The JEC Biofuels Study

Nine biofuel implementation scenarios have been analysed to determine their potential to meet future renewable energy and GHG emissions reduction targets.

Increasing renewable energy in transport

For many years, it has been recognised that energy demand and greenhouse gas (GHG) emissions from the transportation sector are expected to rise over the coming decades, with increasing demand for passenger and freight transport offsetting efficiency gains. In fact, transport is the only European sector in which GHG emissions are increasing rather than decreasing, because energy efficiency measures can be more easily implemented in heavy manufacturing, power generation, building construction and other areas.

In 2009 and 2010, in order to address this trend, the European Union enacted a package of Directives intended to reduce GHG emissions and ensure security of energy supply for the transport sector. These Directives required improvements in the CO_2 emissions performance of passenger vehicles and light-duty vans, as well as an increase in the use of renewable and alternative energies in transport fuels by the end of this decade.

Two of these Directives will have a direct impact on the composition of road fuels over the coming decade and beyond. The Renewable Energy Directive (RED, Directive 2009/28/EC) mandates that 10% renewable energy must be blended into transport fuels by 2020. This energy target translates into more than 14% on a volume basis, assuming that the majority of this obligation will be achieved by blending biofuels into today's service station fuels.

Although advanced biofuel products are being developed that will be manufactured from biomass, e.g. straw and wood, the biofuels that will be available in large volumes by 2020 will either be ethanol fermented from sugars, or esterified vegetable oils and animal fats. Ethanol can be blended today at up to 5% volume in gasoline (E5) while esterified oils, called fatty acid methyl esters (FAME), can be blended at up to 7% volume in diesel fuels (B7)[1]. Smaller volumes of speciality biofuel blends, like E85 or B100, can also be used in specially adapted vehicles. The European Committee for Standardization (CEN) is working to revise the EU-wide fuel standards and increase the allowed blending percentages of biofuels to higher levels.

At the same time, the Fuel Quality Directive (FQD, Directive 2009/30/EC) mandates that fuel suppliers must reduce the GHG emissions of transport fuels by 6% in 2020 compared to 2010 performance. Although efficiency improvements in the fuel manufacturing process will contribute a small amount to meeting this target, the increasing demand for transport fuels, and diesel fuel in particular, means that the majority of this GHG performance improvement must be achieved through biofuel blending. Default values for the GHG performance of different ethanol and FAME manufacturing pathways are included in the FQD.

The 2020 targets have been clearly legislated but the options to reach these targets have not. It has largely been left to Member States and the transport sector to determine these options. Each Member State has now documented how they intend to meet their specific obligations through National Renewable Energy Action Plans (NREAPs), submitted in 2010. These plans vary significantly from one country to the next, depending upon the specifics of the country's transport demands and the availability of alternative energy options for all modes of transport.

The JEC Biofuels Programme

Understanding the achievable options for meeting both the RED and FQD obligations is a complicated task. With different priorities and pace of implementation planned in each Member State, the potential for increasingly uncoordinated changes in fuel blends and vehicle types is considerable. This could lead to fragmentation of the fuel market, making it much more difficult to achieve the 2020 targets.

While the EU Directives were still in draft form, the three partners in the JEC Consortium—the Joint Research Center (JRC) of the European Commission, the European Council for Automotive R&D (EUCAR) and CONCAWE—decided to look closely at this problem. The JEC Biofuels Programme was initiated in early 2008 to examine possible biofuel implementation scenarios for mass market fuels, that could potentially achieve the

The final report of the JEC Biofuels Programme is available for free download at http://ies.jrc.ec.europa.eu/about-jec

[1] Biofuel contents are expressed as a percentage of bio-component in fossil fuel on a volume basis. For example, B7 is 7% v/v fatty acid methyl ester (FAME) in diesel fuel, E5 is 5% v/v ethanol in gasoline, and E85 is 85% v/v ethanol in gasoline.

10% RED target for transport fuels by 2020. Using the scenario results and the FQD's GHG default values for different renewable products, it was also possible to calculate the 2020 GHG emissions reductions associated with different biofuel blending options and volumes.

Nine scenarios were evaluated using reasonable assumptions for the development of the on-road vehicle fleet over the coming decade and the likely penetration of new vehicle technologies, such as plug-in hybrids, electric vehicles, compressed natural gas (CNG) and liquefied petroleum gas (LPG) powered vehicles, etc. A contribution to the RED mandate was also assumed from non-road transport, including inland waterways, rail, aviation and other off-road applications.

The 'Fleet and Fuels' Model

To evaluate these scenarios, the JEC team first needed a handy yet robust modelling tool. The first phase of the study developed and validated a spreadsheet-based simulator called the 'Fleet and Fuels' model. This model is based on historical vehicle fleet data for the EU-27+2 countries (including Norway and Switzerland) and was benchmarked against actual fuel consumption data from the 1990s and 2000s. The model allows independent inputs for seven types of passenger vehicles including flexi-fuel, hybrid electric and battery electric, three classes of commercial vans, and five classes of heavy-duty vehicles and buses. Each vehicle type was described by fixed but adjustable parameters estimating the annual growth rate, typical annual mileage, vehicle fuel efficiency and years of useful life. Fuel alternatives were also considered for each vehicle type.

For service station fuels, two different biofuel levels were allowed for both gasoline and diesel fuels. Fixed percentages of other fuel options were also assumed for E85, CNG, LPG and electricity. Outputs from the model included new vehicle sales, vehicle fleet composition and the projected demand for different fossil fuels, renewable fuels and alternatives.

Figure 1 shows an example in which the energy demand by fuel type is shown from 2005 to 2020. Over this time period and for this 'Reference Scenario', overall gasoline demand is projected to decrease by about 24% while diesel fuel demand increases by about 6%. This increase is due to higher demand from increasingly popular diesel passenger cars and from heavy-duty trucks. Increasing demand for biofuels, gaseous fuels and, to a smaller extent, electricity is also observed. The impact of the 2008–09 economic recession on energy demand is also evident in this figure.

Because the RED counts renewable and alternative energy used in all transport modes, estimating the RED contributions that could be expected from railroads, inland navigation, aviation and other off-road uses was also important. Credible estimates from public sources for non-road transport demand were evaluated so that the RED percentage could be calculated for each scenario using the legislated formula.

Figure 1 Change in energy demand by fuel type in the road transport sector, based on the study's 'Reference Scenario'

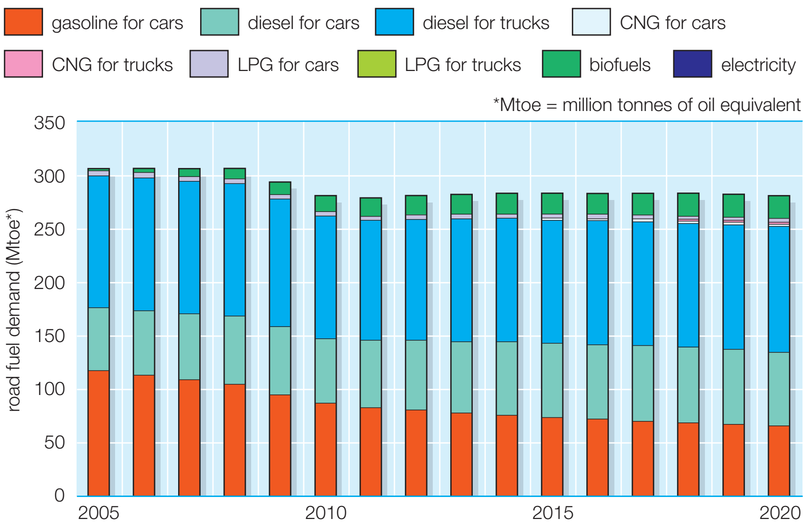


Figure 1: In the study's Reference Scenario, overall gasoline demand will decrease by 24% by 2020, whilst diesel fuel demand increases by 6%. Increasing demand for biofuels, gaseous fuels and, to a smaller extent electricity, is also observed.

The 'Reference Scenario'

With a model of this type, there is no limit to the number of biofuel implementation scenarios that can be tested. In the end, nine scenarios, including the 'Reference Scenario', were selected for more detailed analysis. The Reference Scenario is shown in Figure 2 and represents a baseline scenario relying on the implementation of already-endorsed market fuel standards. As shown in this figure, two gasoline grades are assumed, an E5 'protection grade' for older vehicles and an E10 'main grade' for most vehicles marketed since 2005.

Figure 2 Assumed change in gasoline and diesel biofuel blends in the study's 'Reference Scenario'

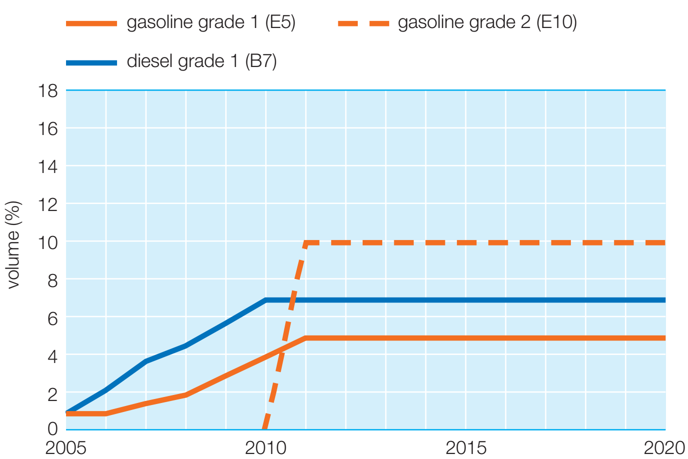


Figure 3 Ethanol and FAME required in 2005 and 2020 to meet the 'Reference Scenario' using E5, E10 and B7 blends

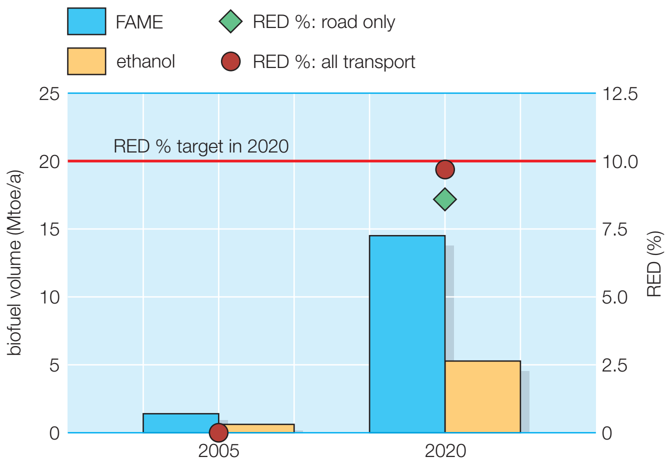


Figure 3: The study's Reference Scenario, which includes a reasonable contribution from non-road transport modes, falls short of the 10% RED target for renewable energy in transport by 2020.

Only one diesel grade was assumed, a B7 grade that can be used in all passenger and heavy-duty diesel vehicles. A contribution for E85 demand from flexi-fuel vehicles was included as well as assumptions for the development of alternatively-powered vehicles including hybrid and battery electrics and vehicles operating on gaseous fuels.

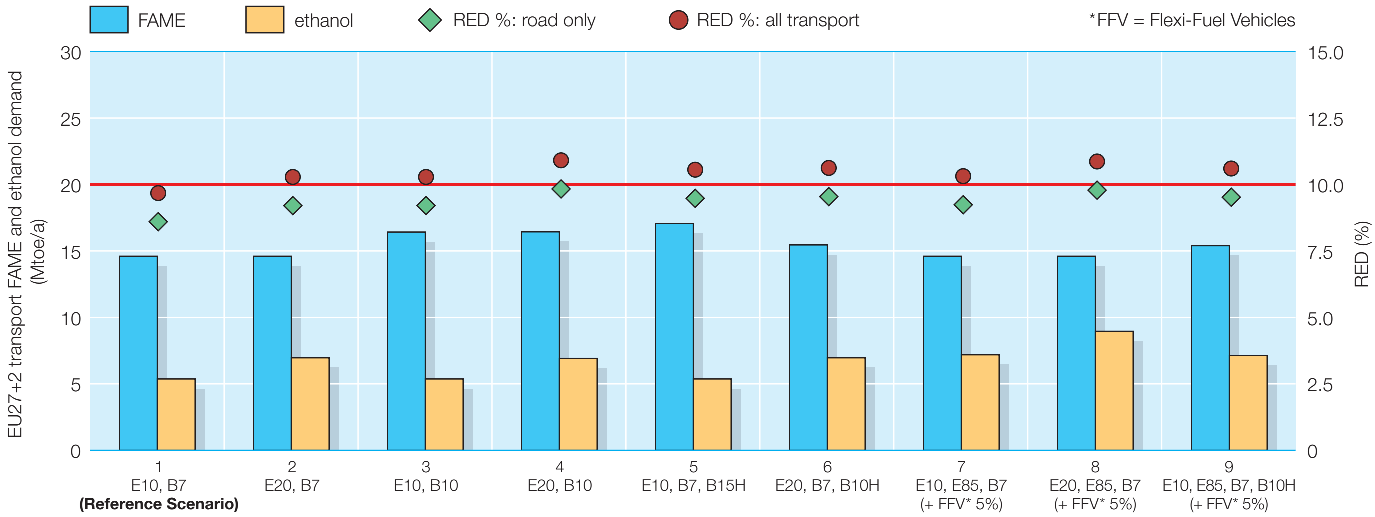
With these vehicle types and fuel grades, the model was then used to estimate the biofuel demand volumes and their overall contribution to the RED mandate. Figure 3 shows that this Reference Scenario would require about 15 Mtoe/a of FAME for diesel blending and about 5 Mtoe/a of ethanol for gasoline blending in 2020. The RED percentage from road use only is about 8.6%, with an additional 1% contribution from non-road transport modes. Thus, the Reference Scenario is projected to fall short of the 10% RED mandate, despite using particularly optimistic assumptions about the pace of advanced biofuel implementation, the number of vehicles compatible with higher biofuel levels, and the willingness of customers to select the fuel grades containing higher biofuel contents. Significant questions related to implementation costs, implications for refining and the fuel supply and distribution system, and the availability and certification of sustainable biofuels have not been addressed so far.

Beyond the Reference Scenario

Eight other 'technically feasible' scenarios were also analysed, based on higher biofuel contents, multiple grades, increasing shares of compatible vehicles in the fleet, and customers' willingness to choose the right fuel for their vehicle. As shown in Figure 4, an evaluation of these eight scenarios shows that the 10% RED target can perhaps be reached using higher biofuel blends, such as E20, B15 for compatible vehicles, or a larger market share for E85. Importantly, the 1% RED contribution from non-road transport is essential in order to meet the RED mandate. Without this contribution, the RED percentage only approaches the 10% mandate using optimistic assumptions about the pace of biofuel implementation and the availability of compatible vehicles.

None of the selected scenarios, however, achieves the minimum 6% GHG reduction target mandated in the FQD, without significant improvements in the GHG reduction performance of readily available biofuels over the next 10 years compared to the legislated GHG default values. The study estimated that the average GHG reduction performance for all biofuels assumed in these scenarios would need to be better than 63% in order to meet the FQD mandate—a value much higher than that included in the FQD legislation. Potential complications due to implementation costs, indirect land use change, and sustainability certification of biofuel production have not been considered in this study.

Figure 4 The demand in 2020 for FAME and ethanol for nine different biofuel implementation scenarios. The projected contributions to the RED % are also shown for road use only and for all transport modes.



An additional part of the study was an assessment of the assumptions used in the modelling work. Because there are many variables for vehicles and fuels, understanding how sensitive the estimated RED percentage might be to these variables was also evaluated. A sensitivity analysis was undertaken which showed that the use of FAME blends higher than B10, the pace of development of advanced biofuels, the E85 demand from flexi-fuel vehicles, and the use of renewable electricity in rail transport were especially important.

Customer acceptance for fuelling their compatible vehicles with higher biofuel levels is also critical in order to reach the RED mandate and to approach the FQD GHG reduction target. For example, the study assumes that all flexi-fuel vehicles will be fuelled with E85 for at least 90% of their distance travelled and that consumers will always choose the highest available biofuel grade that is compatible with their vehicle. Slower introduction of higher biofuel blends and compatible vehicles would have a substantial negative impact on reaching the RED mandate and GHG reduction from the transport sector.

Additional considerations

This study did not assess the viability, costs, logistics or the impact on the supply chain and vehicle industry of the different demand scenarios. Additional work would be needed to determine the technical and commercial readiness of any one scenario. Realising any one of these 'technically feasible' scenarios will depend on a combination of factors, the associated costs, the timelines and coordination of decisions across the EU, and demand trends at the global level.

The suitability of a biofuel scenario will depend on the specific national needs. It is important, however, that harmonization proceeds in a coordinated way to avoid market fragmentation for both vehicles and fuels. The compatibility between fuel blends and vehicles will control the pace of introduction, and it will be important to avoid a proliferation of nationally-adapted solutions. Multi-stakeholder coordination and timely decisions will be essential in order to approach the 2020 targets.

The JEC Biofuels Study recognises that much more technical work is needed to ensure the feasibility of any one scenario. The compatibility of different biofuel types with road and non-road vehicles is not yet proven, and the evaluation process to ensure compatibility will require time, testing and investment. For this reason, these questions need to be addressed using a coordinated European approach and with the input of all stakeholders.

Figure 4: The nine scenarios evaluated in the study show that it may be possible to meet the RED % target but that renewable energy in non-road transport modes and the coordinated implementation of higher biofuel blends will be essential.