The future composition of the EU road fuel pool

The potential impact of climate legislation

The transport sector in general, and particularly road transport, is the focus of much attention at the moment. Demand for mobility keeps increasing, driving up demand for both vehicles and fuels, while road transport relies almost exclusively on oil-based fuels. An upward trend of CO_2 emissions is the inevitable result, while questions are raised as to short-term security of oil supply and long-term sustainability of road transport.

Driven by these issues of climate, security of supply and sustainability, the EU Commission is preparing a package of energy-related legislation designed to address both vehicle efficiency and composition of the pool of transport fuels. Under the voluntary agreement entered into by auto manufacturers, average CO_2 emissions of cars sold in Europe have been decreasing over time but are likely to fail to meet the 140-g/km target foreseen for 2008. A mandatory target of 120 to 130 g/km by 2012 has now been proposed, with the aspiration to reach 95 g/km by 2020. On the fuels side, the Renewables Directive will supersede the current Biofuels Directive and mandate the introduction of 10% biofuels (by energy) in the road fuel pool by 2020. In addition the proposed revised Fuels Quality Directive includes a provision for progressive decrease of the 'life cycle GHG emissions' of road fuels to achieve a reduction of 10% by 2020 compared to 2010.

These proposals could potentially have a momentous effect on the EU road fuel market and on the oil refining sector. In order to better understand the issues at stake, CONCAWE has developed a simple 'fleet and fuels' model and used this to generate a number of scenarios described and discussed in this article.

The fleet and fuels model

Developed as a simple Excel spreadsheet, the model starts from historical data from the past 15 years and realistic assumptions on light-duty (LD) vehicle life time, to describe the average fuel efficiency of gasoline and diesel vehicles for new vehicles and for the total fleet in each past year. An empirical factor of 10% is added to 'official' fuel efficiency figures to represent the difference between the standard driving cycle (New European Driving Cycle, NEDC) and the 'real world'. Relating this data to observed fuel consumption in the 2005 base year gives the distance driven in that year.

Looking into the future, the distance driven is increased at a certain rate to represent the desired increase in mobility demand, whilst efficiency figures for new vehicles can be introduced over time according to the desired scenario. The model can then derive the fleet average efficiency and the demand for both gasoline and diesel fuel. The rate of penetration of diesel vehicles in the new fleet can be varied over time. It is also assumed that new cars are driven 50% more than those near their end of life.

Much less is known about the heavy-duty (HD) fleet, so the model only accounts for a HD diesel consumption increase over time according to the desired growth rate. The latter therefore represents the aggregation of transport demand and HD vehicle efficiency evolution.

Biofuels can be gradually introduced, ethanol into gasoline and either FAME or advanced bio-components (referred to as Biomass To Liquid or BTL) into diesel. Each biofuels component is given a certain 'Well-to-Wheels' GHG emissions footprint, expressed as percentage CO_2 equivalent saving compared to the fossil fuel it replaces. Based on the JRC/EUCAR/CONCAWE Well-to-Wheels (WTW) study[1], values of 40 and 80% for conventional and advanced ethanol respectively, 50 and 90% for FAME and BTL respectively, have been used.

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[1] *Well-to-Wheels analysis of future automotive fuels and powertrains in the European context.*

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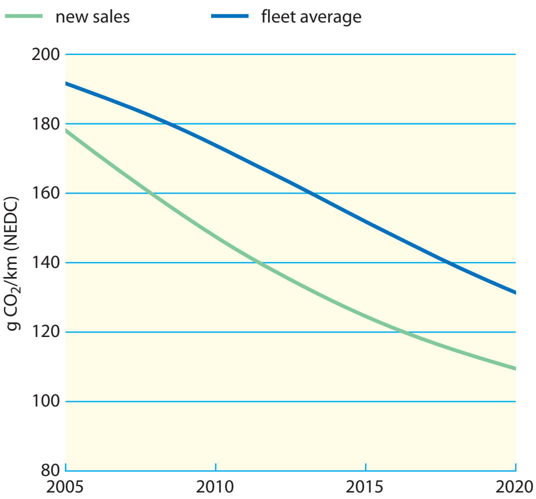
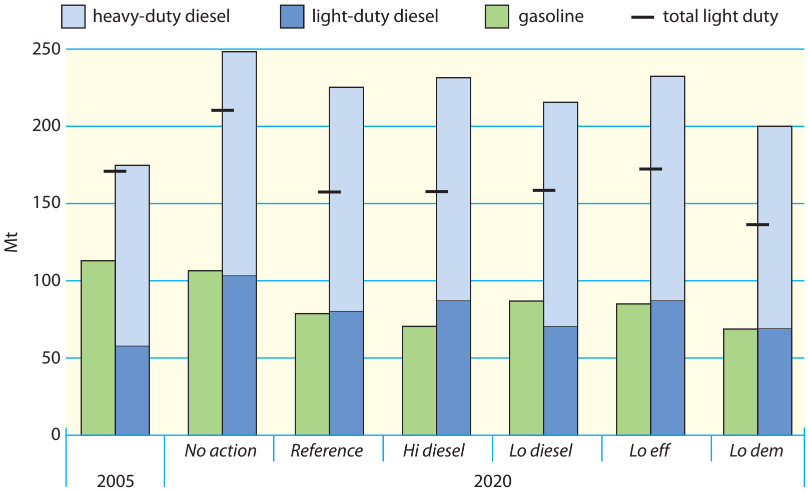
There is a 5-year gap between new vehicles and fleet average performance.

Figure 1 Vehicle emission trends for new sales v. fleet average, 2005–2020



Below: Gasoline demand decreases and diesel demand increases in all scenarios. Large car efficiency improvements are required for the total LD demand to decrease.

Figure 2 Demand for diesel (light-duty and heavy-duty) and gasoline in 2020 in the various scenarios



The model then calculates the gasoline and diesel pool composition and the resulting 'Well-to-Wheels' CO_2 emissions from the whole road transport sector. Forecasts are made year by year up to 2020.

Demand scenarios: impact of vehicle efficiency and mobility demand

In a first series of scenarios we explored the sensitivity of projected fuel demand to vehicle efficiency and mobility demand assumptions. Table 1 summarises the scenarios considered.

With vehicle life in the order of 15 years, the car population evolves only slowly, resulting in a lag of approximately 5 years between new cars and fleet average in CO_2 emissions terms (Figure 1).

Figure 2 shows the 2020 demand for gasoline and diesel (LD and HD) in the various scenarios. All scenarios show a decrease in gasoline demand and a large increase in diesel demand driven by the combination of diesel penetration in LD vehicles and increasing road haulage activities. The car efficiency improvements in the *Lo eff* case broadly compensate the increase in mobility to keep the total LD demand more or less constant. Higher efficiency improvements are required to reduce the demand (*Reference* case).

The rate of 'dieselisation' of the car fleet has a significant impact on the ratio between diesel and gasoline demand

Table 1 Demand scenarios

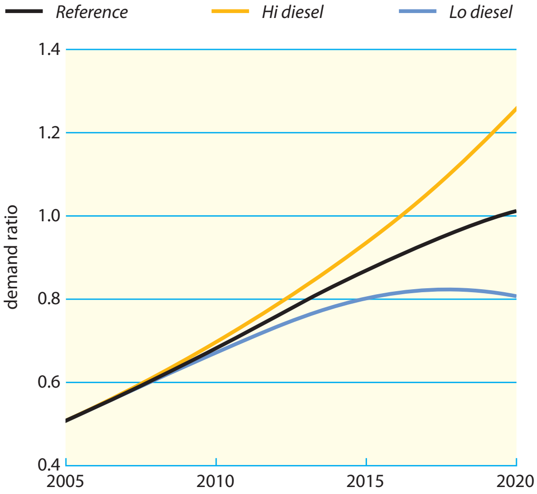
Case	Description
No action	No further changes to LD vehicle efficiency after 2005, LD vehicles distance driven increase of 2% per annum and HD diesel demand increase of 1.5% per annum. Share of diesel amongst new cars starts at 50% in 2005 to reach 55% in 2012 and gradually decreases back to 50% by 2020.
Reference	New LD vehicle efficiency improvement to 125 g CO_2/km by 2012 and 100 by 2020[1].
Hi diesel	As per *Reference* with share of diesel amongst new cars increasing linearly to 70% by 2020.
Lo diesel	As per *Reference* with share of diesel amongst new cars stabilizing to 50% up to 2012 then decreasing linearly to 30% by 2020.
Lo eff	As per *No action* with new LD vehicle efficiency improvement to 135 g CO_2/km by 2012 and 110 by 2020.
Lo dem	As per *No action* LD vehicles distance driven increase of 1% per annum and HD diesel demand increase of 0.7% per annum.
NA, lo dem	A combination of the *No action* and *Lo dem* scenarios.

[1] This corresponds to stated Commission's ambitions of 120 and 95 g CO_2/km for vehicles by 2012/2020 respectively taking into account a 5-g contribution from fuels. The figures are for the official driving cycle NEDC.

for LD vehicles, but here again the already existing fleet creates a long response time to changes. Even in the *Lo diesel* case where the diesel share of new cars falls dramatically after 2012, diesel demand keeps increasing relative to gasoline until well after 2015 (Figure 3). In all cases the diesel to gasoline ratio is much higher in 2020 than in 2005. This is an important observation in a context where the growing imbalance between diesel and gasoline is one of the main challenges for EU refiners.

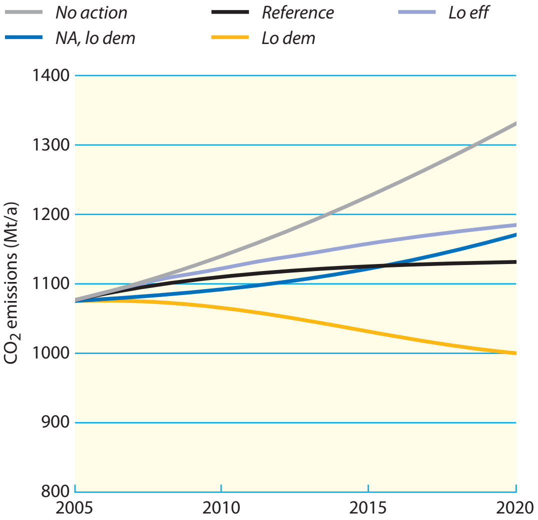
The resulting WTW CO_2 emissions from road transport are shown in Figure 4, which illustrates the relative impact of mobility demand and vehicle efficiency. The efficiency gains considered in the reference case (corresponding to the EU Commission's ambitions) can nearly stabilise emissions. The same result can be obtained through halving the mobility demand growth.

Figure 3 Light-duty diesel/gasoline demand ratio, 2005–2020



Only a steep decrease of the diesel share of new cars can stabilise the diesel demand relative to gasoline albeit at a much higher level than today.

Figure 4 Total EU road transport WTW CO_2 emissions



Vehicle efficiency gains ambitioned in the EU have the same impact as halving the mobility demand growth.

Meeting EU ambitions with biofuels

Having established the base line with fossil fuels we considered biofuels introduction scenarios with a view to meeting either the Renewables Directive target of 10% on an energy basis by 2020 or the ambition of the Fuels Directive to reduce the GHG footprint of road fuels by 10% by 2020 compared to 2010 (10% 'life cycle' (LC) reduction). Starting from the *Reference* case defined above we explored four cases as per Table 2.

In the proposed revision of the Fuels Directive, the 10% LC ambition does not *per se* assume that only biofuels can be used. It is also implicitly envisaged that conven-

Table 2 Biofuels introduction scenarios

Case	Description
Max domestic	Introduction of biofuels at a rate and to a level consistent with forecast for in-EU production (based on the JEC study). This includes ethanol and FAME from crops as well as ethanol from straw and BTL from woody residues.
10% biofuels	Biofuels quantities to meet the 10% by energy target in 2020. Domestic supplies as above but with 50% of FAME crop area now dedicated to woody biomass for BTL, supplemented by FAME imports (7.6 Mtoe/a required).
10% LC	Biofuels quantities to meet the 10% life cycle (LC) reduction by 2020. Supplies as above now with 10 Mtoe/a FAME import and balance by cane ethanol import.
10% LC <E30	As above but with enough FAME import to limit gasoline ethanol content to 30% v/v (25 Mtoe/a FAME).

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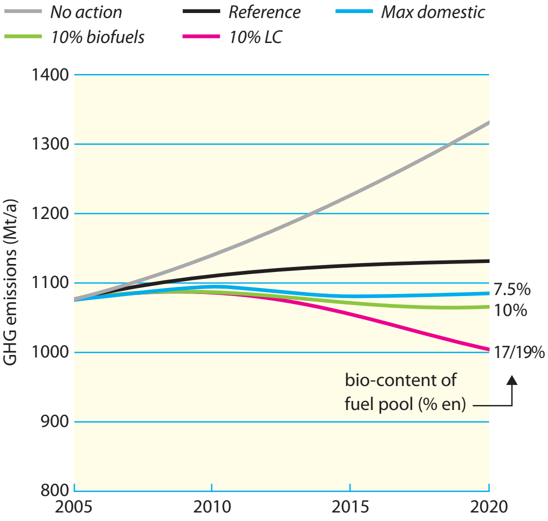
tional fossil fuels could play their part through GHG emission reductions in refining and upstream. Refineries have been continually improving their energy efficiency for many years and are set to continue to do so, although marginal gains are becoming increasingly costly and difficult to achieve. Whereas there may be a certain scope for such schemes as CO_2 capture and storage or use of biomass as fuel in refineries, the many constraints attached to these will confine them to a limited number of cases. On the other hand refineries are faced with increasing product quality and own emissions constraints as well as changes in crude oil supply and product demand pattern that all point towards higher complexity therefore higher energy intensity and higher CO_2 emissions. On balance, we believe that the best EU refiners can hope for is to cancel out the inevitable increases through efficiency improvements and other measures. In practice therefore, biofuels would have to supply essentially all of the required reduction.

The WTW GHG emissions from road transport in the various scenarios are shown in Figure 5. Because it relies mostly on biofuels that have a relatively high GHG footprint, the *10% biofuels* scenario delivers only modest GHG gains, about 1/3 of what the LD vehicles deliver through improved efficiency. The *10% LC* reduction obviously delivers more, but requires much more resources. The bio-content of the total road transport fuel pool increases from 7.5% in the *Max domestic* case to 17 or 19% in the *10% LC* case depending on the amount of ethanol allowed.

The corresponding gasoline and diesel pool mass composition are shown in Figure 6. The proportion of ethanol in gasoline is much higher than that of bio-components in diesel and reaches nearly 50% in the *10% LC* case unless massive FAME imports are allowed. This is because there is potentially enough domestic ethanol to cover more than 10% of the dwindling gaso-

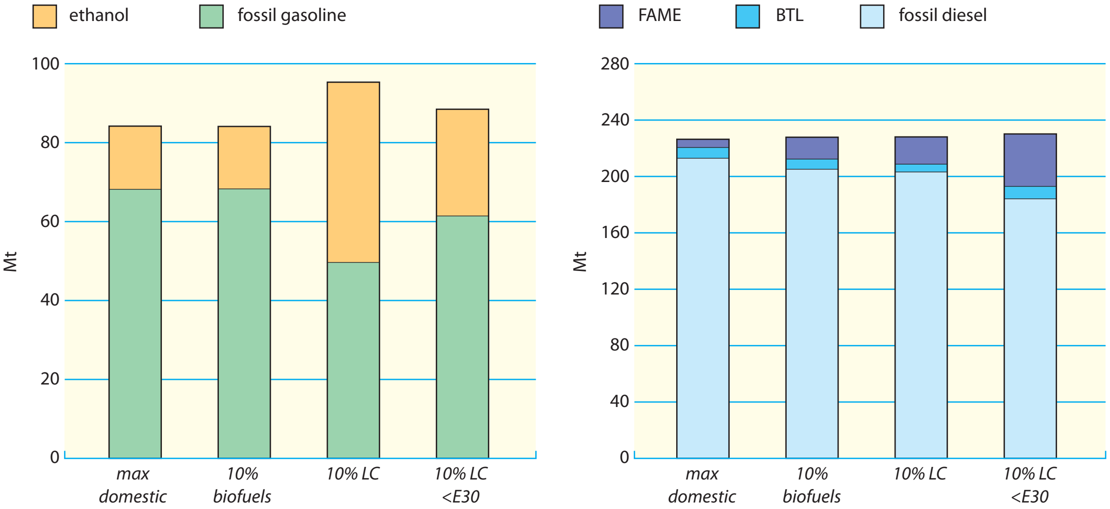
10% biofuels introduction delivers only modest GHG gains. Much larger bio-component volumes are required to reach 10% LC.

Figure 5 Total EU road transport GHG emissions



The proportion of ethanol in gasoline is much higher than FAME in diesel.

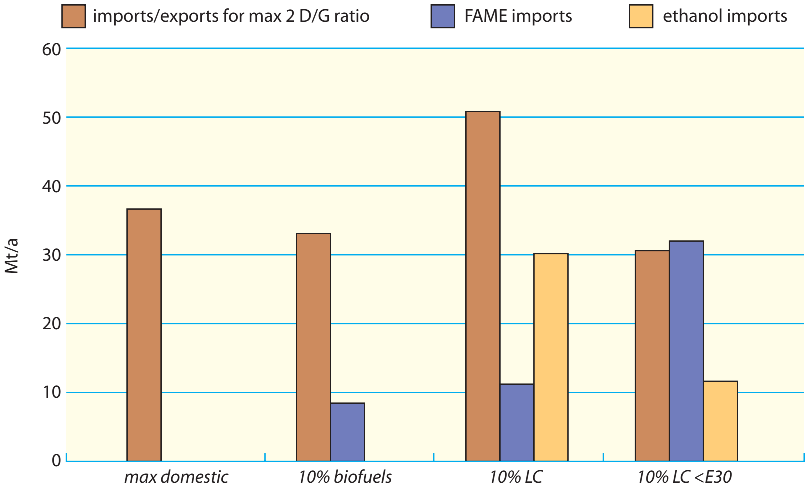
Figure 6 Gasoline and diesel pool mass composition



line demand, and also because ethanol has a lower energy content than FAME or BTL. More than 40 Mt/a biofuels imports are necessary to meet the *10% LC* ambition, increasing to 47 Mt/a when cane ethanol imports are limited and replaced by FAME (which is less efficient from a GHG point of view). Note that these scenarios include the fairly optimistic assumption that advanced biofuels supplies, including up to 8 Mt/a of BTL, would be available within the time frame. Without these advanced components, meeting the *10% LC* ambition would require much larger tonnage.

We have mentioned above the critical nature of the diesel to gasoline ratio for EU refineries. In a previous study where we considered the impact of that ratio on refinery investment and energy requirements, we determined that it would be highly desirable to keep the refinery production ratio below 2 (CONCAWE report 1/07). The way to achieve this is to export gasoline and/or import diesel or similar components. The minimum amounts of gasoline exports and diesel imports that would be required to keep the refinery production ratio under 2 are shown in Figure 7 together with the required ethanol and FAME imports. The most striking observation from this figure is the relationship between ethanol imports and gasoline exports, illustrating the increased reliance on international trade that would result from over-reliance on ethanol to meet the EU biofuels ambitions.

Figure 7 Gasoline exports and diesel imports required to keep the refinery production ratio below 2



It must be noted that the arbitrary limit of 2 for the diesel/gasoline production ratio already represents a marked increase from today's value of about 1.6, and would require significant refinery adaptation. If the current value was to be retained, imports and exports would each have to be in excess of 50 Mt/a.

Ethanol imports would trigger gasoline exports.

This simple analysis sheds some light on the relative impact of mobility demand, vehicle efficiency improvements and biofuels introduction on the evolution of road transport GHG emissions in Europe in the next 12 years. For biofuels to play a significant part they have to be introduced in quantities that would far exceed EU production capabilities. In this respect, over reliance on ethanol would result in an increased dependence of the EU on international trade to rebalance the domestic refineries' diesel and gasoline productions.