will get intermixed with green hydrogen and carbon capture and usage options and as such create synergy between these key mitigation options[65].

Renewable synthetic fuels and many advanced biofuel pathways make use of carbon and hydrogen. Against the commonly used arguments on the low energy efficiency of synthetic fuels (in comparison to electric drivetrains), we do see the value of these fuels at the system level[66]. Hydrocarbon storage creates flexibility at the European energy system level and provides other services such as easy and long term storage characteristics of high energy dense fuels necessary for high-power and high-range applications. Also it is often pointed out that making use of existing fuel infrastructure for the transport and storage of renewable electricity is cost-effective[67]. Major opportunities for European low carbon chemical/fuel industry are ahead with a proper policy vision. It is however important to notice that existing and planned regulations and mandates do not reward the defossilisation of liquid fuels, petrochemicals or materials. The interplay between the energy transition and the ambition for a circular economy is as yet poorly understood[68].

Circular economy

Changing the petroleum-based feedstocks with renewable or recycled carbon feedstock would allow refineries to be integrated into local economic value chains to produce heat, hydrogen and synthetic fuels, biofuels[69] On the short term, renewable fuels will require biofeedstock supply-chains for the refining system and carbon capture and usage (CCU) to design a circular carbon system. CCU is a system-critical component to any defossilisation strategy and will thus be a vital element in any energy system in the world. The relevant technologies are key to a European industry innovation strategy and require substantial and immediate efforts. This requires an investment strategy for the coming decades. The deployment of renewable fuels in the road segment is a stepping stone to build up volumes in aviation and maritime. This strategy to reduce the greenhouse gas impact of liquid fuels and the link with chemical industry transformation has so far not received sufficient policy attention.

[64] Ibidem
[65] SAPEA (2018) Evidence Review Report No. 2, Novel carbon capture and utilisation technologies Research and climate aspects
[66] SAPEA (2018), p.23
[67] For instance pointed out by Frontier Economics and the Institut der Deutschen Wirtschaft (IW), 2018, Synthetische Energieträger – Perspektiven für die deutsche Wirtschaft und den internationalen Handel. Eine Untersuchung der Marktpotentiale, Investitions- und Beschäftigungseffekte
[68] Prof. G.J. Kramer, presentation Sustainable Industry Lab about dutch carbon cyle, 27august 2021
[69] CIEP (2018), Refining the Clean Molecule, http://www.clingendaelenergy.com/publications/publication/refinery-2050-refining-the-clean-molecule

The slow payback of infrastructure investments that replace proven and written- off fossil technologies need stable financing conditions.

6.3 Employment effects

As SAPEA (Science Advice for Policy) suggests "Europe is well advised to learn from the evolution of battery and solar industries and to retain in its hands at least the CCU as a critical component of the design of green circular refining systems (resulting from collaboration between existing strong industries such as chemical, engineering, electrical infrastructure) will connect with the mobility industry (cars, planes ships)". It can be expected that such an industry transition will have both direct and indirect induced jobs in the whole value chain, of which the production of low carbon liquid fuels will make part of. Since this new industry development will still have to crystallize into concrete investment plans, the employment effects are difficult to estimate. Nonetheless, it is recommended to develop a human capital strategy to develop the necessary skills and capabilities for this industry transformation and the upscaling of renewable fuels.

Projected employment effects of LCLF on basis of the European Commission '1.5 tech'-scenario

studio Gear Up has looked at employment effects on basis of the renewable fuels supply-chains and technologies. To establish the expected volumes for Low Carbon Liquid Fuels in 2050 we took the volumes of e-liquids and liquid biofuels in the European Commission's 1.5-tech scenario as a reference. The 1.5-tech scenario considers 40.7 Mtoe for e-liquids and 28.2 Mtoe for liquid biofuels for the transport sector, which is road and aviation, but excluding bunker for international shipping sector. If we include also the 8.3 e-liquids and 27 Mtoe liquid biofuel for maritime bunker this would add to 49 Mtoe of e-liquids and 55.2 Mtoe of liquid biofuels for all transport in 2050.

We estimate that the projected 2050 volume for e-liquid and liquid biofuels in the EC 1.5-tech scenario could require jobs in the range of 1 million full time equivalent (FTE).

Table 1. Projected employment in renewable fuels in 2050. We estimate that the projected 2050 volume for e-liquid and liquid biofuels in the EC 1.5 tech scenario could require jobs in the range of 1 million FTE

	Demand for LC fuels (in Mtoe) in all transport including EU and international aviation and maritime in 2050	Total estimated employment (in FTE)
E-liquids*)	49	245 thousand
Liquid biofuels**)	55.2	820 thousand
Total	104.2	1.07 million
*) **)	Estimate by sGU, based on the liquid biofuels estimated number source: Eurobserver, 2020, The state of renewable energies in Europe	

e-fuels

As e-fuels will require considerable inputs of green hydrogen, the industry forecasts that hydrogen production and storage in hydrocarbon bonds to take mainly place outside of Europe. However, production and export of Power-to-X technologies and equipment will have the potential to create additional jobs. The design and construction phase will likely be the most labour-intensive part of the process. For instance, Germany has identified employment effects in the range of 470,800 new jobs for the production and export of Power-to-X technologies and equipment in case of annual global investments in PtX of around 215 billion, with a Germany market share of about 20%.[70] The operation phase is expected to be less labour-intensive, to some extent comparable to the FTE's required for operating current refineries

Liquid biofuels

Liquid biofuels will create more jobs due to the larger labour intensity especially upstream in the value chain, in the production of the biofeedstocks. Eurobserver (2018) identified in the Biofuels barometer 2020 report[71], 248,000 jobs in 2018 for a total liquid biofuels demand of 16.7 Mtoe in EU28[72]. This volume is in the 1.5 Tech scenario expected to grow to a total of 55.2 Mtoe in 2050 for transport, including bunkers for international shipping.

The biofuel production data for EU 28 provides roughly the same consumption data. BP World Statistical Energy Review Statistics database report liquid biofuel production in EU28 in 2018 to be 16.0 Mtoe. Extrapolating the 2018 number leads to 55.2 Mtoe in 2050.

In sum, **renewable fuels (liquid e-fuels and biofuels) will create more than a million FTEs towards 2050**. In the biofuel value chain the employment effects are mostly present upstream in the feedstock supply and have a strong link with the agricultural sector. The operational side only attain a small part. The liquid biofuels sector is already the third largest renewables employer in the EU-28. A precondition of liquid biofuels production is the availability of agricultural area. Therefore, member states leading in biofuels employment include Poland, Romania, France, Spain, Hungary and Germany. The leading biofuel country, Poland, had over 41 thousand jobs in the biofuel sector in 2018

[70] IW./FrontierEconomics (2018) "Synthetische Energietrager – Perspektiven fur die Deutsche Wirtschaft und den Internationalen Handel", p.42.
[71] https://www.eurobserv-er.org/biofuels-barometer-2018/
[72] We double checked the biofuel production data for EU 28, and these proved equal to the consumption levels. BP World Statistical Energy Review Statistics database report liquid biofuel production in EU28 in 2018 to be 16.0 Mtoe

7 Conclusions and recommendations

1. This study has shown that low-carbon fuels in internal combustion engine vehicle have a comparable GHG-reduction as electricity in battery electric vehicles and are price competitive for consumers in the market that look for low-carbon mobility options.
2. The analysis on basis of total cost of ownership shows that new battery electric vehicles have reached cost parity on basis of TCO in all selected European Member States, under the circumstance of subsidies for EV purchase.
3. In some countries cost parity between battery electric vehicles and internal combustion engines is also the case without a subsidy (the Netherlands, Spain, Greece, Finland and France).
4. However, these vehicles are in most countries only in reach for consumers in the highest income quintile because of the high initial purchase cost of new battery electric vehicles on the market.
5. Most cars are purchased on the used car market and here the penetration of used battery electric vehicles is so far very low, as shown in the case of Germany.
6. Especially for those consumers that cannot yet drive a battery electric vehicle, driving on renewable fuels can be considered price competitive, as our TCO analysis shows.
7. In the example of France, driving on E85 is the most cost-effective low-carbon mobility option, also when subsidies are granted for battery electric vehicles. Although the battery electric drive train and HVO are outperforming the E85 fuel on realised GHG-reductions. If all low-carbon mobility options are treated equally, from a GHG-reduction perspective, then they show all similar total costs of ownership, see also Figure 18, page 36.
8. This study has shown that both the low-carbon fuels and electric drive trains realise significant Well-to-Wheel GHG-reductions. A CO_2-reduction based subsidy for all low-carbon mobility options would result in a similar annual cost position, reaching similar GHG-reductions.
9. Deployment of renewable fuels does not compete with the increasing electrification of this segment. The increased ambition in the CO_2-emission standard to (as proposed) 100% in 2035 is the central instrument to make sure the passenger car park will shift from an internal combustion engine to battery electric drive trains. Scaling up renewable fuels is complementary to electrifying passenger road transport.
10. Both the (amended) RED II-target and possibly extra demand following the proposed extension of an ETS to road transport and buildings will imply the need for higher renewable fuel volumes for the road sector by 2030, than we believe now foreseen in the Concawe scenarios.
11. studio Gear Up recommends to the European refining sector to developing scenarios that explore "plausible scenarios" instead of basing scenarios on probability. That can help to prepare how to accelerate the increase in production capacity for renewable fuels on the short term.

12. The European policy scenarios have shown a blind spot for the deployment of renewable fuels, especially in the passenger road segment. The proposed instruments stimulate the accelerated uptake of battery electric drive trains in the passenger road segment. The GHG-reduction pathway of the mobility sector is therefore highly depending on the pace of electrification in the passenger road segment.
13. This analysis has shown that alongside the progressing electrification of the road passenger segment the large-scale deployment of renewable fuels, also in the passenger road segment, could significantly decrease the GHG-reductions of the mobility sector on the short term.
14. The GHG-reduction potential of the mobility sector can therefore be more ambitious than the European scenarios have shown so far.
15. In this regard, studio Gear Up confirms the (demand scenario 1) in the "Transition towards Low-carbon Fuels by 2050", elaborated by Concawe.
16. Including renewable fuels in the mix of options decreases the societal costs of the energy transition and provides flexibility (storing and transporting renewable electricity in a cost-effective way).
17. Increased deployment of renewable fuels will scale-up the GHG emission savings to reach 2030 GHG-reduction goals in the mobility sector and will also contribute to reaching the overall -55% reduction targets in 2030 and beyond.

7.1 Key-recommendations

Recommendations for the European Commission are:

- To include 100% (drop-in) renewable fuels as a main driver in the policy modelling activities in order to explicitly see their impact and contribution in the resulting policy option results.
- To carry out an assessment to determine the cost-effectiveness of various options from the perspective of:
- final consumers in the market, and
- the level of the transformation of the energy system as a whole, including the infrastructure section and constraints in rare earth metals supply chains.

Recommendations for Fuels Europe are

- To monitor the actual developments of electrification in the European consumer passenger market, including the used-car market. This monitoring helps to determine at an early stage the required volumes of renewable fuels. This is also required to understand the dynamics of the extended ETS on potential renewable fuel demand in the road sector.
- To open a policy dialogue at EU and Member State level that additional instruments are required to secure long-term stability of the capital service conditions for the built up of a green, circular refining system. The central supporting arguments for this are:

- scale-up the GHG emission savings to reach 2030 GHG-reduction goals in the mobility sector
- societal (for instance negative emissions)– economic benefits on the energy-system level
- to scale-up circular refining systems, currently under-represented in policy visions and instrumentation
- This would entail for the European refining sector to develop scenario's that explore how to further scale-up renewable fuels volumes above what is required for meeting (amended) RED 2-targets in 2030 and to prepare for a steep reduction pathway in the ETS immediately beyond 2030.