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Report

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Concawe's Transport and Fuel Outlook towards EU 2030 Climate Targets

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Concawe's Transport and Fuel Outlook towards EU 2030 Climate Targets

This report was prepared by:

Marta Yugo, Ehsan Shafiei, Linda Ager-Wick Ellingsen, John Rogerson

Under the supervision of:

M. Yugo (Concawe Science Executive)

Transport_LowCarbonPathways@concawe.eu

At the request of:

Concawe Fuels Quality and Emissions Management Group

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ABSTRACT

This Concawe report aims at providing an outlook on the European transport sector by modelling elements such as the evolution of the different powertrains and the availability of different alternative fuels over the period 2018-2030.

An analytical fleet-based model has been used, projecting the evolution of the fleet composition as well as the corresponding fuel demand towards 2030. The analytical tool is used to simulate different parameter combinations of vehicle and fuel (and thereof renewable fuel) technologies to assess fuel demand scenarios looking at vehicle fleet mix, fossil fuel demand, total renewable energy demand, and RED-II target. The composition of 2030 new vehicle sales has been defined based on market trends and experts' view, in compliance with the current 2030 CO_2 intensity targets for new sales in road transport. Besides this, a current and future estimate on both the total energy requirements and alternative fuel penetration have been included for other transport modes including aviation, rail and maritime sectors. The analytical tools evaluate fuel supply availability based on an updated market-based outlook on production plants currently in operation as well as the planned capacities for biofuels.

This study finally explores the compliance with RED II regulation and 2030 targets in a baseline scenario considering the impact of two different interpretations of using renewable electricity in the transport sector. Complementing the baseline, additional sensitivities on key individual parameters have been explored, mainly around the uptake of electric vehicles, bio-kerosene, biomethane, liquid biofuels, and gasoline fuel grades. The sensitivity analysis was conducted to show their individual impact on reaching the RED II targets, to inform the currently on-going process on future RED II targets for road transport (to be agreed in 2021).

KEYWORDS

Transport, Energy Demand, CO_2 Emissions, RED II Target, Well-To-Tank, Well-To-Wheels, Alternative Fuels

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Note. The Appendix of this report can be found with the following link: report no. 2/21A

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SUMMARY

Objectives:

This report aims at providing an outlook on the European transport sector by modelling elements such as the evolution of the different powertrains and the availability of different alternative fuels over the period 2018-2030. In this regard, **the main objectives** of this specific baseline outlook are:

- To conduct a thorough assessment for the progressive penetration of energy efficiency measures and different powertrain technologies into the EU vehicle fleet, combined with the market-based availability of alternative fuels and energy carriers.
- To assess the potential of various renewable alternative fuels, with focus on biofuels and electricity taking into consideration factors such as availability of supply, technology readiness levels and existing fleet constraints (only a very limited e-fuel production capacity is reported in the explored timeframe).
- To explore the current status of the potential of the EU transport sector to integrate renewable fuels and reduce GHG emissions towards 2030 (as a baseline), including the comparison of this baseline versus the currently in revision EU targets defined by the CO_2 standards in vehicles, the Renewable Energy Directive 2 (RED II) and the Fuel Quality Directive (FQD).
- To run sensitivity analysis on key parameters identified to show their individual impact on reaching the RED II targets, to inform the currently on-going process on future RED II targets for road transport (to be agreed in 2021).

Analytical tools:

In order to conduct the analysis, an analytical fleet-based model has been used, projecting the evolution of the fleet composition as well as the corresponding fuel demand towards 2030. The fleet model is based upon historical road fleet data (for both light- and heavy-duty vehicles) updated with recent statistics aggregated at European level (EU27 plus UK, Norway and Switzerland). Once the calibration has been conducted up to 2018, projections on the vehicle fleet are conducted towards 2030, including the effect of key parameters such as the potential composition of new sales in 2030 (meeting the CO_2 regulatory targets for both passenger cars and heavy-duty vehicles), scrappage rates, and expected efficiency improvements in different powertrains.

The modelled fleet composition leads to a road transport fuel demand and provides the basis upon which the introduction and availability of alternative fuels are explored to assess the total contribution of renewable energy and GHG emissions in transport. Besides this, a current and future estimate on both the total energy requirements and alternative fuel penetration have been included for other transport modes (aviation, rail and maritime sectors) and compared against current RED II targets.

Results:

The analytical tool is used to simulate different parameter combinations of vehicle and fuel (and thereof renewable fuel) technologies to assess fuel demand scenarios looking at:

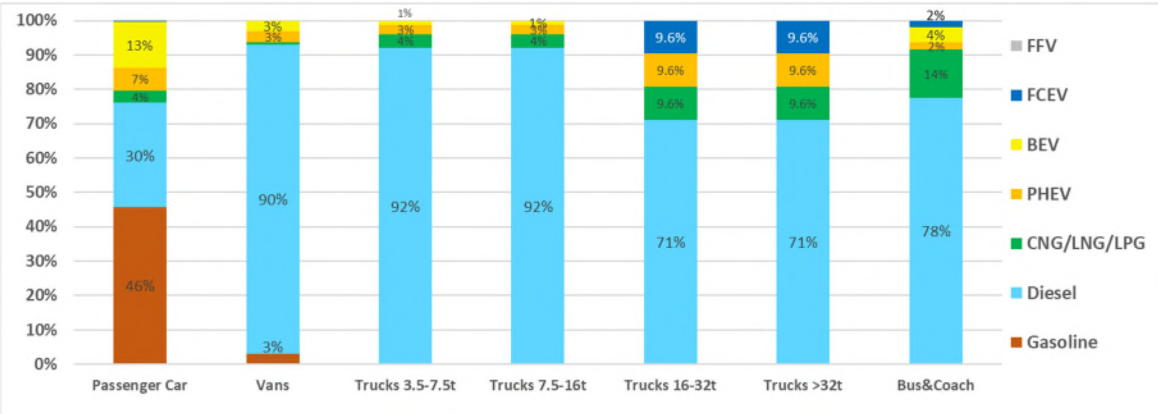
- Vehicle fleet mix;
- Fossil fuel demand and diesel/gasoline balance;

- Total renewable energy demand (including conventional and advanced biofuels);
- Renewable energy demand for transport to be used for achieving the RED-II and FQD targets.

a) **Fleet evolution/Energy demand:**

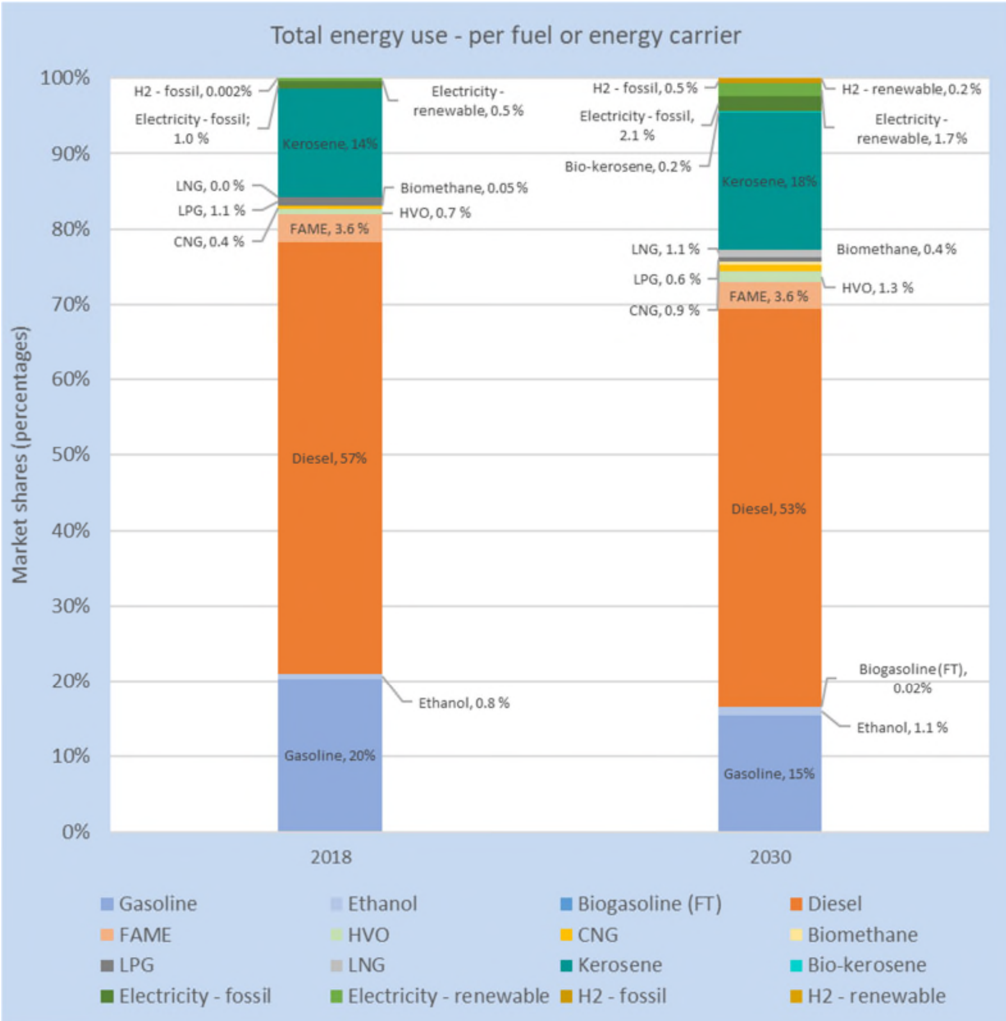
- The composition of 2030 new sales has been defined based on market trends and experts' view, in compliance with the current 2030 CO_2 intensity targets for new sales in road transport (expressed in NEDC terms for comparison purposes):
  - **Passenger cars:** 95 g CO_2/km in 2021 and further 37.5% reduction by 2030 (equivalent to **~59 g CO_2/km** NEDC in 2030 baseline).
  - **Light commercial vehicles** (vans): 147 g CO_2/km in 2020 and being 31% less TTW intensive than in 2020/2021 (equivalent to **~100 g CO_2/km** modelled in the 2030 baseline).
- **Heavy-duty vehicles**: 30% emissions reduction by 2030, compared to 2019 (for Trucks>16t in gCO_2/tkm) and a value of **536 g CO_2/km** as average for heavy-duty commercial vehicles in 2030.

Figure S1. New fleet sale mix in 2030 to meet CO2 emission target



- Overall, the share of alternative vehicles (including PHEV, BEV, FCEV, and CNG/LNG/LPG) in new sales for road transport accounts for ~24% for passenger cars (versus ~4% in 2018), 7% of vans (versus 1.9% in 2018), 8% of heavy-duty trucks <16t (versus 2.2% in 2018), 29% of heavy-duty trucks >16t (versus 0.5% in 2018), and 23% in the case of buses and coaches (versus 4.7% in 2018).
- As a result of the composition of the fleet and the fuel efficiency improvements towards 2030, the total energy demand in road transport has been estimated in 239 Mtoe/y. Besides the road segment, the evolution of aviation, rail and maritime sectors (international extra-EU trips considered), generally increasing their activity towards 2030, represents an additional ~80 Mtoe/y, resulting in an estimated **~318 Mtoe/y** energy demand for the **whole EU transport sector** in the 2030 baseline.

Figure S2. Breakdown per type of fuel (2018 vs 2030) and % market share



b) Energy supply and alternative fuel availability:

Liquid and gaseous (excluding H_2) fuels:

It is based on an updated outlook on production plants **currently in operation, under construction and recent announcements in Europe** (based on the STRATAS's 2017 database mapping the facilities worldwide, updated with recent announcements in Europe), maximising the current utilisation rate of existing plants towards 2030. These volumes are also complemented by additional imports, keeping the same domestically produced vs imported volume ratio in 2030 as today. As a conclusion, it is worth noting that:

- The current alternative fuel production (installed) capacity is still very based on food-crop biofuels and despite some recent announcements about new built plants in Europe, including the production of second-generation biofuels, the market-based signals seem to show a modest ramp-up, at least regarding the projects announced to the public domain.

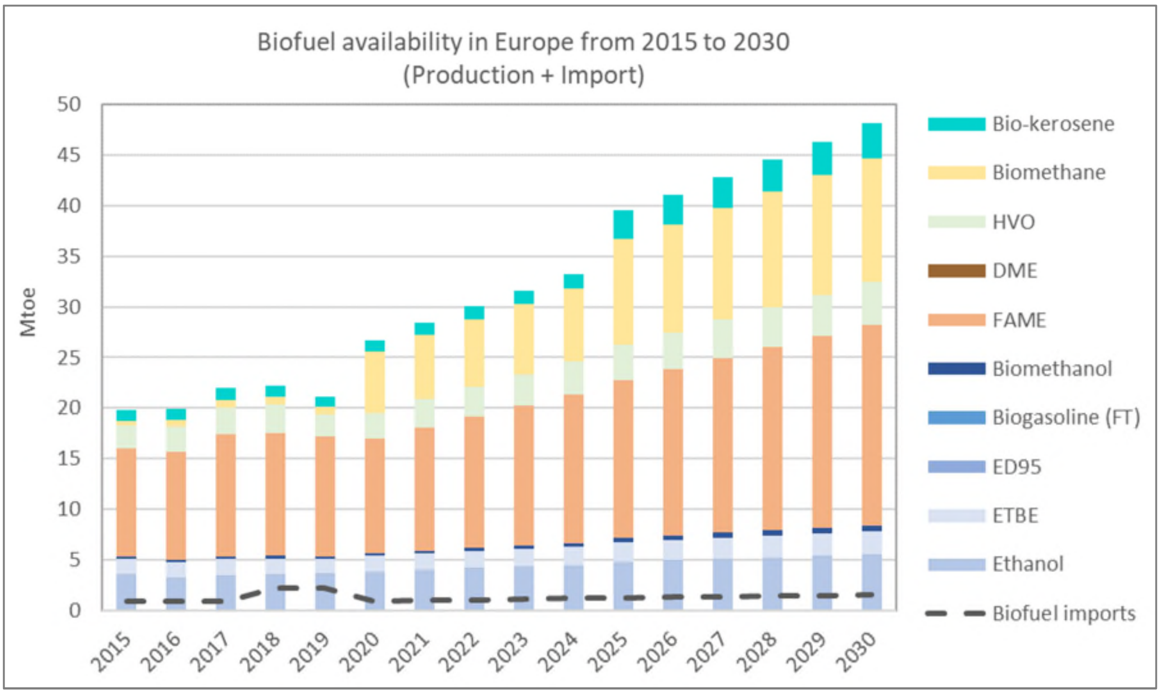
- Fully utilising the existing (installed) capacities in 2018 would be able to deliver an additional volume of ~11 Mtoe/y (100% utilisation considered at the end of the 2030 period). When all existing and new facilities are considered, the 2030 baseline reports a maximum technical availability of **~47 Mtoe/y** (based on the maximum installed capacity), of which only **~21 Mtoe/y** are deemed to be used in transport as a result of the energy demand modelled.

Electricity and hydrogen (as final fuels):

Due to the foreseen electricity demand in transport in the 2030 baseline (**~12 Mtoe/y** of total demand of electricity mainly in road and rail modes representing about 4% of the current gross generation capacity in EU27+3) as a simplification, no limitations on the EU electricity generation capacity have been assumed at this stage (meeting the additionality criteria).

Hydrogen production for transport applications is limited in the 2030 baseline (2.1 Mtoe/y as the total demand in the whole transport sector), where the majority is directed to road transport (2.0 Mtoe/y). Based on the current pace of development of renewable hydrogen in Europe, an increase in renewable hydrogen was assumed for road and rail applications (25% in 2030).

Figure S3. Estimated availability of various biofuel types in Europe. Note that ethanol and FAME includes import volumes as well



c) **RED II targets (baseline and sensitivity analysis)**

As the RED II "*framework on additionality in the transport sector*" (*article 27/point 3*) is in the process of being fully defined by the Commission, this study explores the impact of two different interpretations when this concept the renewable electricity is applied to the transport sector. The results of the baseline, in terms of the percentage of equivalent renewable energy versus the RED-II 14% minimum sub-target in road and rail transport by 2030 are presented below:

(1) Interpretation 1 (*Additionality criteria on renewable electricity in transport*): RES-T 15.6%

(2) Interpretation 2 (*Additionality criteria on total renewable installed capacity)*: RES-T 17.0%

Note that the difference between both interpretations is mainly due to the current electricity consumption in rail, helping meet the RED-II target. In both cases, all the sub-targets are met with the exception of the Annex A (min 3.5%) which, with the current market trends/announcements, is deemed to be at risk of being accomplished.

When the compliance with **RED II regulation** is explored, the 2030 baseline shows that:

- The multipliers boost the contribution of electrically-driven powertrains and the role of biofuels in transport in compliance with RED-II up to a total of 15.6% (Interpretation 1) and 17.0% (Interpretation 2) in the baseline.
- The **impact of these multipliers** is significant and deemed to represent **~5–6% in energy content** within the current baseline (without multipliers, absolute renewable energy share would represent 10.3% (Interpretation 1) and 11.1% (Interpretation 2)).
- Renewable electricity use in transport represents 3.9% (Interpretation 1) and 5.4% (Interpretation 2) of the total renewable energy in transport (RES-T) target (with multipliers) while the contribution of biofuels is ~11.5% (5.3% of which corresponds to advanced biofuels).
- Based on both the expected availability and blending walls, the share of first-generation (crop-based) biofuels remains below the imposed cap (max 7%).
- Regarding advanced biofuels, while the **physical cap on Annex IX Part B** is respected (1.7%), the minimum requirement on Annex IX Part A is not reached (2.2% vs the 3.5% min defined in RED II).
- Based on these results, additional investments/supports on alternative fuels (including liquid, gaseous and electricity) will be required to realise their potential towards 2030, versus current trends/public announced projects.

Complementing the baseline, additional sensitivities on key individual parameters have been explored. The following table summarises the main findings of the sensitivity analysis.

Table S1. Summary of the sensitivity analysis considering a change in model parameters

Case	RED-II % Interpretation 1	RED-II % Interpretation 2	Key Outcome
Baseline	15.6%	17.0%	
30% BEV+PHEV in 2030 sales	16.4%	17.8%	Additional sales of 1.6 million new EVs in 2030 raises RED-II by ~0.8%
5% bio-kerosene in 2030 aviation fuel	16.7%	18.1%	Rising RED-II by 1.1%. Compliance with the food-crop based feedstock cap could be at risk depending on the primary feedstocks selected for the conversion processes.
Higher HVO use to reach min 3.5% Annex A feedstock	16.9%	18.4%	The use of feedstock A is about 60% higher than baseline
40% share of biomethane in total gas	16.8%	18.3%	Towards meeting all RES-T targets and biofuel feedstock sub-targets with Annex A at risk (3.4%)
1.7% administrative cap on Annex B feedstocks	14.1%	15.6%	1.5% lower RED-II compared to baseline
E10 limited uptake (78% of fuel grades by 2030)	15.4%	16.9%	Slight reduction in RED-II by 0.2%
Only E5 grade (theoretical assessment)	14.6%	16.1%	~1% reduction in RED-II
Liquid biofuels in 2030: 20% in maritime and 10% in non-electric rail	16.0%	17.5%	Small increment of 0.5% in RED-II
LNG trucks (>16t segment) with dual-fuel HPDI technology in 2030	15.5%	17.0%	Very small decrease in RED-II due to lower use of biomethane

In summary, regarding the RED-II targets:

- All sensitivity cases meet the RED II target.
- The share of first-generation crop-based feedstocks was successfully kept below the 7% cap under all conditions.
- Reaching the target of 3.5% Annex A feedstocks can be obtained in the sensitivity case of 3x increase in HVO use. Approaching this target was also observed in the case where diverted (or additional production) of biomethane replaced at least 40% of fossil CNG/LNG in transport. Biomethane is envisaged to be a key potential player when reaching RED-II targets in the current market-based scenario. It is important to remark that the higher use of biomethane in transport may not imply any additional GHG reduction versus the baseline unless the whole energy system is considered (potential risk of shifting GHG reduction among sectors).

d) GHG reduction (towards FQD targets):

At the moment of publication of this report, the revision of the **FQD directive** is being undertaken by the EU COM. The results of the assessment based on the accounting routes and Well-To-Tank intensity factors considered in this Concawe report are summarised in the following table. The 2030 baseline estimates a GHG intensity reduction in road transport fuels in 2030 of **8.8%** versus 2010. The results of the 2030 baseline are intended to be used to inform the ongoing revision.

Table S2. Baseline results for road transport fuels in terms of GHG intensity reduction in road

Year	GHG Emissions (Mt CO_2-eq)	Energy Use (Mtoe)	Emission Factor (g CO_2-eq/MJ_{fuel})	GHG intensity reduction from 2010
2030	857	238	85.8	-8.8 %

It should be noted that the 2018 baseline does not represent any individual company's views, and is the result of a consensus prior to the publication of the EU's 2030 Impact Assessment. The modification of various parameters (some of them already explored as sensitivities in this analysis) or any additional policy considerations (e.g. the use of renewable fuels of non-biological origin (RFNBO), electrolytic hydrogen and e-fuels versus electricity) could have an impact, and could effectively enable a higher penetration of renewable energy in the transport sector.

1. INTRODUCTION AND METHODOLOGY

1.1. SCOPE AND OBJECTIVE

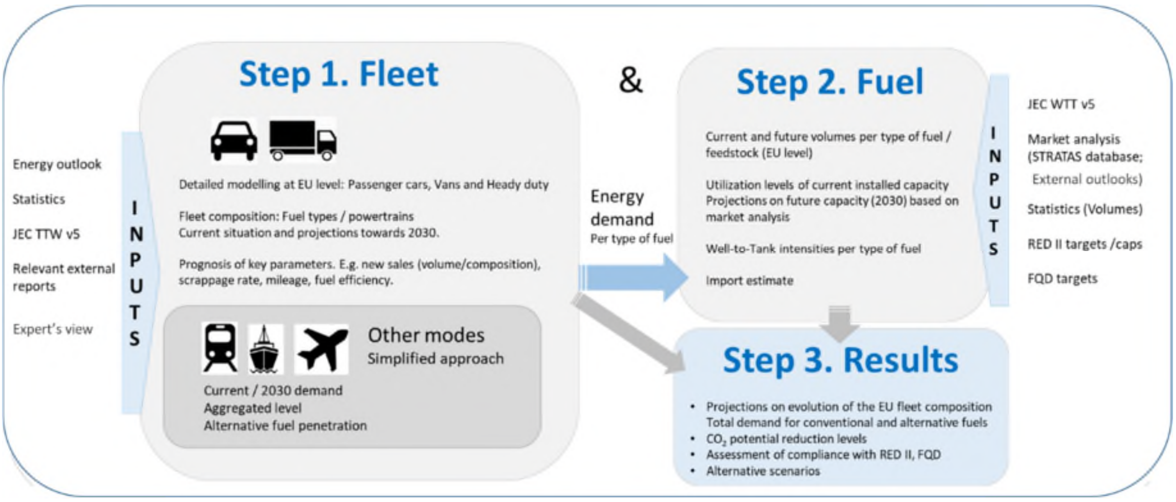
The scope of this fuel outlook is:

- To estimate a **fuel demand baseline scenario** in the EU transport sector towards 2030.
- Through a detailed fleet modelling exercise of both Light- and Heavy-Duty segments, the potential penetration of alternative powertrains and energy efficiency measures is investigated. The currently in place 2030 CO_2 standards for road transport are met as the baseline for future alternative scenarios. Other modes (aviation, maritime and rail) are also investigated following a more simplified approach.
- To integrate a market-based outlook on the potential **availability** of alternative fuels (**supply**), replacing conventional oil-based fuels at EU level for the same timeframe.
- To assess the total impact of the combination of energy efficiency measures and alternative powertrains and fuels to reduce GHG emissions and energy demand in EU transport by 2030.
- To inform the on-going definition of new 2030 EU targets for transport by comparing the GHG reduction and penetration of renewable energy in transport in this market and industry-based scenario (as well as additional sensitivity cases) versus the current 2030 EU Renewable Energy Directive 2 and Fuel Quality Directive targets.

1.2. METHODOLOGY

The methodology to define the baseline for the **2030 fuel supply and demand** in the EU transport sector follows a three-step approach as defined in the figure below:

Figure 1. Methodology followed in the fuel supply & demand outlook presented in this report



How are the fleet projections estimated?

The fleet modelling tool used covers the road vehicle fleet development and the resulting demand for fossil fuels and biofuels and aggregated for 30 European countries (EU27 plus UK, Norway and Switzerland). The model has been developed to enable projections towards the year 2030 based on a set of assumptions.

The model is a spreadsheet-based tool for passenger cars, light-duty commercial vehicles and heavy-duty vehicles including buses and coaches. The model also has the facility to report on the use of each type of fuels (including biofuel breakdown), greenhouse gas (GHG) emissions, share of renewable energy used in each segment and calculate the outcome of the Fuels Quality Directive and the Renewable Energy Directive when applied to the different scenarios and sensitivities.

The key assumptions in the model are: new registrations, fleet stock levels, fleet fuel efficiency and annual vehicle mileage. As a summary:

- Passenger car (PC):
  - PC fleet parameters, for example, new registrations and stock
  - Alternative powertrains (see more details in Section 2.1)
  - Fleet average annual mileage
  - Vehicle fleet fuel consumption and related CO_2 efficiency[1]
- Light commercial vehicles (LCV) or vans
  - LCV fleet parameters: new registration and stock
  - Alternative powertrains
  - Average annual mileage
  - Vehicle efficiency vs. diesel or gasoline vehicle efficiency
- Heavy-duty vehicles (HDV):
  - HDV fleet parameters (such as new registrations and stock per class category)
  - Alternative powertrains penetration
  - Alternative powertrains efficiency vs. diesel vehicle efficiency.
  - Average annual activity per vehicle class category, either as ton kilometres (tkm) or passenger kilometres (pkm) as appropriate.
  - A complete set of assumptions can be found in the Appendix of this report.

Motorcycles are excluded from this modelling, as they only contribute to 1% of all transportation GHG emissions in EU28 (Roland Berger, 2016).

An extensive review of statistics, database, market trends, external outlooks and expert's view gathering has been conducted to calibrate this fleet model. Linear growth patterns have been assumed for forward predictions to 2030 for the major fleet parameters. Besides this, sensitivity cases on key parameters are also explored to investigate the impact on 2030 EU targets. A comprehensive set of assumptions can be found in the Appendix of this report.

[1] For PHEV there is a proportion for the combustion engine efficiency and a proportion for the EV, scaled for the amount of driving in EV mode.

Due to simplifications made and estimates used, the model has not to be considered as a tool for cost optimized strategies but rather looking at a variety of scenarios of fleet and fuel development based on informed and expert views. Therefore, the assumptions made should not be considered as a forecast of or commitment to the future availability of vehicle technologies or vehicle features.

What alternative fuels are included in the baseline?

The result of the model is the fuel consumption estimate and each type of fuel is reported out in PJ/a and Mtoe/a. The model is capable of calculating also the alternative fuel usage as it relates to the Renewable Energy Directive recast (RED-II) and the Fuels Quality Directive (FQD).

For the purposes of this report, alternative fuels (according to Directive 2014/94/EU, Article 2) are ''Fuels or power sources which serve, at least partly, as a substitute for fossil oil sources in the energy supply to transport and which have the potential to contribute to its decarbonisation and enhance the environmental performance of the transport sector. They can be liquid, gaseous or electricity''

In this context, the followings are being considered as examples of alternative fuels (detailed in the JEC WTT v5 report (Prussi, et al., 2020)) and most of them included in the fleet and fuel model depending on the expected availability and/or penetration in the 2030 timeframe:

Table 1. Alternative fuels

Alternative fuels (Examples)		
Liquid	**Gaseous**	**Electricity**
• Ethanol • Hydroprocessed vegetable oils (HVO) • Fatty acid methyl esters (FAME) • Hyroprocessed Esters and Fatty Acids (HEFA) • Synthetic gasoline and diesel from biomass/waste • Synthetic gasoline and diesel via Power-to-Liquid. • Liquefied natural gas (LNG) • Liquefied petroleum gas (LPG) • Liquified upgraded biomethane • Liquified synthetic methane from biomass gasification • Liquified synthetic methane via Power-to-Gas routes • Methanol • ED95	• Hydrogen • Compressed natural gas (CNG) • Compressed upgraded biomethane • Compressed synthetic methane from biomass gasification • Compressed synthetic methane via Power-to-Gas • DME	Electricity

1.3. REGULATORY FRAMEWORK

A number of EU regulations and directives target GHG emissions reduction in the road transport sector; this normative framework has been considered in developing the current analysis.

1.3.1. Fuel Quality Directive – FQD 7a [Directive 2009/30/EC]

The fuel supply industry is regulated via the FQD. The FQD 7a set a minimum 6% reduction target in GHG intensity by 2020 for road transport fuels, compared to 2010 levels. This is accompanied by a definition of sustainability criteria for biofuels.

1.3.2. Renewable Energy Directive – RED II [Directive 2018/2001/EU]

In December 2018, the revised renewable energy directive was adopted. In RED II, the overall EU target for Renewable Energy Sources consumption by 2030 has been raised to 32%, with a specific minimum share of 14% of the energy consumed in road and rail transport by 2030 as renewable energy where aviation and maritime sectors are also eligible towards the target (See Section 5.3.1 for more details).

1.3.3. New Light-Duty Vehicle CO_2 emissions [EC 333'/14, EC 253'/14 and Regulation (EU) 2019/631]

CO_2 emissions from vehicles are regulated via obligations on OEMs (original equipment manufacturers, i.e. carmakers) via vehicle CO_2 emissions targets[2]. This affects fleet CO_2 emissions of new passenger cars and vans. Average CO_2 emissions for all new passenger cars are to be lowered from 130 g/km (2015) to 95 g/km by 2021. This reduction is a step-by-step approach until 2021 and represents a reduction of 40% compared with the 2007 fleet average emission of 158.7 g CO_2/km.

New light commercial vehicles (vans) need to meet a target of 175 g CO_2/km by 2017 and 147 g CO_2/km in 2020. New EU fleet-wide CO_2 emission targets are set for the years 2025 and 2030, both for newly registered passenger cars and newly registered vans (Regulation (EU) 2019/631).

These targets are defined as a percentage reduction from the 2021 starting points:

- Cars: 15% reduction from 2025 on and 37.5% reduction from 2030 on.
- Vans: 15% reduction from 2025 on and 31% reduction from 2030 on.

The specific emission targets for manufacturers to comply with are based on the EU fleet-wide targets, taking into account the average test mass of a manufacturer's newly registered vehicles. A zero- and low-emission vehicles (ZLEV) are defined in the Regulation as a passenger car or a van with CO_2 emissions between 0 and 50 g/km. (Commission, Post-2020 CO2 emission performance standards for cars and vans, 2019). However, these values may be subject to further revision by 2023 (as described in the revision clause (Article 15) below and potentially to any additional modifications as a result of the Green Deal revision in 2021.

Extract from Article 15: *[…] The Commission shall, in 2023, thoroughly review the effectiveness of this Regulation and submit a report to the European Parliament and to the Council with the result of the review. The report shall, where appropriate, be accompanied by a proposal for amending this Regulation, in particular, the possible revision of the EU fleet-wide targets for 2030 in light of the elements listed in paragraph 2, and the introduction of binding emissions reduction targets for 2035 and 2040 onwards for passenger cars and light commercial vehicles to ensure the timely transformation of the transport sector towards achieving net-zero emissions in line with the objectives of the Paris Agreement. […]*

[2] https://ec.europa.eu/clima/policies/transport/vehicles/cars_en

1.3.4. New Heavy-Duty vehicle CO_2 emissions (Regulation (EU) 2019/1242)

In 2019, Europe adopted the first-ever EU-wide CO_2 emission standards for new heavy-duty vehicles (HDVs), the Regulation (EU) 2019/1242, setting CO_2 emission standards for heavy-duty vehicles entered into force on 14 August 2019.

HDV manufacturers will have to meet the targets set for the fleet-wide average CO_2 emissions of their new vehicles registered from 2025, with stricter targets foreseen from 2030 on. The targets are expressed as a percentage reduction of emissions compared to EU average in the reference period (1 July 2019–30 June 2020):

- from 2025 onwards: 15% reduction
- from 2030 onwards: 30% reduction

In 2022, a revision is foreseen and by 2023, the Commission shall evaluate the possibility of developing a common methodology for the assessment and reporting of the full life-cycle CO_2 emissions of heavy-duty vehicles. As part of the 2022 review, the Commission should assess the extension of the scope to other vehicle types such as smaller lorries, buses, coaches and trailers.

The monitoring and reporting Regulation require that, as of 1 January 2019, Member States monitor and report to the Commission information on the heavy-duty vehicles registered for the first time in the Union; and lorry manufacturers monitor and report to the Commission CO_2 emission and fuel consumption data as determined pursuant to the certification Regulation for each new vehicle produced for the EU market. This information will be calculated using the Vehicle Energy Consumption Calculation Tool (VECTO)[3].

1.3.5. Worldwide Harmonized Light Vehicles Test Procedure WLTP

Along with CO_2 emissions reduction, a new test procedure aimed at measuring fuel consumption and vehicle CO_2 emissions will replace the existing New European Driving Cycle (NEDC): The Worldwide Harmonized Light-Duty Vehicles Test Procedure (WLTP). The introduction of the WLTP aims to reduce the gap between CO_2 emissions certified in the laboratory and those experienced under real driving conditions. Until 2020, WLTP will have no effect on the average CO_2 emissions target for new vehicles defined by NEDC.

[3] VECTO is a simulation software that can be used cost-efficiently and reliably to measure the CO_2 emissions and fuel consumption of heavy-duty vehicles for specific loads, fuels and mission profiles (e.g. long haul, regional delivery, urban delivery, etc.), based on input data from relevant vehicle components.

2. BASELINE DEFINITION: FLEET COMPOSITION AND MODEL CALIBRATION

As presented, the current model covers EU27+3. It uses historical data from the Tremove database (Tremove, 2014), updated with the latest statistical data (ACEA, ACEA-pocket-guide, 2019) (ACEA, Registrations-and-press-release-calendar, 2019) for new registrations and stock.

2.1. PASSENGER CARS (PC)

- The major inputs available within the model can be summarized as follow:
- Stock: total fleet mileage by % Year-on-Year (YoY) growth, new registrations,
- g CO_2/km (emission intensity),
- Share of diesel and gasoline of new registrations, %
- Alternative fuel types in new registrations:
  - Compressed Natural Gas (CNG),
  - Liquefied Petroleum Gas (LPG),
  - Flexible Fuelled Vehicles (FFVs),
  - Battery Electric Vehicles (BEVs) and Plug-in Hybrids (PHEVs),
  - Fuel Cell Electric Vehicles (FCEV)
  - % BEV of EVs (BEV + PHEV),
  - Share of Electric driving (e-driving) in PHEV.

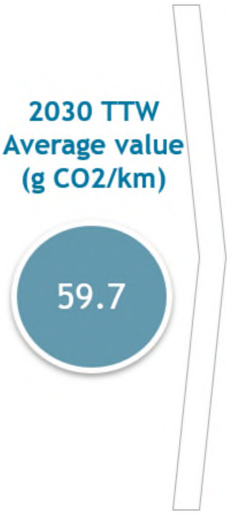
The composition of the fleet and the TTW CO_2 assumptions are shown in **Figure 2**. This data for the composition of the fleet and the TTW CO_2 assumptions were derived following a careful analysis of the JEC TTW study v5 (JEC, 2020). It is worth reminding that in the report only C-segment passenger cars is used as reference for the best available technology for 2025 onwards; therefore, this is to be considered as an estimate and cannot be considered as fully representative of all new registrations.

The fleet model has historically used NEDC figures for the calculation of TTW CO_2 emissions and for vehicle fuel consumption. The JEC TTW v5 report calculated C-segment technology TTW emissions on a WLTP basis. The expert group decided to convert these WLTP figures to NEDC using the JRC conversion factors reported in several publications from the European Commission[4] to ensure continuity with the historical data (JRC, 2017).

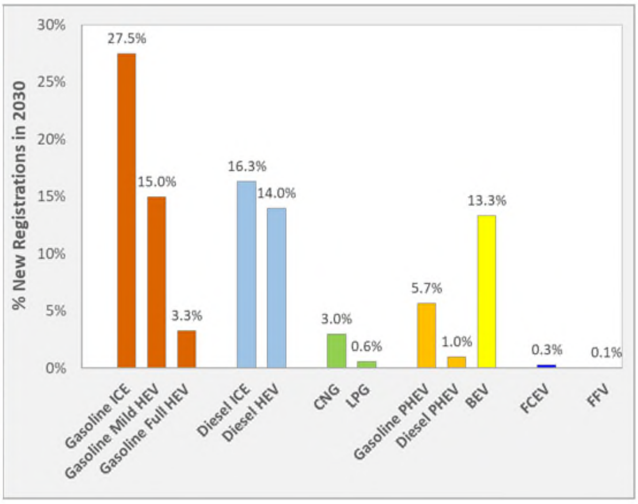
With the 2030 powertrain share, the corresponding NEDC TTW contribution for the C-segment technology, these numbers were combined and then proportioned to meet the 59.7 g/km fleet CO_2 target (equivalent to 37.5% reduction compared to 2021 (95 gCO_2/km) as defined in Regulation (EU) 2019/631).

[4] https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/nedc-wltp-effect-type-approval-co2-emissions-light-duty-vehicles
https://www.sciencedirect.com/science/article/pii/S0965856417312831

Figure 2. NEDC emission figures and new registration for new passenger car sales in 2030



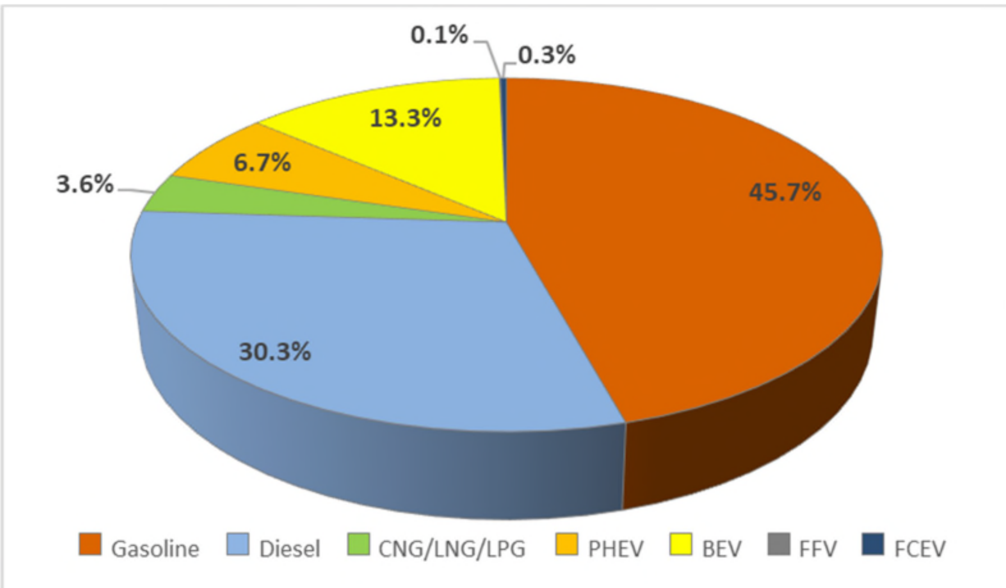
Powertrain	2030 gCO2/km (NEDC)
Gasoline ICE	85
Gasoline Mild HEV	66
Gasoline Full HEV	58
Gasoline PHEV	8
Diesel	80
Diesel Mild HEV	61
Diesel Full HEV	60
Diesel PHEV	8
CNG	58
LPG	81
BEV	0
FCEV	0
FFV	83



It has to be noted that the baseline is not representing any individual company views and it is the result of the consensus within the consulted experts prior to the publication of the Green Deal. The objective is to offer a market and industrial view to inform the on-going discussion on the new 2030 transport related targets.

The aggregated simplified powertrain shares for new registrations in 2030 (baseline) are shown in **Figure 3**, aiming to comply with the current 2030 CO_2 standards.

Figure 3. Powertrain share for new registrations in 2030



Note: Gasoline and diesel categories refer to internal combustion engines with different level of hybridization (see more granularity in **Figure 2**).

Some relevant comments regarding the assumptions:

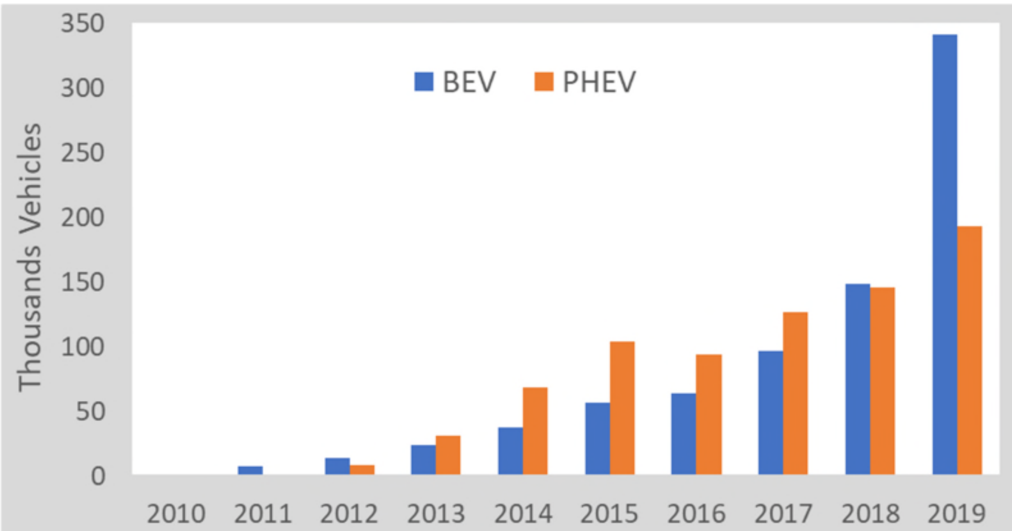
a) Full hybrids and mild hybrids

The 2030 gasoline sales were split between 60% Internal Combustion Engines (ICE) and 33% Mild Hybrid (MH), as used in the French Automotive Organization (*La Plateforme automo*bile – PFA) (Brossard & Duquesnoy, 2019), and 7% full hybrid (higher than the value reported by (Roland Berger, 2016).

b) Electric Vehicle (BEV / PHEV) shares

The 2030 EVs (BEVs/PHEVs) share in new sales has been assumed to be 20% which, together with the assumptions in terms of energy efficiency, could help meet the current 2030 trends. A higher share of 30% reported in other recent studies, e.g. (IEA, 2020), (Deloitte, 2020), is also taken into account as a sensitivity case. Within this study, a **split of 1/3 PHEV and 2/3 BEV** is assumed for EV registration in 2030 (consistent with recent trends shown by Figure 4 and the proposed values by (IEA, 2020) and (Deloitte, 2020).

Figure 4. Electric cars registered in the EU-27, Iceland, Norway and the United Kingdom (EEA, 2019)



c) Diesel share

In recent years, the diesel share of new registrations in EU has fallen from ~55% in 2013 to ~37% in 2018 (Eurostat, 2020). Based on the recent falling trend, the proposed baseline for the fleet model assumes a slower reduction rate towards 2030 to reach about 30% by 2030. This assumption, which is in line with (Emisia, 2019), reflects a reduction of new diesel sales with the expectation that the reduction rate versus gasoline will recover somewhat from present values. Looking at 2030 new sales, the 30% of diesel new car registrations are split 16% diesel ICE and 14% diesel hybrid, this is broadly in line with the PFA study (Brossard & Duquesnoy, 2019). Diesel PHEV's are grouped separately in the PHEV assumptions.

d) Gaseous fuels: CNG, LPG, H2

For CNG, 3% new registrations were assumed for 2030, in line with JEC Biofuel Study (JEC, 2011) and (Roland Berger, 2016). The sales of LPG vehicles adopt Roland Berger assumptions (0.6%).

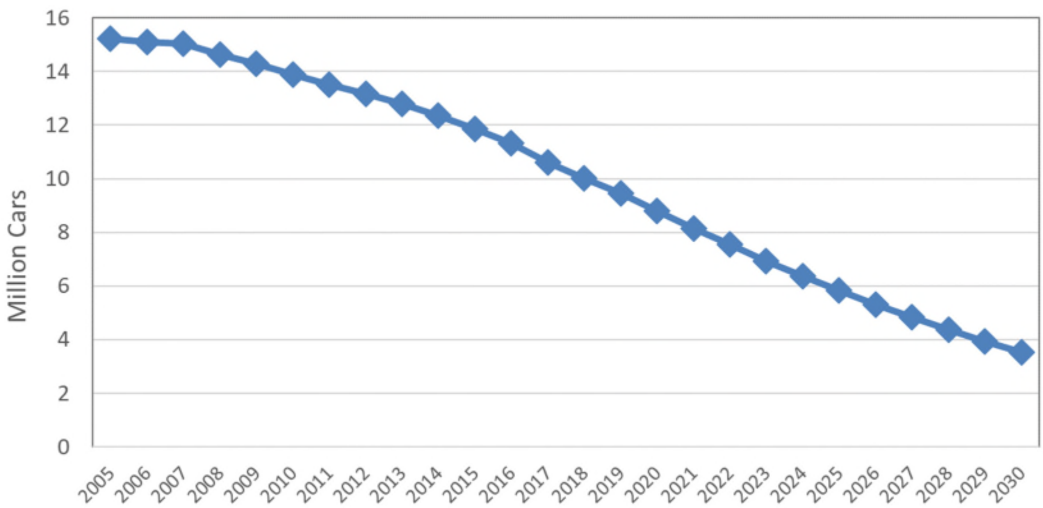
It is assumed that Fuel Cell Vehicles will reach 300,000 by 2030 (Note that this is notably lower than the 800,000 FCEVs by 2030 proposed by the Hydrogen Council). Flex-fuelled vehicles are assumed to have a low penetration, 0.1%, as there is no aggressive deployment foreseen in the supply infrastructure. This assumption is in line with Roland Berger assumptions.

2.1.1. Passenger Car Stock

The passenger cars sales can be correlated to GDP and customer purchase behaviour (e.g. car sharing); in this study, new passenger car sales are assumed to increase with the annual growth rate of 0.11% per year, reaching about 16 million cars by 2030. The passenger car stock has been increased at a lower rate than the historical year-on-year (yoy) growth rate, to reflect a higher scrappage rate as customers may change their behaviour due to access restrictions in cities.

Sales and passenger car stock sizes are linked. In the model, a scrappage function is set up in which the total number of vehicles to be scrapped is distributed over the age profile of an individual car model year. The older the vehicle in the model year, the higher the number of scrapped cars, following a typical S-shaped distribution curve observed in TREMOVE. In updating the fleet model, the scrappage functions have been tuned to obtain an average fleet age in line with the data available from statistics.

Figure 5. Year 2005 model passenger car survival curve



The model contains historical data and based on the input parameters, predicts future road vehicle fleet development in EU27 +3 countries. As an example, the baseline prediction of powertrain types in new sales and the share of the powertrains in the total stock are given in the figures below.

Figure 6. Fleet model output: powertrain types in new sales

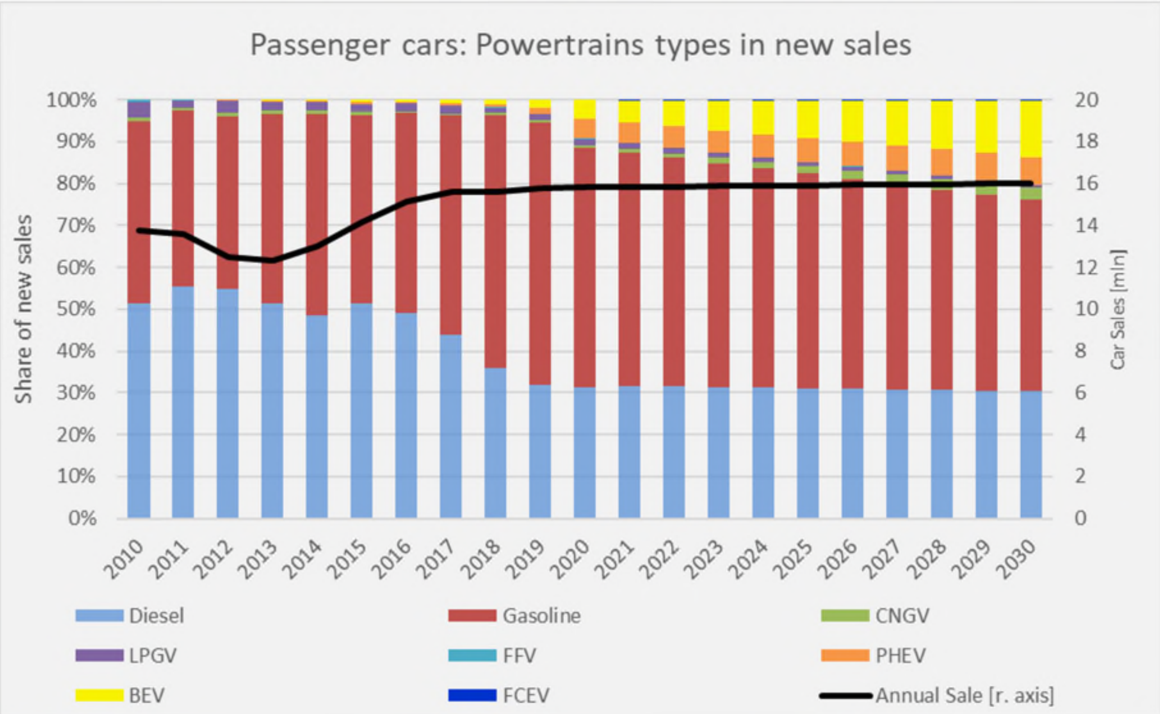
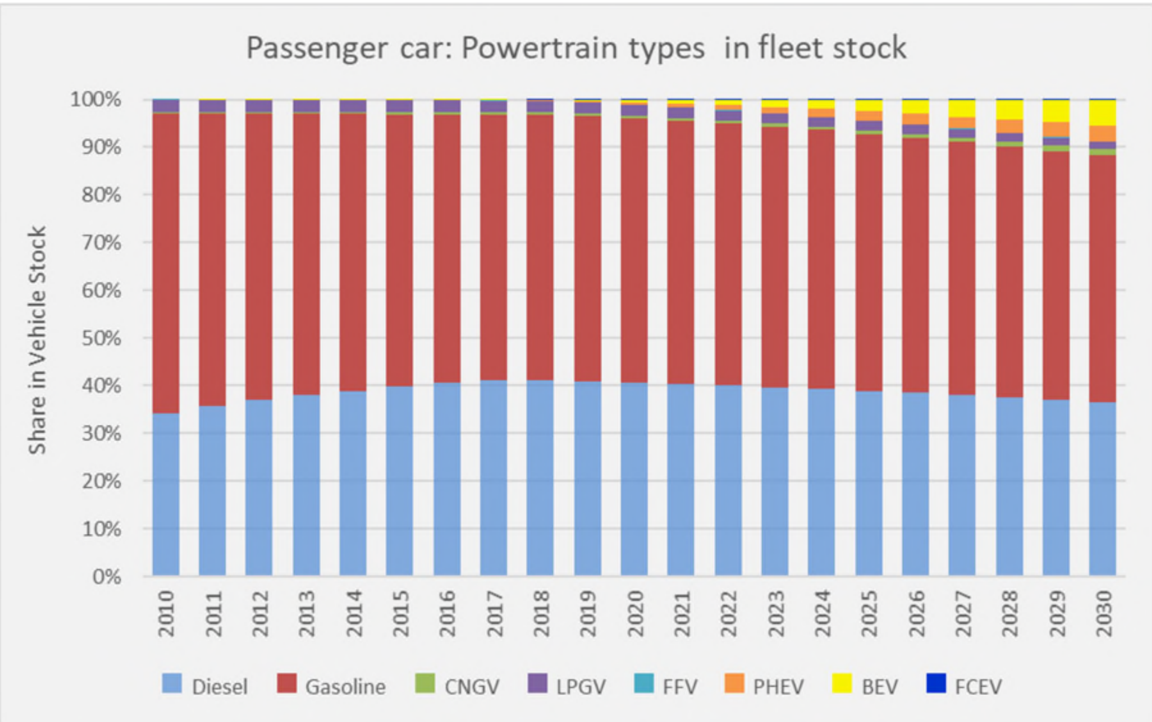


Figure 7. Fleet model output: powertrain types in the fleet stock



Due to the uncertainty about the post-COVID recovery, the baseline analysis of fleet composition assumes no impact towards 2030. The average vehicle mileage is predicted to reduce from about 12,000 km/yr in 2018 to 11,250 km/yr in 2030 (Roland Berger), this is attributed to a slow population growth in Europe, a demographic change resulting in a larger percentage of the elderly with lower mobility requirements, as well as a gradual modal shift towards public transport. This will deliver a relatively constant level of fleet kilometres as there is an increase in the number of vehicles in the stock. The JEC TTW v5 data suggests that with increased battery size allocation for PHEV's, the percentage of distance running on electric drive should be approximately 90% by 2030. The assumptions and settings for the other model inputs are listed in the **Appendix**.

2.1.2. Model Calibration for Ethanol Grades

The model only accommodates three grades of gasoline (E5, E10 and E85). The assumptions for these grades are summarized below:

a) *Grade 1 gasoline* (E5)

- Data for 2010 only has two grades: E0 and E5 (23% of E0 and 77% of E5). This gives E5 a concentration equivalent to 3.85% ethanol.
- Thus, for the baseline in the model, the setting for *Grade 1 gasoline*, nominally E5, was set as a constant factor of 3.95%, introduced in 2010, with a ramp up in volume from 2005 (The actual values used in the model calculations are at 0.1% volume below the model input values, to allow for blending tolerances in the market).

b) *Grade 2 gasoline* (E10)

- *Grade 2 gasoline*, nominally E10, was phased into the model from 2010, at 10% volume.
- The phase-in for Grade 2 used the default ramp up in the model up to 2017 and then the introduction is accelerated to 100% in 2030 in the baseline case, rather than the default values in the model (78% in 2030).

The total gasoline and ethanol content for 2018 is compared to published data by Eurostat in **Table 2**, this shows the model is in good agreement with the published data:

Table 2. Comparison between fleet model output and Eurostat data in 2018 (Eurostat, 2020)

Year 2018	Fleet model	Eurostat[5]
Gasoline (Mtoe/a)	76.6	77.9
Ethanol (Mtoe/a)	2.97	3.01

Figure 8 presents the fleet and fuel demand predictions for gasoline and ethanol usage from 2005 through 2030. The figure is based on full E10 ramp-up and represents the baseline scenario. Note that two separate sensitivity analyses in Section 5 consider E5 uptake only and E10 ramp-up based on extrapolation of historical data.

[5] Eurostat complete energy balances: https://ec.europa.eu/eurostat/databrowser/view/NRG_BAL_C/default/table

Figure 8. Predicted gasoline and ethanol usage to 2030

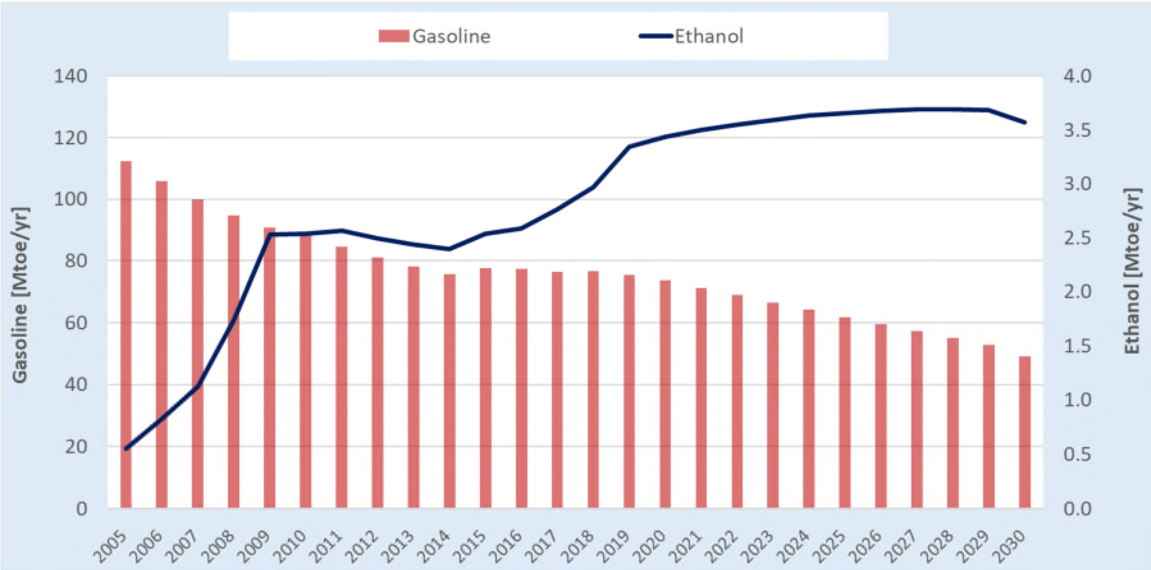
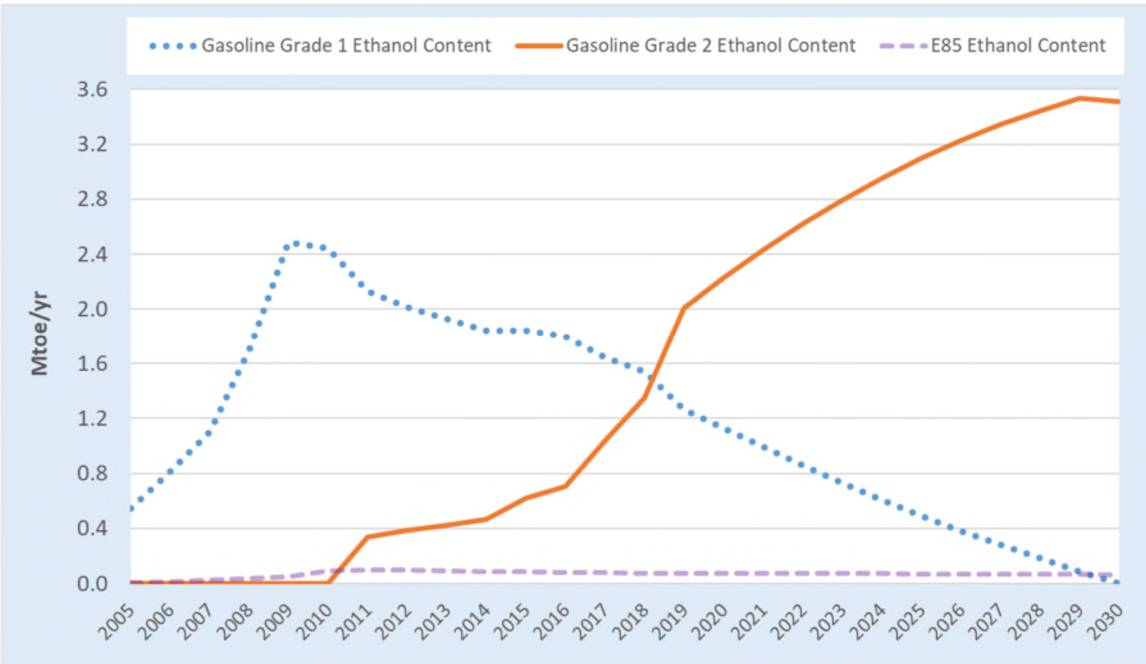


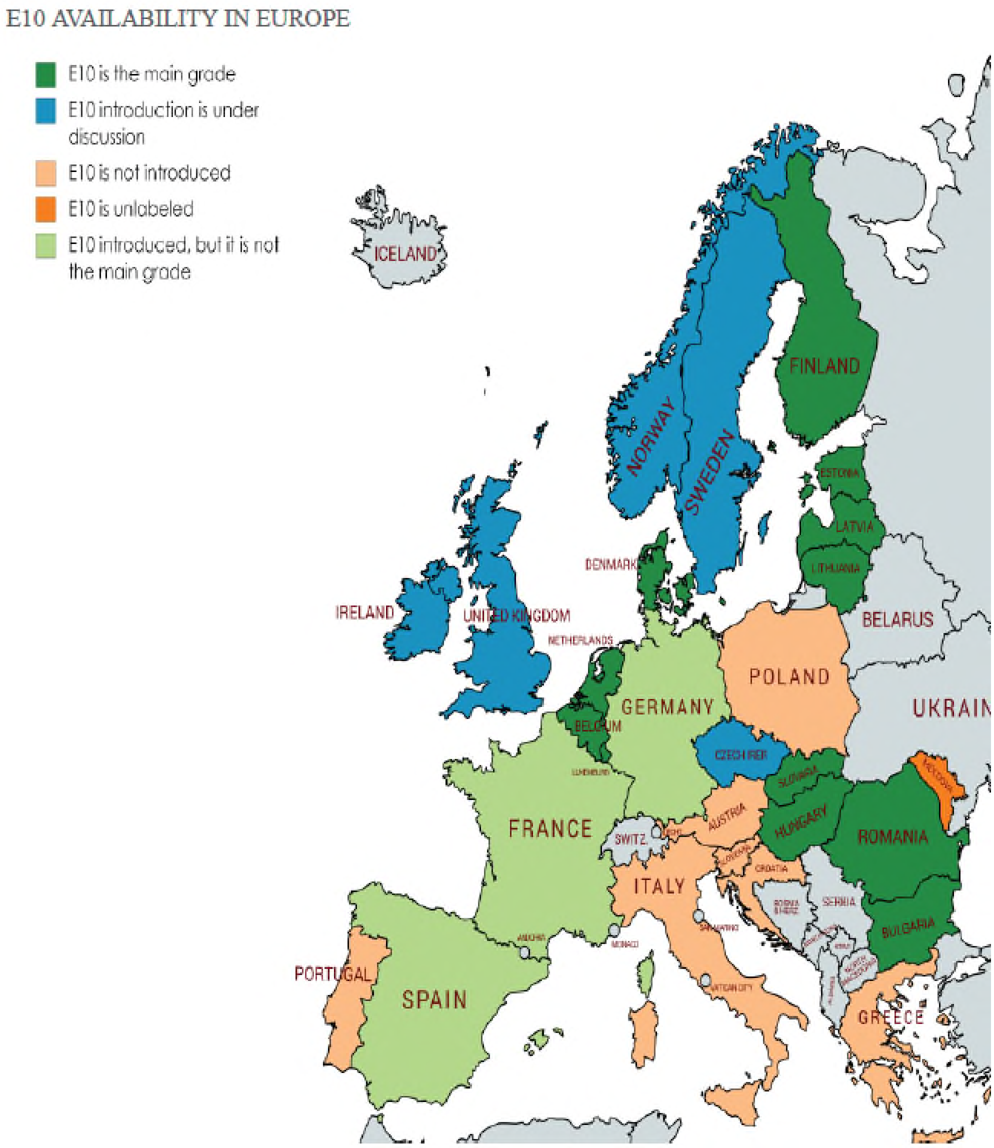
Figure 9 shows the estimated ethanol use in various grades used in the baseline.

Figure 9. Ethanol usage in various grades



Despite the fact that FQD allowed sales of the E10 grade since 2009, only a few countries initially decided to deploy E10 in their markets as part of their biofuels compliance: France, Germany, and Finland. Several countries have recently (2019, 2020) introduced the gasoline grade E10 (Denmark, Hungary, Slovakia, Latvia, Lithuania, and Spain). Numerous countries still distribute only E5 grade: Poland, Italy, Greece, and Portugal (SGS INSPIRE, 2020).

Figure 10. E10 availability in Europe (Figure from SGS Inspire (2020))



2.2. LIGHT COMMERCIAL VEHICLES (LCV)

For vans and other light commercial vehicles, the main inputs can be summarized as:

- new registrations by % YoY growth,
- stock by % YoY growth,
- activity by % YoY growth,
- energy use (MJ/km)
- emission intensity (g CO_2/km),
- % alternative fuel vehicle types in new sales (CNG, LPG, FFV, PHEV, BEV, FCEV, Dimethyl Ether (DME) and 95% Ethanol (ED95)).

The Roland Berger study reports, based on the current market situation and expert assessments, an expected, significant increase in the share of alternative powertrains for LCVs in the coming years. Hybrids (mild, full and plug-in hybrids) are expected to be the most important alternative powertrains.

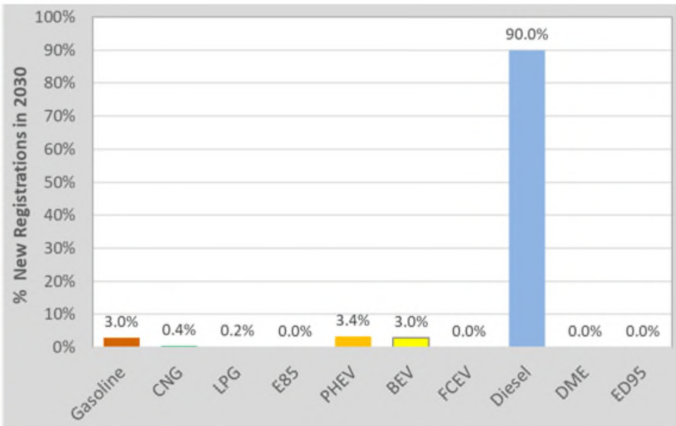
The composition of the fleet and the assumed TTW CO_2 assumptions are shown in **Figure 11**. The assumed fleet composition has been found in good agreement with the Roland Berger report. TTW CO_2 figures reflect legislative targets (Note: the 2030 value in the following figure is assumed to be 31% less than 2020 as the target for 2021 is not given).

Figure 11. NEDC figures and new registration for light-duty commercial vehicle sales in 2030

2030 TTW Average value (g CO2/km)

101.6

Powertrain	2030 gCO2/km (NEDC)
Gasoline	99
CNG	84
LPG	98
E85	107
PHEV	15
BEV	0
FCEV	0
Diesel	108
DME	100
ED95	113



The model has three categories of Light-Duty Commercial Vehicles:

- Gasoline Vans,
- Diesel <2.5 t
- and Diesel >2.5 t.

It has been assumed that the PHEV / BEV and CNG technologies will be accounted for in the gasoline vans segment; as a consequence, a total of 10% of new registrations in 2030 will be in this category, rising from 4.1% from 2015. For this study, it is assumed that the average mileage is 9,900 km/a for gasoline segment and 16,000 km/a for diesel segments as in JRC IDEES database 2015. The main assumptions and model settings for each of these categories are listed in the Appendix, and are based on available statistics, the Roland Berger report, and experts' view analysis.

2.3. HEAVY-DUTY VEHICLES (HDV)

For HDVs the main inputs used can be summarised as:

- Stock segmentation into:
  - Trucks 3.5 to 7.5 tonnes,
  - Trucks 7.5 to 16 tonnes,
  - Trucks 16 to 32 tonnes,
  - Trucks >32 tonnes,
  - Buses and Coaches.

- Sales %YoY growth,
- Stock by % YoY growth,
- Tonne (or passenger) km,
- % load YoY growth,
- % fuel economy improvement,
- Alternative fuel types in new sales (DME, ED95, CNG, LNG, Electric, %BEV in PHEV+BEV),
- % share in e-driving of PHEV

Similar to LCV, Roland Berger study (Roland Berger, 2016) together with expert's views have been used as a relevant source of information, for this commercial sector. The study foresees a significant increase in the share of alternative powertrains for HDVs in the coming years.

In this outlook, the trucks heavier than 16t are assumed as the regulated vehicles under EU heavy-duty vehicles' CO_2 emissions regulation - EU 2019/1242 (see Section 1.3). It is assumed that 50% of new ICE diesel vehicles within the regulated trucks will be hybrid technology by 2030. Due to the market uncertainty around the penetration of alternative powertrains, the new sale composition for 2030 in Baseline has been proposed based on a balanced distribution between LNG, PHEV and FCEV (following a technology-neutral approach) so that the emission reduction target of 30% is met by 2030 (see **Figure 12**). For the truck segment 3.5-16t and buses, CNG is considered to be the most important alternative drivetrains by 2030, with new registration shares of about 4% and 14% respectively.

For this version of the Fleet & Fuel model, the selection of technologies has been expanded, in order to reflect this increased share of alternative powertrains. The composition of the fleet and the TTW CO_2 assumptions are shown in **Figure 12**.

Figure 12. Figures for emission intensity and new registration for heavy-duty commercial vehicle sales in 2030

Category	2019 Fleet gCO_2/km	2030 Fleet gCO_2/km
Truck 3.5 – 7.5t	325	280
Truck 7.5 – 16t	467	402
Truck 16-32t	671	476
Truck >32t	789	560
Bus & Coach	1310	1107

Note. Assumption: 50% of new ICE diesel vehicles (16-32 t segment) will be equipped with hybrid technology by 2030.

In developing the model, a challenging task has been to gathering information about Heavy-Duty commercial vehicles activity. After internal verifications (on the average activity per vehicles, etc.), the project team defined specific assumptions for each HDV segments as listed in the Appendix tables; the defined values are experts' elaboration on data available from available statistics and Roland Berger's report.

2.4. OTHER MODES

Other modes, including aviation, maritime and railway, have been also modelled in a simplified way to provide an estimate of the total fuel demand mix towards 2030.

2.4.1. Aviation sector

2.4.1.1. Background information

Among transport modes, road is still using the largest share of energy, but aviation is showing a significant, steady and quite rapid growth: the total number of passengers travelling by air in the European Union in 2018 have been 1.1 billion, with an increment of 6% compared to 2017. In EU-28, international aviation accounts for ~12.8% of energy consumed (1916 PJ), whereas domestic aviation uses only 1.5% (232 PJ) (EUROSTAT, 2017).

Forecasts for civil aviation in the coming years draw a steady growth and, associated with this growth scenario, an increasing pressure on the environment is expected. The sector industry has set an aspirational goal for a carbon-neutral growth from 2020 onward (IATA, 2017), but specific mandates are not present. The main measures today available to mitigate aviation environmental impact are related to technical engine and aircraft aerodynamic improvements, new materials, better air traffic management (SESAR, 2020), and the utilization of alternative fuels. Despite the high innovation rate that the sector has been showing, decarbonising aviation will be challenging, also due to the few alternatives available (EC, 2018); alternative propulsion options, like liquified natural gas, hydrogen, hybrid systems, etc., have been proposed and several solutions already tested but the most attractive short-to-medium term options for the air transport industry still remains to operate existing engines with lower carbon drop-in fuels (IRENA, 2017), not requiring separate refuelling infrastructure.

At European level, the Renewable Energy Directive recast (RED II) (EC, 2018) contains a set of criteria, which an alternative fuel must meet in order to be considered sustainable. Based on RED II, sustainable biofuels (made in facilities beginning operation after 2020) will have to achieve GHG savings of at least 65% respect to the road fossil fuel comparator; other sustainability criteria in the RED and RED II require that the biofuel feedstock has not been grown in areas converted from land with previously high carbon stock such as wetlands or forests; and does not come from land which has high biodiversity. Beyond these criteria, the RED and RED II also include non-mandatory socio-economic sustainability criteria on the impacts of biofuels production. At international level, CORSIA initiative (ICAO, 2017) limits the definition of sustainability to minimum GHG emissions reduction threshold compared to the jet fuel baseline and to carbon stock concerns defining what it is called as *Sustainable Aviation Fuel* (SAF).

The RED II includes aviation as an opt-in at the discretion of EU Member States and defines no mandates for this transport mode: a multiplier factor of 1.2 has been introduced, towards the mandated renewable energy target in transport.

2.4.1.2. Fuel demand outlook

Several previous studies, e.g. (Alonso, Benito, Lonza, & Kousoulidou, 2014), (EASA & EEA, 2016) , predict a sector growth rate of 3.5%, in the period 2021-2030 (without the COVID distortion of the market); these projections were supported by International Air Transport Association (IATA), which sets a 3.7% Compound Annual Growth Rate (CAGR) in its 20-year air passenger forecast (IATA, 2017). Defining a baseline scenario anticipating the potential medium-long term impact of COVID is, at least challenge, and it is not the objective of this report (which follows a simplified estimate for non-road transport). Therefore, this report considers a baseline scenario without the COVID impact towards 2030 (assuming a recovery in the 2021+ period), considering an increase in fuel consumption of about +3.5% for 2020-2030. A Concawe deep dive on Aviation, being conducted during 2021, will serve as the basis to update this trend in a future publication.

The evaluation of the fuel demand can be performed by coupling the expected increment in passengers with considerations about the efficiency improvements allowed by fleet renewal: according to (EASA & EEA, 2016) the specific consumption (expressed in litres per 100 passenger-kilometres) reduces from 4.4 in 2005 to 3.4 in 2017 (-23%).

According to the baseline of the EU long-term strategy (EC, 2018), **Table 3** reports the fuel needed to support this expected growth; sector is expecting to use biofuels as one of the tools to meet its aspirational goal.

Table 3. Expected jet fuel demand (in Million Tonne and Mtoe) for EU aviation sector (Domestic flights plus international extra-EU *)

Year	Unit	2017	2020 (**)	2025	2030
Fuel demand (*)	Mtoe/yr	53.9	54.9	56.6	58.3

(*) It includes both EU domestic flights and international flights departing from EU.
(**) Pre-COVID estimate (COVID-19 impact, affecting 2020+ demand has not been taken into account in the current baseline, as a simplification, assuming fully recovering in 2030).

2.4.1.3. Expected alternative fuel penetration

Despite the high expectations for biofuels to contribute to impact mitigation of emissions generated by aviation, the current state of play of the biofuel sector still shows low market deployment: (EASA & EEA, 2016) and (de Jong, et al., 2017) reported production volumes of aviation biofuels up to 2015 as being negligible, mainly due to high impact of feedstock on the final production costs, which are at least twice as much as fossil-based jet fuel.

Currently, the market penetration of alternatives to kerosene is hampered by several bottlenecks and, among the others, by high feedstock cost. Moreover, the penetration of biofuels in aviation has to be considered alongside biofuel demand generated in the road sector, where mandates for alternative fuels uptake are implemented. These differences between road transport and aviation are expected to influence the availability and therefore the market uptake of biofuels in the respective modes in the short-medium term with sustainable feedstocks likely shared between road and aviation based on specific regulatory provisions, rather than on price opportunities.

In the absence of current mandates at EU level, perspectives for medium-term demand are based on the aspiration carbon-neutral growth goal set by the sector.

The current market of low-carbon intensity fuels is dominated by hydro-processed esters and fatty acids (HEFA) from lipid feedstocks, and the appearance of significant alternative pathways by 2021 is unlikely. Based on the sector expectations for a neutral growth from 2020 onward, CO_2 growth is balanced by HEFA utilization and the amount of aviation biofuels needed can be calculated based on CO_2 savings for this pathway. For instance, an average GHG saving of 67%[6] respect to fossil derived fuels has been considered for this analysis as the WTW value currently considered within CORSIA (fossil fuel comparator value of 89 g CO_2eq/MJ for kerosene[7]).

In a scenario in which all GHG emissions from the EU growth would be compensated by using biofuel, the theoretical demand will be as shown in **Table 4**.

Table 4. Expected fuel demand for EU aviation sector to completely mitigate growth in GHG emissions (Based on **Table 3**)

Year	**Unit**	**2020 (calc)**	**2025 (calc)**	**2030 (calc)**
Theoretical biofuels demand to reach GHG neutrality vs 2020 (cumulative)	Mtoe/yr	0.5	1.0	1.5

Considering that the current use of biofuels in EU is almost negligible today, the current absence of mandates at EU level and that offsetting mechanisms will be also partially covering the expected GHG increase (potentially reducing the biofuel uptake), a proposal for the market-based baseline for biofuels is defined below covering different timeframes:

- ***Up to 2020***: A moderate ramp up of bio-kerosene production from the almost negligible volumes today until 2020 based on slow-moderate market deployment (no strong measures and/or support assumed in the baseline). This assumption implies that bio-kerosene production would be lower than the theoretical requirement to reach neutrality (**Table 4**), the rest being compensated through offsetting mechanisms).
- ***2020-2030***: the baseline considers the future demand rising from 2020 towards 2030 being able to reach the neutral growth target by means of biofuels only at the end of the period where no offsetting would be required (**Table 5**). A sensitivity case with higher biofuel penetration into the aviation sector is explored in Section 5.3.

[6] This means that to balance the GHG emissions released by burning 1 Mt of fossil fuel (3.16 tCO2eq per $t_{kerosene}$) a larger quantity of biofuel is required (as the saving is not 100%). In particular, based on the 67% average GHG savings mentioned above, 1.5 Mt of biofuel from HEFA have to be blended in fossil fuel, to balance the emissions from 1 Mt of fossil fuel demand increment (67% savings being estimated based on the HEFA WTW value of 30 g CO_{2eq}/MJ estimated based on HVO EU 2030 mix/JEC WTW v5 plus an additional 10% due to the upgrading process to bio-kerosene)

[7] https://www.icao.int/environmental-protection/CORSIA/Pages/SARPs-Annex-16-Volume-IV.aspx

Table 5. Proposed Baseline for aviation (estimate ramping up from today)

Year	Unit	2020	2025	2030
Biofuels uptake (baseline)	Mtoe/yr	0.1	0.2	0.55

Note. This proposal will be reviewed in light of the recent European's REFUEL initiative as well as the results of the deep dive on opportunities to reduce GHG emissions in the aviation sector, currently being conducted by Concawe at the moment of publication of this report.

2.4.2. RAIL

2.4.2.1. Fuel demand outlook

Rail is a very efficient mode of transport and its consumption has been reduced worldwide in the last decade (IEA, 2018), mainly thanks to the increase in electrification. According to (IEA, 2018)], energy demand for the sector is expected to slightly increase in Europe in the next decade, mainly for the expected shift from road. This expected increment will be significant for electricity (electrified roads potentially being covered also within this category depending on the level of penetration), whereas the share of diesel like fuel, that accounted for about 1.8 Mtoe in 2017, is expected to decline to 1.3 Mtoe in 2030.

2.4.2.2. Alternative fuel penetration

According to the RED II, a multiplier of 1.5X can be applied to renewable electricity used for rail. As the sector is already highly supplied by this vector, it is likely that the main effort for decarbonisation will be focused in finding sustainable sources of electricity. In the model, it was assumed that the share of renewable electricity was 29.3% in 2016 and 45.0% in 2030[8]. The renewable shares align with selected JEC WTT v5 GHG intensity factors, are shown in **Table 6**. Note that the share of renewable electricity described here was assumed for all electricity use in the model, regardless of transport mode.

Table 6. Pathways used to model the share of renewable electricity

Electricity mix	JEC WTT v5 pathway	Renewable electricity share	JEC WTT v5 GHG intensity factor (g CO_2-eq/MJ)
EU-mix low (2016 mix) - LV	EMEL3a	29.3%	110.1
EU-mix low (2030 mix) - LV	EMEL3b	45.0%	74.5

Note: LV denotes electricity at low voltage.

Additionally, there are some already commercial initiatives (even if still a pilot/demo scale) for replacing traditional diesel fuel with other alternatives, such as hydrogen and LNG. Alstom has been proposing H_2 trains to substitute diesel-power rolling-stock on un-electrified regional routes; train engines are couples with a Fuel Cell (FC) supplied by Hydrogen (ALSTOM, 2020). The solution allows for greening the sector and it has also some advantages compared to battery-equipped tractors: the possibility to operate the fleet for a whole day, refuelling during night-

[8] Details in the JEC WTT v5 report (Prussi, et al., 2020)

time, low expected cost of H_2 (produced to cut the peak of solar and wind power production) and low maintenance costs.

Other initiatives are on-going in Spain where, for instance, Renfe, ENAGAS and other stakeholders are collaborating in projects to replace diesel train with LNG. First promising tests have been conducted on the line between Mieres and Figaredo (NGV Global, 2019).

2.4.2.3. Inputs to the model - 2030 baseline

For the baseline, we have assumed to substitute the 10% of the expected diesel consumption with a 5% of LNG and a 5% of H_2 in 2030 (with a linear growth over the period, as a simplification). The results are shown in **Table 7**.

Table 7. Baseline for rail (2030). Type of fuels and carbon intensity values used in the present study (Well-To-Tank and Tank-To-Wheels)

Type of fuel			WTT	TTW (HDV Type 5)	
-	Non-electricity fuel mix (%)	Mtoe	(g CO_2-eq/MJ)	(g CO_2-eq/tkm)	(g CO_2eq/MJ calc[vi])
Traditional fuel [i]	84.3%	1.20	18.9	55.7	70.3
Biofuel [ii]	5.7%	0.08	38.7	57.8	79.3
LNG [iii]	5.0%	0.07	-7.3	52.2	59.8
H_2[iv]	5.0%	0.07	97.5	0.00	0.00

Note: For simplicity, the following pathways have been assumed to estimate the CO_2 intensity:
[i] Conventional diesel (fossil) pathway assumed (JEC WTT v5)
[ii] Only FAME by assuming the same diesel/FAME blending ratio used in the road transport
[iii] LNG: based on EU mix 2030 (As a simplification, an equal share of biomethane has been assumed in both LNG and CNG mix). The LNG EU mix for 2030 is shown in **Table 8**.

Table 8. LNG EU mix 2030 (estimate)

2030	WTT v5 pathway	SHARE	WTT (g CO_{2eq}/MJ)
LNG	GRLG1 (LNG in road)	80%	16.6
Biomethane	OWCG21	20%	-102.9
LNG EU MIX (CALC.)			-7.3

Note: For simplicity, the selected pathways are the representative ones considered for the JEC WTW v5 integration.
[iv] H2: 2030 EU mix in transport estimate. Some references forecast a higher role of low-carbon hydrogen in the 2030 transport mix (e.g. up to 50-60% of hydrogen used in transport claimed to be renewable or low carbon by 2030 (CertifHy, 2020)), a more conservative view has been assumed as the baseline in this report due to the current pace of development of renewable hydrogen in Europe. Pathways from the JEC WTT v5 report were used to model production of hydrogen. For 2030, 75% was assumed to stem from natural gas through steam methane reformation without carbon capture and storage (pathway GPCH2b) and 25% from water electrolysis using renewable electricity from wind (pathway WDEL1/CH2). The hydrogen EU mix for 2030 is shown in **Table 9**.

Table 9. H_2 EU mix 2030 (Estimate)

2030	WTT v5 pathway	Share	WTT (g CO_2eq/MJ)
NG w/o CCS	GPCH2b	75%	100.8
NG with CCS	GPCH2bC	0%	39.7
Electrolysis with RES	WDEL1/CH2	25%	9.5
Total H_2 mix 2030			78.0

(v) For the TTW value, due to the lack of detailed information available, the results of the TTW simulation for the state-of-the-art Type 5 trucks (long haul) have been used as an approximation (JEC TTW v5).
(vi) Conversion factor estimated based on engines from HDV JEC TTW v5, for vehicles class V.
The current baseline assumed that the bulk of the low-carbon hydrogen would be produced by water electrolysis using renewable electricity (through Guarantees of Origin or similar schemes). Other routes to produce Blue H_2 (with natural gas coupled with CCS) are also expected to be developed but, for simplicity, we have assumed that the emerging projects with CCS would produce higher volumes dedicated initially to industry and/or injection into the natural gas grid.

2.4.3. Maritime and waterways

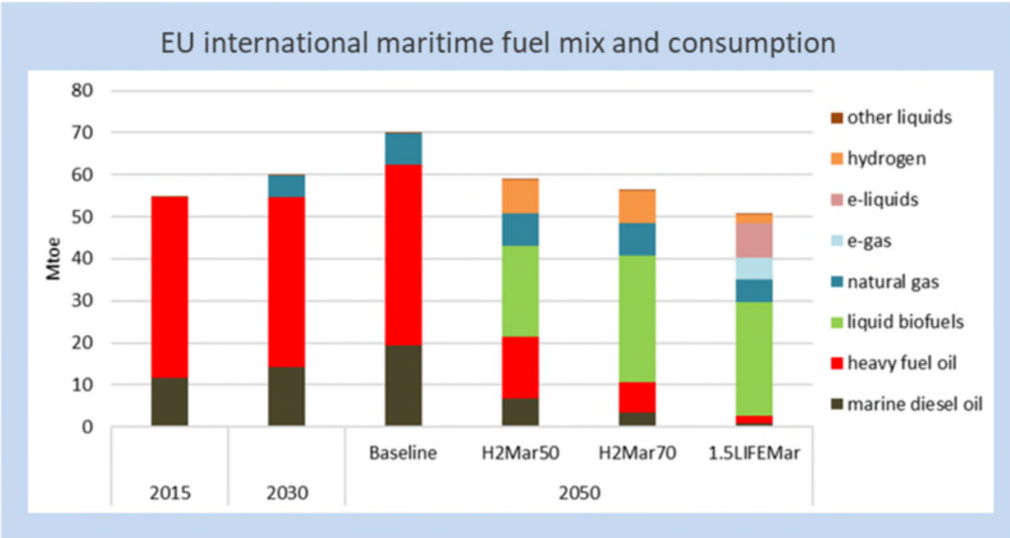
2.4.3.1. Fuel demand outlook

The maritime sector is today supplied by heavy fuel oil (HFO) - used by oceangoing deep-sea vessels - a fuel characterized by a very high viscosity and high sulphur level (IEA, 2017). New regulation for fuel quality is entering into force, with the aim to reduce sector environmental impact: The confirmed implementation of the International Maritime Organization (IMO) 0.50 %m/m global sulphur limit as of 1 January 2020 will result in large changes in marine fuel markets. There are different options available to the shipping industry that could be implemented to comply with this sulphur regulation; these range from the installation of on-ship SO_2 scrubbers (gas cleaning systems which would allow the continued use of high sulphur fuel oil (HSFO)), the shift from residual to low-sulphur fuel oil (LSFO) and marine gasoil (MGO) or the switch to another type of fuel (e.g. LNG). The way the shipping industry will respond to this need for greening the sector is, for the time being, still uncertain.

On the GHG side, a key challenge for shipping will be to decarbonize its activities. In April 2018 (MEPC n°72), United Nations *International Maritime Organization* (IMO) released its initial vision and strategy to reduce GHG emissions aiming to reduce CO_2 emissions per transport work (*carbon intensity*), as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050 when compared to 2009 (IMO, 2018).

As shown in **Figure 13**, the baseline of the EU long-term strategy (EC, 2018) sets the total demand for 2030 around 60 Mtoe, with an increment of about 7.8% respect to 2015. The EU long-term strategy LNG is expected to play a significant role.

Figure 13. EU international maritime fuel mix and consumption[9], in the Baseline and alternative scenario (EC, 2018)



Note that for domestic and inland waterway (included in figure above):

- JRC-IDEES database reports 1.8 Mtoe in 2015.
- The recently issued EC-EMSA (European Maritime Safety Agency) report shows 1.32 Mt of fuel consumption in 2018 for the European Economic Area (EU28+4) (EMSA, 2019).

2.4.3.2. Alternative fuel penetration: Opportunities

Alternative to traditional fuels could contribute meeting the IMO GHG level of ambition. There are several studies about potential routes towards reducing GHG emissions and the contribution of biofuels in maritime sector offering quite **significantly different views** as the possibilities are numerous and the sector still does not show a clear orientation to move forward. At the present stage, there is not a single candidate, able to meet all the sector specific requirements, thus the solutions should be based on a compromise between the expected environmental benefits and drawbacks (mainly related to cost increment) of the various options. Some examples of different reports and on-going initiatives are summarized below with the objective to show the variability in the solutions being portrayed by stakeholders:

- DNV-GL proposed a scenario for 2050 alternative fuels uptake in the international maritime sector (e.g. (DNV-GL, 2018) and (DNV-GL, 2018b)) where LNG, carbon-neutral fuels are envisaged to substitute HFO (Heavy Fuel Oil) /MGO (Marine Gas Oil) up to ~25% in 2030.
- Lloyd's Register in collaboration with University Maritime Advisory Services (UMAS) have recently issued a report *on Zero-emission vessels: Transition pathways* (Lloyd, 2020), identifying potential ways in which shipping industry can switch to net zero CO_2 intensive fuels. In this report, ammonia is presented as a potential cost-effective option when used in compatible IC engines (technology not currently available in the market).

[9] Including both domestic and departures from EEA ports.

- Other experiences have been demonstrating the feasibility of using alternative fuel for this sector; for instance, BALEARIA has been currently operating the first fast ferry supplied by LNG, and they are planning to increase their fleet. Thanks to the momentum given by the incoming new fuel regulation, SEA/LNG (a multi sector industry coalition created to accelerate the widespread adoption of LNG as a marine fuel) carried out an interesting analysis, mapping the main shipping routes and verifying the availability of LNG bunkering the situation appears already promising and plans for future seem to be able to support the development of this fuel. The interest on this pathway is growing and IMO recently reported interesting studies on the feasibility and use of LNG as a fuel for shipping (IMO, 2016).

As a conclusion, multiple pathways are being explored as potential routes to reduce CO_2 emissions. The final adoption of the technologies remains still uncertain with no single nor homogeneous view within the scientific community and different stakeholders.

The drop-in nature of alternative fuels, allowing their blend with conventional fuels in internal combustion engines, are envisaged to be one of the key elements for an effective penetration of these fuels into the marine sector, minimizing change required in both engine and vessel designs. Other potential constrains such as extra fuel cost issues and new infrastructure requirement are deemed as some of the main barriers for non-drop in fuels deployment across the sector.

Additional factors such as the different requirements and the domestic vs international dimension of the different maritime transport sub-segments add a layer of complexity to the way this segment will embrace the transition towards a lower GHG intensity future.

2.4.3.3. Alternative fuel penetration: Inputs to the model – 2030 baseline

Due to the uncertainty around how the sector will evolve, our baseline is not an attempt to predict the 2030 picture but to run an initial scenario allowing us to explore and inform the reader about the potential implications of different alternative cases. Subject to changes in future revisions, the baseline uses the data available from the European Maritime Safety Agency (EMSA) and EU long-term strategy documents (**Table 10**), and draw a plausible scenario for 2030.

<u>**2030 demand**</u>

For the 2030 outlook, an increment of 8% in total energy consumption is considered from the 2017 data presented in the Eurostat database.

Table 10. Comparison of consumption data for EU domestic, inland waterways and international, based on (EC, 2018), (EASA & EEA, 2016)

	Source	**Unit**	**2017**	**2030**	**Increment 2017-2030**
International and domestic / inland	DG CLIMA - Long Term strategy	Mtoe	*56*	60	~8% (<> 4 Mtoe)
Domestic and inland waterways	Eurostat	Mtoe	4.8	-	
	EMSA	Mtoe	1.3	1.4	~8%

Table 11. Baseline for maritime (Domestic and inland waterways) - summary

Baseline (**)	2018	2030
Total Energy consumption (Mtoe)	5.0	5.2
Alternative fuel share in total energy consumption	-	16.7% (*)

(*) Baseline assumption – details included in **Table 12** below. A sensitivity case with ~30% of alternative fuel share is explored in Section 5.3.
(**) Note. This proposal will be reviewed in light of the recent European's REFUEL initiative as well as the results of the deep dive on opportunities to reduce GHG emissions in the maritime sector, currently being conducted by Concawe at the moment of publication of this report.

Note that "*A Clean Planet for all*" [DG CLIMA, 2018] document (EC, 2018) assumes a moderate penetration of natural gas-based fuels (LNG) into the international maritime sector (~8% in 2030). For this study, we have assumed a higher penetration of alternative fuels into the marine diesel (mainly as drop-in diesel-like fuels) as well as a small penetration of electric ships especially in short-distance ferries.

Table 12. Baseline scenario for maritime (domestic and inland waterways): Alternative fuel penetration in 2030

Type of fuel 2030 Baseline			Carbon Intensity (WTT)	Carbon intensity (TTW)(iii)	Note
	%	Mtoe	g CO_2-eq/MJ	g CO_2-eq/MJ (EUCAR Type 5)	-
Traditional fuel(i)	83.3%	4.33	18.9	70.28	Diesel
Liquid biofuels(i)	5.7%	0.29	38.7	79.30	e.g. FAME WTT value as simplification
LNG(i)	10.0%	0.52	-7.3	59.78	LNG 2030 mix
Electricity(ii)	1.0%	0.05	74.5	0	EU Mix

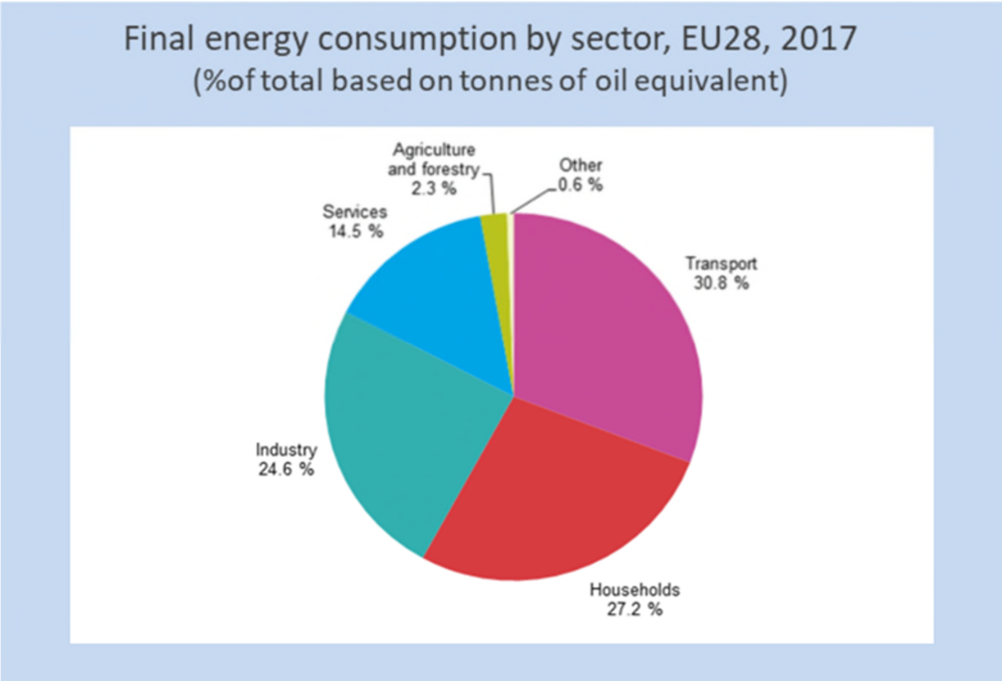
Note.
(i) Same WTT pathways selected as for rail (refer to notes below Table 7 for further details). In 2017, the share of traditional fuel in the mix is 100%. As a representative pathway of a compatible liquid diesel-like fuel, FAME has been selected (due to existing infrastructure and potentially lower fuel costs). Methanol and ammonia have not been included in the 2030 baseline (Subject to revision in the coming versions upon their future market penetration).
(ii) Electricity EU 2030 mix (LV) (Prussi, et al., 2020)
(iii) As in rail, the results of the JEC TTW v5 for Heavy Duty (long haul – Type 5) have been used to estimate the TTW values (refer to Table 7).

3. ENERGY DEMAND

3.1. ENERGY DEMAND OUTLOOK: EUROPEAN COMMISSION (2015-2050)

Eurostat data clearly shows that the entire transport sector represents the largest source of energy consumption in the European Union (Eurostat, 2019). The sector contributes almost one-third (30.8%) of all energy consumption and it is greater than Households and Industry (**Figure 14**).

Figure 14. Final energy consumption from (Eurostat, 2019)



The incremental energy demand from today is expected to be met by increased biofuels content in the fuel and through electrification, whereas the share of diesel and petrol-like fuels is expected to decline.

3.2. FLEET MODEL RESULTS: CURRENT AND 2030 ENERGY DEMAND

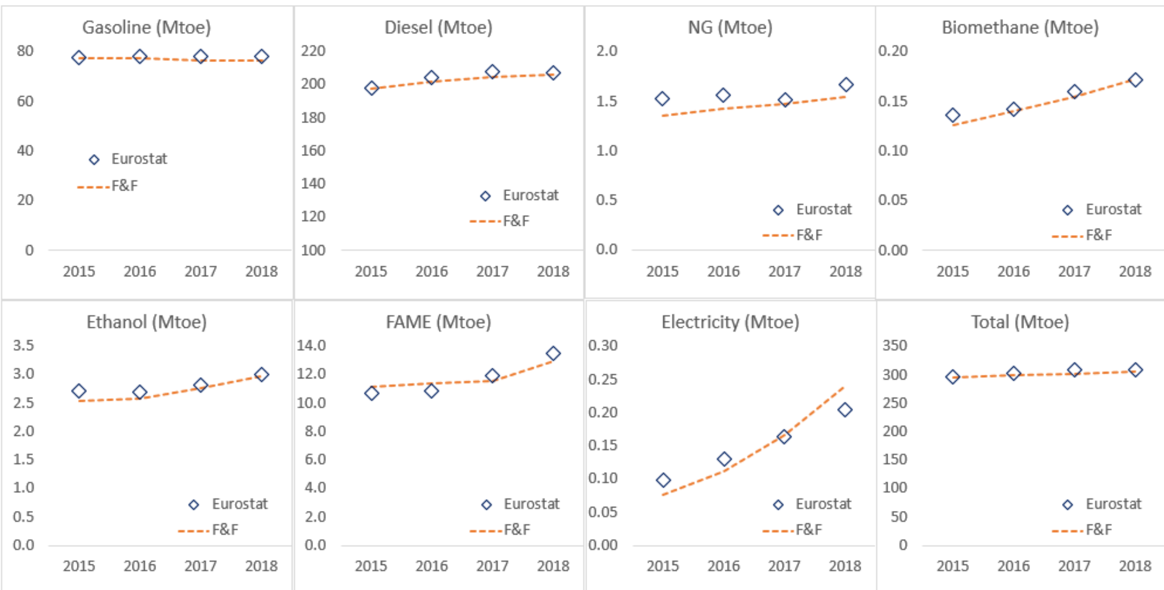
3.2.1. CURRENT ENERGY DEMAND – FLEET MODEL CALIBRATION

In order to calibrate the fleet model, the baseline has been fine-tuned to align to the 2015 and 2018 values, available from publications ((EC, 2017), (EC, 2020)). The reasons for the choice of the JRC IDEES database are related to the quality of the primary data, the public access and good agreement in vehicle segmentation with the fleet model. Table 13 shows the comparison of results of the fleet model with the data from JRC IDEES. The road transport energy consumption by fuel type has been compared with the available Eurostat data during 2015-2018 as shown in **Figure 14**.

Table 13. Comparison in energy demand from different sub-groups between the outcome of the fleet modelling presented in this report and IDEES (Gasoline and Diesel including bio, Mtoe) – Road transport

Source		Fleet Model - Outcome 2015	Fleet Model - Outcome 2030	IDEES 2015
Passenger Cars	Diesel	92.6	58.7	91.7
	Gasoline	78.2	51.4	74.1
Light Commercial	Diesel	34.8	25.4	32.0
	Gasoline	2.0	1.3	1.7
HD 3.5 - 7.5t		7.0	9.7	
HD 7.5 - 16t		9.8	13.5	68.7
HD 16 - 32t		15.8	15.4	(F&F: 66.7)
HD >32t		34.2	34.6	
Bus & Coach		14.4	12.6	13.9
Total		**288.7**	**222.6**	**282.1**

Figure 15. Comparison in different fuel consumption between the outcome of the fleet modelling presented in this report and Eurostat data (Eurostat, 2020) – Road transport



The resulting energy consumption from the fleet model has been considered in good agreement with IDEES 2015 and the published Eurostat data. Therefore, the baseline presented in this report has been considered suitable for the purpose of the analysis.

3.2.2. FUTURE ENERGY DEMAND: 2030 PROJECTIONS

The prediction of total energy demand from the model, including "other modes" (rail, aviation and inland maritime) are shown in **Table 14**.

Table 14. Baseline energy demand

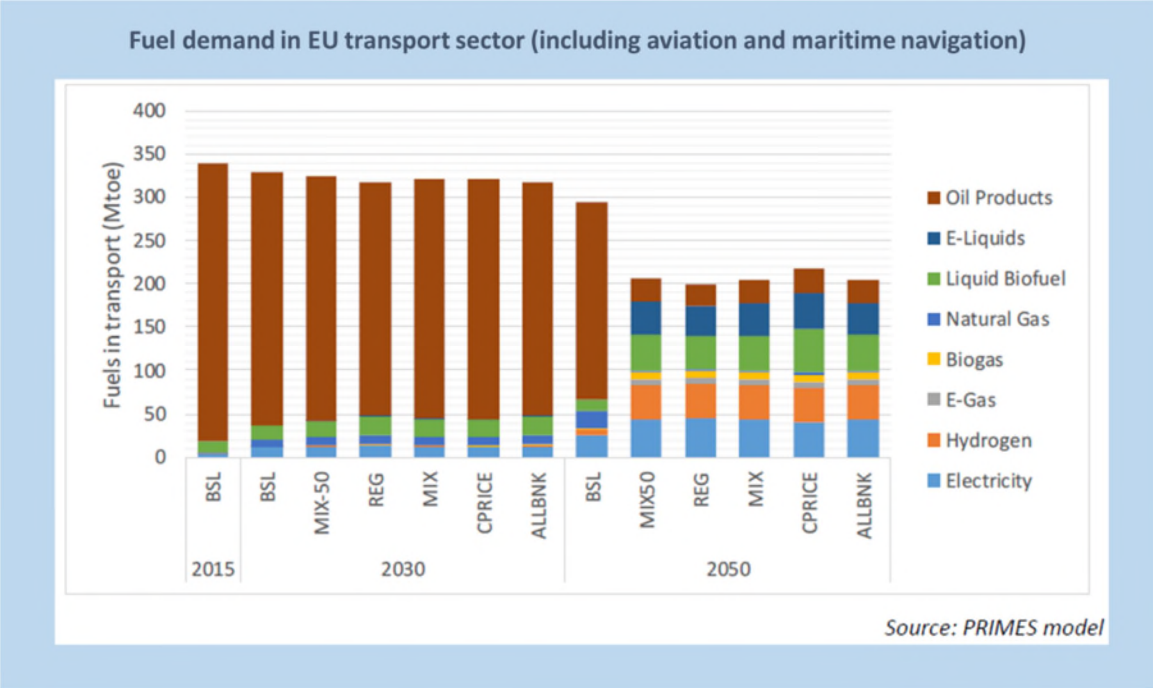
Source	2015 (Mtoe)	2030 (Mtoe)
Total road transport	294.7	238.5
Rail	7.5	8.2
Aviation	52.3	58.3
Inland navigation	4.7	5.2
Other off-road	7.1	7.6
Total	**366.3**	**317.8**

Note: Total Liquid and gaseous fuel demand for road are: 295 Mtoe (2015) and 231 Mtoe (2030).

For comparison purposes, the European Commission **baseline** for final energy demand in transport reported in (EC, 2020), modelled in PRIMES, is shown in **Figure 16**, providing an energy demand outlook out to 2030 and 2050. The EU COM baseline scenario shows:

- Transport energy demand decreasing by ~3% by 2030 compared to 2015 (up to 15% in the most ambitious 2030 scenario), mainly due to the impact of the proposed CO_2 standards for new cars, light commercial vehicles and heavy goods vehicles on overall vehicle fleet efficiency, but also due to improvements in the efficiency of the transport system as a whole.
- Oil product demand still representing about 90% of the EU transport sector needs (including maritime bunker fuels) in 2030 (down to ~85% in the ALLBNK scenario). This share is still high despite the renewables policies and the deployment of alternative fuels infrastructure which support some substitution effects towards liquid and gaseous biofuels, electricity, hydrogen and natural gas (2030 Impact Assessment, 2020). Additional scenarios towards 2050 have not been included in this analysis.

Figure 16. Fuels consumed in the transport sector towards 2050 (2030 Impact Assessment, 2020)



The result for total energy demand in 2030 is in line with the 2030 scenarios reported by EU COM:

Table 15. Comparison between 2030 Impact assessment (baseline and range of scenarios considered) and outcome of the Concawe's baseline presented in this report

Total transport	**2030 Impact Assessment**	**Outcome of fleet scenario (Concawe baseline)**
Total energy demand	330 (Baseline) 290-320 (Alt scenarios)	318
Total demand for liquid and gaseous fuels	310	304

Note: A full comparison between the models have not been conducted as the details behind the PRIMES model for transport are not disclosed in the referred reports and not made publicly available to the knowledge of the authors of this report.

4. BIOFUEL AVAILABILITY AND USE

Once the total demand for transport fuels is defined in the fleet model (as described in Chapter 3), the next step of this analysis is to estimate the potential biofuel availability based on market outlooks (plants in operation, under constructions or announced plans) in 2030, assessing how these projected volumes matched with the potential demand:

a) Biofuels with blending wall

The blending walls, modelled into the fleet model, define the maximum demand for certain type of biofuels (e.g. ethanol). The potential availability, in the timeframe considered, will define whether the maximum blending limits could be reached or if, alternatively, additional fossil fuels will get into the grade to meet the total energy demand as defined by the fleet composition.

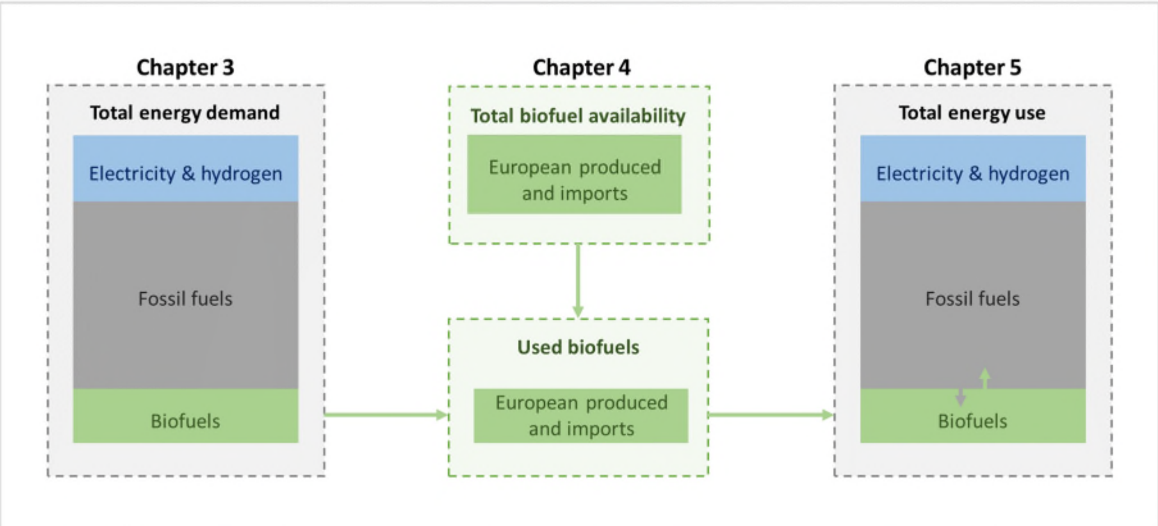
b) Drop-in biofuels

These drop-in fuels refer to the concept of fuels being completely interchangeable and compatible with conventional petroleum derived hydrocarbons without requiring any further engine modification, adaptation of the fuel system or the distribution network.

Similarly, drop-in biofuels with no constraint (limit) on the *demand* side will be incorporated to the maximum potential availability and will reduce the use of fossil fuels. [10]

The approach to map biofuel availability and total energy use is illustrated in **Figure *17***. The co-dependency between fossil fuels and biofuels is denoted by the arrows in the total energy use box on the right side of **Figure 17.**

Figure 17. Schematic drawing of approach to map total energy use.



[10] Note that no additional constrains are included at this stage limiting the potential availability. The caps as defined by RED II will be taken into consideration in Section 5.3.1.

This Chapter first considers total biofuel availability and then total biofuel use. After this, feedstocks used to produce the European biofuels and the imports are presented. Finally, the well-to-tank (WTT) GHG intensity factors for the various biofuels are calculated, based on the feedstocks.

4.1. BIOFUEL AVAILABILITY (2015-2030)

This section estimates the availability of biofuels based on the available information for European (EU27+3) production and trade. The biofuel production in Europe is considered together with trade. Finally, the total estimated biofuel availability in Europe is presented.

4.1.1. Biofuel production in Europe

A database produced by *Hart Energy*[11] (STRATAS database) as of 2017 was used to map the production capacity of biofuels in Europe updated with some new developments. As such, data for 2017 were used to derive past production capacities of 2015 and 2016 as well as prospective production capacities from 2018 through 2030. The assumptions and modifications of the data made in modelling the production capacities can be found in the Appendix.

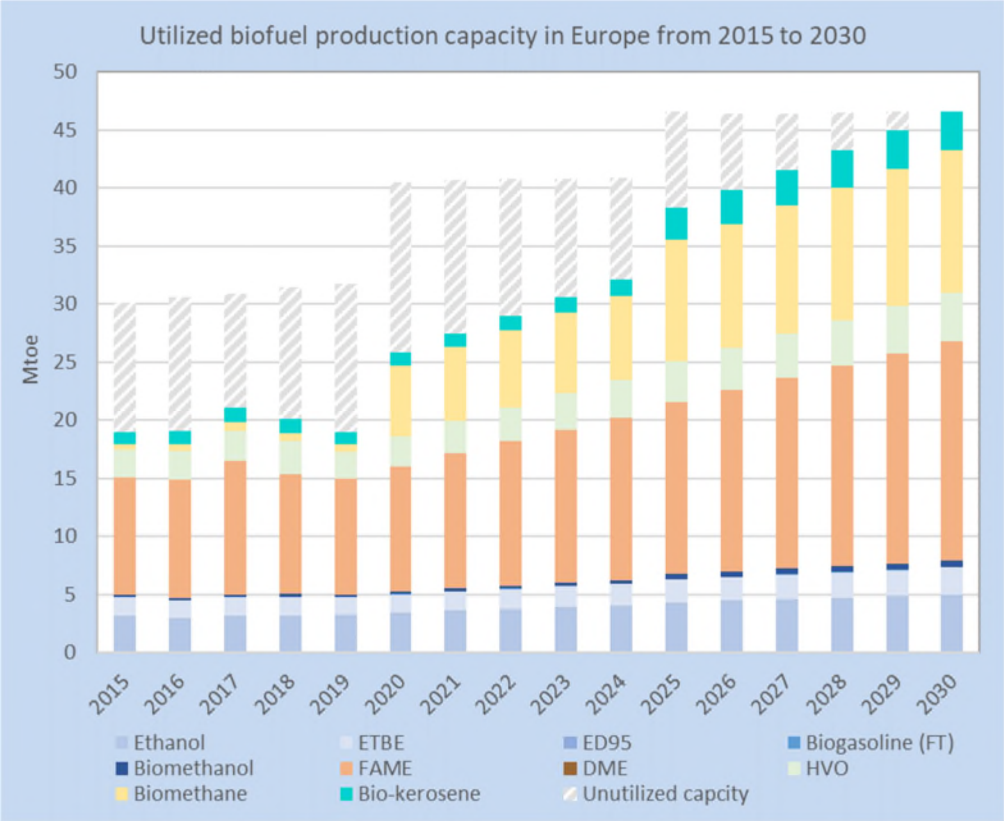
The database reports:

- Production capacities for ten different biofuel categories[12]: ethanol, FAME, HVO, biomethane (including synthetic natural gas (SNG) produced through biochemical or thermochemical processes from lignocellulosic feedstocks), ethyl tertiary butyl ether (ETBE), ED95, dimethyl ether (DME), biomethanol, bio-kerosene (HEFA), and biogasoline (produced through wood gasification).[13]
- Includes production plants already in operation, under construction or plans for future investment announced publicly and additional details on capacity, type of technology and primary/secondary feedstocks among other key parameters for the purpose of this analysis.

As a result, **Figure 18** presents the estimated **utilized production capacities** per biofuel type. The additional installed production capacity that is unutilized is denoted by a grey diagonally striped background. The utilized production capacity was based primarily on the STRATAS database, which reports the installed production capacity, and reported utilization rates of European biofuel production plants (Flach, Lieberz, & Bolla, 2019).

[11] https://www.hartenergy.com/companies/stratas-advisors
[12] At this stage, no e-fuel (Power-To-Liquids) production capacity in included in the study (only a small amount of e-diesel is reported in 2030).
[13] The STRATAS database reports its capacity in terms of the main product (fuel) without providing the full set of expected / production yields (not always available in the public domain). Therefore, as a limitation of the present analysis, the volume of by-products linked to certain conversion technologies have not been analysed in detail in this assessment.

Figure 18. Development of biofuel utilized production capacity in Europe from 2015 through 2030



It is important to highlight that:

- The highest production volumes stemmed from ethanol, FAME, Hydrotreated Vegetable Oil (HVO), biomethane and bio-kerosene. In contrast, low production volumes stemmed from ETBE, ED95 (95% ethanol), biogasoline, biomethanol, and Dimethyl Ether (DME). Of the latter biofuels, ETBE contributes to the largest production volume.
- Much of the predicted increase in production capacity stemmed from assuming higher utilization rates of existing plants, rather than an increase in the number of production facilities. This evaluation is based on the technical production potential and may not result in actual production outputs for a certain year as market conditions affect the real outputs of plants.
- Increased production capacity stemming from new plants are also reported, but there is considerable uncertainty regarding their potential construction and operation. Production of SNG (biomethane) is anticipated to increase dramatically in 2020 and additionally in 2025. The increase stems from two proposed SNG (Synthetic Natural Gas) plants and as such, the completion and operation of these plants is rather uncertain. This is also the case for increase in bio-kerosene production.

4.1.2. Biofuel trade

To estimate biofuel trade, import statistics for 2017 were used to ensure consistency with the production estimate, which is based on data for 2017. Note that the EU exports of biofuels are marginal (Flach, Lieberz, & Bolla, 2018). As such, this report considers potential biofuel excess rather than exports specifically (sub-chapter 4.3). The sources primarily report trade data regarding ethanol and FAME, but not for other biofuels. The reason for this could be that the EU does not have separate customs codes for all biofuels (e.g., HVO) or that the European demand is met by domestic productions (Flach, Lieberz, & Bolla, 2018). The statistics show that Europe is a net importer of both ethanol and FAME, and that there has been a general decreasing trend in imports during the last few years.

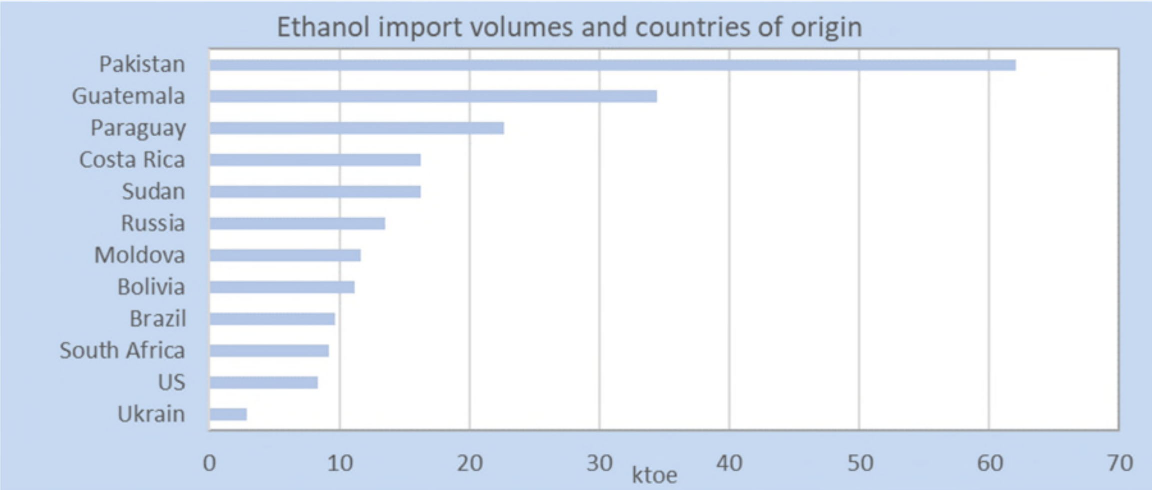
With respect to imports, it is important to establish not only the total volumes, but also the countries of origin. Knowing the countries of origin, provide indications about the feedstocks used to produce the imported fuels. WTT emission factors for import were chosen based on the available feedstocks in the countries of origin. Information regarding the feedstocks was found in the STRATAS database.

4.1.2.1. Ethanol imports (2017)

For ethanol, the trade data from European renewable ethanol association (ePURE) were used (European renewable ethanol, 2018). Some adjustments were made to the data set as the ePURE statistics consider imports to the EU28, rather than Europe (EU27+3). Thus, imports from European countries that are not in the EU27+3 region were omitted. In their statistics, ePURE differentiates between imports of ethanol and imports through inward processing[14]. Imports through inward processing were excluded in our imports estimate as these products may be used as feedstock in the refineries, which have already been accounted for in the estimation of European production. As most imports originating from the US and Russia were imported under inward processing, the import numbers for these two countries were reduced. Imports from origins not specified for commercial reasons accounted for 28% of the total imports (after adjusting for inward processing). Based on ePURE data for 2018, it was assumed that these stemmed primarily from Guatemala and Paraguay, and a small share from the Ukraine (European renewable ethanol, 2019). Figure 19 presents the estimated ethanol import volumes measured in kilo tonnes oil of equivalents (ktoe) and countries of origin. The total import volume of ethanol was 218 ktoe in 2017.

[14] *Inward processing* means that non-Union goods are imported in order to be used in the customs territory of the Union in one or more processing operations, for instance, for the purposes of manufacturing or repair (https://ec.europa.eu/taxation_customs/inward-processing_en).

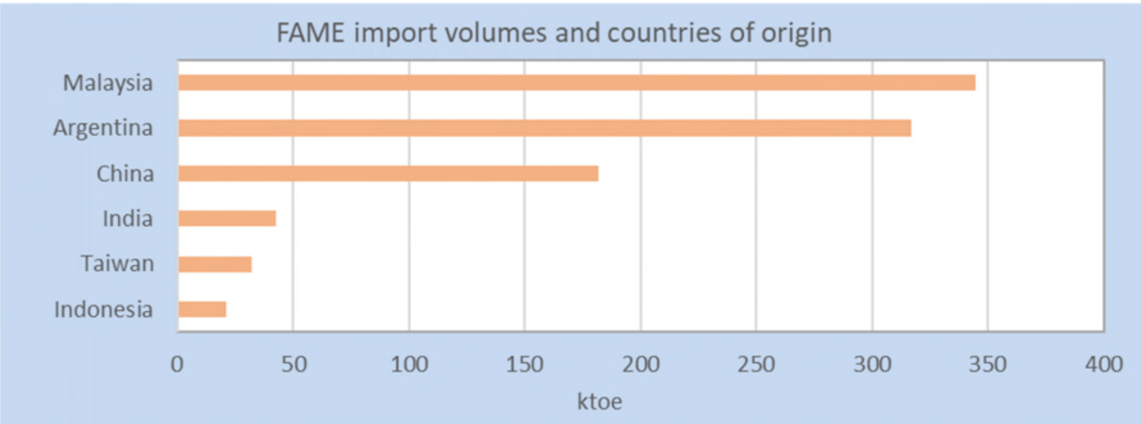
Figure 19. Estimated import volumes and countries of origin for ethanol (Concawe estimate)



4.1.2.2. FAME imports (2017)

For FAME, the import estimate was based on trade data from Bioenergy International (Bioenergy International, 2019) and the USDA report (Flach, Lieberz, & Bolla, 2018). These data sources were in good agreement with respect to total import volumes and countries of origin. Both sources were used as they provided complementary information about countries of origin. Both data sources consider imports to the EU28, rather than Europe. Thus, imports from the abovementioned European countries that are not EU27 member states were subtracted in our estimate of FAME imports. Figure 20 presents the estimated FAME import volumes measured in ktoe and countries of origin[15].

Figure 20. Import volumes and countries of origin for FAME (Concawe estimate)



It was estimated that the total import volume of FAME to Europe was 939 ktoe in 2017.

[15] While the statistics from Bioenergy International were provided in 1000 tons, the USDA report used Ml. The numbers measured in 1000 tons were multiplied with a conversion factor of 1.126 to obtain the import volume in Ml. These numbers were subsequently converted to ktoe.

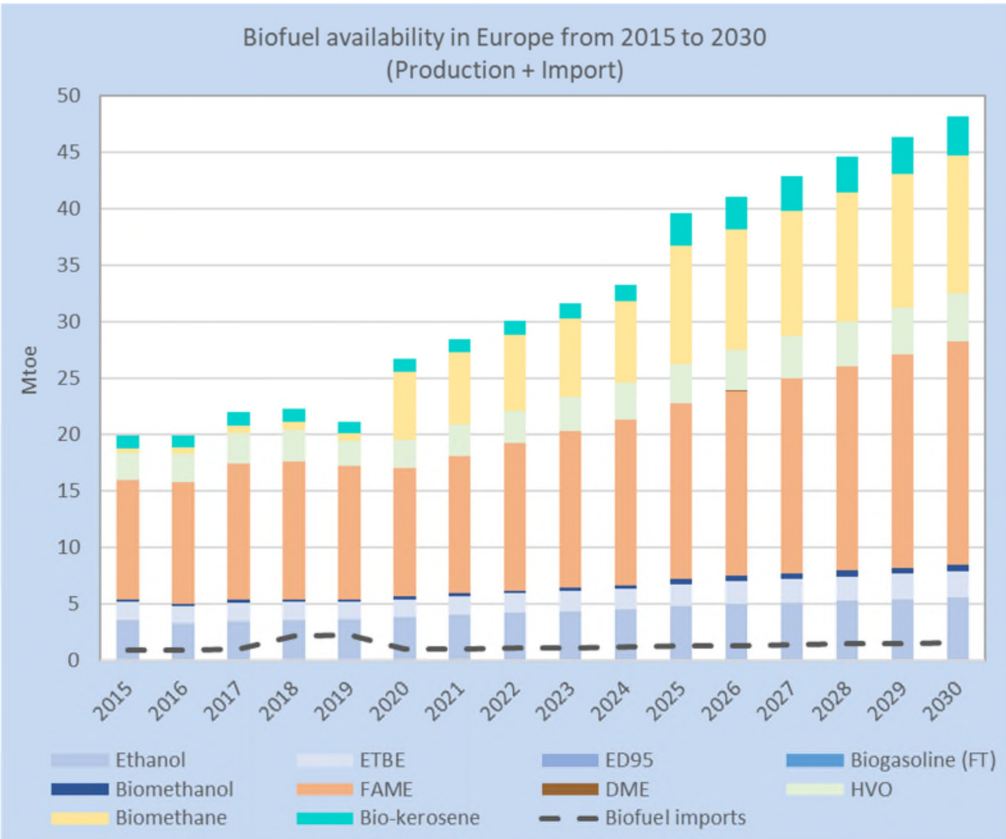
4.1.2.3. Projection of future imports

Based on these estimates, it was calculated that imports made up 7.6% and 6.5% of total FAME and ethanol availability in Europe in 2017, respectively. To estimate future import volumes, it was assumed that the **import rates were kept constant** at 7.6% for FAME and 6.5% for ethanol. As an exception, 2018 and 2019 FAME imports were modelled separately as FAME imports surged three-fold in 2018 compared to 2017 due to the removal of anti-dumping duties on FAME from Argentina (September 2017) and Indonesia (March 2018) (Flach, Lieberz, & Bolla, 2019). For 2019, the imports are likely to increase only slightly (1%) compared to 2018 (Flach, Lieberz, & Bolla, 2019). As the imports from Argentina and Indonesia are expected to decline as the European Commission has imposed countervailing duty on biofuels from these two countries, the assumed import rate of 7.6 % for FAME was applied from 2020 through 2030. For past and future import volumes, it was assumed that the import rates remained at 7.6% for FAME and 6.5 % for ethanol.

4.1.3. Total biofuel availability

The total biofuel availability was estimated based on the production capacity as defined in the 2017 STRATAS database (adjusted to represent the most up-to-date data on HVO production capacity and some bio-jet additional projects) and imports volumes as defined in Section 4.1.2.3. **Figure 21** illustrates the availability development from 2015 to 2030.

Figure 21. Estimated availability of various biofuel types in Europe. Note that ethanol and FAME also includes import volumes. The total import volumes are denoted with a dashed line in the figure.



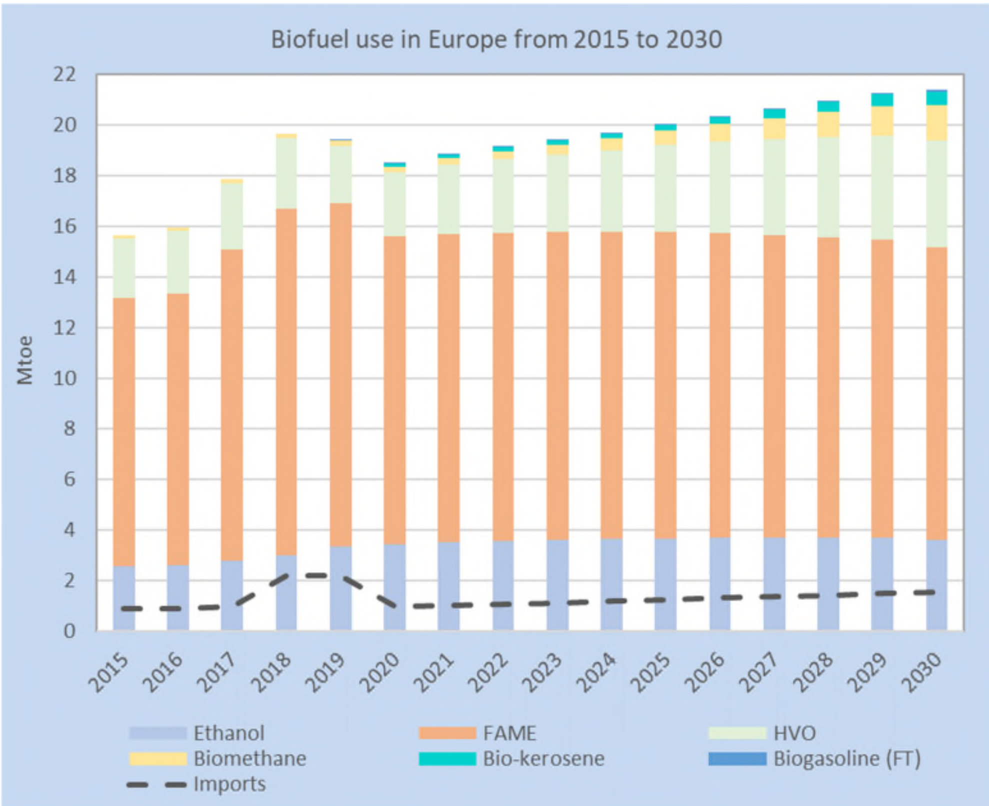
The biofuel availability is somewhat higher than the European production volume as it includes import volumes as a fixed ratio (%) of the domestic ethanol and FAME production in Europe. Recall that for 2018 and 2019 an exception to the fixed ratio was made to account for the surge in imports from Argentina and Indonesia due to the removal of anti-dumping duties on Argentinian and Indonesian biofuels in September 2017 and March 2018, respectively. As the European Commission has subsequently imposed countervailing duty on biofuels from these two countries, the imports are expected to decline.

As the most prominent growth of European production stems from biomethane and to some extent HVO and bio-kerosene, the relative size of imports decreases towards 2030. In absolute terms, there is a growth as the European production of ethanol and FAME are assumed to increase from 13 Mtoe in 2015 to 24 Mtoe in 2030. While this section considered estimated biofuel availability, the next section considers biofuel use.

4.2. BIOFUEL USE IN EUROPE (2015-2030)

Based on the potential biofuels supply availability and the total fleet demand for biofuels with defined blend walls, the total biofuels use projections have been estimated and shown in **Figure 22**. The dashed line indicates how much of the total biofuel use stemmed from imports.

Figure 22. Biofuel use per fuel type. The ethanol and FAME imports are included in the total uses of the fuels, and the total import volume is denoted by a dashed line



It is worth mentioning that:

- **Overall:**

  Total biofuel use increases from 19.6 Mtoe in 2018 to 21.4 Mtoe in 2030, resulting in a 9% increase in this time period. Note that the total biofuel availability presented in section 4.1.3 and use differs (the difference is further examined in section 4.3). Ethanol use increases by 20%, while FAME use decreases by 16%. HVO use increased by 52%. The use of biomethane and bio-kerosene were low compared to the other biofuels, but in relative terms their predicted use increases dramatically.

- **Ethanol**:

  The demand for ethanol is primarily limited due to the blending wall, but also due to the development of the gasoline passenger car fleet. The blending wall on ethanol limits the maximum uptake potential in gasoline. Additionally, as the stock of gasoline passenger cars decreases and become more fuel efficient towards 2030, this limits the growth potential for ethanol demand. Consequently, the demand for ethanol increases only from 3.0 Mtoe in 2018 to 3.6 Mtoe in 2030. Note that a sensitivity analysis considers ethanol uptake in section 0.

- **FAME**:

  The estimated availability of biofuels generally exceeds the demand, except for a possible FAME deficit (compared to the maximum % potentially blended into diesel). It was assumed that the unmet demand of FAME was met by fossil diesel instead. Because the modelling of end-use applications has implications for the calculation of RED II targets, the somewhat limited availability of FAME was shared relative to demand from end-uses (road, rail, other off-road transport, and inland navigation). This was done not to favour any of the end-uses.

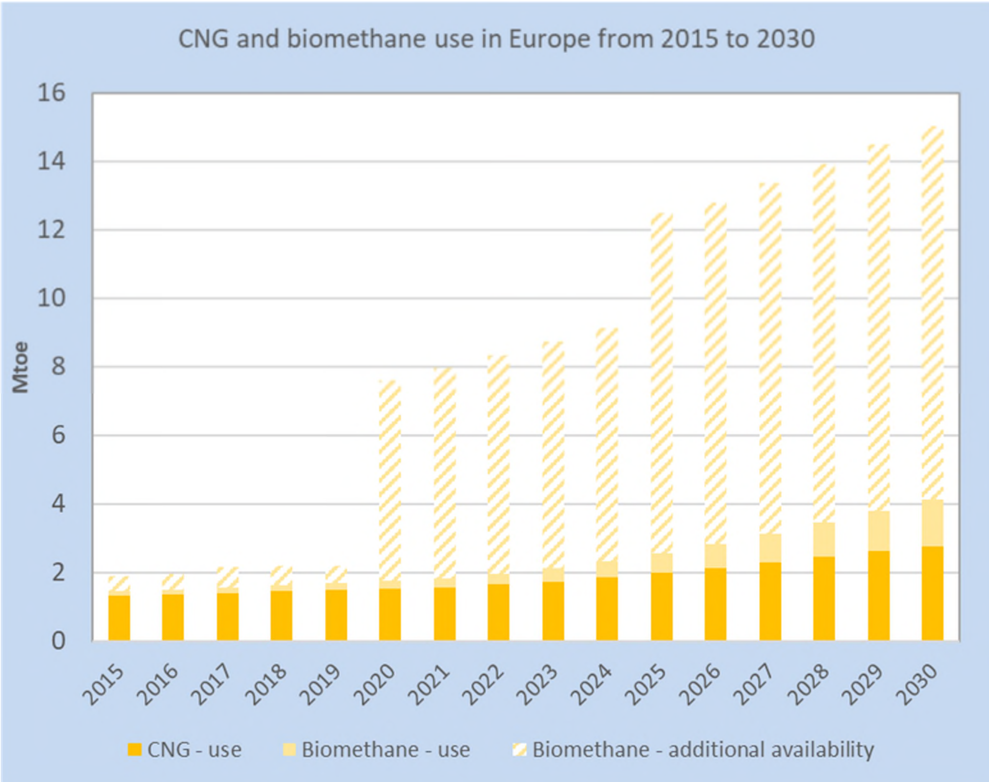
- **HVO**:

  In contrast, there is no constraint in HVO demand coming from the fleet model because, as a drop-in fuel, there is no blending limits in its uptake in road transport at EU level (worth noting that economic considerations are out of the scope of this study). Therefore, all available HVO from first generation and Annex IX Part A feedstocks are used to replace fossil diesel demand as drop-in fuel with no additional compatibility constraints, while feedstocks from Annex IX Part B is used within the cap placed on these feedstocks.

- **Biomethane**:

  The largest difference in biofuel availability and demand was found for biomethane, where availability by far exceeds the demand. The excess availability becomes particularly large from 2020 and additionally in 2025, when SNG production capacity is projected to increase dramatically. The assumed use of CNG and biomethane is modelled according to the projected demand from the fleet model. As a reference, the CNG and biomethane use as well as the additional biomethane availability is shown in **Figure 23**.

Figure 23. CNG and biomethane use, and additional biomethane availability



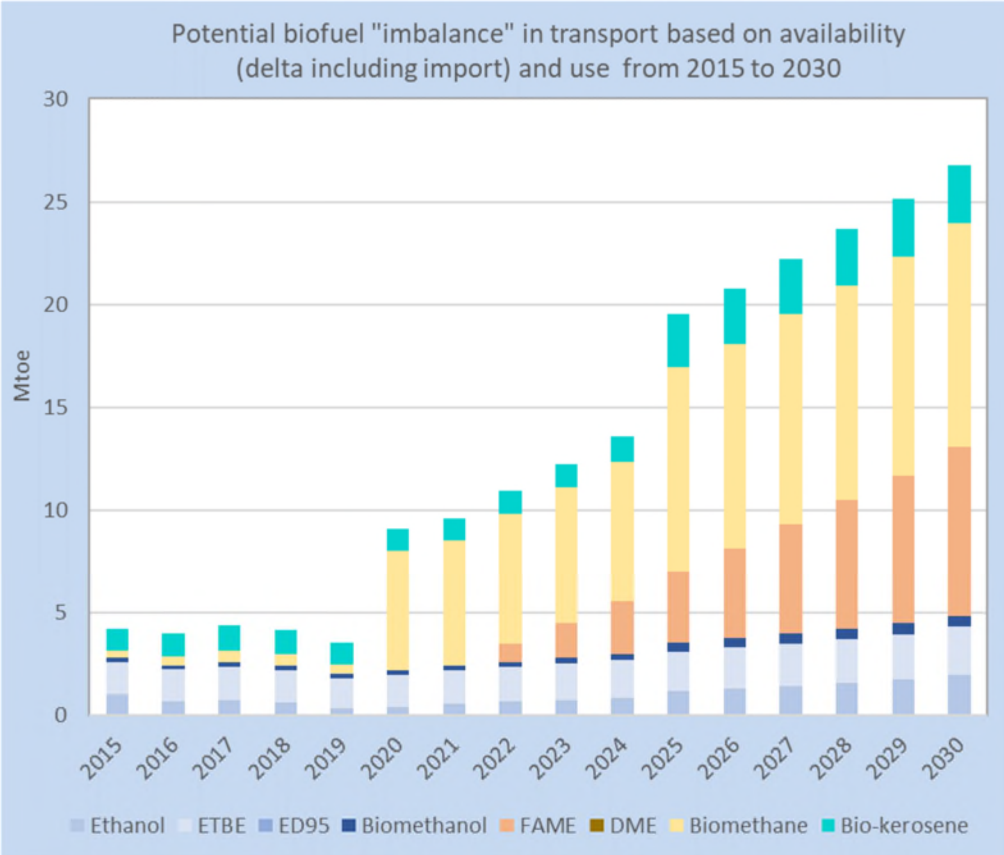
Use of both CNG and biomethane is estimated to increase towards 2030. While the excess availability could potentially replace CNG, such a replacement was not considered in the baseline scenario due to the competition with other uses of biogas/biomethane other than transport. However, this was explored through a sensitivity analysis and the effect this has on the estimated RED II results are explored in Section 5.3.

4.3. BIOFUELS BALANCE: AVAILABILITY VERSUS USE (2015-2030)

In this section and based on the assumptions already mentioned, we are looking into the balance between biofuel availability (production as reported in the STRATAS database + assumptions on imports) and demand (defined by use / blending limits). Ultimately, this will define the **imbalance (“excess”) between supply & demand** based on the assumptions defined in the present baseline.

In this case, when the availability exceeds demand in transport (as given by the fleet model), there is an excess in biofuels that may be exported. The estimated imbalance of different biofuels is shown in **Figure 24**.

Figure 24. Estimated imbalance of biofuels in transport based on availability and use (delta)



Some key conclusions derived from this imbalance (**Figure 24**):

- The imbalance on biofuel volumes increases dramatically from 2020 to 2030.
- This imbalance is due to several factors:
  - Non-dedicated engines simulated in the fleet modelling tool. As a proxy for a baseline representative of the EU market, we have not included niche markets for specific engines (captive fleet) in the fleet model described in Section 2. This could have created additional demand for fuels such as ED95 or DME (limited though in the time period considered).
  - Assumption on a linear growth of biomethane in transport leading to some potential biogas diverted into other sectors (see section 4.2)
  - For biofuels such as ethanol, it seems that the projected import volumes (fixed ratio versus total demand as defined in section 4.1.2.3) will imply that some European capacity could get underutilised or, alternatively, an overall surplus is generated. This could mean that, either this “unbalance” is translated into exported volumes or a reduction in the European capacity. This also shows a potential incentive for the development of higher ethanol grades (e.g. E20) at EU level, use of higher shares (e.g. E85) in niche markets or import reduction.

- Bio-methanol could potentially be used to produce additional ethers (e.g. MTBE) potentially blended into the gasoline pool as bio-components, constrained by the current oxygenate content defined in the baseline (E10 equivalent).
- It is worth noting that, other oxygenates than ethanol (e.g. ETBE) have not been modelled separately and the volume in gasoline blend has kept constant at current levels.
- As an indication of the potential role of ethers, based on the potential availability as defined in the STRATAS database, this volume could potentially be increased from 1.7% in 2015 up to the maximum oxygen specification of 5.2% in 2030 (replacing the equivalent ethanol volume) which, as a simplification, has not been included in this report.
- Limitation on bio-kerosene production to the volumes projected in section 2.4.1.3 (factors such as price issues could potentially constrain the realisation of the projected volumes and their penetration into the aviation sector). The maximization of bio-kerosene into aviation sector to reduce the unbalance to zero (as defined in **Figure 24)** is also explored as a sensitivity case in section 0.

- Based on the abovementioned comments, some additional remarks on how the imbalances evolve over time are presented below (potentially defining the net export/import balances or usage in other sectors based on the assumptions included in this fleet and fuel baseline):
  - In the 2015-2019 time period, the overall excess biofuel decreases gradually by 16% from 4.2 Mtoe to 3.5 Mtoe.
  - In 2020, production of SNG ramps up significantly and as a result, the overall excess increases rapidly by 160% from 3.5 Mtoe in 2019 to 9.1 Mtoe in 2020.
  - From 2020 to 2024, the overall biofuel excess increases gradually by 49% to reach 13.6 Mtoe in 2024.
  - In 2025, the production of both SNG and biokerosene is modelled to increase significantly, resulting in an overall biofuel increase by 43% from the previous year to reach 19.5 Mtoe.
  - Overall increases from 2025 to 2030 are primarily due to assumed increases in utilization rates of European biofuel plants, which reach 100% in 2030, but also due to limited growth in biofuel demand in this time period. In fact, FAME use is estimated to decrease by 5% from 2020 to 2030.

The key question is whether this European capacity will be effectively realised to produce fuels for transport, as they will require some dedicated fleet, in some cases with adapted engines, to be able to absorb this volume into transport sector. Alternatively, these commercial plans (investments reported in the database) may serve also as a trigger to accelerate fleet-related investment into some potential niche markets in the timeframe considered.

To provide an overview of the supply and demand for ethanol and FAME, the estimated use, production, import, and excess (“imbalance”) in the baseline are shown in **Figure 25** and **Figure 26**, respectively.

Figure 25. Estimated development of ethanol supply and demand

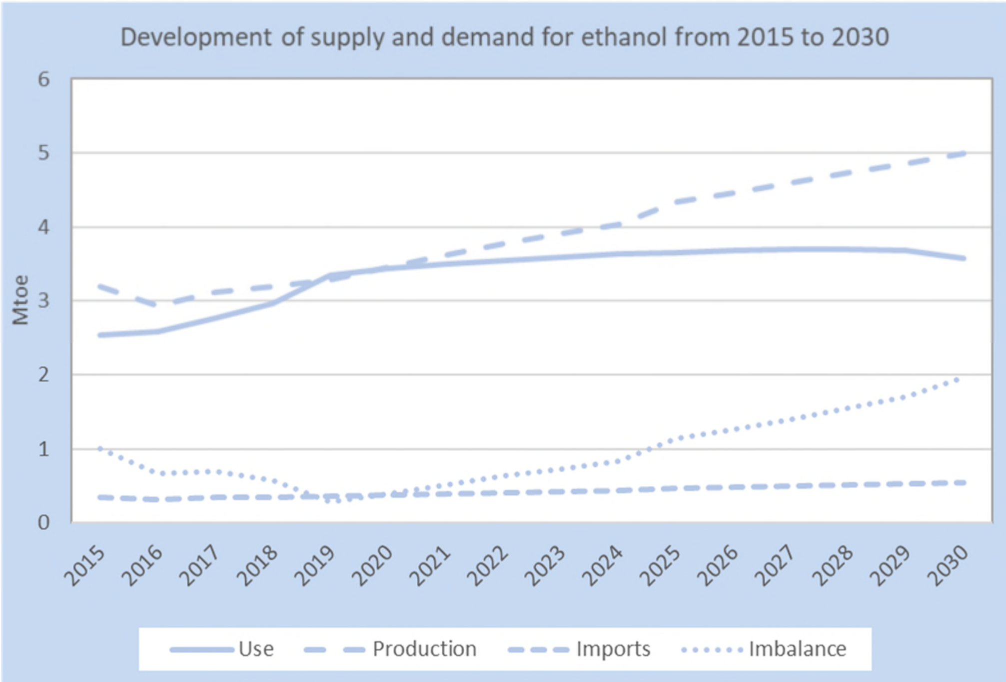
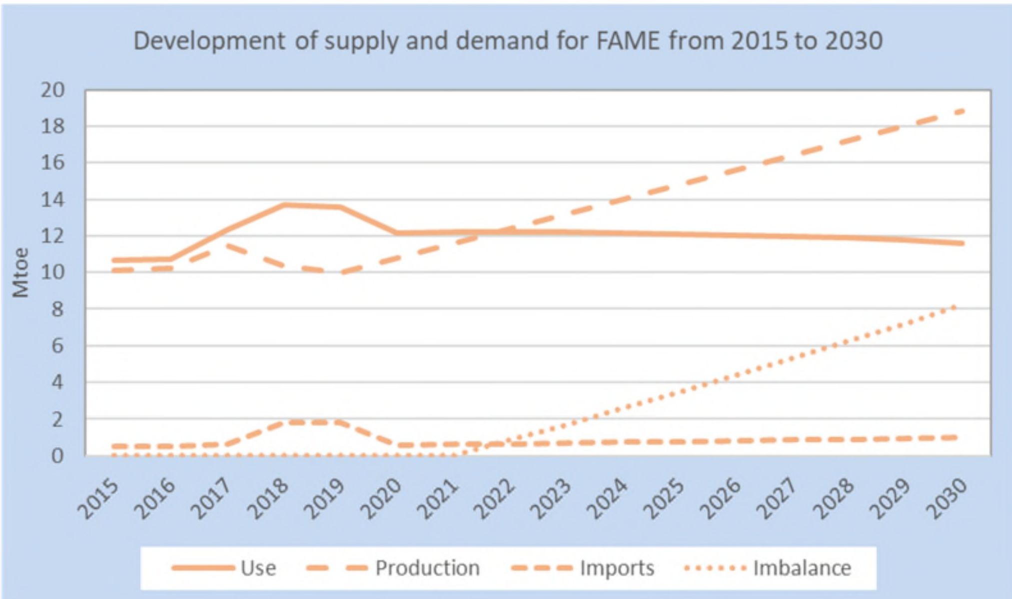


Figure 26. Estimated development of FAME supply and demand



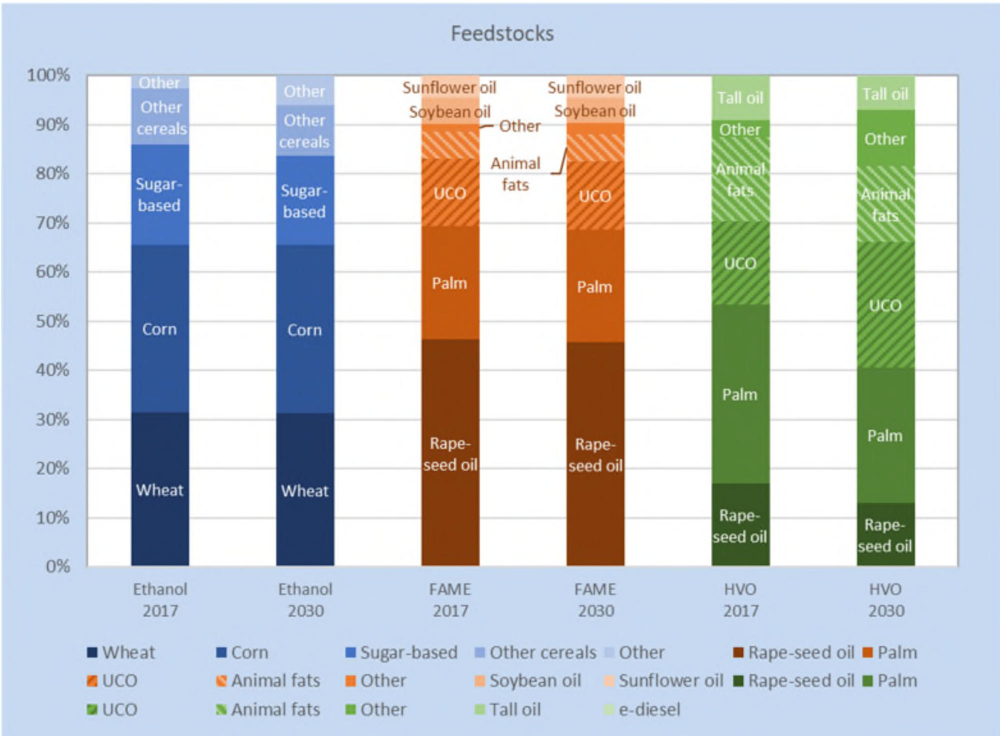
4.4. A LOOK INTO FEEDSTOCKS (2015-2030)

This section considers the feedstocks used for both European produced and imported biofuels. The feedstock use was established for 2017 and estimated for previous and later years to obtain a complete overview from 2015 to 2030. In the text below, we present the feedstocks for 2017 and 2030.

4.4.1. Feedstocks for ethanol, FAME, and HVO produced in Europe

The feedstocks used for production of biofuels in Europe were mapped based on information from the 2017 STRATAS database. The relative distribution of feedstocks for ethanol, FAME and HVO as of 2017 and 2030 is presented in **Figure 27**. Feedstocks from 1st generation sources have a solid coloured background, while advanced sources (from both part A and B of Annex IX of RED II) have a striped background.

Figure 27. Feedstocks for ethanol, FAME, and HVO in Europe in 2017 and 2030.



According to the mapping, biofuel production in Europe is largely based on 1st generation feedstocks. This is particularly the case for ethanol. Note that other feedstocks in ethanol production is solely from advanced feedstocks (e.g., cellulosic), and that this share is increasing somewhat towards 2030. The use of used cooking oil (UCO) and animal fats make up nearly 20% of the FAME production. The distribution of feedstock shares for FAME changes very little from 2017 to 2030. For HVO, however, there is a significant share (43%) of advanced feedstocks (e.g., UCO, animal fats, and tall oil) already in 2017, and this increases to 48% in 2030. While there is increased use of advanced feedstocks for ethanol and HVO, the shares remain nearly constant for FAME.

To verify the findings of European production, the 2017 results for ethanol, FAME, and HVO were compared to external sources. These three biofuels were considered as they are in highest demand of the biofuels and because they make up as much as 82% of the total estimated biofuel production in Europe in 2017. For ethanol, STRATAS results were compared to data reported from the European ethanol association ePURE. For FAME and HVO, the STRATAS results are compared to data reported from the European Biodiesel Board, which is based on data from Eurostat.

The STRATAS results were compared to the external sources with respect to total production volume and feedstocks. The full comparisons can be found in the Appendix, while the next paragraph summaries the main findings.

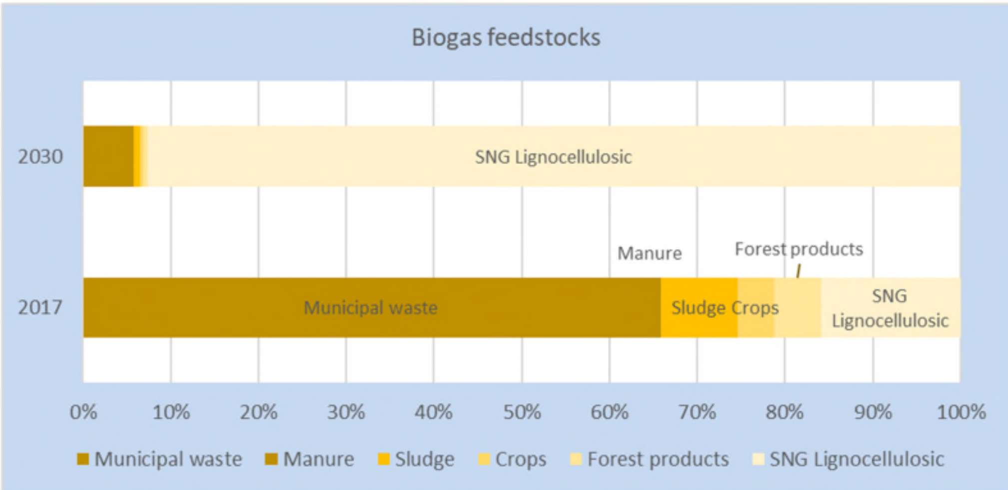
The total production volume and the feedstocks presented in this report (primarily based on STRATAS) were generally in good agreement with the external sources. There were some differences:

- For total production volumes, the differences were largely explained through the difference in system boundaries; while external sources estimate only considered the EU (EU28), our estimate considered Europe (EU27+3).
- There was good agreement with respect to feedstocks for ethanol and FAME, but there was some discrepancy for HVO. The discrepancy was mainly concerning the shares of rapeseed oil, used cooking oil and animal fat. It is worth noting, that our HVO estimate includes supplementary data from newer data sources compared to the external sources. The adjustment was done to capture the apparent fast development in HVO production.

4.4.2. Feedstocks for other biofuels

The feedstocks for biomethane were given in the STRATAS database. According to the database, biomethane in Europe is produced from advanced A feedstocks (Annex IX RED II). **Figure 28** presents the biomethane feedstocks as of 2017 and 2030.

Figure 28. Feedstocks for biomethane



The feedstocks used for biomethane production changes drastically from 2017 to 2030. Due to the expected growth in SNG production, particularly in 2020 and additionally in 2025, lignocellulosic feedstock becomes the largest feedstock for biomethane production. In 2017, there is a pilot plant producing SNG through thermochemical treatment of biomass (e.g., wood). SNG production through biochemical treatment (mono fermentation) of straw was to be finalized in 2019 and assumed to go onstream in 2020. An additionally proposed plant using thermochemical treatment of biomass was assumed to go onstream in 2025. As the additional SNG plants have significantly higher production capacities than the operating biomethane plants, there's a drastic change in feedstocks, as observed in **Figure 28**.

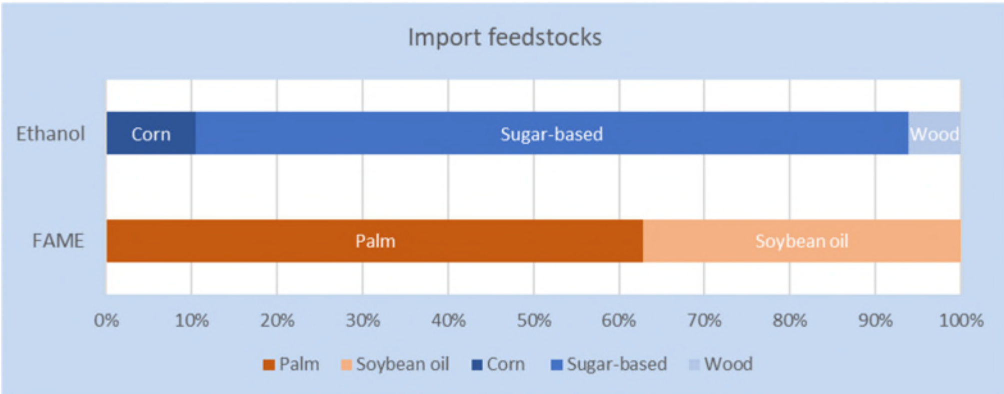
The STRATAS database did not provide detailed feedstock information for bio-kerosene (HEFA). Due to the lack of detailed information, it was assumed that feedstocks denoted as cellulosic or lignocellulosic feedstocks were advanced Annex IX Part A feedstocks and feedstocks denoted as oils, fats or N/A were first generation crop-based feedstocks. Due to the lack of detailed feedstock information and bio-kerosene pathways, the WTT GHG intensity factor for bio-kerosene was assumed to be the same HVO.

In line with the information provided by the database, it was assumed that biogasoline was produced from wood.

4.4.3. Import feedstocks

The STRATAS database was consulted to obtain information about feedstocks used for production of biofuels in exporting countries to Europe. The assumed feedstocks and their shares of the total biofuel import is shown in **Figure 29**.

Figure 29. Feedstocks for ethanol and FAME imports



For ethanol production, most of the exporting countries use sugar-based feedstocks, such as sugarcane or molasses, in their ethanol production. Smaller shares of the imports are likely to be derived from corn and forest products. For FAME, it is likely that either palm- or soy-based feedstocks are used in the exporting countries. It was assumed that the share of feedstocks would remain constant except for FAME imports in 2018 and 2019 when palm- and soy-based feedstocks made up 47% and 53%, respectively. The large increase in soy-based feedstocks in 2018 stems from the removal of the anti-dumping duties on Argentinian imports.

4.5. WELL-TO-TANK (WTT) CARBON INTENSITY OF BIOFUELS

The JEC Well-to-Tank v5 data (Prussi, et al., 2020), production phase, have been used to define the carbon intensity values of the biofuels included in this analysis. These values will ultimately be used to calculate their related GHG emissions (as the CO_2 emitted during the combustion is considered as equal to the CO_2 absorbed during the plant growth with a net zero impact). See section 5.2 for more information.

In this section, all WTT GHG intensity factors are reported in terms of g CO_2-eq/MJ_{fuel}. As the biofuels may be produced from a pool of feedstocks that may differ over time, the biofuel WTT factor may also vary over time. Thus, WTT figures were calculated for each biofuel on a yearly basis with increasing benefits on reducing GHG emissions of the transport sector as a whole.

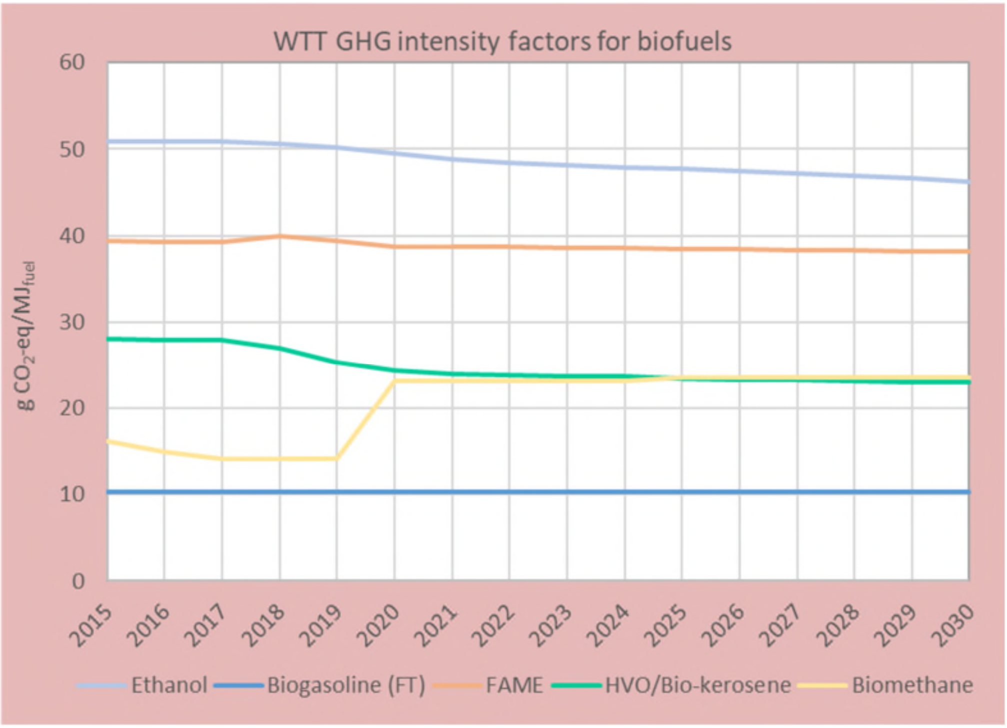
Methodology

Each of the feedstocks used to produce various biofuels was assigned a WTT GHG intensity factor. The JEC WTT v5 pathways were used to assign the feedstocks with a suitable WTT GHG intensity factor. The summary of chosen WTT pathways and GHG intensity factors are detailed in Appendix. The text below provides a brief description of the approach to select the pathways and appropriate WTT GHG intensity factors before presenting the consolidated emissions of various biofuels.

- For some feedstocks, where more than one pathway option was available, a combination of multiple pathways was used to describe current production.
- Note that in some cases, different assumptions were made for 2017 and 2030, in an attempt to model the expected developments in production technologies. This was the case for sugars and wheat used in ethanol production, rapeseed, soy and palm used in FAME production, and soy and palm used in HVO production. For these cases, linear interpolation has been used to estimate the WTT CO_2 factors between 2017 and 2030. It was assumed that the WTT GHG intensity factors were the same in 2015 and 2016 as in 2017.
- The chosen feedstock pathway combination for 2017 and 2030 is shown in the Appendix. The selection of pathway combinations for the European mix (HVO, Ethanol, FAME) is consistent with the information reported in the JEC WTW v5 report.
- For feedstocks that did not have a listed pathway, a chosen pathway was assigned as a proxy. For example, sugar cane (SCET1) used for molasses for ethanol production, tallow oil (TOFA3a) used for fish oil for FAME production, and wood residue (WWSD1a) used for straw for HVO production. The selection was based on the feedstock and the deemed appropriateness of the WTT factor. As such, the chosen pathway code may not always be specific for the feedstock or even biofuel type.

Based on the projected use of biofuel feedstocks and their assigned WTT GHG intensity factors (EU mix estimate), **Figure 30** presents the consolidated WTT figures for final biofuels:

Figure 30. Estimated WTT GHG intensity factors based on the projected biofuel feedstocks and their assigned WTT GHG intensity factors (simplified approach).



Over this timeframe, the change in WTT GHG intensity values results from a shift in feedstocks and in some cases, an assumed change in production pathways as described below:

- For ethanol, the WTT GHG intensity value decreased by 9.0% from 2015 to 2030. The reduced emission factor of ethanol primarily stems from the assumed change in production pathways for wheat and sugar beet.
- For biogasoline, a fixed WTT GHG intensity value was chosen, which explains the flat line
- For FAME, the WTT GHG intensity value decreased by 3.0%. The decrease stems mainly from an assumed change in production pathways for palm oil and partially from a small increase (1.0% from 2015 to 2030) in the share of advanced feedstocks (such as UCO).
- The WTT GHG intensity value of HVO/bio-kerosene decreased by 18% from 2015 to 2030, but the main reduction took place between 2017 to 2021 where it was reduced by 14%. The rapid reduction was caused by two main changes in feedstocks for HVO production in this time period; while the share of vegetable oil decreased, the share of waste as feedstock increased.
- The largest change in WTT GHG intensity value was found for biomethane with a total increase of 46% from 2015 to 2030. As SNG produced from biochemical treatment of straw has a much higher emission factor than conventionally produce biomethane from municipal waste or manure (see Appendix for pathways), the increase of SNG production had tremendous effect on the emission intensity value as a whole. This was particularly observable in 2020, when the dramatic increase in SNG production from straw resulted in a 64% increase in the biomethane emission factor compared to 2019.

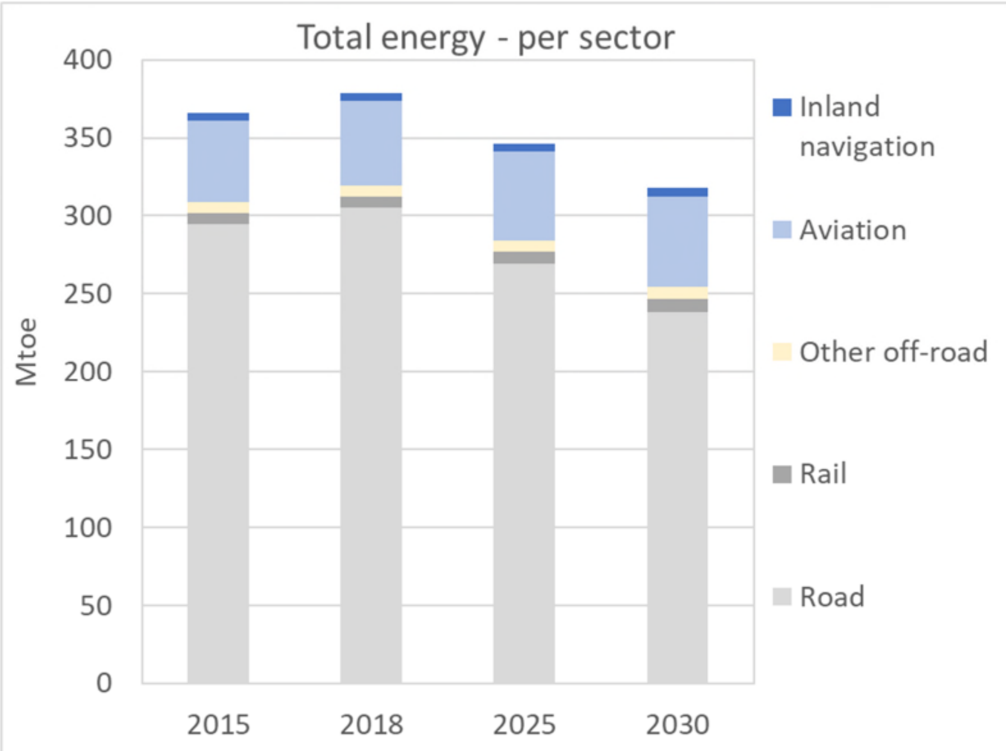
5. RESULTS. IMPACT ON GHG EMISSIONS AND COMPLIANCE WITH EXISTING REGULATORY FRAMEWORK

This Chapter presents the total transport energy use and GHG emissions for EU27+ transport sector, and its compliance with 2030 existing regulatory frameworks such as RED II (Renewable Energy Directive II) and a look into FQD (Fuel Quality Directive).

5.1. TOTAL ENERGY USE FOR THE TRANSPORT SECTOR

The total energy use was estimated based on the energy demand (Chapter 3) and biofuel availability and use (Chapter 4). The total energy use is presented per transport sector in **Figure 31** and per fuel or energy carrier in **Figure 32**.

Figure 31. Total energy use per sector

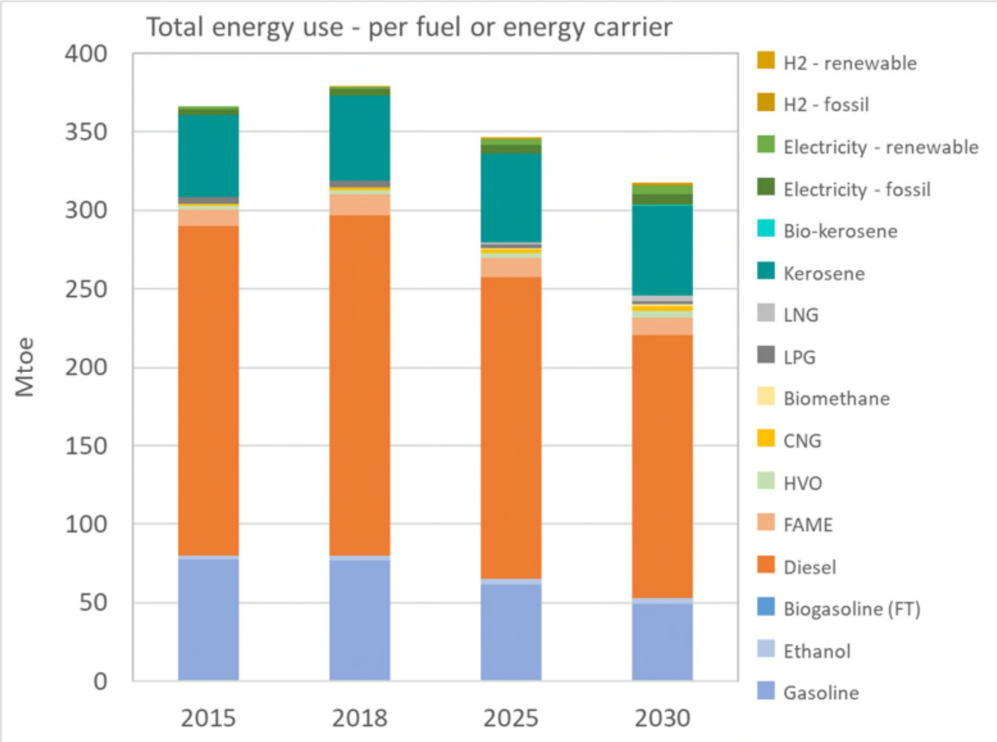


As a result:

- The total energy use is expected to decrease by 13% from 366 Mtoe in 2015 to 318 Mtoe in 2030. For road and inland navigation reduction rates of respectively 19% and 9% were found. For rail, other off-road, and aviation, the trend was reversed with an increase in use of respectively 13%, 6%, and 12%.
- While road energy use is expected to decrease the most, it remains the highest end-use application by 2030. Aviation, on the other hand, is increasing its share of total transport energy use from 14% in 2015 to 18% in 2030.

While **Figure 31** presented the total energy use per sector, **Figure 32** presents the total energy use per fuel or energy carrier:

Figure 32. Total energy use per fuel or energy carrier

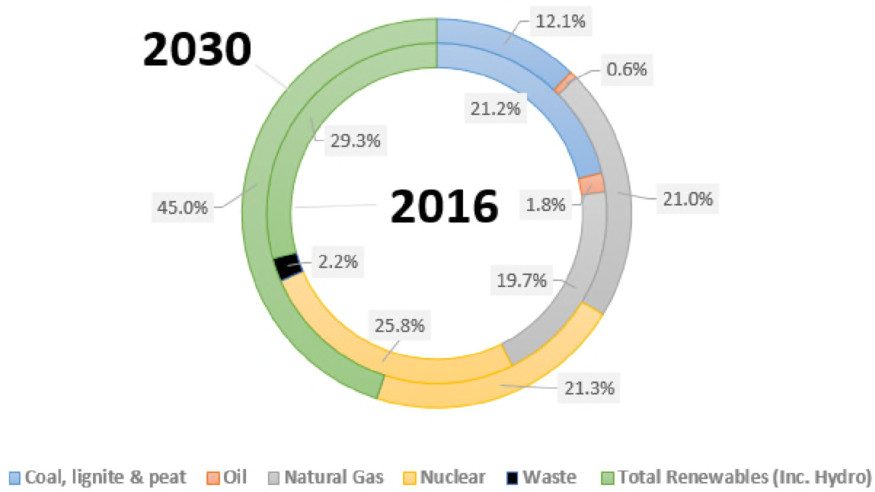


Notes:

- **Gasoline and diesel** use remained predominant, despite a declining trend towards 2030. The majority of gasoline and diesel demand stems from road applications. The decline stems primarily from reduced energy use (due to improvement in energy efficiency of vehicles) and to some extent, a shift from fossil fuels towards biofuels and electricity.
- **Gasoline** demand will see a sharp reduction from 77 Mtoe in 2018 to 49 Mtoe in 2030 (representing a 36% reduction). One of the main drivers of this reduction is the decreased number of gasoline vehicles in 2030 (about 6% reduction for gasoline car stock), replacing with alternative fuel vehicles. Another important reason is the significant improvement of gasoline vehicles' fuel consumption through the scrappage of older vehicle vintages and replacing with more efficient ones. For example, the stock average MJ/km of gasoline vehicles (grade 2) is reduced by about 25% during 2018-2030 (assuming the same NEDC approach for all numbers). In addition, increasing the blending ratio from 3.95% to 10% for gasoline grades and reducing the share of gasoline use in PHEVs are the other factors influencing the gasoline demand reduction.
- **Kerosene** use is the third largest item, after gasoline and diesel. In contrast to gasoline and diesel, the use of kerosene increases as mentioned earlier in the chapter. The kerosene use increases by 6% from 2018 to 2030. Although bio-kerosene use increases in our baseline, it still only contributes to 0.9% of the total aviation energy use in 2030.

- CNG, biomethane, LNG, electricity, and hydrogen use also increase in this period and their combined use accounts for 7.4% of the final energy demand in 2030.
- As a proxy for both electricity and hydrogen, we have assumed a linear increase in the share of renewable energy sources in transport. The share of renewables for electricity and hydrogen goes from 34% in 2020 to 45% in 2030 and from 0% in 2020 to 25% in 2030, respectively (the assumed renewable share in the EU electricity mix aligns with the JEC WTT v5 estimate). The WTT factor for electricity is 99.9 g CO_2-eq/MJ in 2020 and 74.5 g CO_2-eq/MJ in 2030, for hydrogen the WTT factor is 100.8 g CO_2-eq/MJ in 2020 and 78 g CO_2-eq/MJ in 2030.

Figure 33. Extracted from JEC WTT v5 - EU electricity production mix (2016 data and projections for 2030)



5.2. GREENHOUSE GAS EMISSIONS FROM TRANSPORT

A simple and commonly used approach was applied to calculate the greenhouse gas (GHG) emissions for the European transport sector. The approach involves combining information on the extent of a human activity with a coefficient quantifying the emissions from that activity (Thomas, Tennant, & Rolls, 2000; Eurostat, 2010).

In this report, the total GHG emissions were calculated based on the total energy use and associated Well-to-Wheels GHG intensity factors. Note that, as mentioned in section 4.5, the combustion emission factor of biofuels is set to zero as the combustion of biofuels is offset by the renewable credit given to biofuels and the use of electricity and hydrogen does not entail combustion. Thus, for biofuels, electricity, and hydrogen, the JEC WTT v5 intensity factor is used in the calculation of GHG emissions. For the fossil fuels, the JEC v5 Well-to-Wheels GHG intensity factor have been used. All emission factors used in the calculations are specified in the Appendix.

The GHG emissions were estimated both per transport sector and per fuel or energy carrier. Both results are presented below.

5.2.1. GHG emissions per transport sector

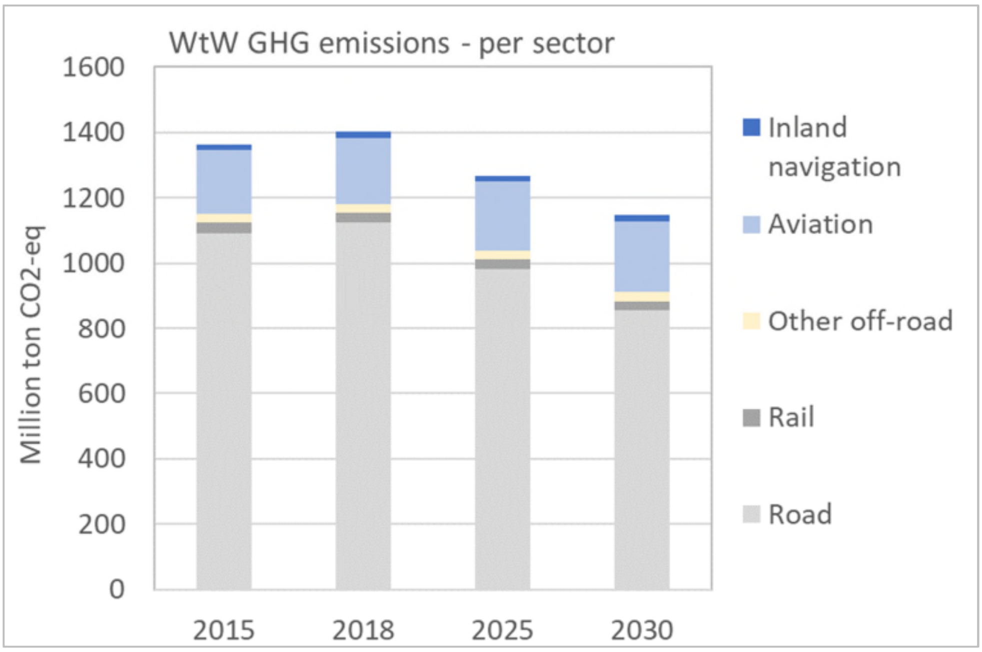
The sectoral GHG emission was calculated based on sectoral use of fuels and energy carriers and the emission factors. The approach is summarized in the equation below.

$$GHG_{sector} = \sum (E_{sector,fuel} * EF_{fuel})$$

In the equation, GHG_{sector} is the total GHG emissions per sector, $E_{sector,fuel}$ is the total use of fuels or energy carriers per sector, and EF_{fuel} is the GHG intensity factor of a fuel or energy carrier.

Figure 34 presents the total WtW GHG emissions measured in million tonnes CO_2-eq per sector.

Figure 34. Total GHG emissions per sector



Notes:

- With reduced energy use, the emissions from European transport sector decline by 18% from 2018 to 2030.
- For road, other off-road, and inland navigation, there is a close correlation between the reduction in energy use and reduction in GHG emissions.
- In the rail sector, GHG emissions are reduced by 12% during 2018-2030. This reduction stems from the sector’s extensive use of electricity, which sees an increasing use of renewable sources in its generation towards 2030.
- For aviation there is a close correlation between the increase in energy use and increase in GHG emissions (not completely offset by the use of sustainable aviation fuels in the period considered).

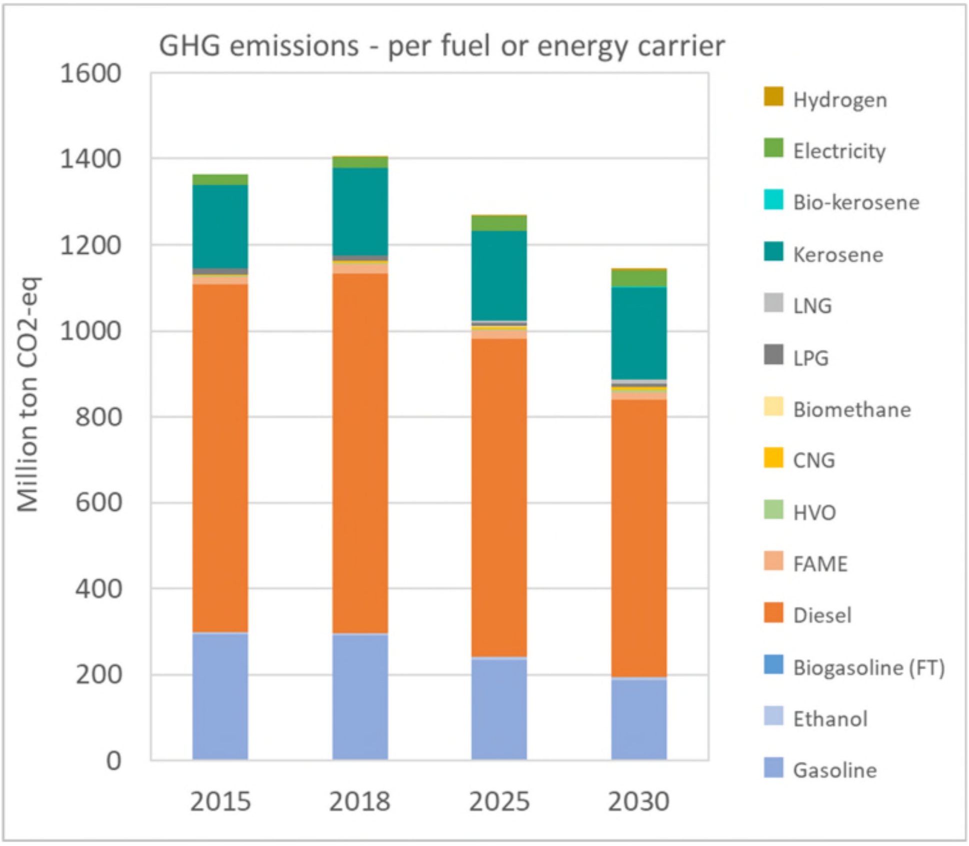
5.2.2. GHG emissions per fuel or energy carrier

As an alternative to reporting GHG emissions per transport sector, GHG emissions can also be reported per fuel or energy carrier. The GHG emissions per fuel or energy carrier is the sum of GHG emissions associated with the energy use of each fuel or energy carrier from a given transport sector and the emission factor of each fuel or energy carrier. The approach is summarized in the equation below.

$$GHG_{fuel} = \sum (E_{fuel,sector} * EF_{fuel})$$

Where GHG_{fuel} is the total emissions per fuel, $E_{fuel,sector}$ is the total sectoral use of fuels or energy carriers per fuel, and EF_{fuel} is the GHG emission factor for that fuel or energy carrier. **Figure 35** presents the total GHG emissions measured in million tonnes CO_2-eq per fuel or energy carrier.

Figure 35. Total GHG emissions per fuel or energy carrier



In line with the energy use, gasoline, diesel, and kerosene are the largest contributors to GHG emissions. Interestingly, kerosene use becomes a larger source of emissions than gasoline use towards 2030, which reflect the energy use development of the two fuels.

5.3. COMPLIANCE WITH CURRENT REGULATORY FRAMEWORK

In this sub-chapter, compliance with the current RED II targets (as baseline) as well as a look into GHG intensity reduction (FQD) is evaluated.

5.3.1. RED II (Recast of Renewable Energy Directive, Directive (EU) 2018/2001)

Currently, RED II sets a minimum of 32% by energy content of renewable energy sources consumed in EU28 by 2030. RED II sets a specific target for renewable energy consumed in transport (RES-T) of minimum 14% by 2030 as well as specific targets for biofuel use. The target set for advanced biofuels from feedstocks defined in Annex IX Part A is set to a minimum share of 3.5%. First generation crop-based feedstocks have a cap at maximum 7%. Advanced biofuels from feedstocks defined in Annex IX Part B have a maximum cap at 1.7% by 2030.

5.3.1.1. RED II calculations

In RED II, the targeted share for renewable energy in transport (RES-T) has been set to at least 14% by 2030. When estimating the RES-T share, JEC follows the general equation below derived from RED II:

$$RES - T = \frac{E_{RES,road} + E_{RES,rail} + E_{RES,off-road} + E_{RES,aviation} + E_{RES,inland\ maritime}}{E_{Fossil,road} + E_{RES,road} + E_{Fossil,rail} + E_{RES,rail}}$$

It is worth noticing that:

- The denominator considers the total fossil and renewable energy content used by *only road and rail*, while the numerator considers the renewable energy content in compliant biofuels, renewable electricity, and renewable hydrogen used by *all transport sectors (including maritime and aviation)*.
- For the calculation of the **denominator**, the energy content of gasoline, diesel, natural gas, biofuels, biogas, renewable liquid and gaseous transport fuels of non-biological origin, recycled carbon fuels and electricity supplied to the **road and rail transport** sectors shall be considered.
  - Note that in line with the calculation rules, LPG is not included in the calculation. For the calculation of the numerator, the energy content from all renewable sources supplied to all transport sectors shall be considered.
  - Where $E_{RES,sector}$ denotes use of renewable energy sources and $E_{Fossil,sector}$ denotes use of fossil energy in a given sector.

How to address the "additionality" for renewable electricity in transport

a) Interpretations on the *additionality* concept when applied to transport:

The RED II, at article 27, point 3 recalls the concept of *additionality*, for defining of the renewable electricity used in transport sector as follows:

*"In order to ensure that the expected **increase in demand for electricity** in the **transport sector beyond** the **current baseline** is **met** with **additional renewable energy** generation capacity, the **Commission** shall **develop a framework on additionality** in the transport sector and shall develop different options with a view to determining the baseline of Member States and measuring additionality".*

As the "*framework on additionality in the transport sector*" has not been proposed yet by the Commission, from the text above, two different interpretations have been explored regarding how to consider the energy demand for electricity in the transport sector "[…] *beyond the current baseline*" "*is met with additional renewable energy* […]".

(1) **Interpretation 1**

This interpretation considers the amount of renewable electricity used in transport as the difference between the use in a certain year, and the value for the baseline. It is worth noticing that the cited paragraph does not explicitly define this baseline so in order to estimate the contribution of renewable electricity in road and rail sector, and so to apply the multipliers designed for these specific cases, the year 2020 (entry into force of RED II) has been assumed as the reference year. The "additional renewable energy" uptake in road and rail, between the year 2030 and the year 2020 has been calculated according the equation below (as the difference between the renewable electricity used in those years) which will be used to estimate the contribution of electricity in transport to the RES-T target:

$$RES-T(RES-electricity\ in\ transport)_{interpretation\ 1} = Share_{RES\ electricity\ in\ the\ grid\ (2028)} * Electricity_{use\ in\ transport\ in\ road\ and\ rail\ (2030)} - Share_{RES\ electricity\ in\ the\ grid\ (2018)} * Electricity_{use\ in\ transport\ in\ road\ and\ rail\ (2020)}$$

Note.

- The amount of renewable electricity used in road/rail in the year "n" has been estimated as the multiplication of the total electricity use (regardless the origin) this year (output of our Fleet & Fuel model) multiplied by the share of renewable electricity in the grid in the year "n-2" (as currently reported by Member States). The share of renewable electricity in the grids is aligned with the assumptions in the JEC WTT v5 report (and detailed in Figure 36).
- Only the delta between the renewable electricity consumed in the reference year (2020) and 2030 in transport can be eligible to comply with the overall RED II target.
- We are assuming that no preferred allocation of renewable electricity is made to the transport sector. This means that the amount of renewable electricity to RES-T calcs (before applying any multiplicators) are as follows (see detailed results in Table 17):
  - For road, the renewable electricity share is:

    $$RES_{electricity\ in\ road} = 42.8\% * 5.14\ Mtoe - 31.5\% * 0.73 = 1.97\ Mtoe$$

  - For rail, the renewable electricity share is:

    $$RES_{electricity\ in\ rail} = 42.8\% * 6.8\ Mtoe - 31.5\% * 5.5 = 1.2\ Mtoe$$

(2) **Interpretation 2**

In this second interpretation, we are focusing the interpretation on the total additional renewable generation capacity installed in Europe and the cross-check that the aforementioned capacity is enough to satisfy the total electricity demand in transport. In this case, as the increase in additional renewable capacity is expected to be much higher than the transport electricity requirements, the contribution of electricity to the RES-T calculations has been implemented as follows:

$$RES - T\ (RES\ electricity\ in\ transport)_{interpretation\ 2} = Share_{RES\ electricity\ in\ the\ grid\ (2028)} * Electricity_{use\ in\ transport\ in\ road\ and\ rail\ (2030)}$$

- This means that the amount of renewable electricity to RES-T calcs (before applying any multiplicators) are (see detailed results in Table 19):
  - For road the renewable electricity share is:

$$RES_{electricity\ in\ road} = 42.8\% * 5.14\ Mtoe = 2.2\ Mtoe$$

  - For rail the renewable electricity share is:

$$RES_{electricity\ in\ rail} = 42.8\% * 6.8\ Mtoe = 2.9\ Mtoe$$

5.3.1.2. Multiplicator values

According to the RED II Directive:

- Energy consumed in transport only refers to road and rail (other off-road, aviation and maritime are not included in the energy baseline (denominator).
- Various fuels and energy carriers eligible to comply with the RED II targets may have different multiplicator values:
  - Fuels and energy carriers from fossil sources do not have multiplicator values.
  - Biofuels and energy carriers from the same origin may have different multiplicator values depending on the end-uses.
  - For example, FAME consumed in inland maritime applications have a higher multiplicator value compared to FAME going to road and off-road applications.
  - Renewable electricity used in road has a higher multiplicator value (x4) compared to electricity used in rail (x1.5).
  - Biofuels from advanced feedstocks have a higher multiplier value compared to first generation crop based (food) feedstocks.
- Compliance with the targets may be calculated with and without the use of multiplicators, as Member States have the possibility to apply them or not.

Table 16 provides an overview of the multipliers for the numerator (bioenergy used in road, rail, aviation and maritime sector), as well as the values for the denominator (energy used in road and rail) both without and with multiplicators values.

In order to explore the impact of the multiplicator factors, three approaches are explored:

a) Total volume without multiplicators

In the first approach, the calculation was done using no multiplicator values in numerator or denominator. This will provide us with an estimate of the **real volumes** (expressed in Mtoe) of each type of biofuel / energy carrier included in the baseline.

b) RED II target (multiplicators applied to Road & Rail)

In the second approach, the calculation was done using multiplicator values in the numerator but not in the denominator. **This is the reference used in this report to compare versus the RED II target for transport.**

c) Modified RED II– impact of multipliers in both numerator and denominator

This approach explores a hypothetical case where multiplicator values are used in both the numerator and the denominator.

Table 16. Multiplicator values for various fuels and energy carriers used in the numerator (num.) as well as the denominator without (den. w/o) or with (den. w)

Fuel/energy carrier	Category	Biofuel feedstock type	Num.	Den. (w/o)	Den. (w)
Gasoline	Fossil		0	1	1
Diesel	Fossil		0	1	1
Ethanol	Renewable	1st generation - crop based	1	1	1
	Renewable	Advanced - Annex IX Part A	2	1	2
Biogasoline (FT)	Renewable	Advanced - Annex IX Part A	2	1	2
FAME - road and rail	Renewable	1st generation - crop based	1	1	1
	Renewable	Advanced - Annex IX Part A	2	1	2
	Renewable	Advanced - Annex IX Part B	2	1	2
FAME for off-road	Renewable	1st generation - crop based	1	0	0
	Renewable	Advanced - Annex IX Part A	2	0	0
	Renewable	Advanced - Annex IX Part B	2	0	0
FAME for inland maritime	Renewable	1st generation - crop based	1	0	0
	Renewable	Advanced - Annex IX Part A	2.4	0	0
	Renewable	Advanced - Annex IX Part B	2.4	0	0
HVO - road	Renewable	1st generation - crop based	1	1	1
	Renewable	Advanced - Annex IX Part A	2	1	2
	Renewable	Advanced - Annex IX Part B	2	1	2
e-diesel	Renewable	Electricity	2	1	2
Kerosene	Fossil		0	0	0
Bio-kerosene	Renewable	1st generation - crop based	1	0	0
	Renewable	Advanced - Annex IX Part A	2.4	0	0
CNG	Fossil		0	1	1
Biomethane	Renewable	Advanced - Annex IX Part A	2	1	2
LPG	Fossil		0	0	0
LNG	Fossil		0	1	1
Electricity fossil	Fossil		0	1	1
Electricity renewable - rail*	Renewable		1.5	1	1.5
Electricity renewable - road*	Renewable		4	1	4
Hydrogen fossil	Fossil		0	1	1
Hydrogen renewable**	Renewable		1	1	1

Note:
(*) Additional from 2018
(**) Due to the uncertainty on how to consider the use of renewable hydrogen for the production of fuels within the RED II framework, this outlook only considers the direct use of renewable H2 as final fuel (with no additional multiplicator factor). This is likely to be reviewed in the coming months/year and will be updated conveniently in future publications, as required.

5.3.1.3. RED II results -2030 Baseline

This sub-section presents the results for the 2030 Baseline. Note that the results of various sensitivity analyses are presented in sub-section 5.3.1.4.

(1) RES-T results (Interpretation 1 - Additionality criteria on renewable electricity in transport)

Table 17 presents the inputs to the RES-T equation in terms of energy content. The inputs are given both (a) without the multiplicator values, (b) with the multiplicator values for the numerator, and (c) with the multiplicator values in both numerator and denominator and for the two interpretations regarding the renewable electricity use in transport (as detailed in Section 5.3.1.1).

Table 17. Results in terms of energy content for 2030 Baseline - Interpretation 1

Approach		(a) Total volumes	(b) RED II target	(c) RED II - Modified
Fuel or energy carrier	**Unit**	**Without multiplicators**	**With multiplicators in numerator**	**With multiplicators in numerator and denominator**
Ren. electricity in road transport	Mtoe	2.0	7.9	7.9
Ren. electricity in rail transport	Mtoe	1.2	1.7	1.7
Ren. electricity in all other transport modes	Mtoe	0.0	0.0	0.0
Compliant biofuels	Mtoe	21.5	28.1	28.1
Advanced - Annex IX Part A	*Mtoe*	2.7	5.3	5.3
First generation - crop based	*Mtoe*	15.0	15.0	15.0
Advanced - Annex IX Part B	*Mtoe*	3.9	7.8	7.8
Other compliant biofuels	*Mtoe*	0.0	0.0	0.0
Non-compliant biofuels	Mtoe	0.0	0.0	0.0
Other renewable energies	Mtoe	0.5	0.5	0.5
Total RES-T numerator (all transport sectors)	Mtoe	25.2	38.2	38.2
Total RES-T denominator (road and rail)	Mtoe	244.9	244.9	259.6

Table 18 presents the results of the RES-T equation in terms of percentage shares. The results are given both (a) without the multiplicator values, (b) with the multiplicator value for the numerator, and (c) with the multiplicator values in both numerator and denominator. It is important to recall that the renewable electricity estimate provided in **Table 17** and used in the RES-T calculation in **Table 18** is based on the additional renewable electricity using Interpretation 1.

Table 18. Results in terms of percentage shares for the 2030 Baseline - Interpretation 1

Approach		**(a) Total volumes**	**(b) RED II target**	**(c) RED II - Modified**
Fuel or energy carrier	**RED II Target**	**Without multiplicators**	**With multiplicators in numerator**	**With multiplicators in numerator and denominator**
Ren. electricity in road transport		0.8 %	3.2 %	3.0 %
Ren. electricity in rail transport		0.5 %	0.7 %	0.7 %
Ren. electricity in all other transport modes		0.0 %	0.0 %	0.0 %
Compliant biofuels		8.8 %	11.5 %	10.8 %
Advanced - Annex IX Part A	Min. 3.5%	1.1 %	**2.2 %**	2.1 %
First generation - crop based	Max. 7.0%	6.1 %	**6.1 %**	5.8 %
Advanced - Annex IX Part B	Max. 3.4%	1.6 %	**3.2 %**	3.0 %
Other compliant biofuels		0.0 %	0.0 %	0.0 %
Non-compliant biofuels		0.0 %	0.0 %	0.0 %
Other renewable energies		0.2 %	0.2 %	0.2 %
Total RES-T share	**Min. 14%**	10.3 %	**15.6 %**	14.7 %

i. In the most favourable calculation, where multiplicators are used in the numerator but not in the denominator, the share reaches **15.6%.**

ii. The minimum target of 3.5% for advanced biofuel feedstocks from Annex IX Part A will not be obtained, even with the most favourable use of multiplicator values.

iii. The maximum cap set to 7% on first generation biofuel feedstocks is upheld regardless of whether the multiplicator values are applied or not.

iv. The uptake of advanced feedstocks from Annex IX Part B did not exceed the administrative target set at 3.4% (equivalent to the physical target of ~1.7%).

(2) RES-T results (Interpretation 2 - Additionality criteria on total renewable installed capacity)

Table 19 presents the inputs to the RES-T equation in terms of energy content. The inputs are given both (a) without the multiplicator values, (b) with the multiplicator values for the numerator, and (c) with the multiplicator values in both numerator and denominator and for the two interpretations regarding the renewable electricity use in transport.

Table 19. Results in terms of energy content for the 2030 Baseline - Interpretation 2

Approach		(c) Total volumes	(d) RED II target	(c) RED II - Modified
Fuel or energy carrier	**Unit**	**Without multiplicators**	**With multiplicators in numerator**	**With multiplicators in numerator and denominator**
Ren. electricity in road transport	Mtoe	2.2	8.8	8.8
Ren. electricity in rail transport	Mtoe	2.9	4.4	4.4
Ren. electricity in all other transport modes	Mtoe	0.0	0.0	0.0
Compliant biofuels	Mtoe	21.5	28.1	28.1
Advanced - Annex IX Part A	*Mtoe*	2.7	5.3	5.3
First generation - crop based	*Mtoe*	15.0	15.0	15.0
Advanced - Annex IX Part B	*Mtoe*	3.9	7.8	7.8
Other compliant biofuels	*Mtoe*	0.0	0.0	0.0
Non-compliant biofuels	Mtoe	0.0	0.0	0.0
Other renewable energies	Mtoe	0.5	0.5	0.5
Total RES-T numerator (all transport sectors)	Mtoe	27.1	41.8	41.8
Total RES-T denominator (road and rail)	Mtoe	244.9	244.9	259.6

Interpretation 2 provides higher energy estimates of renewable electricity going to road and rail than Interpretation 1. The difference in energy estimates arises from the difference in how to interpret the additionality concept.

Table 20 presents the results of the RES-T equation in terms of percentage shares. The results are given both (a) without the multiplicator values, (b) with the multiplicator value for the numerator, and (c) with the multiplicator values in both numerator and denominator. It is important to recall that the renewable electricity estimate provided in **Table 19** used in the RES-T calculation in **Table 20** is based on the additional renewable electricity using Interpretation 2. Based on Interpretation 2, we find that the RES-T share is 17.0%.

Table 20. Results in terms of percentage shares for 2030 Baseline - Interpretation 2

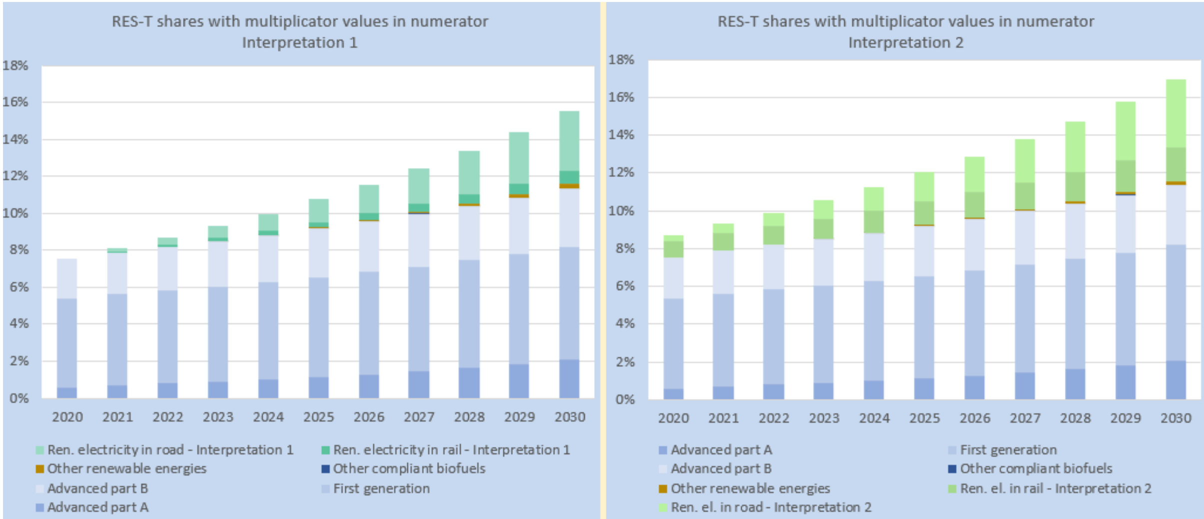
Approach		**(c) Total volumes**	**(d) RED II target**	**(c) RED II - Modified**
Fuel or energy carrier	**RED II Target**	**Without multiplicators**	**With multiplicators in numerator**	**With multiplicators in numerator and denominator**
Ren. electricity in road transport		0.9 %	3.6 %	3.4 %
Ren. electricity in rail transport		1.2 %	1.8 %	1.7 %
Ren. electricity in all other transport modes		0.0 %	0.0 %	0.0 %
Compliant biofuels		8.8 %	11.5 %	10.8 %
Advanced - Annex IX Part A	Min. 3.5%	1.1 %	**2.2 %**	2.1 %
First generation - crop based	Max. 7.0%	6.1 %	**6.1 %**	5.8 %
Advanced - Annex IX Part B	Max. 3.4%	**1.6 %**	**3.2 %**	3.0 %
Other compliant biofuels		0.0 %	0.0 %	0.0 %
Non-compliant biofuels		0.0 %	0.0 %	0.0 %
Other renewable energies		0.2 %	0.2 %	0.2 %
Total RES-T share	**Min. 14%**	11.1 %	**17.0 %**	16.1 %

i. In the most favourable calculation, where multiplicators are used in the numerator but not in the denominator, the share reaches **17.0%.**

(3) Comparison Interpretations 1&2 – Evolution towards 2030

The development of the RES-T in terms of percentage shares with multiplicator values in the numerator in the time period 2020-2030 (baseline) is shown in **Figure *36***. Biofuels are denoted by a blue colour, other renewable energies (hydrogen) in brown, and electricity in green shades. Note that the share from biofuels and other renewable energies (hydrogen) are the same for both interpretations, and that the difference in RES-T shares stems entirely from the interpretation of additionality for renewable electricity (mainly due to the current use of electricity in rail sector).

Figure 36. Development of the RES-T percentage shares with the multiplicator values in the numerator. Interpretation 1 are shown on the left chart while Interpretation 2 are shown on the right chart



An increase of renewables in the transport sector is expected towards 2030 regardless of whether Interpretation 1 or 2 is applied. Based on the calculations detailed in previous sections, the % renewable energy in transport ranges from **15.6% (Interpretation 1) up to 17.0% (Interpretation 2)**, both cases meeting the current 2030 targets. However, in terms of sub-targets, based on the current market trends, the minimum 3.5% of advanced biofuels from Annex IX Part A are not met and, highlighting the risk and need to further developments in this area in the coming decade.

Comparing the results of these two interpretations for the renewable electricity in transport, it is clear that the road sector results are less affected by the difference in interpretation compared to the rail sector results (due to the current use of electricity which is more significant in rail, being almost negligible in road). The difference on the RED II overall goal between the two approaches is 1.4%. Interpretation 2 reduces the space for road sector contribution to meet the 14% goal, but at the same time, under the other assumptions used to define the baseline, it allows to fully meet the 14%.

In addition to the calculation done in line with the RED II regulatory framework, the total renewable share was also calculated based on the entire transport sector, using all transport (road, rail, other off-road, aviation, and maritime) energy in the denominator (rather than just energy use from road and rail). The interested reader can find these additional results in the Appendix.

5.3.1.4. RED II results – sensitivity analyses

5.3.1.4.1 Key parameters

In order to assess how sensitive the RED II target is to some selected key criteria, different sensitivity analyses have been performed around the same baseline. In these cases, only one selected parameter is modified at the time, evaluating how this change would affect the RES-T results compared to the 2030 baseline. These sensitivities are not intended to be considered as **alternative scenarios** to meet the current targets but to provide the reader with additional insights on the relative importance of different criteria towards meeting current and future RED II targets.

The sensitivity analyses considered eight main aspects that are described below.

Table 21. Sensitivity cases

#	Sensitivity	Description
1	**EV: Higher share in passenger cars**	30% EV share (BEV+PHEV) in 2030 new sales
2	**Bio-kerosene: Higher uptake**	5% in the kerosene mix by 2030
3	**Annex A feedstock**	What is needed to reach min 3.5% sub-target (HVO as reference fuel used to provide an estimate)
4	**Biomethane: Higher uptake**	40% share of biomethane in total gas used in road, rail, and maritime transport sectors
5	**Annex B feedstock: Administrative cap**	Impact of 1.7% cap being applied to Annex B feedstock as an administrative cap with multipliers
6	**Ethanol: E10 limited uptake**	Progressive ramp-up of E10 based on historical trends (no full E5 replacement in 2030)
7	**Ethanol: Theoretical only E5 grade**	Only E5 grade aiming to quantify the impact of E10 penetration at EU level (theoretical assessment)
8	**Liquid biofuels in other modes**	Higher share of liquid biofuels in 2030: 20% in maritime and 10% in rail
9	**Dual-fuel LNG trucks**	All heavy LNG trucks (>16t segment) enabled with dual-fuel HPDI technology in 2030

Description:

1) Increase the share of **EVs in passenger car** fleet

The first sensitivity analysis considers an increase in the share of EVs (BEV+PHEV) in the new sales of passenger cars. In the baseline scenario it was assumed that the share of EVs was 20% by 2030, while this sensitivity analysis assumes that this share is increased to 30%. Similar to Baseline, the split of 1/3 PHEV and 2/3 BEV is assumed for EV registration in 2030.

2) Increase the share of **bio-kerosene** in aviation

The second sensitivity analysis considers the share of bio-kerosene in aviation. In the baseline, the share of bio-kerosene in aviation fuel was estimated to be 0.9% in 2030. This sensitivity analysis explores how a bio-kerosene share of 5% affects the RES-T share. Additional levels of bio-kerosene will replace fossil-based jet fuel beyond the penetration levels defined in the baseline (0.9% of total EU energy demand in aviation in 2030 as defined in section 2.4.1).

3) Increase the share of Annex A feedstocks (expressed as HVO equivalent)

The RED II targets a minimum 3.5% of Annex IX Part A advanced biofuels by 2030, indicating the wish to increase the production and use of these feedstocks. This third sensitivity analysis considers what is the required increase of Annex A feedstocks for HVO production (as the selected fuel for illustrative purposes) to reach the 3.5% target for Annex A feedstocks (without considering any current supply constraints).

4) Use supply of **biomethane** to replace CNG and LNG from fossil natural gas

The fourth sensitivity analysis considers the increasing use of biomethane in transport sector, which is solely based on Annex A feedstocks in this outlook. As shown in **Figure 23**, there is an excess in the availability of biomethane production compared to the modelled use in the baseline when only transport is considered. This sensitivity analysis estimates the RES-T share when **higher biomethane volumes are diverted to transport**, replacing natural gas. The share of biomethane in total CNG/LNG consumption was 20% in 2030. This case explores the impact of 40% share of biomethane in total gas used in road, rail, and maritime transport sectors.

It is relevant to note that this case may not imply any additional GHG reduction versus the baseline when the whole EU system is considered. This is because the biomethane production volume potentially diverted towards transport sector in this sensitivity case was actually already used to reduce emissions in other sectors in the baseline (e.g. industrial heating, power generation).

5) Annex B feedstocks: 1.7% administrative cap

The fifth sensitivity analysis explores the impact of physical vs administrative cap for Annex B feedstock. In this case, the 1.7% cap is applied to Annex B feedstock as an administrative cap with multipliers (not physical).

6) Limit the ethanol uptake: Historical E10

The baseline assumes the phase-in of E10 to fully replace E5 by 2030 (100% market share); the first ethanol sensitivity analysis considers E10 uptake based on historical data to reach 78% of gasoline fuel grades in 2030. The estimated uptake data are based on extrapolations of historical use data for E10 and E5.

7) Limit the ethanol uptake

This ethanol sensitivity analysis solely considers E5 uptake towards 2030 and aims to quantify the impact on RED II of the E10 uptake at EU level for merely informative purposes.

8) Higher share of liquid biofuels in other transport modes

In baseline, the share of liquid biofuels in rail and maritime sectors was determined based on the share of FAME equivalent in diesel fuel grade in the road transport sector (i.e., 5.7% in 2030 in energy content terms). This sensitivity case is defined to evaluate the impact of higher use of liquid biofuels in the fuel mix to achieve 10% of non-electric rail and 20% in maritime sector.

9) Dual-fuel LNG trucks

LNG trucks in baseline were defined based on spark ignited LNG ICE as a simplification and no dual-fuel LNG trucks (HPDI technology) was considered in the new sales. HPDI trucks are still in niche market and due to the uncertainty about their market penetration at EU level, a sensitivity analysis is performed where all heavy-duty LNG trucks (>16t) are based on this technology by 2030. This sensitivity case shows the potential impact of an accelerated development/penetration of this HPDI concept and the potential impact on the RED II target.

5.3.1.4.2 Results of sensitivity analysis

As mentioned, the sensitivity analyses were performed individually, rather than combined, and the results in terms of RES-T shares are reported below in **Table 22** (Interpretation 1) and **Table 23** (Interpretation 2). The full tables with detailed results for each sensitivity can be found in the Appendix.

RES-T results (Interpretation 1 - Additionality criteria on renewable electricity in transport):

Table 22. Summary of the sensitivity analysis considering a change in model parameters (Interpretation 1)

#	Case	RES-T in Mtoe without multiplicators	RES-T in % with multiplicators in numerator
-	Baseline	25.2	15.6%
1	**EV: Higher share in passenger cars**	25.7	16.4%
2	**Bio-kerosene: Higher uptake**	27.5	16.7%
3	**Annex A feedstock**	26.8	16.9%
4	**Biomethane: Higher uptake**	26.7	16.8%
5	**Annex B feedstock: Administrative cap enforced**	23.4	14.1%
6	**Ethanol: E10 limited uptake**	24.7	15.4%
7	**Ethanol: Theoretical only E5 grade**	23.0	14.6%
8	**Liquid biofuels in other modes**	26.0	16.0%
9	**Dual-fuel LNG trucks**	25.0	15.5%

(1) Increase the share of EVs in passenger car fleet

In Baseline, the share of new EV registration (i.e. BEV+PHEV) within the total registration of all passenger cars is set to 20% in 2030 (6.7% for PHEV and 13.3% for BEV). The sensitivity case (1) shows the impact of increasing the share of EVs to 30% in 2030 sales on RES-T. It calls for the registration of 4.8 million new EVs, a third of which are expected to be PHEVs. Compared to baseline, the additional sales of 1.1 million BEVs and 0.5 million PHEVs will be required in 2030 to replace gasoline and diesel cars. Compared to baseline, about 8.4 million additional EV stock would be on the EU's roads by 2030, of which at least 5.6 million would be BEVs. Higher uptake of EV raised the use of renewable electricity in road transport from 2.0 Mtoe in the baseline to 2.5 Mtoe.

(2) Increase in bio-kerosene

Increasing bio-kerosene, so that it makes up 5% of total aviation fuel demand, raised the use of biofuels in aviation from 0.6 to 2.9 Mtoe (with an estimated potential availability of 3.4 Mtoe). Even though most of the biofuel going to aviation stems from first generation crop-based feedstocks, the 7% cap on first generation biofuels was not surpassed. This sensitivity case shows that increasing the use of bio-kerosene by fivefold versus the baseline increases the RED II share by over 1%. It is important to note that this sensitivity case considers additional capacity, in the case of HEFA, assuming no competition with the projected use/availability of HVO in the road sector (with an impact on additional feedstock / new capacity requirement). Further sensitivity analysis on the feedstock type showed that if all biokerosene is produced from Advanced Annex IX Part A, assuming the multiplier of 2.4, the RED-II share can increase up to 18.2%.

(3) Increase the share of annex A feedstock: HVOeq

Reaching the 3.5% target for Annex A biofuels through a theoretical increase of Annex A feedstocks for HVO production (used as a reference fuel) may require an additional production capacity of ~1.6 Mtoe/y (from 0.8 in baseline to 2.4 Mtoe/y). This is translated to more than the threefold of the projected HVO Annex A feedstock use.

(4) Biomethane

By assuming a higher share of 40% for biomethane diverted from other sectors to transport (and replacing fossil CNG and LNG), an increment of 1.2% would be expected for RED II. With this assumption, the Annex A share reaches 3.4% with the use of multiplicators in the numerator, approaching to the minimum requirement of 3.5%. This share reaches 3.2% with the use of multiplicators in both the numerator and the denominator. It is worth reinforcing the same message as mentioned in the description section: the different allocation of biomethane to the transport sector in this sensitivity case may not deliver additional GHG emission savings versus the baseline, should biomethane was effectively used to replace other fossil-based sources in other sectors.

(5) 1.7% administrative cap for Annex B feedstock

Applying the 1.7% cap on Annex B reduces the RES-T share to 14.1% when multiplicators are used in the numerator. In this case, the RES-T target of 14% and all biofuel feedstock sub-targets are met. The Annex B share decreases to 1.7% with multiplicators in the numerator and 1.6% with multiplicators in both numerator and denominator.

(6) Limiting the ethanol penetration: Historical E-10 ramp-up

Limiting the ethanol penetration in the fleet resulted in a lower RES-T compared to the baseline. A slow penetration of E10 modelled through the historical ramp-up of E10 leads to 15.4% RES-T by 2030, slightly lower than the corresponding share in baseline, which assumes a full market penetration of E10 by 2030. The lower ethanol uptake mainly reduces the use of first-generation feedstocks, which is estimated to make up 95% of the ethanol feedstocks in 2030. Compared to the baseline, the total share of first-generation feedstocks goes down from 6.1% to 5.9% for the E10 sensitivity analysis when multiplicator values are applied to only the numerator.

(7) Limiting the ethanol penetration: Only E5 grade

The extrapolation of historical E5 data and excluding E10 from gasoline fuel grades, resulted in a lower RES-T share of 14.6%. This theoretical case shows that the full deployment of E10 gasoline grade may have an impact of ~1% versus the current RED II target, under the baseline assumptions considered in this fleet modelling.

(8) Higher share of liquid biofuels in other transport modes

Expectedly, assuming the higher share of liquid biofuels use in rail (10% of non-electric fuel mix in 2030) and maritime (20% in 2030) raises the RES-T to 16%. Compared to baseline, the share of first-generation feedstock increases from 6.1% to 6.4% in 2030.

(9) Dual-fuel LNG trucks

This sensitivity case slightly reduces the RES-T share by 0.1% versus baseline. This is mainly due to the fact that dual-fuel LNG trucks installed with the HPDI technology, about 20% more efficient than spark ignited LNG ICE trucks, reduces the demand for LNG, and thus for biomethane uptake, compared to baseline.

In summary, regarding the RED II targets:

- All sensitivity cases meet the RED II target.
- The share of first-generation crop-based feedstocks was successfully kept below the 7% cap under all conditions.
- Reaching the target of 3.5% Annex A feedstocks can be obtained in the case of 3x increase in HVO use. Approaching this target was also observed in the case where diverted biomethane replaced at least 40% of fossil CNG/LNG in transport. Biomethane is envisaged to be a key potential player when reaching RED II targets in transport with the caveat around competition with other sectors (risk of delivering no additional GHG savings across the whole EU economy unless further capacity or additional low GHG technologies are implemented in other sectors, "freeing" some additional biomethane volumes for the transport sector).

Combinations of the various sensitivity analyses (only modifying **one parameter** versus the baseline to explore how sensitive the results are to the assumptions made, without any further modification in the fleet composition) will form alternative scenarios not analysed in the present outlook. Therefore, this report intends to inform the current discussion on future targets and present a market-based picture, identifying key areas and major challenges / barriers that would need to be considered when developing more ambitious 2030 targets.

RES-T results (Interpretation 2 - Additionality criteria on total renewable installed capacity):

The sensitivity analyses that considered how a change in the modelling would affect the results are presented in **Table 23**. Aside from the higher RES-T share due to difference in interpretation of the additionality concept for electricity (mainly due to the current use of electricity in rail transport), there are no other differences compared to Interpretation 1.

Table 23. Summary of the sensitivity analysis considering a change in the modelling (Interpretation 2)

#	Case	RES-T in Mtoe without multiplicators	RES-T in % with multiplicators in numerator
-	Baseline	27.1	17.0%
1	**EV: Higher share in passenger cars**	27.7	17.8%
2	**Bio-kerosene: Higher uptake**	29.5	18.1%
3	**Annex A feedstock**	28.8	18.4%
4	**Biomethane: Higher uptake**	28.6	18.3%
5	**Annex B feedstock: administrative cap enforced**	25.3	15.6%
6	**Ethanol: E10 limited uptake**	26.7	16.9%
7	**Ethanol: Theoretical only E5 grade**	25.0	16.1%
8	**Liquid biofuels in other modes**	27.9	17.5%
9	**Dual-fuel LNG trucks**	27.0	17.0%

5.3.2. GHG emission intensity reduction (Fuel Quality Directive)

The FQD sets a minimum GHG reduction target of 6% for road transport fuels and non-road-mobile machinery by 2020 compared to 2010 and, although the future criteria beyond 2020 is still unclear, this section explores a 2030 scenario under the following basis:

- The baseline GHG intensity factor in 2010 was set to 94.1 g CO_2-eq/MJ_{fuel}. The stated factor includes WTT plus combustion, the same as the GHG intensity factors used to calculate the GHG emissions in section 5.2.
- To make the comparison against the 2010 baseline, the total GHG intensity factor for all road transport must be calculated. The total road GHG intensity factor can be determined by dividing the total road GHG emissions by the total road energy use, as shown in the equation below.

$$EF_{road} = \frac{GHG_{road}}{E_{Fossil,road} + E_{RES,road}}$$

It is worth remarking that this section is not intended to be used as a direct comparison with the FQD targets as it is only focused on road (e.g. **G**asoil used in non-road-mobile machinery, included in FQD, is not considered) but gives a good indication on the potential GHG reductions based on the WTT intensity considered/described in the Appendix of this Concawe report.

As a result of the baseline scenario defined in this document, the following WTT intensity related conclusions could be derived:

- *2020:*

The total GHG emissions from the road sector (GHG_{road}) was estimated to be 1097 million tonne CO_2-eq in 2020 (as shown in Figure 34) and the total energy from fossil and renewable energy sources ($E_{Fossil,road}$ + $E_{RES,road}$) was estimated to be 297 Mtoe in 2020 (as shown in Figure 31). It has to be noted that the JEC WTT v5 data are used, which refer to state-of-the-art technologies. The current efficiency / average efficiency of plants already in operation may be different and could make the CO_2 intensity to be higher than the one presented in the present report.

Note that the multiplicator values do not apply towards the FQD calculation.

- *2030:*

The GHG intensity calculations were also made for 2030, where the total road GHG emissions reached 857 million tonne CO_2-eq (as shown in Figure 34) and the total energy from both fossil and renewable energy sources was 238 Mtoe (as shown in Figure 31). The same JEC WTT v5 data are used so that the delta between the 2020 and 2030 data is due to the higher penetration of alternative fuels and changes in the type of feedstocks / conversion technologies used.

Table 24 reports the estimated reduction compared to the fossil fuel comparator and the emission factor for the 2030 baseline showing that **the GHG emission reduction target was reached in both 2020 and 2030** timeframe:

Table 24. Baseline results for road transport fuels in terms of GHG intensity reduction

		Concawe's baseline		
Year	GHG Emissions ($Mt\ CO_2$-eq)	Energy Use (Mtoe)	Emission Factor ($g\ CO_2$-eq/MJ_{fuel})	GHG intensity reduction from 2010
2030	857	238	85.8	-8.8 %

Note that:

- The emission factors were estimated to 85.8 g CO_2-eq/MJ_{fuel} in 2030.
- Compared to the fossil fuel comparator, the estimated GHG intensity factors resulted in reductions of 8.8% in 2030 (compared to 2010). The reduction of the emission factor stemmed from two sources. First, the shares of fossil fuels were reduced with time, making room for the increased shares of renewable biofuels and energy carriers. Second, the emission factors for biofuels, electricity, and hydrogen decreased with time.

6. GLOSSARY

This main report as well as the Appendix use a list of acronyms for various fuels. This Chapter presents a brief overview of the acronyms used in the report and Appendix.

BEV	Battery Electric Vehicle
B7	Fuel with max 7% (volume) blending of FAME into diesel
CCS	Carbon Capture and Storage
CNG	Compressed Natural Gas
CO_2-eq	Carbon dioxide equivalent
Den. (w)	Denominator value with multiplicator values
Den. (w/o)	Denominator value without multiplicator values
DME	Dimethyl Ether
E10	Fuel with 10% (volume) blending of ethanol into gasoline
E20	Fuel with 20% (volume) blending of ethanol into gasoline
E5	Fuel with 5% (volume) blending of ethanol into gasoline
E85	Fuel with max 85% (volume) blending of ethanol into gasoline
EBB	European Biodiesel Board
ED95	95% ethanol fuel
e-diesel	Synthetic diesel fuel made from carbon dioxide, water, and electricity
ePURE	European renewable ethanol
$E_{sector,fuel}$	Total use of fuels and energy carriers from all sectors per sector
$E_{fuel,sector}$	Total use of fuels and energy carriers from all sectors per fuel
$E_{res,sector}$	Total use of renewable energy source in sector
$E_{Fossil,sector}$	Total use of fossil energy in sector
EF_{fuel}	Emission factor of a given fuel or energy carrier
ETBE	Ethyl Tertiary Butyl Ether
EU27+3	EU27 plus United Kingdom, Switzerland, and Norway
EU28	EU27 and United Kingdom
EV	Electric Vehicle (BEV+PHEV)
FAME	Fatty Acid Methyl Ester
FCEV	Fuel Cell Electric Vehicle
FFV	Flex-Fuel vehicle
FQD	The Fuel Quality Directive
FT	Fischer-Tropsch
GHG	Greenhouse gas
H2 - fossil	Hydrogen from fossil sources
H2 - renewable	Hydrogen from renewable sources

HDV	Heavy-Duty Vehicle
HEFA	Hydro-processed esters and fatty acids
HEV	Hybrid Electric Vehicle
HFO	Heavy Fuel Oil
HSFO	High Sulphur Fuel Oil
HVO	Hydrotreated Vegetable Oil
IMO	International Maritime Organization
JEC	Joint Research Center, EUCAR, CONCAWE
ktoe	kilo tonnes oil equivalent
LCV	Light Commercial Vehicle
LDV	Light-Duty Vehicle
LNG	Liquified natural gas
LPG	Liquefied petroleum gas
MGO	Marine Gas Oil
MTBE	Methyl Tertiary Butyl Ether (MTBE)
Mtoe	Million tonnes oil equivalent
NEDC	New European Driving Cycle
PC	Passenger Car
PHEV	Plug-in Hybrid Electric Vehicle
RED-II	The Renewable Energy Directive II
RES	Renewable Energy Source
RES-T	Renewable Energy in Transport
SAF	Sustainable Aviation Fuel
SNG	Synthetic Natural Gas
TTW	Tank-to-Wheel
UCO	Used Cooking oil
WLTP	Worldwide Harmonised Light Vehicle Test Procedure
WTT	Well-to-Tank
WTW	Well-to-Wheel

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Environmental Science for European Refining

Concawe
Boulevard du Souverain 165
B-1160 Brussels
Belgium

Tel: +32-2-566 91 60
Fax: +32-2-566 91 81
e-mail: info@concawe.org
http://www.concawe.eu

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