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EU renewable energy targets in 2020: Analysis of scenarios for transport

JEC Biofuels Programme

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EU renewable energy targets in 2020: Analysis of scenarios for transport fuels

JEC Biofuels Programme

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This report is the result of the JEC Biofuels Programme, a joint study carried out by EUCAR (the European council for Automotive R&D), CONCAWE (the oil companies' European association for environment, health and safety in refining and distribution) and JRC (the Joint Research Centre of the European Commission).

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Executive Summary

The on-going research collaboration between the Joint Research Centre of the European Commission, EUCAR and CONCAWE has investigated the potential for biofuels and other alternative energy sources to achieve the 10% renewable energy target for the EU transport sector by 2020 as mandated by the Renewable Energy Directive (RED)[1]. Consideration has also been given to other relevant regulations impacting the transport sector in the coming decade.

This study provides a robust scientific assessment of different renewable energy implementation scenarios and their associated impacts on the RED mandatory target for transport. The primary focus is on road transport demand although all other transport modes (aviation, rail, inland navigation and off-road) have been considered and are important contributors towards reaching the targets. Associated calculations of the Greenhouse Gas (GHG) reductions mandated in Article 7a of the Fuel Quality Directive (FQD)[2] have been performed for the different RED implementation scenarios.

An analytical tool, called the Fleet and Fuels (F&F) model, has been developed and used to support this study. The model is based upon historical road fleet data (both passenger and freight) in 29 European countries (EU27 plus Norway and Switzerland). It projects the development of the vehicle fleet until 2020 based on reasonable assumptions including the impact of regulatory measures. The modelled fleet development leads to a road transport fuel demand and provides the basis upon which the introduction and availability of renewable and alternative motor fuels are analysed. The impacts of key modelled parameters on the RED 10% renewable energy target are also analysed in sensitivity cases.

During the development of the F&F model, the most recent energy and fuel demand data were used and experts in related projects were consulted via webinars and meetings to ensure that the model had been constructed using sound data and reasoning.

Reasonable assumptions regarding the projected development of the European vehicle fleet, including different vehicle technology options and the resulting demand for conventional and renewable fuels have been made. From this starting point, the F&F model was used to evaluate a reference scenario and eight additional market fuel demand scenarios. The results were then compiled to compare the potential contributions of renewable energy in transport from each scenario. These scenarios have also been studied by sensitivity analysis and provide both information and material for further investigation in several research areas at the crossroads of energy and transport.

The reference scenario based on currently approved biofuel blends (B7[3], E5, E10) for broad market road fuels almost meets the RED 10% renewable energy target, when the renewable energy contribution from road transport is combined with additional contributions from non-road transport modes.

Eight other "technically feasible" scenarios have been analysed, based on higher biofuel contents, multiple grades, increasing shares of compatible vehicles in the fleet, and increasing

[1] RED: EU Renewable Energy Directive (Dir 2009/28/EC) of 23 April 2009
[2] FQD: EU Fuel Quality Directive (Dir 2009/30/EC) of 23 April 2009
[3] In this report, biofuel contents are expressed as the percentage of bio-component in fossil fuel on a volume basis. For example, B7 stands for 7% v/v Fatty Acid Methyl Ester (FAME) in diesel fuel while E5 stands for 5% v/v ethanol in gasoline.

acceptance of customers to choose the right fuel for their vehicle. Evaluation of these eight scenarios has shown that the 10% RED target can be reached.

However, although the RED target can be reached, none of the considered scenarios achieves the minimum 6% GHG reduction target mandated in FQD Article 7a with the assumptions taken for the FQD calculations. Indirect Land Use Change has also not been considered in this analysis.

Following the definition and evaluation of different market fuel demand scenarios, an analysis of likely biofuel supply through 2020 was carried out. The demand/supply analysis combines the results of the demand scenarios with biofuel availability scenarios. Demand/supply tensions that could impact the likelihood that different demand scenarios achieve the RED 10% renewable energy target were highlighted.

This study does not assess the viability, costs, logistics, or impact on the supply chain and vehicle industry of the different demand scenarios. Additional work would be needed before determining the commercial readiness of any one scenario. Overall, the RED implementation scenario results depend on the underlying assumptions and should be considered as "theoretically" achievable. Realisation of these "technically feasible" scenarios depends on a combination of factors, the associated costs and the timelines of decisions

Additional considerations

Consumer acceptance of biofuels is a critical element of the optimal conditions required to reach the RED target. The assumed levels of biofuel uptake in these scenarios depend on customer behaviour. For example, it is assumed that Flexi-Fuel Vehicles (FFV) will be fuelled with E85 for 90% of their distance travelled and that consumers will always choose the highest available biofuel grade that is compatible with their vehicle.

On the supply side, the pace of introduction of alternative solutions presented in the scenarios depends not only on the availability of the fuels but also on the compatibility of the supply and distribution system for all fuel products. It also depends on the contribution of non-road transport modes towards achieving the RED 10% target.

Some scenarios may need certain policy measures to enable a smooth transition from today to the "technically feasible" solutions identified and analysed in the scenarios.

Furthermore, scenarios suit national contexts differently. It is therefore important that standardisation proceeds in a co-ordinated way to avoid market fragmentation for fuels and their supply. Market fragmentation will also negatively impact vehicle manufacturing and even lead to customer dissatisfaction. Compatibility between fuel blends and vehicles is important in determining the pace and the uniformity of introduction of alternatives in a single market, avoiding a proliferation of nationally-preferred and nationally-adapted solutions. Multi-stakeholder coordination and timely decisions will be essential in order to approach the RED target.

The JEC Biofuels Programme acknowledges among its findings that much more technical work will be needed to ensure the feasibility of identified scenarios. The compatibility between fuels having higher biofuel contents with road transport vehicles and those in other transport modes is not proven and the evaluation process to ensure compatibility will require time, testing and investments.

Report Outline

In this report, the potential for renewable fuels to achieve EU mandatory targets for renewable energy by 2020 has been assessed. Contributions from the road and non-road transport sectors have been considered as well as a broader view on other alternative fuels.

Following a review of the EU regulatory framework in Section 2, Section 3 describes the F&F model developed by JEC and includes details of the reference scenario. Section 4 discusses the selection of technically feasible scenarios. Section 5 outlines biofuel supply projections and compares them with the demand scenarios described in Section 4 thus providing an indication of the achievability of EU 2020 regulatory targets. Conclusions from the study are presented in Section 6.

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1 Introduction

What is JEC?

The JEC research collaboration between the Joint Research Centre of the European Commission, EUCAR (the European Council for Automotive Research and Development) and CONCAWE (the Oil Companies' European organisation for environment, Health and Safety) began in the year 2000. The three organisations have collaborated in several areas related to the sustainability of the European vehicle and oil industries, providing facts relating to energy use, efficiency and emissions from a broad range of road vehicle powertrain and fuel options. The JEC Well-to-Wheels (WTW) reports and methodology (WTW 2007) have become a scientific reference in the European energy research landscape.

The JEC Biofuels Programme

The JEC Biofuels Programme was a self-funded three-year (2008-2010) technical exercise intended to assess possible biofuel implementation scenarios for achieving mandated renewable energy targets in the European Union's transport sector by 2020.

The JEC partner organisations agreed to initiate research in this area when the – now adopted – Renewable Energy Directive (RED) of 23 April 2009 (EC 2009a) was still a draft. This was because they considered that a robust scientific basis for decision making was needed that could best be provided by a collaborative analysis. This work focussed initially on the role of biofuels in road transport, although the RED mandated target does not solely focus on biofuels as alternative fuels nor does it solely focus on road transport contributions. Accordingly, in line with the RED target, other alternatives to both conventional fuels and biofuels have been investigated in the JEC Biofuels Programme and are reported here. In addition, non-road transport modes have been considered for their potential contribution to the RED target as well as complementary or competing demands for the same alternative fuel products as road transport.

This technical exercise was aimed at identifying and characterising a set of technically-feasible scenarios to achieve the RED target and to provide an initial analysis of the advantages and disadvantages of each scenario. It was conceived and intended as a technical exercise, thus not committing JEC partners to deliver any particular scenario or conclusion included in the study and presented in this report.

The JEC Biofuels Programme, including the methodology and activities, was defined by its objectives, scope and approach. These are schematically presented below with the aim of clearly defining the system boundaries within which the technical exercise reported here was carried out by the three partner organisations.

Objectives of the JEC Biofuels Programme

The objectives of the JEC Biofuels Programme are:

- To clarify the opportunities and barriers to achieve 10% renewable energy (on an energy basis) in the transport sector by 2020, by developing theoretical fuel demand scenarios which can be evaluated and compared to supply projections of biofuel types and availability;
- To focus on fuel blends with conventional and advanced biofuels while accounting for growth in alternative motor fuels in the European fleet until 2020 and considering both domestic production and imports;
- To ensure that the introduction of biofuel blends in Europe results in no detrimental impact on vehicle performance and emissions, while including in the analysis the most recent updates on Well-to-Wheels (WTW) energy and Greenhouse Gas (GHG) implications.

Scope of the JEC Biofuels Programme

The scope of the JEC Biofuels Programme is summarised as:

- Focusing analysis on road transport energy demand while at the same time including non-dynamic analysis of other transport modes;
- Analysing possible implementation scenarios within the 2010-2020 time horizon focusing on fuel alternatives in terms of requirements to road vehicle fleet developments.

Other aspects were also considered, including requirements for phasing-in of fuel standards, (fuelling) infrastructure requirements, fuel production and distribution requirements, user/customer acceptance, and availability of demanded amounts of fuels (supply).

Approach of the JEC Biofuels Programme

In line with the objectives and scope of the JEC Biofuels Programme outlined above, partner organisations developed a consensus demand and supply picture of biofuel types to meet the 2020 10% renewable energy target in the transport sector adopted by the RED (EC 2009a). The approach has therefore been one of

- Creating a ‘Fleet and Fuels’ model based on historic data and consensual assumptions of future technological developments, covering:
  - Fleet development of passenger cars, vans, and heavy-duty (HD) trucks including alternative powertrains
  - Fuel and energy demand development
- Reviewing and analysing projections and other data for the period 2008-2020, covering:
  - biodiesel, ethanol and others, including conventional and advanced products
  - domestic biofuel production and imports
  - most recent updates on WTW energy and GHG implications
- Analysing possible biofuel implementation scenarios within the 2010-2020 timeframe and subject to the existing regulatory framework.

To ensure the accuracy of the methodology and assumptions, the consortium work was accompanied by expert and stakeholder consultations as well as practical research. Consultations throughout the study in order to review the analysis carried out in the JEC Biofuels Programme, including data availability and reliability and the as well as underlying reasoning to assumptions in the F&F model.

In general terms, the “vision” of the coming decade for European road transport as portrayed by the JEC Biofuels Programme is summarised below:

- ***Vehicle technology.*** There is a plausible expectation for more advanced propulsion systems, thus resulting in more diversification in engines and subsequently in fleet composition. At the same time, the total demand for gasoline by light-duty vehicles (LDV) in the on-road fleet is expected to fall while the heavy-duty vehicle (HDV) demand for diesel fuel could increase slightly. Vehicles will be expected to be compatible with fuels containing increasing volumes of bio-components, such as B7 and E10. On the regulatory side, it is expected that increased attention will be on CO_2 emissions reductions in the transport sector which will result in higher costs incurred by vehicle manufacturers for compliance.
- ***Refinery technology.*** In line with road fuel development expectations, the diesel/gasoline demand ratio in Europe is expected to increase. In refineries, this will lead to higher CO_2 emissions in order to satisfy the increasing diesel demand and more stringent product quality specifications. Growing attention to CO_2 emissions reductions via increasingly stringent regulation will result in higher production costs in refining which could in turn contribute to pressure on European refining margins and competitiveness.
- ***Biofuels and other renewable energy sources for transport.*** On the regulatory side, the 10% renewable energy target for 2020 was fixed by the RED (EC 2009a). It is expected that conventional biofuels will be widely available but sustainability concerns will exist for some products. Advanced biofuels are likely to show a slower-than-expected pace of development and there is likely to be competition for supplies of advanced biofuels between parts of the world with respective biofuel policies and between transportation modes (e.g. road and air transport). It is reasonable to expect that fleet renewal and adoption of alternative fuels could differ across EU Member States due to inherent energy and transport demands and diverse energy policy priorities. As a consequence, fuel markets in the EU could become increasingly diverse. In this respect, a robust, sound and timely standardisation process (i.e. CEN specifications) is key to implement potential future fuel options.

2 EU Regulatory Framework

The reference regulatory framework within which the JEC Biofuels Programme was defined is the so-called "EU Energy Package", and more specifically the RED (EC 2009a) and FQD (EC 2009b).

The Renewable Energy Directive

The RED imposes two key requirements for the uptake of renewable energy and – more specifically – biofuels in the transport sector.

1. EU Member States are required to meet a minimum binding target of 10% renewable energy share in the transport sector by 2020. All types of renewable energy used in all transport modes are included in the target setting.

   Some renewable energy sources are counted differently. For example, the contribution of advanced biofuels[4] towards achieving the 10% target is counted twice[5] while electricity from renewable energy sources for road transport is counted 2.5 times[6] (see

   Figure 1. Renewable Energy Calculations in the RED

   Biofuels must also meet minimum sustainability criteria as well as minimum GHG savings per unit of energy.

2. Each Member State is requested to establish a National Renewable Energy Action Plan (NREAP), including information on targets for different transport and non-transport sectors.

   In addition, Member States are expected to implement measures to achieve these targets, assessing the contribution of both energy efficiency and energy saving measures.

   The RED places the responsibility for fulfilling the RED targets on the Member States.

[4] See Art. 21.2 of the RED "biofuels produced from wastes, residues, non-food cellulosic material, and ligno-cellulosic material"
[5] Biofuels according to Art. 21.2 are counted twice in the numerator of the RED calculation – not in the denominator
[6] See Art. 3.4 of the RED; the factor of 2.5 is used in the numerator and the denominator

Focus of the JEC Biofuel Programme:

- Model renewable energy in road transport.
- Use RED methodology to calculate ROAD-% contributions. These ROAD-% must be combined with assumptions for other transport sectors to calculate the RED-%.

Calculation of the contribution of road transport to the RED 10% target:

$$\text{ROAD-\%} = \frac{\text{All types of energy from renewable sources consumed in road transport}}{\text{Petrol, diesel, biofuels consumed in road and rail transport and electricity (in transport) but excluding off-road}^{2)}}$$

Calculation of the overall RED-% of renewable energy in transport (Art. 3(4) of the RED):

$$\text{RED-\%} = \frac{\text{All types of energy from renewable sources consumed in all forms of transport}^{1)}}{\text{Petrol, diesel, biofuels consumed in road and rail transport, and electricity (in transport) but excluding off-road}^{2)}}$$

1) Renewable energy in Road, Rail, Aviation, Inland Navigation and Pipeline Transport
2a) Off-road means mobile machinery (forestry, agriculture, and construction) ~20Mtoe
2b) CNG & LPG in road transport are not included, BUT: Biogas (= biofuel) is included

Application of factors:

- "*Advanced Biofuels"* count 2 times in numerator (support)
  - Definition: biofuel from waste, residue and non-food cellulosic material, Article 21(2)
- *"Green Electricity"* for road transport counts 2.5 times in numerator & denominator (efficiency factor)
  - Definition: electricity from renewable sources, Article 3(4)

Figure 1. Renewable Energy Calculations in the RED

The Fuel Quality Directive

The FQD sets environmental requirements for petrol and diesel fuel in order to reduce their air pollutant emissions. These requirements consist of technical specifications for fuel quality parameters and binding targets to reduce the fuels' life cycle GHG emissions.

Article 7a of the FQD requires fuel suppliers to gradually reduce life cycle GHG emissions from fuel or energy supplied by 6% in 2020, compared to the 2010 fossil fuel GHG emissions baseline. This will primarily be done by refinery efficiencies and biofuel blending. Member States may choose to increase this percentage up to 10% and they may also choose to set intermediate targets of 2% by 2014 and 4% by 2017.

Fuel suppliers must also reach an additional indicative reduction target of 2% by 2020 by either supplying electric vehicles or using GHG emission reduction technologies (including carbon capture and storage technology). Another indicative target of 2% by 2020 is to be achieved by the purchase of credits through the Clean Development Mechanism (CDM) under the Kyoto Protocol[7]. The last two targets are subject to review.

The FQD Article 7a target takes into account the impact of renewable fuels on life cycle GHG emission savings of fuels supplied for on-road vehicles, non-road mobile machinery (including rail and inland marine), agricultural and forestry tractors and recreational craft. With respect to transport activities, the main difference between these two Directives is that

[7] http://cdm.unfccc.int/index.html

the FQD excludes fuel consumed by air transport while the RED includes it. The FQD calculation also includes off-road fuel consumption which is excluded from the RED calculation.

Additionally, the FQD requires a 2010 reference value for life cycle GHG emissions per unit of energy from fossil fuels to enable the calculation of GHG savings from biofuels and alternative fuels.

From 2011 fuel suppliers must report annually to Member States on the life cycle GHG emissions per unit of fuel supplied.

The JEC Biofuels Programme scope of analysis is the identification and characterisation of technically feasible solutions to meet the RED 10% renewable energy target with an associated calculation of GHG savings as regulated in Article 7a of the FQD.

Nevertheless other regulatory acts at EU level are also relevant because they contribute to setting the boundaries of the projected development of both fleet and fuels demand in Europe. These are briefly outlined in the following paragraphs.

CO_2 emission level averages for new passenger light duty vehicles

The regulation of CO_2 emissions from light duty vehicles (LDVs) is addressed by Regulation 443/2009 (EC 2009c). This Regulation sets emissions performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from LDVs. Manufacturers must reduce CO_2 emissions in the new fleet of passenger cars reaching new fleet averages of 130g CO_2/km in 2015. For 2020, a target of 95g CO_2/km[8] has been confirmed, with implementation modalities subject to review.

This Regulation places the burden of complying with the target on car manufacturers and recognises the role of alternative motor fuels (namely E85) and innovative technologies, by accounting for additional CO_2 reductions on overall emissions. Regarding E85 vehicles, the Regulation foresees that until the end of 2015, a CO_2 emissions reduction of 5% may be applied providing that at least 30% of filling stations in the Member States provide E85 and that the E85 meets sustainability criteria. This provides an incentive for car manufacturers, fuel producers and distributors to work together, e.g. by sharing a common knowledge basis.

A regulation on CO_2 from light commercial vehicles (vans) has been proposed by the European Commission in October 2009 (EC 2009e) and adoption is expected in 2011. The targeted EU fleet average for all new light commercial vehicles of 175 g CO_2/km is to be implemented as of 2017. For 2020, a target of 147 g CO_2/km has been proposed with implementation modalities subject to revision.

Tailpipe emission standards for passenger cars and heavy duty vehicles

Regulation 715/2007 (EC 2007) introduces new common requirements for emissions from motor vehicles and their specific replacement parts (Euro 5 and Euro 6 standards[9]) for passenger cars, vans and light duty commercial vehicles (categories M1, M2, N1 and N2) (EC 2001). The regulation covers a wide range of pollutant emissions with specifications for each category of pollutant emissions and for the different regulated vehicle types.

[8] see Art. 13(5) of Regulation 443/2009.

[9] The Euro 5 emissions standard entered into force on the 1st September 2009 for type approval, and will come into force from the 1st January 2011 for the registration and sale of new types of cars. The Euro 6 standard will come into force on the 1 September 2014 for type approval, and from the 1st January 2015 for the registration and sale of new types of cars.

The Euro VI standard for HDVs (categories N2, N3, M2 and M3) has been introduced by Regulation 595/2009 (EC 2009d) with new emission limits coming into force on 1 January 2013 (new type approvals) and 2014 (new registrations)[10].

European CEN standards

European CEN fuel specifications are also relevant to the analysis presented in this report insofar as they determine the specifications for fuel quality parameters and biofuel blending.[11]

Standardisation of high-quality fuels containing sustainable bio-components is essential not only to ensure performance in the current and future European road vehicle fleet but also to enable common fuel grades in the European internal market.

Member States initiatives

Initiatives at Member State level provide a somewhat more diversified, heterogeneous situation. An example of such initiatives is the marketing of E10 in France in 2009 while B7 was marketed in 2008 and B30 for captive fleets. Similarly in Germany, B7 plus 3% renewable diesel (but not FAME) was placed on the market in 2008 before it was approved at European level and B100 was also distributed for specially adapted vehicles (mainly for larger HD trucks). Examples from other countries range from B20 in Poland and B30 in the Czech Republic (for captive fleets in both cases) to E85 in Austria, France, Germany and Sweden.

[10] Technical details will be specified in the implementing Regulation being developed by the European Commission in the course of 2010.

[11] These specifications include:
EN15376 for ethanol when used as a blending component in gasoline
EN 14214 for Fatty Acid Methyl Esters (FAME) when used as a neat fuel or as a blending component for diesel fuel
EN228 for gasoline containing up to 5% v/v (E5) ethanol and 2.7% oxygen
EN590 for diesel fuel containing up to 7% v/v (B7) FAME meeting the EN14214 specification
Generally, fuel specifications do not limit the addition of 2nd generation renewable diesel fuels, namely Hydrogenated Vegetable Oils (HVO) and animal fats or and Biomass-to-Liquids (BtL).

3 Description of model and methodology

The JEC "Fleet and Fuels" (F&F) model is a spreadsheet-based simulation tool covering the on-road vehicle fleet development and the resulting demand for fossil fuels and biofuels in aggregate for 29 European countries (EU27 plus Norway and Switzerland). The model has been developed to enable projections to the year 2020 based on a set of assumptions.

The flow chart depicted below provides a schematic overview of the blocks and flows comprising the F&F model.

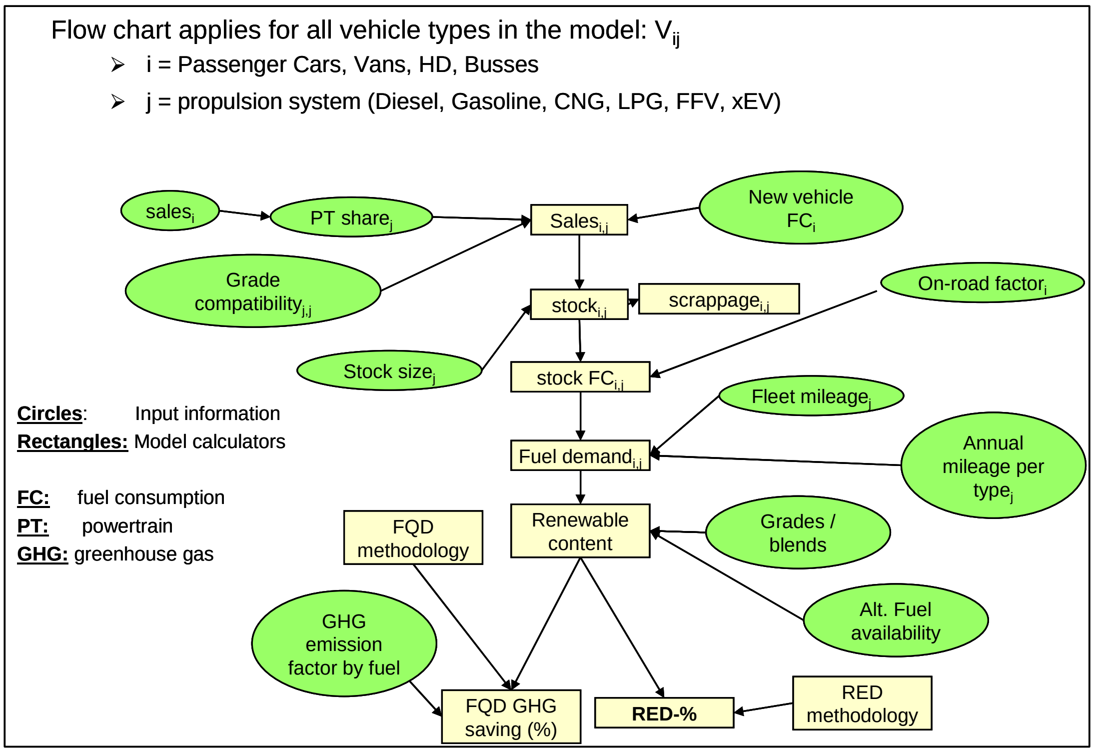


Figure 2. Simplified flow chart for the JEC F&F model

The F&F model is thus a scenario assessment tool based on a 2010 reference case and anticipates future trends in the fleet, fuel and market developments over the coming decade.

Reference data sources

In order to input historical fleet data into the F&F model, TREMOVE Version 2.7b[12] has been used to model information on fleet composition, and activity (vehicle-km and tonne-km), per vintage and per year. JEC WTW data[13] have been used for fuel properties, e.g. energy content, GHG emission factors, etc.

Although the reference source for historical vehicle fleet data was TREMOVE, the following modifications were also made:

[12] http://www.tremove.org/documentation/index.htm
[13] http://ies.jrc.ec.europa.eu/jec-research-collaboration/activities-jec/jec-well-to-wheels-analyses-wtw.html

- the "European Energy and Transport Trends to 2030 – Update 2007"[14] (EC 2008) was used to establish the 2020 time horizon;
- the iTREN2030 (iTREN 2030 2010) methodology was used to include the impact of the 2008-09 economic recession, and;
- the latest ACEA[15] sales data were used for HDVs.

In addition, International Energy Agency (IEA) data on energy demand in the transport sector have been used as a benchmark.

Comparisons of energy demand projections towards 2020 using the F&F model and the sources mentioned above were not straightforward due to differences in the underlying assumptions. Despite inevitable uncertainties, considerable efforts were made while developing the F&F model to consult JEC members and obtain consensus on the modelling methodology, thereby ensuring the highest degree of transparency regarding assumptions and data used.

In TREMOVE, the on-road fleet composition is modified by old vehicles being removed from the fleet (scrappage) and new vehicles entering the fleet based on historical new vehicle registrations per geographical coverage. It should be noted that the F&F model departs from this approach, in that the new vehicle sales is an input parameter while scrappage is a function of sales and stock size. The scrappage function in the F&F model has been defined to ensure alignment with fleet turn-over in TREMOVE. This approach has also been benchmarked against ANFAC[16] data. The scrappage function therefore better reflects the number of vehicles in the fleet which – due to vintage (i.e. model year) – are affected by a loss of fuel 'protection grade' (e.g. replacement of E5 by E10 or even E20[17]).

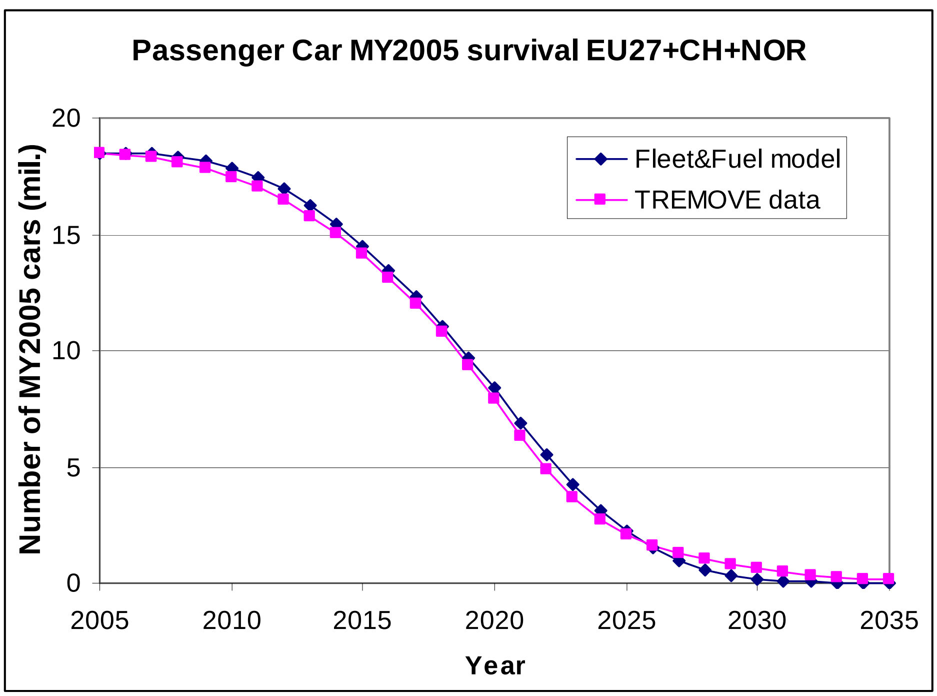


Figure 3. MY2005 passenger cars' survival rate – an example of the scrappage function

[14] http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2007/energy_transport_trends_2030_update_2007_en.pdf
[15] http://www.acea.be
[16] http://www.anfac.com/
[17] E20 is used in selected scenarios; see Chapter 4

The effect of this approach for treating vehicle scrappage in the F&F model is that all vehicles older than Model Year (MY) 2005 will have a fleet share of about 10% by 2020, which is well in line with TREMOVE projections. This means that there will be approximately 17 million gasoline cars older than MY2005 in 2020, which is about 13% of the on-road gasoline car fleet in that year.

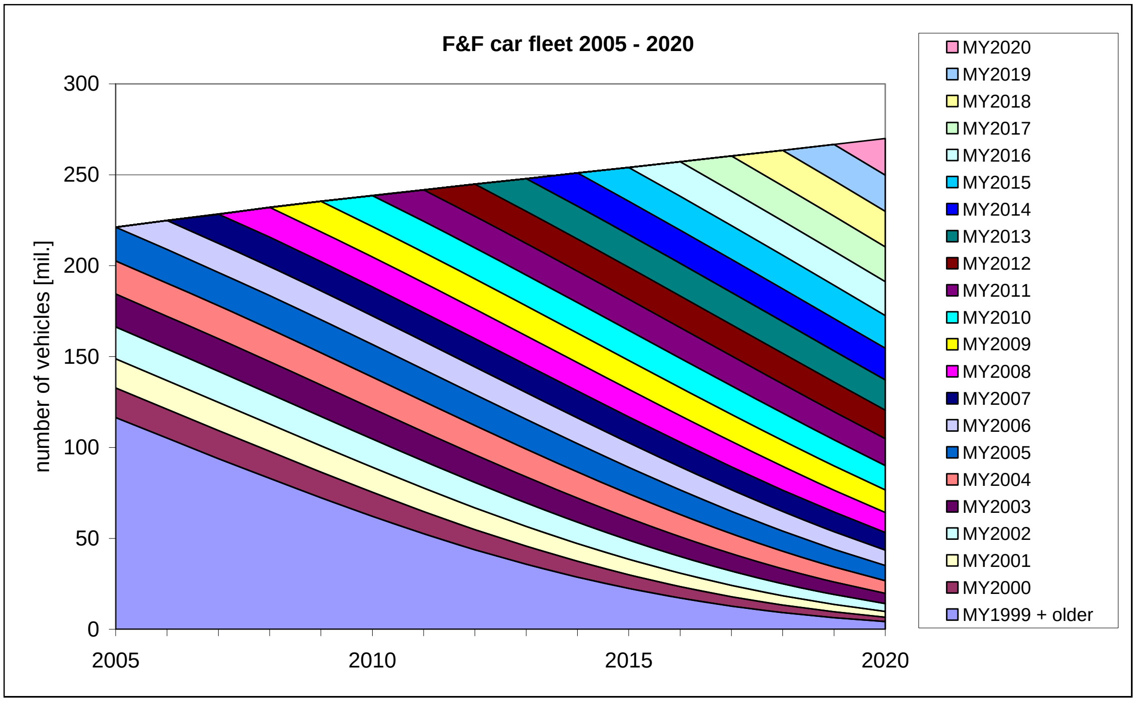


Figure 4. Change in the passenger car fleet by vehicle Model Year (MY)

Figure 4 shows the consequences of the scrappage function applied in the F&F model on the passenger vehicles as a function of the vehicle Model Year (MY). This shows, for example, that all vehicles older than MY2000 will represent 1.5% of the total passenger fleet by 2020. Gasoline cars older than MY2000 will represent 2.5% of the on-road gasoline vehicle fleet.

The F&F model further enables simulations of scenarios to achieve the targets of the RED and FQD. Specific factors for advanced biofuels and renewable electricity for road transport are factored in as specified in Article 21(2) and Article 3(4) respectively of the RED. The robustness of the model and the modelling activity has been checked with a number of sensitivity analyses of the main parameters (see Section 4).

As shown in Table 1 below, the 2020 reference scenario, based on the listed data sources and with the assumptions used in the JEC F&F model, is in line with other main reference data sources in this field.

EU27+2 Transport Energy Demand: [Mtoe]	2008 EuroStat	2020 JEC F&F Reference Scenario	2020 projection as in European Energy and Transport Trends to 2030
1. Road mode	**303**	**281**	**350**
1.1 Diesel	188	186	
1.1.1 Light Duty		69	
1.1.2 Heavy Duty incl. Vans		117	
1.2 Gasoline	100	66	
1.3 Biofuels	10	21.5	
1.4 Other: CNG, LPG, electricity	5	7.8	
2. Other modes	**84**	**109**	**89**
2.1 Rail (Diesel & Electricity)	9.5	10	10
2.2 Aviation	54	73	73
2.3 Inland navigation	6.5	6	6
2.4 Off-road (Diesel)	14	20	
Total	**387**	**390**	**439**

Table 1. Transport demand projections (Mtoe[18]), including JEC F&F Reference Scenario

Vehicle classes and fuel options

Because the F&F model is a simulation tool, it does not lead to a single globally optimised solution but does allow a side-by-side comparison of different scenarios of fleet and fuel development. Very importantly, the F&F model does not assess or value the cost implications associated with the various scenarios.

Due to the assumptions introduced in the JEC Biofuels Programme and subsequently in the F&F model as its main analytical tool, the F&F model cannot be considered as a quantitative tool for predicting the future. In fact, no model can truly do this.

On the other hand, the F&F model can be used to simulate different parameter combinations of vehicle and fuels (and thereof biofuels) technologies to assess renewable energy implementation scenarios looking at:

- Total fuel demand and gasoline/diesel balance;
- Total biofuels (conventional and advanced) demand;
- Total renewable energy demand, including electricity, biogas, etc. for transport;
- Renewable energy demand for road transport to be used for achieving the RED target (together with an evaluation of the associated FQD GHG emission reduction).

The F&F model considers the following vehicle classes and related fuel type options:

Seven light duty passenger car types (and related fuel type options)

- Gasoline (also Petrol)
- Diesel
- Flexi-Fuel Vehicles (FFV)
- Compressed Natural Gas (CNG)
- Liquefied Petroleum Gas (LPG)
- Plug-in Hybrid Electric Vehicle (PHEV)
- Battery Electric Vehicle (BEV)

[18] Million tones oil equivalent (Mtoe)

Three van classes (and related fuel type options)

- Gasoline (Gasoline, CNG, LPG, xEV[19])
- Small Diesel <2.5 tonnes Gross Vehicle Weight (GVW) (Diesel, CNG, LPG, xEV)[20]
- Large Diesel >2.5 tonnes GVW (Diesel, CNG, LPG, xEV)

Five heavy-duty vehicle (HDV) classes (and related fuel type options)

- 3.5 to 7.5 tonnes GVW (Diesel, CNG)
- 7.5-16 tonnes GVW (Diesel, CNG)
- 16 to 32 tonnes GVW (Diesel, CNG, E95, DME)
- > 32 tonnes GVW (Diesel)
- Buses and coaches (Diesel, CNG, E95)

Fixed and adjustable parameters

Key parameters relevant to fuel demand included in the F&F model cover the following areas:

- Passenger car, van, bus & coach, and HDV fleets organised in several segments, as indicated in the previous section;
- Vehicle efficiency and projected efficiency improvement over time;
- Percentage of diesel cars in new car sales;
- Fleet introduction of alternative vehicles;
- Vehicle model year (vintage) assumed to be compatible with specific fuel blending grades for biofuels.

As mentioned in the previous section, the model section dedicated to past and future road vehicle fleet development in EU27+2 provides the background for analysis of variable parameters and their sensitivity to variation.

[19] xEV stands for PHEV, BEV or FCEV. In the JEC Biofuels Programme the focus was on PHEV (or E-REV) and BEV for the given timeframe. Those xEV are assumed to be capable of be charged from the electricity grid.
[20] CNG and LPG vehicles are options to replace diesel vehicles in the respective class. It is not assumed to use LPG or CNG in a diesel engine.

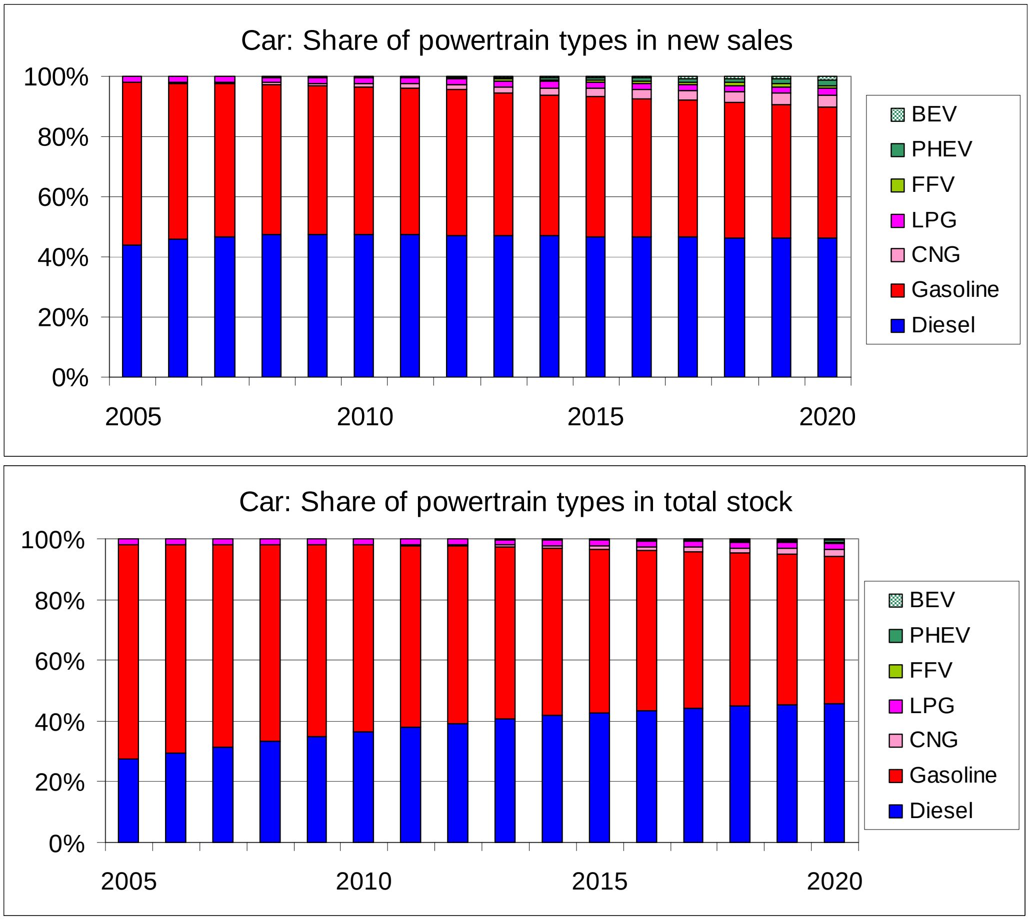


Figure 5. Example of F&F Model Output: Vehicle Fleet Development

The F&F model includes a set of ***adjustable parameters*** that can be changed individually for each vehicle type and fuel option.

Adjustable parameters include:

- Annual growth rate for sales and stock per vehicle class and split of fuel type used;
- Vehicle activity (annual distance driven), vehicle-km driven for passenger cars, vans and bus & coach as well as tonne-km for HDVs;
- Vehicle fuel efficiency development year-on-year;
- Alternative vehicle sales share in projected vehicle fleet in the year 2020;
- Alternative vehicles sales start year and therefore final stock composition (fleet penetration) in the year 2020;
- % replacement of gasoline or diesel passenger cars by alternative vehicles;
- % use (on total activity) of alternative fuels in alternative (bi-)fuel vehicles (e.g. E85 take-up rate for FFV[21]).

With regard to biofuel blending in the F&F model, it was assumed that ethanol and FAME would be blended to the maximum volume concentration allowed by the Exx or Bxx specification. To reflect laboratory test accuracies and other tolerances, 0.1% by volume was

[21] Flex-Fuel vehicles (FFV) could fill up with either E85 or "conventional" (lower E-blend) gasoline

subtracted from the blending limit for each blending grade, i.e. an E5-blend would effectively mean a 4.9% (by volume) blending of ethanol into gasoline for all E5 sold in Europe.

The F&F model allows up to 3 different gasoline grades (a “protection grade”, a main grade, and an E85) and up to 2 different diesel grades (a “protection grade” and a main grade). Additionally, for the main diesel grade, market uptake can be set differently for the HDV fleet and Light-Commercial Vehicles compared to the diesel LDV fleet. The LDVs and their compatibility between fuels and vehicles of specific model years can be independently set.

The F&F model allows setting compatibility between vehicle vintage (Model Year) and fuel grade. HVO and BTL are included in the diesel pool assuming backward compatibility. Advanced ethanol (lignocellulose-based) is added to gasoline in the same way as conventional ethanol and is therefore limited by the same blending grade limits as conventional ethanol in the F&F model. Other oxygenates (e.g. Ethyl tertiary butyl ether, ETBE) were not modelled separately but would be allowed up to the maximum oxygen specification.

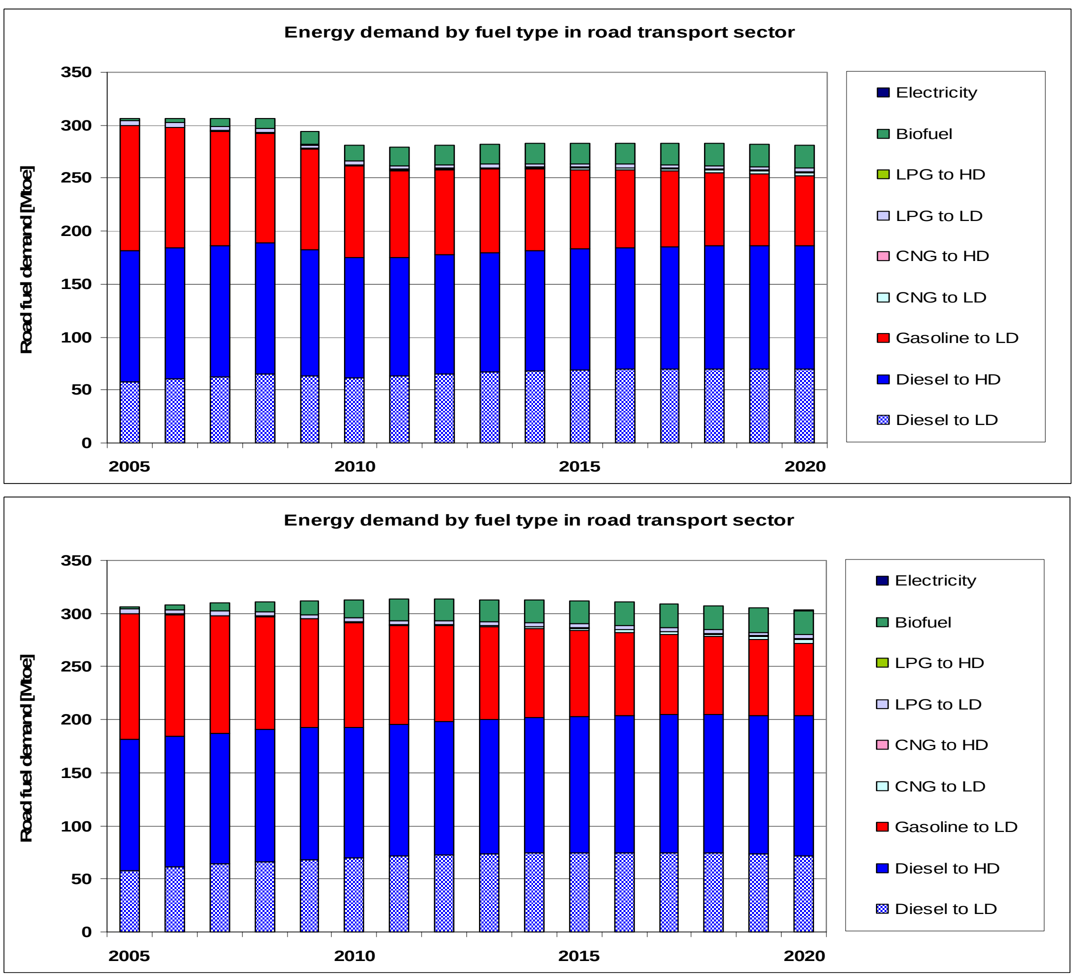


Figure 6. Example of F&F Model Output: Road Transport Fuel Demands

Non-road transport modes

In order to identify and characterise biofuel implementation scenarios to achieve the 10% RED (EC 2009a) target, the F&F model includes energy demand generated by non-road transport modes using historic data from Eurostat[22] as well as projections in reference sources by the European Commission (iTREN2030 2010 and EC 2008), as listed in Figure 7. Data were verified by expert advice from key European stakeholders of non-road transport modes as well as by developers of reference modelling tools.

The F&F model is mainly devoted to the analysis of road transport fleet composition and the related fuel demand. Nonetheless, it is not sufficient to consider and analyse road transport in isolation. This is true for at least four reasons:

- Fuel types and energy used in non-road transport modes are also counted as contributions towards the targets of the RED and FQD;
- Road and non-road transport modes share fuel pools and will increasingly do so, e.g. EN 590 diesel fuel;
- Non-road transport mode demand for alternative transport fuels, including (but not limited to) biofuels may represent a competing demand, limiting the uptake opportunity of such fuel options in the road transport sector;
- The demand from other transport modes may provide opportunities for investment in new biofuel plants and/or funding for advanced research and development activities (this seems to be realistic with a longer term perspective).

The rail contribution towards meeting the RED target has been split into its electricity and diesel components assuming 35% average renewable electricity in the grid by 2020 (EREC 2008, JRC 2009), accounting for slightly less than 1% of the RED target from this mode. The renewable electricity component in rail is excluded from the FQD target.

Aviation is assumed to make no contribution to the RED target by 2020, although the sector could deliver renewable energy consumption. For the FQD GHG reduction, the aviation sector is excluded.

For inland navigation, the assumption is that on-road diesel quality fuel will be used. Hence, a minor contribution to the RED target is considered due to a relatively small total fuel demand in this mode. Even with the assumption of full uptake of B7, inland navigation accounts for less than 1% contribution towards the RED target.

Diesel for "other off-road", namely agriculture, earth-moving machinery, etc., is also assumed to be on-road quality. However, the consumption of renewable energy (by biodiesel blend) in this sector is not considered in the RED – but is included in the FQD.

At the same time, it is important to note that non-road transport modes are not "actively" used in the F&F model. A fixed contribution of non-road transport modes is assumed towards achieving the 10% RED target. This non-road contribution amounts to 1%, which remains fixed in the reference scenario as well as in the alternative scenarios.

[22] http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

Aviation

- Projections range from 56[2)] - 73[1)] Mtoe consumption by 2020
- Jet fuel specification likely to allow only HVO or BTL in this decade
- HVO/BTL or ETS certificates are options to offset GHG emissions
- Aviation fuel consumption excluded from FQD but included in RED

Rail

- ~10 Mtoe consumption by 2020 [1) 2)]
- Fuel by 2020: ~70% electricity, ~30% Diesel (DG TREN[1)])
- Rail Diesel: likely shifts to road diesel quality fuel by 2020
- Diesel will likely contain FAME, HVO, BTL, the same as road diesel (i.e. B7 = reference blend)

Inland navigation

- ~6 Mtoe consumption by 2020 [1) 2)]
- Likely shifts to road diesel quality fuel by 2020
- Diesel will likely contain FAME, HVO, BTL, the same as road diesel (i.e. B7 = reference blend)

Other off-road diesel

- ~20 Mtoe consumption by 2020 (JEC estimate)
- Diesel will likely contain FAME, HVO, BTL, the same as road diesel (i.e. B7 = reference blend)
- Other off-road fuel consumption excluded from RED but included in FQD

1) DG TREN: "European Energy and transport trends to 2030, Update 2007"
2) iTREN 2030, 2009

Figure 7. Projected energy demand by non-road transport modes in year 2020

Extra credits for advanced biofuels and the efficiency factor for renewable electricity (see Figure 1) as provided for in the RED (EC 2009a) are implemented in the F&F model for all transport modes.

Greenhouse gas (GHG) reduction calculation for FQD Article 7a

Based on the latest available version of the WTW study (WTW 2007) and the 2010 fossil fuel demand mix, the JEC Biofuels Programme assumes that the fossil fuels baseline emissions value is 86.7 g CO_2/MJ

The other normative assumptions used in this study to calculate the impacts of the set of selected scenarios on FQD targets are listed below:

- The life cycle GHG savings achieved in biofuel production do not exceed 60%
  - 50% GHG reduction for products from biofuel plants that are in operation before January 1st 2017;
  - 60% GHG reduction for new biofuel plants from January 1st 2017.
- Reductions apply uniformly to all ethanol, FAME, HVO, BTL, DME, road electricity and biogas component in CNG;
- Road electricity receives an efficiency factor of 2.5;
- Rail electricity is excluded.

4 Scenario assumptions

Using the F&F model, a reference scenario has been defined, which represents the expected energy demand development towards 2020 mutually agreed by the JEC Consortium and fully in line with the EU energy and transport regulatory and policy framework.

Following this fundamental step, eight additional scenarios were developed and analysed, which were considered feasible to approach the RED 10% renewables target in 2020.

Fleet parameters in the reference scenario have been assumed to be the following:

- Sales and stock in 2020 for all vehicle classes as in TREMOVE except for sales of HDV classes which are expected to be lower due to the 2008-2009 economic recession;
- The economic recession impacts fleet activity (vkm and tkm), based on input from the iTREN2030 project;
- Efficiency improvements are specific to each vehicle class;
- Alternative fuel vehicles enter the market assuming a specific start year for market introduction and a target sales share by 2020.

The assumptions for fleet parameters by vehicle class in 2020 are listed below. Note that these assumptions apply equally to the reference scenario and to the eight additional scenarios:

- Passenger car assumptions for 2020:
    - New car average CO_2 target is 95g CO_2/km[23];
    - Diesel/gasoline new car sales share is 50%/50%;
    - Car sales grow at an average of 1.7% per annum (p.a.), reaching 20 million vehicles p.a.;
    - Total EU27+2 fleet is 270 million vehicles in 2010;
    - Alternative fuel vehicles enter the market as detailed in Table 2;
    - Although the economic recession causes total passenger fleet mileage to decrease by 3.5% p.a. in 2009 and 2010, it subsequently grows by 2.25% p.a. from 2011 to 2020.

- Van assumptions for 2020:
    - New van average CO_2 target is 175 g CO_2/km[24];
    - Sales reach 1.5 million vehicles p.a.;
    - Total EU27+2 fleet is 28 million vehicles in 2010;
    - Alternative fuel vehicles enter the market as detailed in Table 2;
    - Although the economic recession causes total van fleet mileage to decrease by 3.5% p.a. in 2009 and 2010, it subsequently grows from 2011 to 2020 by 1.0% p.a. for diesel vans and 2.1% p.a. for gasoline vans.

- Heavy Duty vehicle assumptions for 2020:
    - New truck and bus average year-on-year energy efficiency improvement is 1.45%;
    - Sales reach 0.8 million vehicles p.a.;

[23] Value of 95g CO_2 /km is used for calculation purposes only; this value is not a regulatory target and still subject to review
[24] Value is used for calculation purposes only; so far relevant legislation is at the negotiation stage.

- Total EU27+2 fleet is 15 million vehicles in 2010;
- Alternative fuel vehicles enter the market in specific heavy duty classes as detailed in Table 2;
- Although the economic recession causes activity (tkm) in all HDV classes to decrease by 2.3% p.a. in 2009 and 2010, continued dynamic growth can be expected (assumed increase from 2011 to 2020: 2.25% p.a.).

Alternative Fuel Passenger Cars	**In 2020 New Sales**	**In 2020 Vehicle Fleet**		
Flex-Fuel Vehicles (FFV)	1%	0.5%		
Compressed Natural Gas Vehicles (CNGV)	4% 0.8 Million	2% ~5 Million		
Liquefied Propane Gas Vehicles (LPGV)	2% 0.4 Million	2% ~5 Million		
Electric Vehicles Battery Electric (BEV) & Plug-in Hybrid (PHEV)	3% 0.6 Million	1% 2.7 Million		
Alternative Fuel Vans	**In 2020 New Sales**	**In 2020 Vehicle Fleet**		
Compressed Natural Gas Vehicles (CNGV)	4%	1.7%		
Liquefied Propane Gas Vehicles (LPGV)	1%	0.4%		
Flex Fuel Vehicles (FFV)	1%	0.3%		
Electric Vehicles Battery Electric (BEV) & Plug-in Hybrid (PHEV)	2% 24 Thousand	0.4% 90 Thousand		
	In 2020 New Sales			
Alternative Fuel Heavy Duty Vehicles	3.5t to 7.5t	7.5t to 16t	16t to 32t	Bus-Coach
Compressed Natural Gas Vehicles (CNGV)	2%	1%	1%	5%
Di-Methyl Ether Vehicles (DMEV)	==	==	0.5%	==
95% Ethanol (E95) Vehicles	==	==	1%	2%

Table 2. Assumptions for Alternative Fuel Fleet Parameters (all scenarios)

The biofuel blending grades modelled in the reference scenario are as follows:

- For conventional biofuels
  - Ramping up to E5 by 2011 with no fuel/vehicle compatibility restriction (the so-called ‘protection grade’);
  - New E10 (main) grade from 2011 with fuel/vehicle compatibility with E10 from 2005+ model year;
  - Ramping up to B7 by 2010 with no fuel/vehicle compatibility restriction;
  - Assumed 1 Mtoe FAME/HVO coming from waste oils, which count double towards meeting the 10% RED target. Quality of produced FAME or HVO is expected to be unaffected.

- Non-conventional biofuels
  - Ramping up of HVO, BtL and advanced ethanol according to assumptions outlined in Table 3

	Biomass-to-Liquid (BTL)	Hydrogenated Vegetable Oil (HVO)	Advanced Ethanol
Start year	2012	2009	2012
Production simulation	Linear ramp-up to 2020	+1.6 Mtoe to 2012 +1.4 Mtoe and linear ramp from 2012 to 2020	Linear ramp-up to 2020
Availability in 2020	0.25 Mtoe	3 Mtoe	0.64 Mtoe

Table 3. Assumptions for Advanced Biofuels Parameters (all scenarios)

Outcomes of the reference scenario analysis

The energy demand results for the 2020 reference scenario compared to 2010 can be summarised as follows:

- Fossil energy demand changes
  - Gasoline demand decreases by 24%
  - Diesel demand increases by 6%
  - Diesel demand increases 13% for light duty and 3% for heavy duty vehicles
  - Diesel/ gasoline demand ratio increases from 2.0 to 2.8

- Large biofuel volumes are needed, with increasing demand for CNG and CBG (compressed biogas). CBG is assumed to make up 20% of the total CNG and CBG demand and contains 50% “advanced” biogas;

- The RED 10% target is not met, but reaches 9.7% including 1.0% contribution from non-road transport modes;

- The FQD target of 6% GHG emissions reduction is not met, with 4.4% savings from all relevant transport modes included.

Road fuel (Mtoe)	**2005**	**2010**	**2020**
Fossil Gasoline to car	118	87	66
Fossil Diesel to car	58	61	69
Fossil Diesel to HD	123	114	117
Sum fossil Diesel	181	175	186
Diesel to Gasoline ratio (road only)	1,5	2,0	2,8
CNG	0,42	0,85	3,26
CBG			0,82
LPG	4,17	3,32	3,24
FAME	1,50	11,90	12,80
HVO	0,00	1,00	3,00
BTL	0,00	0,00	0,25
DME	0,00	0,00	0,09
Total Ethanol	0,72	2,47	5,32
EtOH conv.	0,72	2,47	4,68
EtOH Adv.	0,00	0,00	0,64
"Fossil" Electricity	0,00	0,00	0,28
Renewable Electricity			0,15
Sum road fuel demand	**306**	**281**	**281**
RED Contributions			
Non-road			1,0%
Road			8,6%
Sum RED-%			**9,7%**
FQD GHG saving			**-4,4%**

Table 4. Energy demand in the reference case and EU Directives targets

Alternative fuel demand in the reference scenario

The results in terms of alternative fuel demand for the transport sector to 2020 are:

- FAME dominates the biofuel market: the steep demand increase in 2010 is driven by B7 blending specification
- The steep demand increase for ethanol in 2010 is driven by E5 blending specification while the increase beyond 2010 is due to E10 blending specification
- HVO and BtL demand follows availability assumptions (backward compatible vehicles imply no grade dependency)
- CNG and CBG demand is driven by the introduction of CNG vehicles in the LDV fleet but also in the HDV fleet.

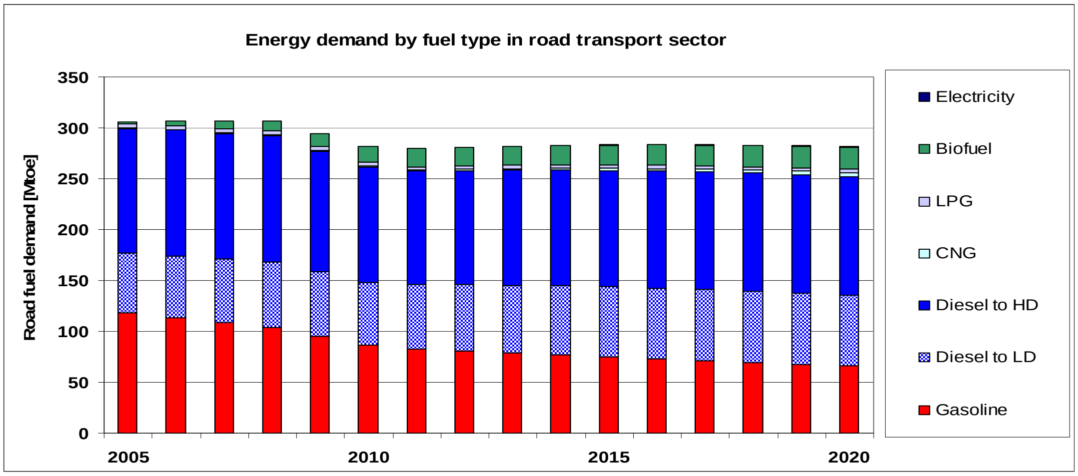


Figure 8. Energy demand by fuel type in road transport sector in the reference scenario

In absolute terms, FAME demand in all transport sectors in 2020 is expected to reach approximately 15 Mtoe per year, increasing from 1.5 Mtoe per year in 2005 and 7.9 Mtoe in 2008. Ethanol demand is expected to be about 5 Mtoe per year, increasing from 0.7 Mtoe in 2005 and 1.8 Mtoe in 2008.

Scenario analysis using the Fleet & Fuels model

The eight additional scenarios analysed with the F&F model examined specific developments of the vehicle fleet with given years of introduction of fuel grades and given compatibility between fuel grade and vehicles of specific model years. Each scenario resulted in a unique split of energy demand and fuel type per fleet vintage.

The rationale for defining the scenarios was based on the following criteria:

- Respect the constraints identified in the definition of the reference scenario;
- Reflect differences in current situations and – therefore – in likely future priorities, which are present across EU Member States;
- Maintain the number of scenarios to a reasonable number allowing a detailed analysis, including their advantages and disadvantages as well as a sound sensitivity analysis.

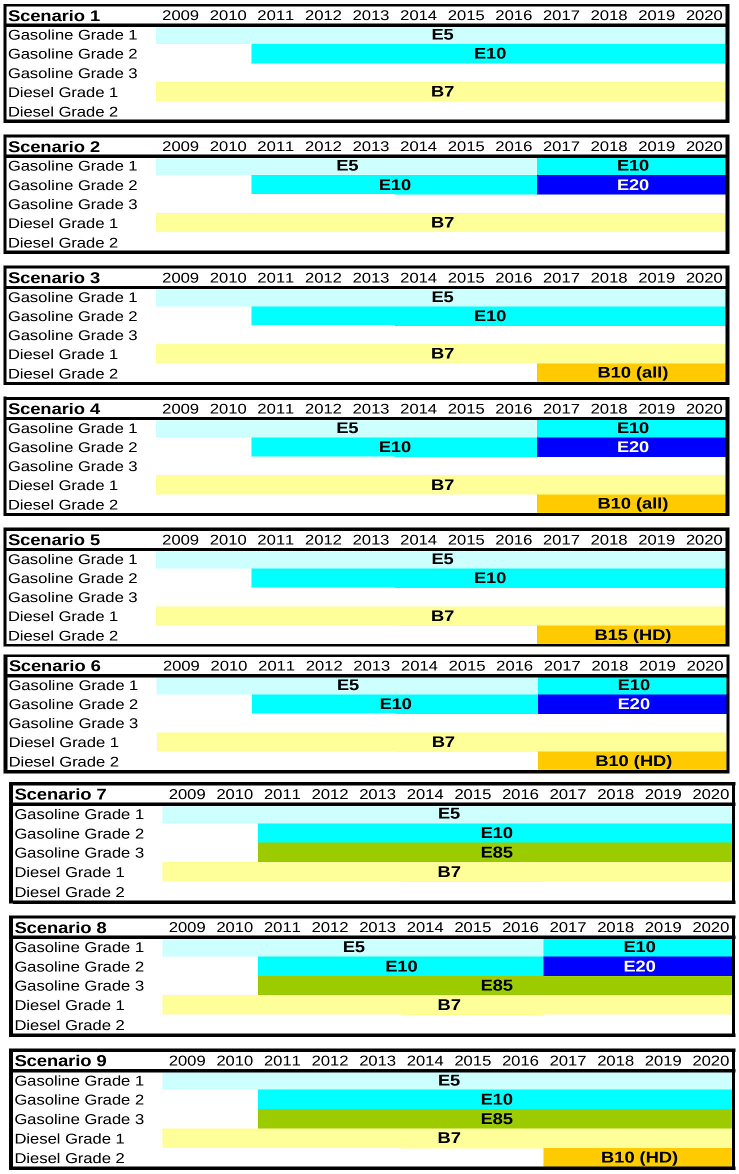


Figure 9. Visual representation of analysed scenarios

Scenario 1 is the reference case described in detail in the previous section.

Scenarios 2-9 can be characterised as follows:

- Scenarios 2-4: “high biofuel grades for all vehicle classes”;
- Scenarios 5-6: “high biodiesel grades for heavy duty vehicles only”;
- Scenarios 7-9: “additional FlexFuel vehicles (FFV)”

Compared to the other scenarios, the FFV scenarios 7-9 feature a higher sales share of 4.5% resulting in a 2.5% FFV stock (6.5 million vehicles) in 2020.

Detailed information on each scenario is presented in the Appendix to this report in both text and graphic format. The information is structured according to fuel demand per road transport vehicle fleet segment in the years 2005, 2010 and 2020, including the contribution of each scenario towards reaching the 10% RED (EC 2009a) target and the FQD (EC 2009b) GHG emissions reduction target.

From the analysis of scenarios, it must be assumed that the road transport mode – with the given assumptions – is expected to make deliver the largest contribution towards achieving the 10% RED target. At the same time, the role of non-road transport modes is essential to actually achieve that mandatory target. This is clearly presented in Figure 10 below with the contributions of road transport and all non-road transport modes towards reaching the 10% RED Directive target shown.

With respect to fuel types, conventional biofuels are expected to play a major role in the coming decade (see Ethanol and FAME amounts in Figure 10 while considering that advanced ethanol is expected to have a very minor share, as indicated in Table 4). Nevertheless, the pace of development and uptake in the fleet of advanced biofuels is instrumental in achieving the 10% RED target.

This point is linked to the interactions between road and non-road transport modes for at least two reasons. First, the demand for such advanced biofuels generated by non-road transport modes (especially aviation) may constrain supply to the road transport mode. Second, advanced biofuels are developing at a slower pace than expected. It is possible that a sustained increase in the combined demand for advanced biofuels from different transport modes may provide incentives to new production which is currently not economic.

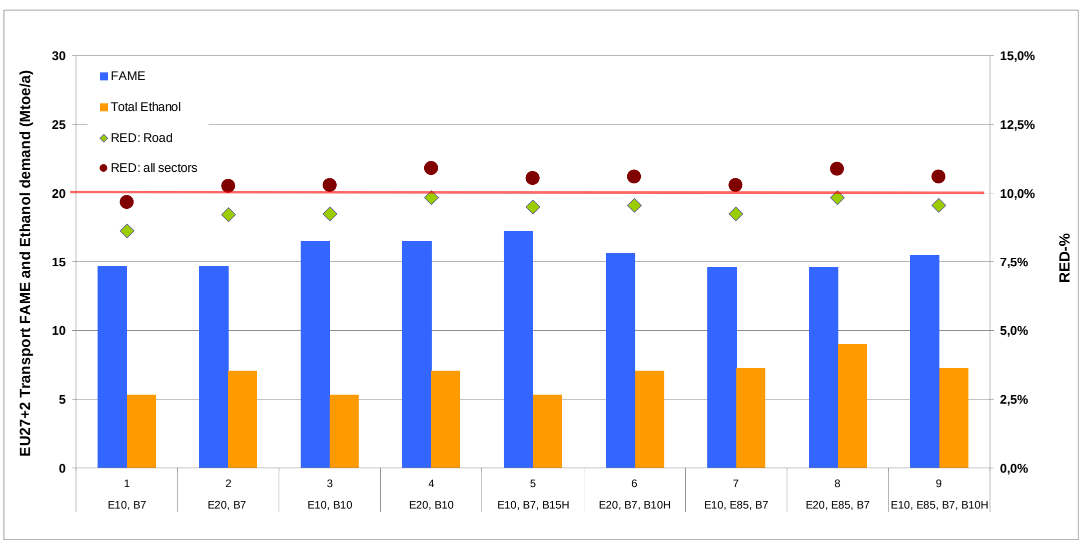


Figure 10. Summary of scenario results

Sensitivity analysis

As described in Section 3, the F&F model has several adjustable parameters that influence projections to the year 2020. These can be grouped in three categories with the main outcomes of the sensitivity analysis.

Passenger Cars

Passenger Cars Parameter		**reference**	**min**	**max**
Sales	M cars/a in 2020	20,20	16,2	24,2
Total fleet	M cars in 2020	270	216	324
Total Mileage	% yoy growth (2011+)	2,25%	1,8%	2,7%
CO2 sales avg 2020	g/km	95	95	120
Diesel reg. 2020	% of G+D	50%	30%	70%
CNGV	sales	4,0%	2,0%	6,0%
	sales start year	2006		
LPGV	sales	0,40%	0,0%	2,6%
FFV	sales	1,00%	0,0%	4,0%
	sales start year	2005		
Electric vehicle	sales	3,00%	1,5%	10,0%
	sales start year	2011		

Table 5. Sensitivity analysis for passenger cars

Vans and Heavy Duty Vehicles

Vans Parameters	reference	min	max
CO2 sales avg 2020 g/km	175	160	175
vkm YoY growth 2011-2020	1,00%	0,8%	1,2%
CNGV sales share 2020	4,0%	2,0%	6,0%
FFV sales share 2020	1,0%	0,0%	4,0%

HD Parameters			
Efficiency 2011+ ALL HD classes YOY improvement 2011 - 2020	-1,45%	-1,00%	-1,45%
Load factor ALL HD classes w/o bus&coach Load YOY growth 2005-2020	0,080%	0,06%	0,10%
Transport demand ALL HD classes w/o bus&coach tkm YoY growth 2011-2020	2,250%	1,8%	2,70%
HDV Vehicles 3.5-7.5 Tonnes			
CNGV sales share 2020	2,0%	0,00%	4,00%
HDV Vehicles 7.5-16 Tonnes			
CNGV sales share 2020	1,0%	0,00%	2,00%
HDV Vehicles 16-32 Tonnes			
DME sales share 2020	0,50%	0,00%	1,00%
E95 sales share 2020	1,00%	0,00%	2,00%
CNGV sales share 2020	1,00%	0,00%	2,00%
HDV Vehicles bus&coach			
E95 sales share 2020	2,00%	1,00%	4,00%
CNGV sales share 2020	5,0%	0,00%	10,00%

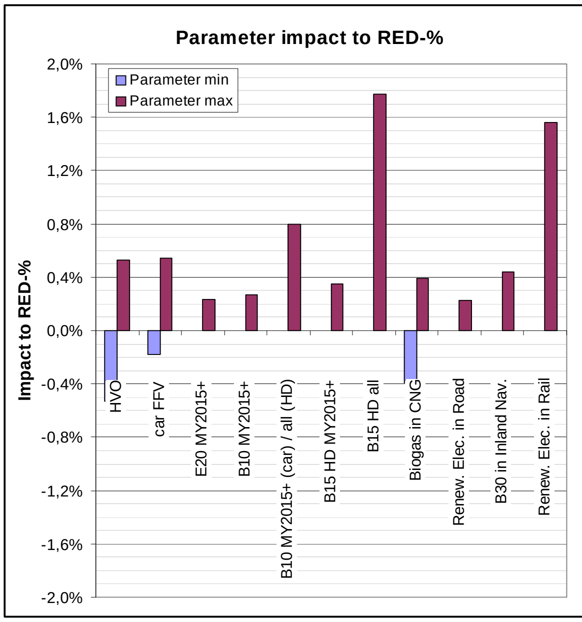
Table 6. Sensitivity analysis for vans and heavy duty vehicles

Fuels: HVO, BTL, and Advanced Ethanol

Biofuels availability 2020		reference	min	max
HVO	[Mtoe/a]	3,0	1,5	4,5
BTL	[Mtoe/a]	0,25	0,0	0,5
Adv. Ethanol	[Mtoe/a]	0,64	0,00	1,28

Table 7. Sensitivity analysis for specific fuels in all scenarios.

Sensitivity was tested on scenario-specific additional parameters, chosen based on expert advice.



Additional sensitivities		Reference	min	max
HVO availability in 2020	[Mtoe/a]	3,0	1,5	4,5
FFV	sales% 2020	1,0%	0%	4,0%
E20 MY 2015+	first model year	2017		2015
B10 MY2015+	first model year	2017		2015
B10 MY2015+ (cars) & all (HD)	first model year	2017		2015/all
B15 HD MY2015+	first model year	2017		2015
B15 HD all	first model year	2017		all
Biogas in CNG	Share e/e [%]	20%	0%	40%
Renewable electricity in road trans.	Share e/e [%]	35%		100%
B30 for Inland Navigation	FAME blend	B7		B30
Renewable electricity in rail trans.	Share e/e [%]	35%		100%

Impacts of sensitivity:
E20 MY2015+: requires add. **0.7 Mtoe Ethanol** in 2020
B10 MY2015+: requires add. **0.8 Mtoe FAME** in 2020
B10 MY2015+(cars)/all(HD): requires **2.3 Mtoe FAME** in 2020
HD B15 all: requires add. **5.2 Mtoe FAME** in 2020
B30 for Inl. Nav. requires add. **1.3 Mtoe FAME** in 2020

Figure 11. Additional parameters' sensitivities.

As a conclusion to the sensitivity analysis and of Section 4, the following statements are highlighted as most relevant:

- The pace of development of advanced biofuels (BTL and advanced ethanol) and HVO significantly impacts the ability to reach the RED % target;
- Sales assumptions for alternative fuel passenger cars, namely Flex-Fuel Vehicles (FFV) impact the capacity to reach the RED % target;
- Sensitivity assumptions for both vans and heavy duty vehicles do not make a significant difference in terms of reaching the RED % target;
- Timely implementation and uptake of higher biofuel levels significantly impacts the RED % target. For instance, a 50% reduction in the uptake of E10 grade in the reference scenario would decrease the RED% from 9.7% to 9.3%;
- Implementing higher biodiesel levels in non-road sectors significantly impacts the RED % target;
- Renewable electricity in rail transport mode can contribute significantly to the RED % target.

5 Biofuel Supply Outlook

Inevitably, the question that accompanies the projected biofuel demand for different fuels based on the assumptions and analysis of the F&F model is whether sufficient quantities of these biofuels will be available over the coming decade given concerns related to sustainability, certification, and ILUC. Perhaps of greater interest for this study is whether these biofuels will be available for European use through 2020 and, if so, from domestic production or from imports. In addition, will they be produced globally from sustainable sources meeting GHG reduction targets?

The biofuel supply part of the analysis is based on a literature review and exchange with other research projects and is less detailed than the modelling and analytical work performed for the demand side. The primary focus is on availability rather than on costs and investments although these are indirectly factored into the main reference source[25] (WMac 2009) used for this section of the study. This approach was taken because many factors can affect the cost of biofuels in the market place and therefore the pace of their production.

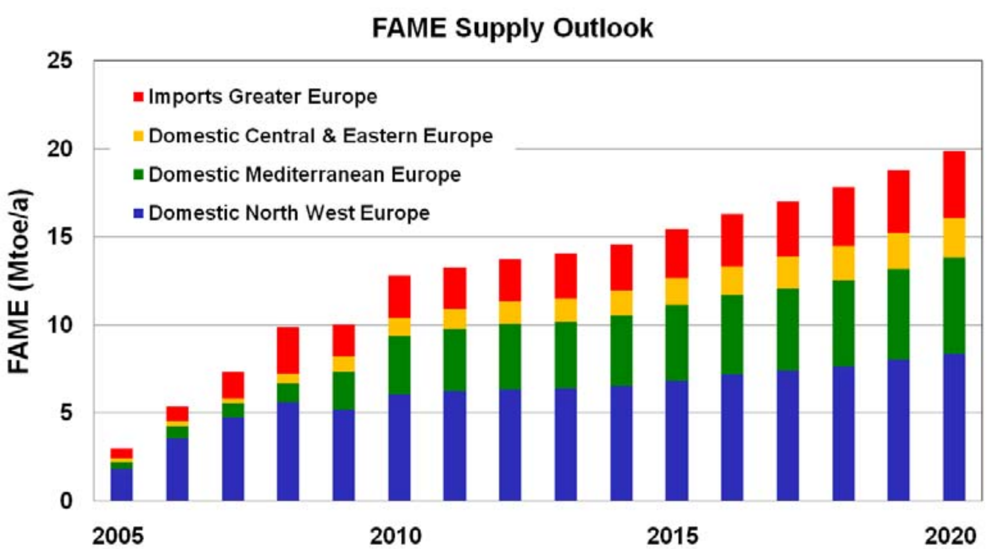


Figure 12. Supply projection for EU-produced and imported FAME

It is worth highlighting that FAME and HVO supply is limited by availability of the same pool of natural and waste oils.

[25] Data from European Biodiesel Board (http://www.ebb-eu.org) and European Bioethanol Fuels Association (http://www.ebio.org) have been considered for the analysis.

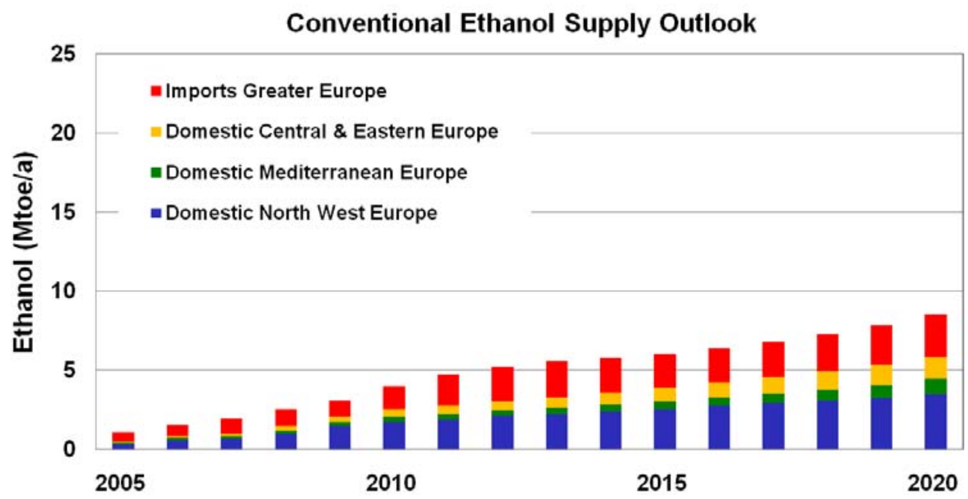


Figure 13. Supply projection for EU-produced and imported ethanol

It is worth noting that the supply of domestically produced ethanol in 2020 is projected to be less than half the volume of FAME supply and major increases in imported ethanol are not expected.

Table 8 shows the demand ranges from the F&F model scenarios that would need to be correlated with the supply outlook

	Biofuel Type	Demand Outlook (Scenarios)	Demand Outlook (Scenarios & parameter variation)
Conventional Biofuels	Bio-ethanol from fermentation	Up to 8.5 Mtoe	Up to 12 Mtoe
	FAME (and FAEE)	Up to 17.5 Mtoe	Up to 19 Mtoe
Advanced Biofuels	Bio-ethanol from lignocellulose	0.6 Mtoe	1.3 Mtoe
	Hydrogenated Natural Oils (HVO)	3.0 Mtoe	4.5 Mtoe
	Biomass to Liquids (BTL)	0.25 Mtoe	0.5 Mtoe
Other Renewables	Biogas	Up to 0.7 Mtoe	Up to 1.0 Mtoe
	Electric from renewables	Up to 0.5 Mtoe	Up to 1.0 Mtoe

Table 8. Biofuel demand from F&F model scenarios

Today's European bioethanol production capacity[26] installed in Europe (GBC 2010) is in the range of 3.4 Mtoe operating at 43% of its capacity, producing approximately 1.5 Mtoe bioethanol per year (Table 9). Currently, 13 plants are under construction with a capacity: of 0.9 Mtoe. European biodiesel production capacity installed in 2009 reaches 18.4 Mtoe per year, with 6.9 Mtoe actually produced in 2008 (utilisation rate: 37%).

[26] JEC analysis for conventional and advanced biofuels, based on data provided in referenced sources.

Bioethanol (EU27)		
Production capacity installed	6.8 M-liters (68 plants)	3.4 Mtoe
Actual production	2.9 M-liters	1.5 Mtoe
Installed capacity utilized	43%	
Production capacity under construction	1.8 M-liters (13 plants)	0.9 Mtoe

Biodiesel (EU27)		
Production capacity installed (2009)	20.9 Metric-tonnes (276 plants)	18.4 Mtoe
Actual production (2008)	7.8 Metric-tonnes	6.9 Mtoe
Installed capacity utilized (2008)	37%	

Source: European Biodiesel Board (*www.**ebb**-eu.org)*
European Bioethanol Fuels Association *(www.**ebio**.org)*

Table 9. European domestic biofuel production

Furthermore, HVO production needs to be taken into account. The annual production capacity in Europe is expected to reach almost 2 Mtoe by 2015 (with the majority planned to be on stream by 2011) and approximately 3 Mtoe worldwide. Hence, the F&F model HVO demand assumptions for 2020 are in line with the production outlooks for Europe. However, it is important to note that the demand for HVO in other regions of the world may increase over the next decade.

	HVO capacity (Mt/a)	HVO capacity (Mtoe/a)
Neste Oil Porvoo (running)	0.38	0.40
Neste Oil Rotterdam (2010)	0.80	0.84
ENI/UOP, Livorno, IT (2010)	0.35	0.37
Neste Oil Singapore (2011)	0.80	0.84
Galp Energia, Portugal (2015)	0.25	0.26
PREEM Oil (co-processing)	0.1	0.1
Others / co-processing	?	?
Sum (EU sites only)	**1.88**	**1.97**
Sum	**2.68 +?**	**2.81 + ?**

Source: JEC analysis
GBC 2010

Table 10. HVO supply outlook to Europe for the year 2020

Because the supply of both FAME and HVO is limited by the total availability of the commonly used vegetable oil and waste oil feedstocks, imports are therefore essential to fully utilise higher biodiesel blends to the volume levels suggested by the demand scenarios. The same statement is valid for ethanol where both imports and the development of advanced ethanol are key to meeting projected demand volumes.

Key messages comparing biofuel supply and projected demand

Although there are many uncertainties, the results of our demand and supply analysis allow us to draw these preliminary conclusions:

- Ethanol is likely to be available in volumes needed to cover EU demand given lower gasoline volumes and the availability of imported ethanol;
- Advanced ethanol: despite growing global supply, uncertainties remain about European production through 2020 and availability to EU transport sector;
- FAME may possibly be available in needed volumes with open questions regarding domestic production, global demand, and competition for vegetable oils and waste oils for HVO production;
- HVO availability for the road transport sector may be reduced by demand from the global aviation sector and competition for vegetable oils and waste oils for FAME production;
- Scaling up of BTL seems difficult within the given time horizon due to technical issues. Furthermore, BTL availability might be limited by demand from the global aviation sector.

Other related issues that could affect supply include:

- Sustainability and certification criteria are not yet fully defined;
- The impact of Indirect Land Use Change (ILUC) on life-cycle GHG emissions of fuels is not yet resolved;
- Impact of taxation and tariffs on imports/exports.

The following graphs show the supply outlook taken from the “Global Biofuels Outlook” (WMac 2009) compared with the demand for biofuels arising from (a) the reference scenario modelled with the F&F tool and (b) the scenario resulting in the maximum demand per biofuel type.

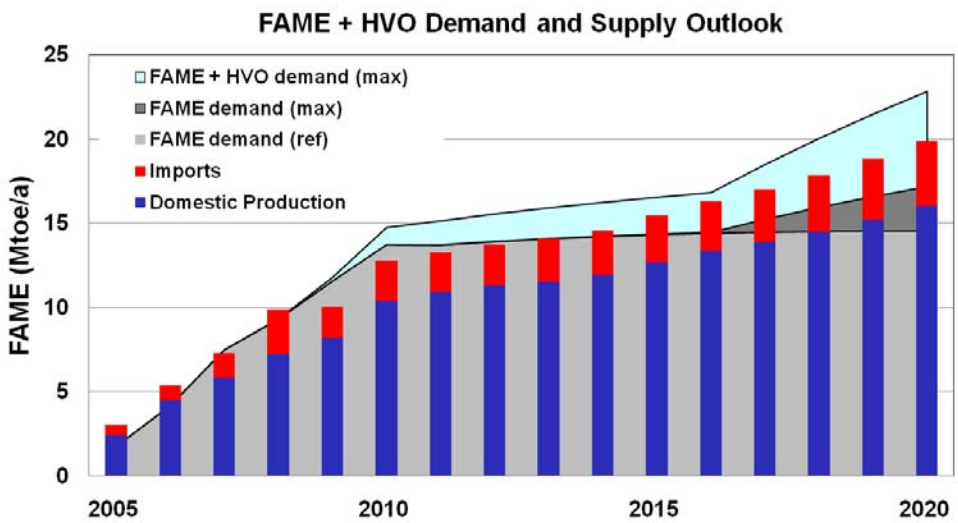


Figure 14. Demand and supply: FAME and HVO

Imports are essential to fully satisfy demand arising from higher biofuels blends.

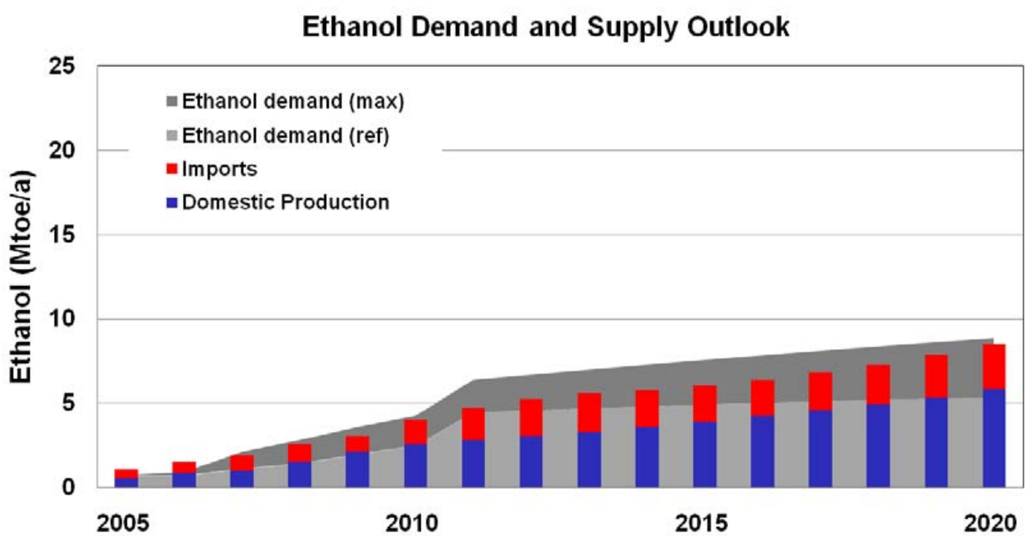


Figure 15. Demand and supply: Ethanol

Both imports and the development of advanced ethanol are key to meeting projected demand, particularly when there is a step-wise increase in demand resulting from the introduction of new blend levels, e.g. E10.

6 Conclusions

The coming decade for European road transport will be characterised by the implementation of legislative targets that will impact car manufacturers (vehicle technology), refineries (refinery technologies as well as fossil fuels and final market fuels) and biofuel producers. The results of the JEC Biofuels Programme and its F&F model can be summarised with respect to these three impacts of EU policy.

– ***Vehicle technology.*** In the coming decade vehicle manufacturers will be faced with tighter regulations on emissions of CO_2 and air pollutants (NOx, SOx, etc.). Hence, vehicles can be expected to be equipped with more advanced powertrain and after-treatment systems, while at the same time we will see an increasing diversification in powertrain (conventional, hybrid, battery electric, etc.) technology and fuel types. Fuel consumption of the light-duty vehicle fleet is expected to fall while heavy duty fleet diesel demand is likely to show slight growth. Increasing pressure from regulations on limiting emissions is expected to lead to higher associated costs. Customer vehicle preferences may potentially be in conflict with transport and energy policies.

  Current vehicles are already E10 (from model year 2005 onwards) and B7 compatible. Compatibility with higher biofuel blends is still to be proven and this will take time, testing effort and investment.

– ***Refinery technology.*** To meet the projected fuel demand, refinery production will need to continue the current trend characterised by an increasing diesel/gasoline demand ratio. This leads to higher CO_2 emissions due to more hydrogen and energy-intensive processing to satisfy the increasing diesel demand and the tighter product specifications. The tightening of diesel fuel specifications for non-road diesel fuels will add further pressure. Similarly to the “vehicles” component, increasing pressure from regulations on limiting CO_2 emissions is expected and likely to push up associated costs.

  It is uncertain whether the existing fuel supply and distribution infrastructure will be fully compatible with higher blending grades. A coordinated development of CEN specifications is needed for higher blending grades to match the needs and/or payback investments needed to adapt the infrastructure. The scenario analysis shows that potential higher blends need to be fully utilised in order to approach regulatory EU targets mandated by the RED and FQD, especially since the FQD Article 7a GHG emissions reduction target was not achieved in the evaluated scenarios. To achieve the 6% GHG saving target of the FQD, average GHG savings for all renewable fuels assumed in the scenarios of the JEC Biofuels Programme would need to be in the range of 63-73%.

– ***Biofuels and other renewable energy sources for transport.*** In the first place, the 10% (energy basis) mandatory target by 2020 is a fixed goal. Conventional biofuels are widely available but are accompanied by sustainability concerns in the face of increasing demand. This concern is heightened by the slower than expected pace of development of some advanced biofuels.

  It is also worth noticing the different pace of development and the different priorities across EU Member States, potentially leading to a proliferation of fuel varieties and specifications. As a counter point to this, the standardisation process (CEN specifications) is striving to keep pace with the regulatory targets, which are more quickly adopted. Therefore a robust and forward-looking standardisation process (CEN specifications) is necessary to enable the timely implementation of future fuel roadmaps to achieve the RED (and FQD) target.

Significant questions remain regarding biofuel sustainability, the pace of development, and imports. Given these uncertainties, ethanol and FAME are likely to be available and predominantly used to achieve the RED 10% target over the coming decade. However, there remain some open questions, in particular concerning the pace of development of non-conventional biofuels and the uptake of HVO/BTL by the aviation sector.

To conclude, key messages to be learned from this study are as follows:

- The attractiveness of different biofuel scenarios will vary considerably by Member State.

  However, it must be ensured that the future of fuel/energy for transport is implemented in a harmonised way throughout Europe.
- The contribution of non-road transport modes to achieving the RED 10% target is important, although the current JEC estimate for this contribution is 1%, leaving the majority of the burden for achieving the RED target on road transport;
- Potential exists for higher biodiesel blends to be used in non-road transport in order to meet targets but this will require time, testing and investment;
- Costs and investments for these biofuel implementation scenarios could be significant and were not evaluated in this study;
- Any decision on future transport fuels/ energy must be based on sound and detailed impact analysis, covering all vehicle, powertrain and infrastructure challenges as well as the global sustainable biofuel and feedstock supply situation;
- Maintaining the confidence of consumers and citizens in the European fuel and biofuel strategy is critical to achieve the regulatory objectives, particularly in cases where the consumer has the freedom to choose between fuels containing higher or lower levels of biofuel (e.g. for Flexible Fuel Vehicles).

7 References

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8 Appendix

Scenario analysis: graphic presentation

The Scenario assumptions described in Section 4 of this report cover the technically feasible scenarios selected by the three JEC partner organisations. Section 4 focuses on the main characteristics of each scenario and comparative results, while this Appendix provides more detailed information on each scenario.

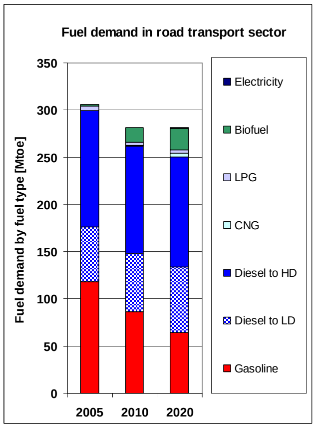
Scenario		1 (Ref)	2	3	4	5	6	7	8	9
	Blends in 2020	E5, E10, B7	E10, **E20**, B7	E5, E10, B7, **B10**	E10, **E20**, B7, **B10**	E5, E10, B7, **B15 (HD)**	E10, **E20**, B7, **B10 (HD)**	E5, E10, **E85,** B7	E10, **E20, E85,** B7	E5, E10, **E85,** B7, **B10 (HD)**
RED Contri-bution by	**1st Gen Biofuels**	6.4%	7.0%	7.0%	7.6%	7.2%	7.3%	6.4%	7.0%	6.7%
	HVO, BTL, Adv. Ethanol	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%
	Alt. vehicles LD: CNGV, EV, FFV HD: CNGV, E95V, DMEV	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	1.4%	1.4%	1.4%
RED: Road contribution *)		8.6%	9.2%	9.2%	9.8%	9.5%	9.5%	9.2%	9.8%	9.6%

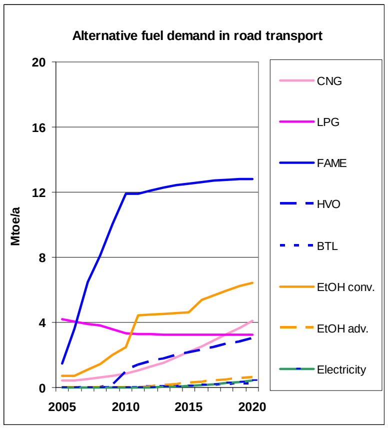
RED contributions	Road	8.6%	9.2%	9.2%	9.8%	9.5%	9.5%	9.2%	9.8%	9.6%
	Rail	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%
	Water	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
	Aviation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Other off-road	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RED-% *)		**9.7%**	**10.3%**	**10.3%**	**10.9%**	**10.5%**	**10.6%**	**10.3%**	**10.9%**	**10.6%**

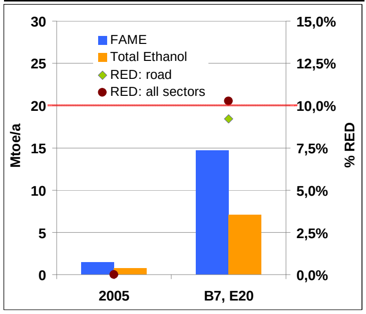
Figure 16. Overview of analysed scenarios

Figures 17 to 24 below give detailed information on each scenario, structured according to fuel demand per road transport vehicle fleet segment in the years 2005, 2010 and 2020, including the contribution of each scenario towards reaching the 10% RED (EC 2009a) target and the FQD (EC 2009b) GHG emissions reduction target.

Road fuel (Mtoe)	2005	2010	2020
Fossil Gasoline to car	118	87	64
Fossil Diesel to car	58	61	69
Fossil Diesel to HD	123	114	117
Sum fossil Diesel	181	175	186
Diesel to Gasoline ratio (road only)	1,5	2,0	2,9
CNG	0,42	0,85	3,26
CBG			0,82
LPG	4,17	3,32	3,24
FAME	1,50	11,90	12,80
HVO	0,00	1,00	3,00
BTL	0,00	0,00	0,25
DME	0,00	0,00	0,09
Total Ethanol	0,72	2,47	7,09
EtOH conv.	0,72	2,47	6,45
EtOH Adv.	0,00	0,00	0,64
"Fossil" Electricity	0,00	0,00	0,28
Renewable Electricity			0,15
Sum road fuel demand	**306**	**281**	**281**
RED Contributions			
Non-road			1,0%
Road			9,2%
Sum RED-%			**10,3%**
FQD GHG saving			**-4,7%**





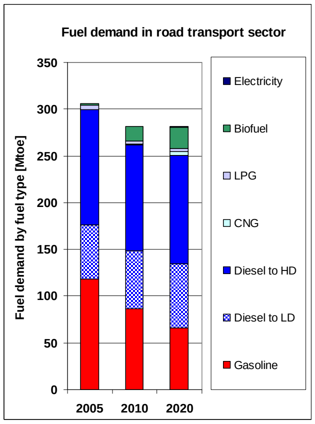


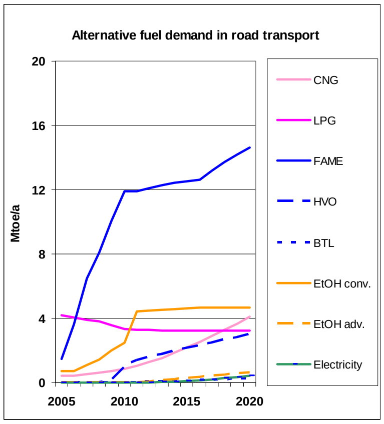
Results:

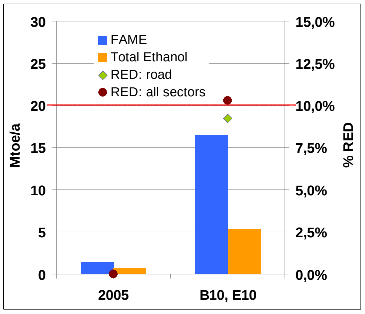
- Fossil demand changes:
  - Gasoline demand decreases
  - Diesel demand increases
  - Diesel/gasoline ratio increases from 2.0 to 2.9
- Large biofuel volumes will be needed
  - Additional 1.8 Mtoe Ethanol over scenario 1 in 2020
- Increasing demand for CNG & CBG
- RED target reached (10.3%) with given assumptions

Figure 17. Scenario 2 (E20, B7) results

Road fuel (Mtoe)	2005	2010	2020
Fossil Gasoline to car	118	87	66
Fossil Diesel to car	58	61	69
Fossil Diesel to HD	123	114	116
Sum fossil Diesel	181	175	184
Diesel to Gasoline ratio (road only)	1,5	2,0	2,8
CNG	0,42	0,85	3,26
CBG			0,82
LPG	4,17	3,32	3,24
FAME	1,50	11,90	14,61
HVO	0,00	1,00	3,00
BTL	0,00	0,00	0,25
DME	0,00	0,00	0,09
Total Ethanol	0,72	2,47	5,32
EtOH conv.	0,72	2,47	4,68
EtOH Adv.	0,00	0,00	0,64
"Fossil" Electricity	0,00	0,00	0,28
Renewable Electricity			0,15
Sum road fuel demand	**306**	**281**	**281**
RED Contributions			
Non-road			1,0%
Road			9,2%
Sum RED-%			**10,3%**
FQD GHG saving			**-4,7%**





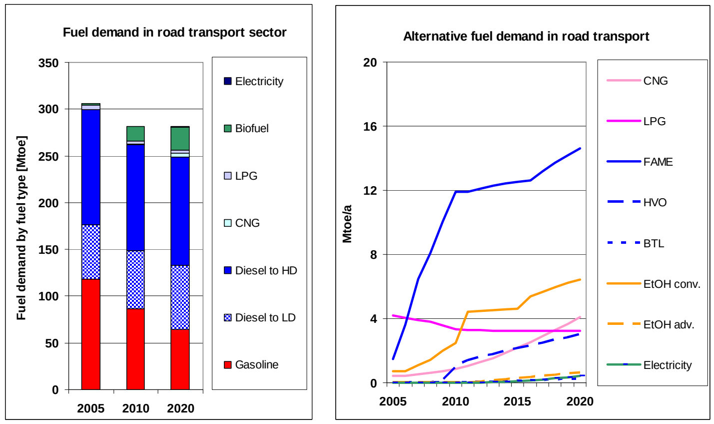


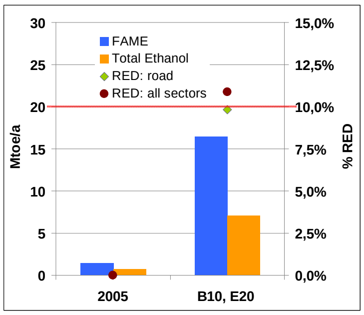
Results:

- Fossil demand changes:
  - Gasoline demand decreases
  - Diesel demand increases
  - Diesel/gasoline ratio increases from 2.0 to 2.8
- Large biofuel volumes will be needed
  - Additional 1.8 Mtoe FAME over scenario 1 in 2020
- Increasing demand for CNG & CBG
- RED target reached (10.3%) with given assumptions

Figure 18. Scenario 3 (B10, E10) results

Road fuel (Mtoe)	2005	2010	2020
Fossil Gasoline to car	118	87	64
Fossil Diesel to car	58	61	69
Fossil Diesel to HD	123	114	116
Sum fossil Diesel	181	175	184
Diesel to Gasoline ratio (road only)	1,5	2,0	2,9
CNG	0,42	0,85	3,26
CBG			0,82
LPG	4,17	3,32	3,24
FAME	1,50	11,90	14,61
HVO	0,00	1,00	3,00
BTL	0,00	0,00	0,25
DME	0,00	0,00	0,09
Total Ethanol	0,72	2,47	7,09
EtOH conv.	0,72	2,47	6,45
EtOH Adv.	0,00	0,00	0,64
"Fossil" Electricity	0,00	0,00	0,28
Renewable Electricity			0,15
Sum road fuel demand	**306**	**281**	**281**
RED Contributions			
Non-road			1,0%
Road			9,8%
Sum RED-%			**10,9%**
FQD GHG saving			**-5,1%**



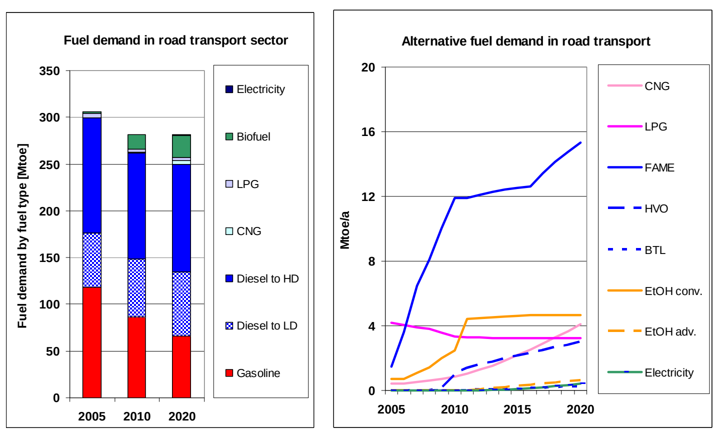


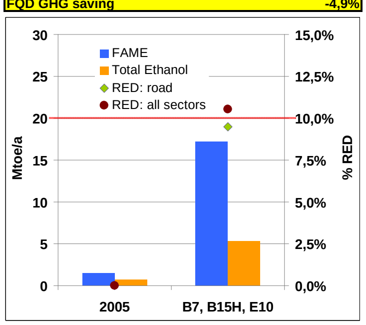
Results:

- Fossil demand changes:
  - Gasoline demand decreases, Diesel demand increases
  - Diesel/gasoline ratio increases from 2.0 to 2.9
- Large biofuel volumes will be needed
  - Additional 1.8 Mtoe Ethanol over scenario 1 in 2020
  - Additional 1.8 Mtoe FAME over scenario 1 in 2020
- Increasing demand for CNG & CBG
- RED target reached (10.9%) with given assumptions

Figure 19. Scenario 4 (B10, E20) results

Road fuel (Mtoe)	2005	2010	2020
Fossil Gasoline to car	118	87	66
Fossil Diesel to car	58	61	69
Fossil Diesel to HD	123	114	115
Sum fossil Diesel	181	175	184
Diesel to Gasoline ratio (road only)	1,5	2,0	2,8
CNG	0,42	0,85	3,26
CBG			0,82
LPG	4,17	3,32	3,24
FAME	1,50	11,90	15,35
HVO	0,00	1,00	3,00
BTL	0,00	0,00	0,25
DME	0,00	0,00	0,09
Total Ethanol	0,72	2,47	5,32
EtOH conv.	0,72	2,47	4,68
EtOH Adv.	0,00	0,00	0,64
"Fossil" Electricity	0,00	0,00	0,28
Renewable Electricity			0,15
Sum road fuel demand	**306**	**281**	**281**
RED Contributions			
Non-road			1,0%
Road			9,5%
Sum RED-%			**10,5%**
FQD GHG saving			**-4,9%**



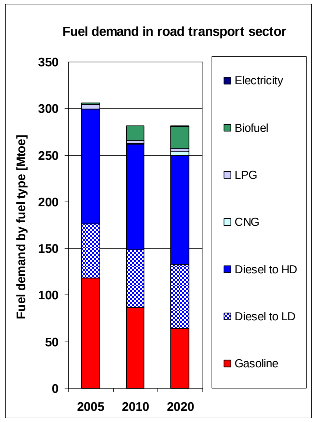


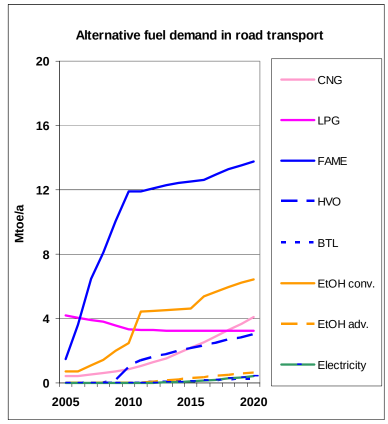
Results:

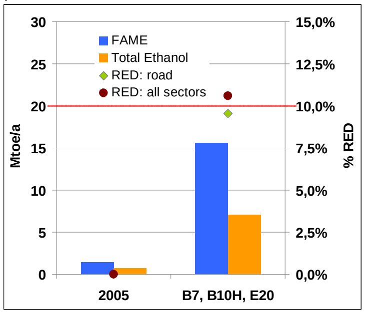
- Fossil demand changes:
  - Gasoline demand decreases
  - Diesel demand increases
  - Diesel/gasoline ratio increases from 2.0 to 2.8
- Large biofuel volumes will be needed
  - Additional 2.6 Mtoe FAME over scenario 1 in 2020
- Increasing demand for CNG & CBG
- RED target reached (10.5%) with given assumptions

Figure 20. Scenario 5 (E10, B7, B15 for HDV) results

Road fuel (Mtoe)	2005	2010	2020
Fossil Gasoline to car	118	87	64
Fossil Diesel to car	58	61	69
Fossil Diesel to HD	123	114	116
Sum fossil Diesel	181	175	185
Diesel to Gasoline ratio (road only)	1,5	2,0	2,9
CNG	0,42	0,85	3,26
CBG			0,82
LPG	4,17	3,32	3,24
FAME	1,50	11,90	13,75
HVO	0,00	1,00	3,00
BTL	0,00	0,00	0,25
DME	0,00	0,00	0,09
Total Ethanol	0,72	2,47	7,09
EtOH conv.	0,72	2,47	6,45
EtOH Adv.	0,00	0,00	0,64
"Fossil" Electricity	0,00	0,00	0,28
Renewable Electricity			0,15
Sum road fuel demand	**306**	**281**	**281**
RED Contributions			
Non-road			1,0%
Road			9,5%
Sum RED-%			**10,6%**
FQD GHG saving			**-4,9%**





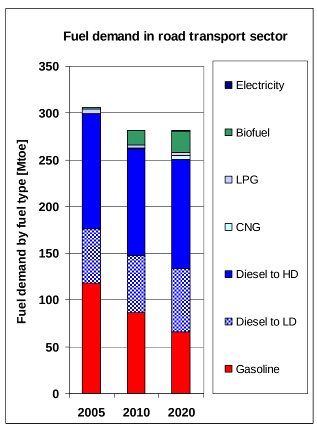


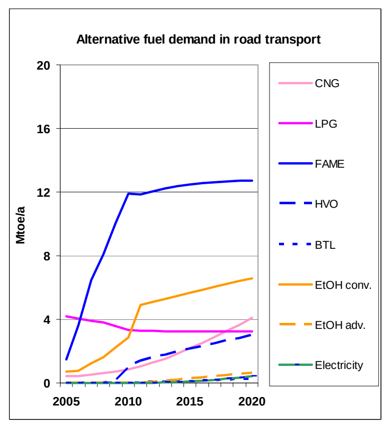
Results:

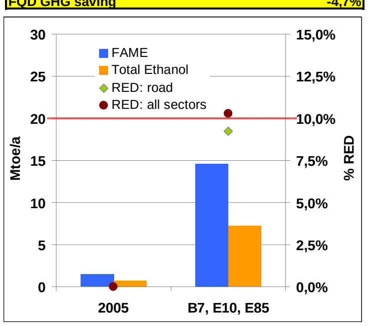
- Fossil demand changes:
  - Gasoline demand decreases, Diesel demand increases
  - Diesel/gasoline ratio increases from 2.0 to 2.9
- Large biofuel volumes will be needed
  - Additional 1.8 Mtoe Ethanol over scenario 1 in 2020
  - Additional 1.0 Mtoe FAME over scenario 1 in 2020
- Increasing demand for CNG & CBG
- RED target reached (10.6%) with given assumptions

Figure 21. Scenario 6 (E20, B7, B10 for HDV) results

Road fuel (Mtoe)	2005	2010	2020
Fossil Gasoline to car	118	87	66
Fossil Diesel to car	58	61	68
Fossil Diesel to HD	123	114	117
Sum fossil Diesel	181	175	185
Diesel to Gasoline ratio (road only)	1,5	2,0	2,8
CNG	0,42	0,85	3,26
CBG			0,82
LPG	4,17	3,32	3,24
FAME	1,50	11,88	12,70
HVO	0,00	1,00	3,00
BTL	0,00	0,00	0,25
DME	0,00	0,00	0,09
Total Ethanol	0,72	2,83	7,23
EtOH conv.	0,72	2,83	6,59
EtOH Adv.	0,00	0,00	0,64
"Fossil" Electricity	0,00	0,00	0,28
Renewable Electricity			0,15
Sum road fuel demand	**306**	**281**	**281**
RED Contributions			
Non-road			1,0%
Road			9,2%
Sum RED-%			**10,3%**
FQD GHG saving			**-4,7%**





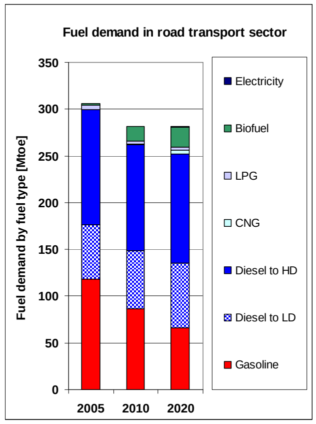


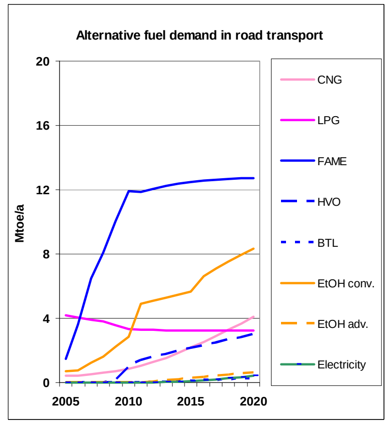
Results:

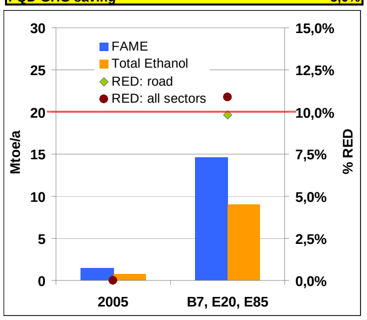
- Fossil demand changes:
  - Gasoline demand decreases, Diesel demand increases
  - Diesel/gasoline ratio increases from 2.0 to 2.8
- Large biofuel volumes will be needed
  - Additional 1.9 Mtoe Ethanol over scenario 1 in 2020
  - Less 0.1 Mtoe FAME over scenario 1 in 2020
- Increasing demand for CNG & CBG
- RED target reached (10.3%) with given assumptions

Figure 22. Scenario 7 (E10, E85, B7) results

Road fuel (Mtoe)	2005	2010	2020
Fossil Gasoline to car	118	87	64
Fossil Diesel to car	58	61	68
Fossil Diesel to HD	123	114	117
Sum fossil Diesel	181	175	185
Diesel to Gasoline ratio (road only)	1,5	2,0	2,9
CNG	0,42	0,85	3,26
CBG			0,82
LPG	4,17	3,32	3,24
FAME	1,50	11,88	12,70
HVO	0,00	1,00	3,00
BTL	0,00	0,00	0,25
DME	0,00	0,00	0,09
Total Ethanol	0,72	2,83	8,98
EtOH conv.	0,72	2,83	8,34
EtOH Adv.	0,00	0,00	0,64
"Fossil" Electricity	0,00	0,00	0,28
Renewable Electricity			0,15
Sum road fuel demand	**306**	**281**	**281**
RED Contributions			
Non-road			1,0%
Road			9,8%
Sum RED-%			**10,9%**
FQD GHG saving			**-5,0%**





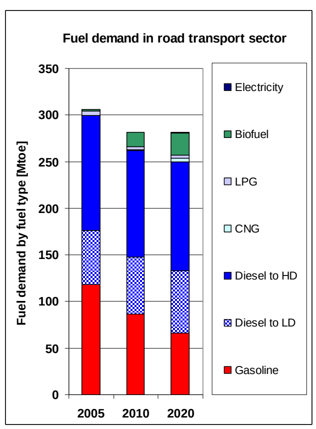


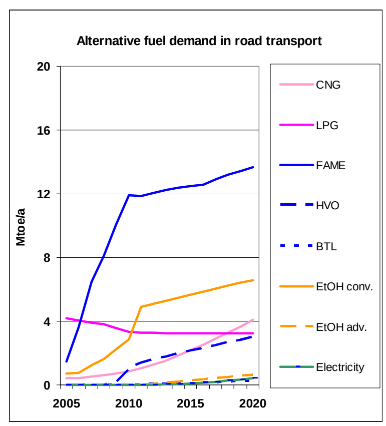
Results:

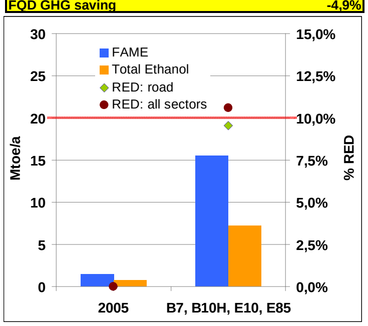
- Fossil demand changes:
  - Gasoline demand decreases, Diesel demand increases
  - Diesel/gasoline ratio increases from 2.0 to 2.9
- Large biofuel volumes will be needed
  - Additional 3.7 Mtoe Ethanol over scenario 1 in 2020
  - Less 0.1 Mtoe FAME over scenario 1 in 2020
- Increasing demand for CNG & CBG
- RED target reached (10.9%) with given assumptions

Figure 23. Scenario 8 (E20, E85, B7) results

Road fuel (Mtoe)	2005	2010	2020
Fossil Gasoline to car	118	87	66
Fossil Diesel to car	58	61	68
Fossil Diesel to HD	123	114	116
Sum fossil Diesel	181	175	184
Diesel to Gasoline ratio (road only)	1,5	2,0	2,8
CNG	0,42	0,85	3,26
CBG			0,82
LPG	4,17	3,32	3,24
FAME	1,50	11,88	13,65
HVO	0,00	1,00	3,00
BTL	0,00	0,00	0,25
DME	0,00	0,00	0,09
Total Ethanol	0,72	2,83	7,23
EtOH conv.	0,72	2,83	6,59
EtOH Adv.	0,00	0,00	0,64
"Fossil" Electricity	0,00	0,00	0,28
Renewable Electricity			0,15
Sum road fuel demand	**306**	**281**	**281**
RED Contributions			
Non-road			1,0%
Road			9,6%
Sum RED-%			**10,6%**
FQD GHG saving			**-4,9%**







Results:

- Fossil demand changes:
  - Gasoline demand decreases, Diesel demand increases
  - Diesel/gasoline ratio increases from 2.0 to 2.8
- Large biofuel volumes will be needed
  - Additional 1.9 Mtoe Ethanol over scenario 1 in 2020
  - Additional 0.8 Mtoe FAME over scenario 1 in 2020
- Increasing demand for CNG & CBG
- RED target reached (10.6%) with given assumptions

Figure 24. Scenario 9 (E10, E85, B7, B10 for HDV) results

The fuel demand per fuel type and per scenario are presented in the summary table below, including each scenario's contribution towards meeting the 10% RED (EC 2009a) target and the 6% FQD (EC 2009b) GHG savings target.

Scenario		1 (Ref)	2	3	4	5	6	7	8	9
	Blends in 2020	E5, E10, B7	E10, **E20**, B7	E5, E10, B7, **B10**	E10, **E20**, B7, **B10**	E5, E10, B7, **B15 (HD)**	E10, **E20**, B7, **B10 (HD)**	E5, E10, **E85,** (FFV ~5% sales '20) B7	E10, **E20, E85,** (FFV ~5% sales '20) B7	E5, E10, **E85,** (FFV ~5% sales '20) B7, **B10 (HD)**
Road	**1st Gen Biofuels**	18.5 Mtoe	**20.3 Mtoe**	**20.3 Mtoe**	**22.1 Mtoe**	**21.0 Mtoe**	**21.2 Mtoe**	18.5 Mtoe	**20.2 Mtoe**	**21.2 Mtoe**
	Adv. Biofuels HVO, BTL, Adv. Ethanol	4.8 Mtoe	4.8 Mtoe	4.8 Mtoe	4.8 Mtoe	4.8 Mtoe	4.8 Mtoe	4.8 Mtoe	4.8 Mtoe	4.8 Mtoe
	Alt. vehicles LD: CNGV, EV, FFV HD: CNGV, E95V, DMEV	1.8 Mtoe	1.8 Mtoe	1.8 Mtoe	1.8 Mtoe	1.8 Mtoe	1.8 Mtoe	**3.6 Mtoe**	**3.6 Mtoe**	**3.6 Mtoe**
Rail	Renew. Electricity	2.5 Mtoe	2.5 Mtoe	2.5 Mtoe	2.5 Mtoe	2.5 Mtoe	2.5 Mtoe	2.5 Mtoe	2.5 Mtoe	2.5 Mtoe
	B7 in Diesel	0.2 Mtoe	0.2 Mtoe	0.2 Mtoe	0.2 Mtoe	0.2 Mtoe	0.2 Mtoe	0.2 Mtoe	0.2 Mtoe	0.2 Mtoe
Water	B7 in Diesel	0.4 Mtoe	0.4 Mtoe	0.4 Mtoe	0.4 Mtoe	0.4 Mtoe	0.4 Mtoe	0.4 Mtoe	0.4 Mtoe	0.4 Mtoe
Air	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Sum renewable		**28.1 Mtoe**	**29.8 Mtoe**	**29.9 Mtoe**	**31.7 Mtoe**	**30.6 Mtoe**	**30.8 Mtoe**	**29.9 Mtoe**	**31.6 Mtoe**	**30.8 Mtoe**
Denominator (road & rail) according to RED		**290.9 Mtoe**	**290.9 Mtoe**	**290.9 Mtoe**	**290.9 Mtoe**	**290.9 Mtoe**	**290.9 Mtoe**	**290.9 Mtoe**	**290,9 Mtoe**	**290.9 Mtoe**
RED-%		**9.7%**	**10.3%**	**10.3%**	**10.9%**	**10.5%**	**10.6%**	**10.3%**	**10.9%**	**10.6%**
GHG Savings FQD Art 7a		**-4.4%**	**-4.7%**	**-4.7%**	**-5.1%**	**-4.9%**	**-4.9%**	**-4.7%**	**-5.0%**	**-4.9%**

Note: might show rounding effects

Figure 25. Summary of analysed scenarios including each scenario's contribution towards meeting the 10% RED (EC 2009a) target and the 6% FQD (EC 2009b) GHG savings target."

JEC Fleet & Fuel Model for Europe (2020) – Annotations and Assumptions

The “JEC Fleet & Fuel Model” was developed to estimate potential passenger car and heavy duty vehicle fleet progressions and the corresponding fuel demand in Europe assuming certain fleet and fuel scenarios. For setting up the model several fleet parameters were defined and assumptions were made with respect to their values. These are listed in the following table along with some explanatory remarks. A “Base scenario” was defined as a kind of “most probable” expected trend. For testing the sensitivity of the model with respect to selected parameters, significantly lower and higher values compared to the “base scenario” were additionally assumed. These are denoted in the table as “low scenario” and “high scenario”.

We aligned the **passenger car** and the **heavy duty fleet** with TREMOVE information and applied historic TREMOVE data where available and appropriate. For the time towards 2020, we applied linear growth rates of major fleet parameters towards 2020 TREMOVE data points in the "base scenario". Even though the model was set up to calculate over the 2005-2035 timeframe, the model is only equipped with input for the time until 2020 and intended to deliver scenarios in the 2005-2020 time frame exclusively. This enabled us to effectively run "low" and "high" scenarios by varying the 2020 data point.

What the model can do:

The model should be seen as a scenario tool that enables the user to make rough estimations of the total fuel and biofuel demand in Europe for 2020 assuming certain vehicle fleet and market development trends (scenarios). It further allows the evaluation of the sensitivity and impact of certain vehicle fleet parameters on the fuel demand.

What the model can not do:

Due to simplifications made and estimates used, the model is not a precise projection tool.
It will not lead to one optimized strategy but rather allows looking at a variety of scenarios of fleet and fuel development. Therefore the assumptions made are not a forecast of or commitment to the future availability of vehicle technologies or vehicle features.

In particular, the “JEC Fleet & Fuel Model” results do not allow or reflect any cost optimizations. For example, reaching a certain 2020 passenger cars (PC) sales average CO_2 efficiency might require the application of costly technologies. On the supply side, cost of (bio-)fuel, (e.g. BTL or HVO production) and distribution and retail operations are not cost-optimized.

Parameters described in this document:

The type of parameters referred to in this document include:

- PC:
    - PC Fleet Parameters
    - Alternative Powertrains
    - Average Annual Mileage

  - Vehicle CO_2 Efficiency and Fuel Consumption vs. Reference Gasoline Vehicle
- Heavy Duty (HD):
  - Heavy Duty Vehicles (HD) Fleet Parameters
  - Alternative Powertrains (HD)
  - Vehicle Efficiency vs. Diesel Vehicle Efficiency (HD)
- Vans
  - Van Fleet Parameters
  - Alternative Powertrains (Van)
  - Vehicle Efficiency vs. Diesel or Gasoline Vehicle Efficiency (Van)

The parameters used in the model can be distinguished as:

- Fixed Parameters
- Variable Parameters (which show a "high" and "low" variant)

Passenger Car (PC) Fleet Parameters

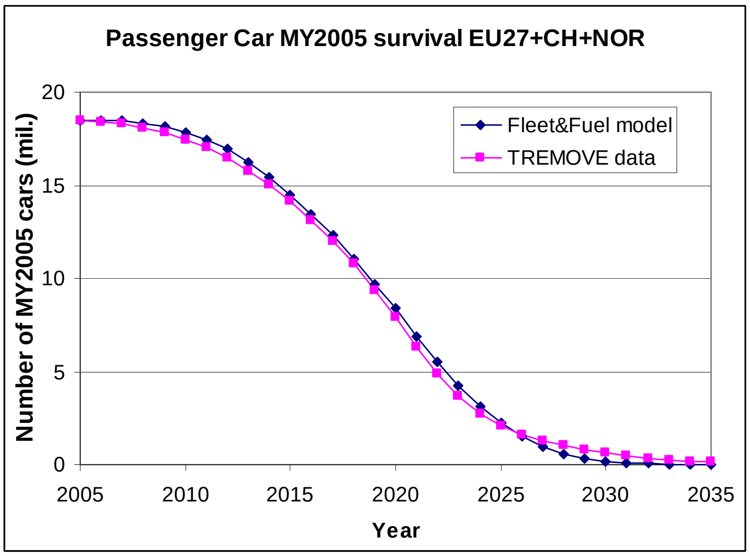
Model Parameter	Unit	Explanation/Annotation	Values in 2020
PC Sales (new PC)	million cars/a	Sales figures are currently taken from TREMOVE data base. Considered growth rates: • Until 2006: TREMOVE data • 2006-2020: we used linear growth towards 2020 TREMOVE sales figure of 20.2 million/year We did not consider the uncertain impact of the current financial crisis.	Base: 20.2 Low: -20% (16.2) High: +20% (24.2) **(variable parameter)**
PC Stock size (total PC population)	million cars	Stock size figures currently taken from TREMOVE data base Considered growth rates: • Until 2006: TREMOVE data • 2006-2020: we used linear growth towards 2020 TREMOVE figure of 270 million vehicles. We did not consider the uncertain impact of the current financial crisis.	Base: 270 Low: -20% (216) High: +20% (324) **(variable parameter)**

PC Stock mileage (total PC activity)	billion vkm/p.a.	Stock mileage currently taken from TREMOVE data base
		
		Considered growth rates:
		• Until 2006: TREMOVE data
		• 2006-2020: we used linear growth towards 2020 TREMOVE figure of 3285 billion vkm/a
		• Growth rate: 2,25% p.a.
		  o Low: 1,8% p.a.
		  o High: 2,7% p.a.
		
		We did not consider the uncertain impact of the current financial crisis.
			Base: 3285
			Low: 3143
			High: 3432
			
			(variable parameter)

Scrappage function: Sales and Total Population (Stock size) are linked/interdependent parameters They are free to be varied individually, but the interdependencies must be considered. Here the scrappage function is set up in a way that the chosen parameters still make sense. Hence, the number of scrapped cars is defined by the stock size and the sales.

Furthermore, the age distribution in individual model years needs to be realistic (in our model, they need to reflect the TREMOVE considerations).

In the model this is assured by distributing the total number of to-be-scrapped vehicles per year (time step) across the vintages (model years) in the stock according to their age, hence the older the vintage in a year, the higher is the number of scrapped cars. This methodology assures an S-shaped age-distribution of the model years as observed in TREMOVE (see below).



Diesel Share in PC sales by 2020	%	Assumption on share of diesel vehicles in car sales in year 2020. Development of car sales from 2005 is assumed to change linearly to value of share in 2020	**Base scenario: 50%** "Low" scenario: 30% "High" scenario: 70% **(variable parameter)**
Real World Factor	./.	Factor considering a higher fuel consumption of vehicle in real on-road operation compared to NEDC cycle. 10% higher fuel consumption is assumed (=Factor 1,1) reflecting the application of an on-road factor in TREMOVE and to also capture uncertainty and to fit the modelled energy demand with the actual 2005 fuel sales figures, sources: Wood Mackenzie, IEA (which also includes uncertainty, e.g. to fuel tourism)	**Base scenario: 1,1** "Low" scenario: ./. "High" scenario: ./. **(fixed parameter)**

Alternative powertrains (PC)

Alternative powertrains considered for passenger cars in the model include CNGV, LPGV, BEV, PHEV, and FFV.

Model Parameter	Unit	Explanation/Annotation	Values
Start year	[year]	First year in which corresponding alternative powertrain type is considered in the model. In case of CNGV, LPGV and FFV this is the most recent year for which confirmed statistics are available (e.g. TREMOVE) even if there were some sales much earlier. In case of BEV, PHEV it is the year when market introduction (year of first sales) is assumed.	CNGV: 2006 LPGV: 2008 BEV: 2011 PHEV: 2011 FFV: 2005[27] **(fixed parameter)**
Share of alternatives vehicles in <u>stock</u> in 2020 (triggers new alternative vehicle sales growth rate)	[%]	This stock share will trigger growth rates of corresponding alternative powertrain type assumed for its new sales Example for CNGV: 2% stock share requires an annual growth rate (from 2006 on) of 0.27% to reach approx. 4% share in sales to get to 2% stock share. Details for electric vehicles: Base case is 1% (~2.7 million) in stock by 2020. We assume electric vehicles to be 33% BEV (likely small city vehicles) and 66% E-REV or PHEV. High electric vehicle scenario (PHEV 1.32% in stock, BEV 0.66% in stock) reflects ERTRAC[28] figure of 5 million EV (~2%) in stock by 2020. The stock share of FFV in 2020 fleet will heavily depend on the policy measures to support the market penetration of E85 fuel and FFV vehicles. Therefore, in addition to the base scenario and the high and low sensitivities, a separate (stand-alone) E85 FFV intensive scenario is also modelled.	CNGV: 2% (lo: 1%, hi: 3%) LPGV: 2% (lo: 1%, hi: 3%) BEV: 0.33% (lo: 0.17%, hi: 0.66%) PHEV: 0.66% (lo: 0.33%, hi: 1.32 %) FFV 0.5% (lo: 0%, hi: 2 %) **(variable parameter)**
Share replacing gasoline vehicles	[%]	The share of new sales of corresponding alternative powertrain type replacing gasoline vehicles. e.g.: CNGV 50% means that 50% of CNG vehicle new sales replace gasoline vehicle new sales FFV/CNGV/LPGV: could in principle be Diesel-like usage patterns, but limited range – at market introduction and limited infrastructure (filling stations) BEV/PHEV: more like gasoline cars. limited range when running on electric	CNGV: 50 % LPGV: 50 % BEV: 90 % PHEV: 90 % FFV: 50 % (fixed parameters) Maybe vary FFV replacement figure in E85/FFV intensive scenarios

[27] Market entry of FFV is set to 2005 to reducing the modelling complexity.
[28] ERTRAC, EPoSS, Smartgrids: "European Industry Roadmap: Electrification of Road Transport, 12 October 2009", http://tinyurl.com/ylgr3yv

			(fixed parameter)
Share replacing diesel vehicles	[%]	The share of new sales of alternative powertrain type replacing diesel vehicles e.g.: 20 % in case of CNG vehicles means that 20% of CNG new vehicle sales replace diesel new vehicle sales	CNGV: 50 % LPGV: 50 % BEV: 10 % PHEV: 10 % FFV: 50 % **(fixed parameter)**
Share of distance travelled using alternative fuel	[%]	The share of km driven using the alternative fuel e.g. 90% in case of CNG vehicles means 90% of the distance travelled is driven by using CNG fuel and 10% by gasoline fuel. Note that it most relevant to reflect 2020 situation, i.e. market intro done (chicken / egg problem on vehicles / infrastructure readiness resolved). For most alternative powertrain vehicle types a share 90% was assumed since customers were thought to buy such type of vehicles only if they mostly can run it with the alternative fuel /have this fuel available on their most frequently used route. A share of 100% in case of the BEV is fixed since it only runs with electricity as “alternative fuel”.	CNGV: 90 % LPGV: 90 % BEV: 100 % PHEV: 90 % FFV: 90 % **(fixed parameter)**

Average Annual Mileage (PC)

Model Parameter	Unit	Explanation/Annotation	Values
Average Annual Mileage compared to gasoline vehicle …..		Factor describing the average annual mileage of vehicle type compared to gasoline vehicle. e.g.: a factor of 1,4 for a diesel vehicle means that the average annual mileage of a diesel vehicle is assumed to be 30 % higher than for a gasoline vehicle Base TREMOVE value of gasoline vehicle average annual mileage is 11300 km/a, however, depending on year and vehicle vintage	
	[-]	**…. Diesel vehicle** Factor of “1,4” taken from TREMOVE data base (higher annual mileage compared to gasoline vehicle)	Base scenario: 1,4 **(fixed parameter)**
	[-]	**…. CNG vehicle** Factor resulting from gasoline and diesel car replacement factors for CNGV (gasoline vehicles: 50 %, diesel vehicles: 50%) and average mileage factors of gasoline (1,0) and diesel cars (1,4): 1,0 x 50% + 1,4 x 50% = 1,2 (higher annual mileage compared to gasoline vehicle)	Base scenario: 1,2 **(fixed parameter)**

	[-]	**….. LPG vehicle** This number is based on LPG sales volumes to meet historic number of LPG vehicles (AEGPL data)	Base scenario: 1,4 **(fixed parameter)**
	[-]	**…. BEV** Factor assumed to be 0,5 in 2010+ taking into account limited range of electric vehicles in the introduction period. Over time improvements of technology and infrastructure (battery capacity, number of charging points and fast charging) enabling higher ranges are expected. Therefore an increase of factor to 0,8 in 2020 is assumed. (=50% lower annual mileage compared to gasoline vehicle for 2005+). 2011 until 2019: linear transition until 2020, then: 20% lower annual mileage compared to gasoline vehicle for 2020	Base scenario: 2010+ 0,5 2020 0,8 **(fixed parameter)**
	[-]	**… PHEV** Factor assumed to be similar like for a gasoline vehicle. Due to range limitations in the electric mode the PHEV is assumed to mainly replace gasoline vehicles with a corresponding annual mileage	Base scenario: 1,0 **(fixed parameter)**
	[-]	**….. FFV** Factor resulting from gasoline and diesel replacement factors for FFV (gasoline vehicles: 50 %, diesel vehicles: 50%) and average mileage factors of gasoline (1,0) and diesel cars (1,4): 1,0 x 50% + 1,4 x 50% = 1,2 (higher annual mileage compared to gasoline vehicle)	Base scenario: 1,2 **(fixed parameter)**

Vehicle CO_2 efficiency and fuel consumption vs. reference Gasoline Vehicle (PC)

Model Parameter	Unit	Explanation/Annotation	Values
Sales average CO_2 efficiency by 2020	[g/km]	This represents the average of the specific emissions of CO_2 of all new sold passenger cars in 2020. Base scenario: currently foreseen EU target value of 95 g CO_2/km according to Regulation R (EC) No. 443/2009. This was done irrespective of the probability that corresponding vehicle technology is available and without consideration of the potential implications on economics. **This assumption must not be considered as any commitment of the automotive industry towards this target, but has to be understood to model the likely fuel consumption in**	**(fixed parameter)**

		2020 based on current - even if pending - legislative targets. As for the purpose of calculating the fuel demand in 2020 a differentiation between conventional vehicle technology and hybrid vehicle technology is not necessary, there is only one new sales fleet average number for the gasoline consuming vehicle fleet and no split into "gasoline vehicle fleet" and "gasoline hybrid vehicle fleet". Same is true for diesel fuel consuming vehicle fleet. Nevertheless, as the economic impact of reaching a certain 2020 new sales fleet average heavily depends on the applied technologies (improvement of conventional powertrains versus increased share of hybrid vehicle fleet), it is essential to consider the impact of implicit HEV new sales when assessing the implementation of different fuel scenarios. To test the sensitivity of the 2020 fuel and biofuel demand, an additional “High” scenario with 120 g CO_2/km is modelled. To enable a simple modelling approach, the CO_2-emission reduction trend is considered to change linearly from 2005 to 2020 without consideration of interim EU targets in 2013-2015.	
Diesel vehicle CO_2-efficiency (2020)	[-]	Factor expressing the diesel vehicle TTW CO_2 efficiency compared to gasoline vehicle for 2020. A factor of 0,95 means that the average diesel vehicle fleet emits 95% of the CO_2 of the average gasoline vehicle fleet. It takes into account the higher fuel efficiency of a diesel vehicle technology compared to a gasoline vehicle technology (about 15%). It also considers the effect of different shares of diesel vehicles in the different car segments. As the diesel vehicle share in the larger/heavier segments is higher than for the small cars segment, the advantage for the total new sales fleet average for the diesel fleet is lower than the individual technical vehicle potential. The data range for this parameter is covered by the reported new vehicle CO_2-emission	Base Scenario: 0,95 **(fixed parameter)**

		monitoring[29].	
CNG vehicle CO_2-efficiency	[-]	Factor expressing the CNG vehicle TTW CO_2 efficiency compared to gasoline vehicle assumed for 2020. The factor reflects the lower carbon content of CNG (factor of 0,77) compared to gasoline fuel. Additionally, an improvement of efficiency is assumed due to more intensive development of engine combustion process for CNGV application.	Base scenario: 0,75 **(fixed parameter)**
LPG vehicle CO_2-efficiency	[-]	Factor expressing the LPG vehicle TTW CO_2 efficiency compared to gasoline vehicle. The factor assumed for 2005+ vehicles reflects the lower carbon content of LPG (factor of 0,89) compared to gasoline fuel. The combustion efficiency (MJ/km) was assumed to be identical to gasoline vehicle. For LPG vehicles prior to 2005 a lower CO_2 efficiency was fixed (25% less) since gasoline cars converted to LPG operation were assumed to generally be larger vehicles and significantly less efficient with respect to fuel consumption. This approach reflects the reported automotive LPG fuel consumption in relation to the LPGV fleet size in 2003-2006 time frame	Base Scenario: 2005+: 0,89 Prior to 2005: 1,25 **(fixed parameter)**

[29] Please see http://ec.europa.eu/environment/air/transport/co2/co2_monitoring.htm

FFV vehicle CO_2-efficiency	[-]	Factor expressing the FFV vehicle TTW CO_2 efficiency compared to gasoline vehicle. The factor reflects the lower carbon content of E85 (0,96) compared to gasoline fuel. The combustion efficiency (MJ/km) was assumed to be the same as for gasoline vehicle.	Base Scenario: 0,96 **(fixed parameter)**
PHEV CO_2-efficiency	[-]	Factor expressing the PHEV TTW CO_2 efficiency compared to gasoline vehicle assumed for 2020. The factor takes into account current regulations for electric vehicle with respect to NEDC certification. A value of 30% of the CO_2 emission of a conventional gasoline vehicle was estimated for PHEV (=factor 0,3)	Base scenario: 0,3 **(fixed parameter)**
BEV CO_2 efficiency	[-]	Factor expressing the BEV TTW CO_2 efficiency compared to gasoline vehicle. According to current vehicle certification regulation CO_2 emission of a BEV is considered to be “0”	Base scenario: 0 **(fixed parameter)**

CO_2 emission factors of gasoline use (or "in gasoline-consuming mode") in alternative powertrains / BEV electricity consumption

Model Parameter	Unit	Explanation/Annotation	Values
LPGV CO_2 efficiency in gasoline-consuming mode cp. To gasoline vehicle	[-]	Factor reflecting CO_2 efficiency of LPGV in gasoline-mode compared to conventional gasoline vehicle Factor is assumed to be 1,0 meaning that CO_2 emission of LPGV is equal to conventional gasoline vehicle of corresponding vintage when operating it with gasoline fuel	Base Scenario: 1,0 **(fixed parameter)**
FFV CO_2 efficiency in gasoline-consuming mode cp. To gasoline vehicle	[-]	Factor reflecting CO_2 efficiency of FFV in gasoline-mode compared to conventional gasoline vehicle Factor is assumed to be 1,0 meaning that CO_2 emission of FFV is equal to conventional gasoline vehicle of corresponding vintage when operating it with gasoline fuel	Base Scenario: 1,0 **(fixed parameter)**

PHEV CO_2 efficiency in gasoline-consuming mode cp. To gasoline vehicle	[-]	Factor reflecting CO_2 efficiency of PHEV in (charge sustaining) fuel consuming-mode compared to conventional gasoline vehicle A factor of 0,80 is assumed for years 2010+ meaning 20% less CO_2 emission for PHEV when operated charge sustaining fuel consuming hybrid. Due to increasing efficiency of conventional ICE powertrains the factor is assumed to increase to 0,85 in 2020.	Base Scenario: 2010+: 0,80 2020: 0,85 **(fixed parameter)**
PHEV electric energy consumption	[MJ_e/km]	Electric energy consumption ("plug-to-wheel") of PHEV in electric mode Assumption made is based on current public available data and EUCAR internal data	Base scenario: 0,55 MJ_e/km **(fixed parameter)**
BEV electric energy consumption	[MJ_e/km]	Electric energy consumption of BEV ("plug-to-wheel") Assumption made is based on current public available data and EUCAR internal data	Base scenario: 0,5 MJ_e/km **(fixed parameter)**

Heavy Duty Vehicles (HD) Parameters

The model follows the TREMOVE classification of HD (gross vehicle weight[30]) classes:

- HD 3.5t-7.5t
- HD7.5t-16t
- HD16t-32t
- HD>32t
- Busses and Coaches: B&C

Heavy Duty Vehicles (HD) Fleet Parameters

Model Parameter	Unit	Explanation/Annotation	Values
HD Sales	Year on Year (YoY) % development	Sales development is taken from TREMOVE. Economic crises not considered for this parameter.	Base: HD3.5t-7.5t: 1.5% HD7.5t-16t: 1.8% HD16t-32t: 2.0% HD>32t: 2.0% B&C: 1.3% Low: -20% High: +20%

[30] "total maximum weight" see TREMOVE documentation http://www.tmleuven.be/methode/tremove/Final_Report_TREMOVE_9July2007c.pdf

HD Stock size	YoY % development	Stock development is taken from TREMOVE. Economic crises not considered for this parameter.	Base: HD3.5t-7.5t: 2.4% HD7.5t-16t: 2.35% HD16t-32t: 2.45% HD>32t: 2.5% B&C: -0.35% Low: -20% High: +20%
HD tkm / (pkm for bus&coach) mileage development	billion vkm/a	Development taken from TREMOVE data base	**Central control:** Without crisis impact: Base 2005-2020: 2.3% With crisis impact: 2005-2008: 2.4% 2008-2011: -2.3438% 2011-2020: 2.25% **Individual control:** Without crisis impact: Base 2005-2011: 2.3% Base 20011-2020: HD3.5t-7.5t: 2.25% HD7.5t-16t: 2.25% HD16t-32t: 2.25% HD>32t: 2.25% With crisis impact: For all classes: 2005-2008: 2.4% 2008-2011: -2.3438% 2011-2020: 2.25% Valid for all cases Low: -20% High: +20% Special for bus&coach and pkm development: 2005-2020 Base: -0.25% Low: -20% High: +20%
Scrappage function: See passenger car function for description, same procedure			
Load factor	%YoY	Factor describing the development of the load factor (factor that determines how much load is carried by a HD vehicle; tkm/vkm) Note:	**Central control:** Base: 0.08% **Individual control:** Base: HD3.5t-7.5t: 0.08%

		For B&C, load refers to pkm/vkm. All others to tkm/vkm	HD7.5t-16t: 0.105% HD16t-32t: 0.1% HD>32t: 0.09% B&C: -0.2% **For all cases** Low: -20% High: +20%
FC development	%YoY	Factor describing the development of the Fuel consumption of new vehicles. Based on an ACEA announcement to improve FC by 20% in 2005-2020 timeline for new HD vehicles and on fuel consumed per tkm basis. 20% improvement 2005-2020 equals -1.45% YoY; a 10% improvement would result in approx. -1.0% YoY	Base: All: -1.45% Valid for central control / individual. Low: -1.0%

Alternative powertrains (HD)

Alternative powertrains considered for HD vehicles in the model:
CNGV, DMEV, E95V

Model Parameter	Unit	Explanation/Annotation	Values
Start year	[year]	First year in which corresponding alternative powertrain type is considered in the model.	DME: 2015 E95: 2012 BEV: 2015 CNG: 2012 (fixed parameter)
CNGV in 3.5-7.5t class	Sales% 2020	Sales share in 2020; builds up linearly from start year Start year (fixed parameter):2012	Base: 2% Min: 0% Max: 4%
CNGV in 7.5t-16t class	Sales% 2020	Sales share in 2020; builds up linearly from start year Start year (fixed parameter):2012	Base: 1% Min: 0% Max: 2%
DMEV in 16t-32t class	Sales% 2020	Sales share in 2020; builds up linearly from start year Start year (fixed parameter):2015	Base: 0.5% Min: 0% Max: 1%
E95V in 16t-32t class	Sales% 2020	Sales share in 2020; builds up linearly from start year Start year (fixed parameter):2015	Base: 2.5% Min: 0% Max: 5%
CNGV in B&C	Sales% 2020	Sales share in 2020; builds up linearly from start year Start year (fixed parameter):2005 (to reflect existing CNG bus fleet)	Base: 5% Min: 0% Max: 10%
CNGV in B&C 2005	Fleet% 2005	CNG – busses are on the road already. According to NGVA information, this is approx. 1% by 2005	1% (fixed parameter):

Vehicle Efficiency vs. Diesel Vehicle Efficiency (HD)

Model Parameter	Unit	Explanation/Annotation	Values
DME vehicle MJ/km efficiency	[-]	Factor expressing the new DME vehicle MJ/km efficiency compared to new diesel reference vehicle (same model years) in the respective HD class when in alternative fuel mode.	Base scenario: 1 (fixed parameter)
E95 vehicle MJ/km efficiency	[-]	Factor expressing the E95 vehicle MJ/km efficiency compared to diesel reference vehicle in the respective HD class when in alternative fuel mode.	Base scenario: 1 (fixed parameter)
CNG vehicle MJ/km efficiency	[-]	Factor expressing the CNG vehicle MJ/km efficiency compared to diesel reference vehicle in the respective HD class when in alternative fuel mode. The development between 2005 and 2020 reflects tendency to shift from spark ignited engines to advanced combustion systems.	Base scenario: 2005: factor of 1.2 2020: factor of 1.1 Linear development of factor between 2005-20 (fixed parameter)

Van Parameters

Van Fleet Parameters

The model follows the TREMOVE classification of van classes:

- Gasoline vans (GV)
- Diesel vans <2.5t (DV<2.5t)[31]
- Diesel vans >2.5t (DV>2.5t)

Model Parameter	Unit	Explanation/Annotation	Values
Van sales	YoY % development	Sales development is taken from TREMOVE. Economic crises not considered for this parameter.	Base: GV: 1.5% DV<2.5t: 2.4% DV>2.5t: 0.3% Low: -20% High: +20%
Van stock	YoY % development	Stock development is taken from TREMOVE.	Base: GV: 2.4

[31] "total maximum weight" see TREMOVE documentation http://www.tmleuven.be/methode/tremove/Final_Report_TREMOVE_9July2007c.pdf

		Economic crises not considered for this parameter.	DV<2.5t: 1.1% DV>2.5t: 1.2% Low: -20% High: +20%
Van vkm	YoY % development	vkm development is taken from TREMOVE. Economic crises not considered for this parameter.	Base: GV: 2,1% DV<2.5t: 1.0% DV>2.5t: 1.0% Low: -20% High: +20%
Van FC development	YoY % development	Striving to reflect upcoming regulation: -1.45% or -1.0%YoY or approx. -20% or -10% for 2005-2020 timeline Economic crises not considered for this parameter.	Base: GV: -1.0% DV<2.5t: -1.0% DV>2.5t: -1.0% Low: -1.45%

Glossary

ANFAC	Asociación Española de Fabricantes de Automóviles y camiones
BEV	Battery Electric Vehicle
BTL	Biomass-to-Liquids
CDM	Clean Development Mechanism
CEN	European Committee for Standardisation
CNGV	Compressed Natural Gas Vehicle
DME	Dimethyl ether
DMEV	DME vehicles
E95	E95 fuel, 95%vol Ethanol, remainder mainly ignition enhancer
E95V	E95 vehicle
E-REV	(Battery) Electric vehicle with Range Extender
ETBE	Ethyl Tertiary Butyl Ether
EU	European Union
EU27+2	EU 27 Member States plus Norway and Switzerland
F&F Model	Fleet and Fuels Model
FAME	Fatty Acid Methyl Ester
FFV	Flexible Fuel Vehicle (Vehicle able to run with ethanol blends up to E85)
FQD	Fuel Quality Directive
GHG	Greenhouse Gas(es)
GVW	Gross Vehicle Weight
HD/HDV	Heavy Duty/Heavy Duty Vehicle
HVO	Hydrogenated Vegetable Oil
ILUC	Indirect Land Use Change
JEC	Consortium of European Commission's Joint Research Centre (JRC), EUCAR and CONCAWE
LD/LDV	Light Duty/Light Duty Vehicle
LPGV	Liquefied Petroleum Gas Vehicle
Mtoe	Million tonnes oil equivalent
MY	Model Year
PHEV	Plug-In Hybrid Vehicle
pkm	Passenger-kilometres (used for buses and coaches instead of annual mileage) transport of one passenger over a distance of one kilometre
RED	Renewable Energy Directive
tkm	Tonne-kilometres (used for HD instead of annual mileages) transport of one tonne over a distance of one kilometre
TREMOVE	Policy assessment model to study the effects of different transport and environment policies on the transport sector for all European countries more information: www.tremove.com
TTW	Tank-to-Wheels
vkm	Vehicle-kilometres
WTT	Well-to-Tank
WTW	Well-to-Wheels

European Commission

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Abstract
In the three-year JEC Biofuels Programme, the research collaboration between the **J**oint Research Centre of the European Commission, **E**UCAR and **C**ONCAWE has investigated the potential role of biofuels and other renewable and alternative energy sources in achieving the mandatory 10% Renewable Energy Directive (RED) target for renewable energy in the transport sector by 2020 with an associated calculation of the Fuel Quality Directive target for 6% reduction in GHG emissions.

The focus of the analysis was on road transport although all other transport modes have been considered.

A dedicated analytical tool, called the Fleet and Fuels (F&F) model, has been developed and used. The modelled fleet development leads to a transport fuel demand and constitutes the basis on which penetration and distribution of alternative motor fuels – and availability thereof – are analysed. The impacts of key parameters on the achievement of the RED 10% renewables target are analysed in sensitivity cases.

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