Regulations to control emissions and fuel implications

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ABSTRACT

Air quality and greenhouse gas (GHG) emissions are of continuing concern in the European Union. More recently, the EU Commission has raised security of energy supply as a further concern. Major progress has been made on air quality improvement and emissions will continue to decrease as a result of the Directives arising from the European Auto-Oil Programmes. The full benefits of these measures will be realised as vehicle fleets are turned over to newer, cleaner technologies. Fuel quality improvements are contributing to the solutions, mainly through the concept of “enabling quality”, where improved fuels lead to a step change in emissions by enabling the introduction of significant new engine or exhaust after-treatment technologies. Notably, sulphur-free fuels (10 ppm S max) will be gradually introduced into the European market during the course of this decade, enabling further steps in emissions control to be achieved.

Greenhouse gas emissions, in particular CO_2 emissions, remain a challenge. The new sulphur-free fuels, which will commence introduction in 2005 in-line with EU specifications, should contribute to the fuel efficiency of future vehicles, by minimising the number of regenerations needed by advanced exhaust after-treatment systems. These fuels fully satisfy the requirements of the expected new engine and after-treatment technologies and should enable a wide range of new technologies to be introduced, including hybrid concepts. Other changes, beyond the currently legislated EU 2005 fuel specifications, would not bring significant further environmental improvements and would increase refinery CO_2 emissions and production costs. Looking to the longer term, novel combustion concepts, such as HCCI, are being actively researched and the fuel requirements of such systems may need to be investigated.

The EU Commission’s concerns over greenhouse gas emissions and security of supply have also led to a number of recent initiatives in the area of alternative fuels and vehicles, in particular with regard to biofuels, CNG and hydrogen. These alternatives need to be considered on a well-to-wheels basis, also taking into account technical feasibility, scale potential, costs and their contribution versus alternative ways of meeting societal objectives. CONCAWE are actively engaged in work in this area via a joint study with EUCAR and JRC, which will feed into the EU Commission activities. Such cooperative approaches are essential if we are to find optimum long term solutions which can be implemented effectively by the industries.

1 INTRODUCTION

Air quality has been a major focus of EU legislators over the last 10–20 years. In 1996, the Air Quality Framework Directive [1] established a framework for the improvement of air quality in Europe which has now been implemented through the Air Quality Daughter Directives [2-4] and National Emissions Ceilings Directive [5].

The European Auto-Oil programmes used air quality as the basis for defining needed improvements and identifying cost-effective measures which could be taken in the road transport sector. The EPEFE programme [6] provided a comprehensive data-base of vehicle / fuel effects on emissions for engine technologies up to the Euro-2 vintage. Currently, the Clean Air For Europe (CAFE) programme [7] is extending this approach, considering all sources of emissions, in order to develop a “long-term, strategic and integrated policy to protect against the effects of air pollution on human health and the environment”.

As a consequence of the effect of Auto-Oil programmes and related Directives on vehicles and fuels, reductions in emissions from EU road transport are well underway. By 2010, as the vehicle fleet turn-over progresses, the real impact of these measures will be felt and substantial reductions in regulated emissions from road transport will have been achieved (**Figure 1**).

However, from **Figure 1** it is also clear that the one emission that is not improving is CO_2. As concerns over climate change mount, the GHG emissions issue is pushed to the forefront, while Europe's dependence on imported fossil fuels has also brought security of energy supply high on the political agenda. The EU Commission's activities reflect this through their Green Paper on energy supply [8], the proposed Biofuels Directive [9] and initiatives on other Alternative Fuels, in particular compressed natural gas (CNG) and hydrogen.

The current challenge for the road transport/ energy sectors is to reduce greenhouse gas emissions while maintaining low emissions of other pollutants. Understanding greenhouse gas emissions requires consideration of future fuel / vehicle options on a well-to-wheels basis, since energy is consumed and greenhouse gases are emitted in the fuel production processes as well as in their use in powering vehicles.

This paper discusses the recent developments in emissions regulations and fuel specifications and provides CONCAWE's views on future fuel quality implications. It highlights the current and future work needed to provide a firm technical basis for identifying optimal solutions to the current challenges.

2 VEHICLE EMISSIONS LEGISLATION

2.1 Regulated emissions

Vehicle emissions legislation has been progressively tightened over the past 20 years. The Auto-Oil programme resulted in new Directives on emissions from both light duty (LD) vehicles [10] and heavy duty (HD) engines [11], with increasingly stringent requirements; so-called Euro-3 from 2000, Euro-4 from 2005 and Euro-5 from 2008 (HD only). The Euro-5 HD NOx emissions limit for 2008 was specified subject to an EU Commission review that is currently in progress and to be completed by 31 December 2002.

Figure 2 shows the dramatic reductions in regulated emissions limits that have been achieved, typically over 90%, since the "pre-Euro" emissions era. Reductions in HD NOx emissions lag slightly behind, but will catch up by 2008, assuming that EU legislation confirms the 2008 HD NOx limit.

The European exhaust emissions limits for LD vehicles and HD engines, for year 2000 and beyond, are summarised in **Appendices 1 and 2**. Further details and the history of developments in emissions legislation can be found in CONCAWE's reports on world-wide motor vehicle emissions legislation and fuels specifications [12, 13].

2.2 Particle emissions

Particle emissions have, to date, been controlled through legislation on particulate mass. While tighter limits on particulate mass have been applied, concerns over possible health effects of particle emissions have led to research into other properties of particles with special emphasis on particle size and number.

CONCAWE have been actively engaged in research into automotive particle emissions over a number of years [14-17]. It now seems clear that automotive particle emissions fall into two generic types (**Figure 3**):

- Solid, so-called "accumulation mode" particles, which form the vast majority of the particle mass, generally >30 nm in diameter, consisting mainly of carbonaceous material with some adsorbed hydrocarbons.

- Volatile, so-called "nucleation mode" particles, generally <30 nm in diameter, composed mainly of sulphate and hydrocarbons.

Although the two particle types have different characteristics, there is often some overlap in the size range. Size distribution profiles tend to be similar but there can be considerable influence of engine types and after-treatment technologies on the number of particles emitted (**Figure 4**).

The current status of knowledge on the measurement of automotive particle emissions was summarised recently via the International Workshop on Vehicle Exhaust Particulate Emission Measurement Methodology, organised by the CRC in cooperation with SAE, JSAE, CONCAWE and ACEA [18]. The conclusions from the workshop included that:

- Further improvements in the particulate mass (PM) method are still feasible,
- Measurements of the "solid" particles by size/number can be reasonably repeatable but significant challenges remain for application to anything other than research purposes,
- Measurements of "nucleation mode" particles are highly sensitive to exhaust gas dilution conditions (e.g. see **Figures 5 and 6)**.
- There is still no clear understanding on relevant measurements of nucleation mode particles, their fate in the atmosphere, or their role in possible health effects. Further research continues to be needed on this topic.

Looking towards the next stage in particulate emissions regulation, a number of European Member States have initiated a work programme under the auspices of the UN-ECE GRPE, to develop new measurement methodologies which may be suitable for type approval testing [19]. This is focussing on the "solid" particles, in view of the greater uncertainties on the nucleation mode.

2.3 Greenhouse gases

Whenever greenhouse gas emissions from road transport are discussed, the main emphasis is on CO_2 as it is by far the largest emission from internal combustion engines. Smaller amounts of other greenhouse gases, chiefly CH_4 and N_2O, also need to be considered as their greenhouse effect is much higher than that of CO_2 (e.g. N_2O is around 300 times more potent than CO_2).

Although CO_2 emissions produced by the transport sector currently represent only about 30% of the total EU-15 CO_2 emissions, it is clear from **Figure 1** that the CO_2 emissions from road transport are not decreasing like the other transport-related pollutants. As the first step towards curbing CO_2 emissions from road transport, the motor industry entered into a voluntary agreement to achieve a fleet average of 140 gCO_2/km by 2008 [20]. The EU Commission has indicated that this should be further reduced to 120 g/km by 2012. More recent initiatives to reduce greenhouse gas emissions are discussed further in **section 5**.

2.4 Ability to meet the standards

With regard to meeting the upcoming emissions standards, the challenges lie in different directions for the different engine technologies. Many gasoline engines today already surpass the Euro-4 emissions limits, well in advance of the 2005 deadline. The real challenge for gasoline engines is to reduce CO_2 emissions, while maintaining their low regulated pollutant emissions. Lean burn direct injection engines carry the promise of significant efficiency gains, but require complex exhaust after-treatment systems for control of NOx emissions. A range of other gasoline engine technologies will also compete.

The challenge for diesel engines is to improve particulate and NOx emissions, while maintaining good fuel economy and CO_2 emissions. As engine measures to improve particulates generally increase NOx and vice versa, some form of exhaust after-treatment is likely to be required. Application of NOx storage catalysts to diesel engines is technically feasible but still requires considerable development and for the near term, alternative approaches are more likely to be used.

For HD diesel engines, two basic technology routes are on the table. One option is to reduce engine out NOx by engine measures, including cooled Exhaust Gas Recirculation (EGR) and then to reduce particulates by means of a particle filter. An alternative strategy is to optimise the engine for low particulates, in the process creating higher engine-out NOx, which is then controlled with a selective catalytic reduction (SCR) after-treatment system, using urea as the reducing agent. This system appears to be gaining favour due to its inherently better fuel economy (and CO_2 emissions) [21, 22]. A combination of SCR/urea with a particle filter is also feasible. The SCR/urea system is well proven in laboratory and field tests [23] but a number of issues remain to be resolved regarding practical real world use. If SCR/urea is required, time will be needed to resolve these practical issues, as well as to set-up a new distribution infrastructure to supply urea.

In the LD diesel sector, small vehicles are able to meet the 2005 standards with simple oxidation catalysts. Larger vehicles are likely to require particulate traps, with systems catalysed by fuel additives [24] likely to be used in the near term. Only the largest LD vehicles may need after-treatment for NOx reduction to meet the 2005 standards. However, due to the different legislative cycles and in-use operating conditions between LD and HD vehicles, use of SCR/urea is considered less likely in the LD sector.

3 EU FUEL SPECIFICATIONS

EU fuel specifications have been dramatically tightened over the last decade, culminating in the EU Fuels Directive (98/70/EC) [25] and its proposed update [26]. The proposed update calls for EU-wide availability of sulphur-free (10 ppm max sulphur) gasolines and diesel fuels by 2005, with 100% of such fuels across the EU market by 2009.

Figure 7 summarises the history of the key gasoline and diesel fuel property changes over the period from 1993 - 2009. The continuing challenge for the Oil Industry is to supply the needed market volumes at the specified quality. Diesel volumes are limited by constraints on density and back-end distillation points, while demand increases steadily. For gasoline the challenge is to satisfy the octane and distillation requirements with a decreasing choice of molecules available to the blending pool [27]. Reducing gasoline sulphur to extremely low levels while minimising destruction of valuable high octane molecules, such as olefins, will be facilitated by new process developments.

To minimise GHG emissions as new lower sulphur fuels are introduced, a progressive introduction is planned. This raises distribution system challenges, in addition to the refinery issues, especially in the interim period when several fuel grades may be available in any given market. The Oil Industry will also need to respond to the increase in demand for diesel fuel and reduction in demand for gasoline, which is expected to continue due to increased demand for HD road haulage as well as the further shift from gasoline to diesel passenger cars to meet CO_2 targets.

4 FUEL / VEHICLE TECHNOLOGY INTERACTIONS

CONCAWE's report 99/55 [28] described the importance of engine technology / fuel interactions with regard to emissions. The major benefits from fuels on emissions occur when the new fuels enable a step-change in engine or exhaust after-treatment technologies. Notably, the removal of lead from gasoline enabled the introduction of catalytic after-treatment systems and the forthcoming introduction of sulphur-free fuels should enable the introduction of a range of advanced exhaust after-treatment technologies for both gasoline and diesel vehicles.

More recently, in order to update knowledge on diesel fuel effects on emissions with more modern technologies, CONCAWE carried out a study on Euro-3 diesel engines and vehicles [29]. Fuel properties studied were selected to address two of the questions remaining from EPEFE, i.e. the role of cetane and aromatics. This work showed that diesel fuel aromatics content and cetane number had only a small effect on emissions with Euro-3 technologies. Cetane trends did not differentiate between natural and additive-derived cetane. **Figures 8 & 9** illustrate two examples from that study. Further work is underway with more advanced engine technologies.

As more advanced emission control technologies, along with sulphur-free gasolines and diesel fuels, are introduced to meet the legislative requirements for 2005 and beyond, very low emissions will be achieved. At these levels, changes to fuel quality are even less likely to make further significant contributions to air quality improvement. For example, the limited effect from further fuel changes with advanced vehicle technologies is evident in a number of studies with diesel vehicles equipped with particulate filters [17, 30].

To meet the requirements of Euro-4 and beyond, together with the CO_2 targets, a range of advanced vehicle technologies is likely to be used. The most likely of these include:

- Advanced gasoline engines:
  Direct injection, variable valve actuation, downsizing
- Improved diesel engines:
  Multiple high pressure injections, cooled EGR
- Advanced exhaust after-treatment:
  Improved 3-way catalysts, lean NOx converters, particulate filters
- Hybrid concepts.

Sulphur-free fuels meet the needs of all these vehicles.

More extreme fuel changes such as those proposed by Category 4 of the manufacturers World-Wide Fuels Charter (WWFC) [31] would provide no significant benefit for air quality but would increase refinery CO_2 emissions due to the increased processing needed and would further restrict the available fuel volumes.

However, there are other novel combustion systems under development such as homogeneous charge compression ignition (HCCI) engines which may provide the next step in cost-effective emissions control [32-34]. Such systems may have different fuel requirements to conventional engines and this is an area which clearly needs more study. This could lead to entirely different fuel requirements to those suggested in the WWFC.

Looking to the longer term, hydrogen fuel cell vehicles offer potential for efficiency gains, as well as potential for near zero emissions from the vehicles. However, it is important to recognize that hydrogen is an energy carrier, not an energy source and if it is to be considered as a transport fuel, it has to be manufactured, distributed and stored. Depending on how the hydrogen is produced, CO_2 emissions during the hydrogen production and distribution processes can be higher than the total CO_2 emissions from the use of conventional fuels.

For a long time to come, renewable energy sources will be limited and energy users will have to compete for them. A recent CONCAWE Review article [35] shows that, from the point of view of global CO_2 savings, renewable electricity can be much more effective if used as such, rather than through production of hydrogen for road transport.

Nevertheless, fuel cell vehicles powered by hydrogen are a likely long term option, although the best way to deliver hydrogen to the vehicle is not yet clear: gasoline-type or methanol with on-board reforming, or direct hydrogen ? ***New fuels may be required, but more work is needed to ascertain their precise use and nature.***

5 ALTERNATIVE FUELS / VEHICLES

5.1 EU Commission Activities

In 2001, the EU Commission launched its Green paper on Energy [8] and White Paper on Transport [36]. These highlighted the Commission's concerns over greenhouse gas emissions and security of energy supply and formed the basis for further initiatives on alternative/renewable fuels.

A proposed Directive on biofuels was issued [9], followed by a number of other initiatives, mainly focussing on CNG and hydrogen. Sustainable transport is a key element of the 6th Research Framework programme, again with focus on hydrogen. In October 2002, placing even more emphasis on the hydrogen scenario, the Commission launched a new high level group on hydrogen and fuel cells [37].

The motor manufacturers are also promoting a variety of alternative fuel schemes. BMW are championing hydrogen, mainly as an IC engine fuel [38], while VW and Daimler-Chrysler have just announced a research initiative on synthetic fuels from biomass ("Sunfuels") [39, 40] where bio-diesel can be produced via gasification of biomass followed by a Fischer-Tropsch synthesis. The main issues in this latter case are how much biomass could practically be made available, at what cost could such fuels be produced, and what would be the real overall contribution to energy and GHG savings.

5.2 Well-to-wheels analysis

Climate change is a global issue and any serious attempt to assess the potential of alternative fuel / vehicle options to reduce GHG emissions requires a global "well-to-wheels" approach, assessing the total cycle GHG emissions, not just the CO_2 emissions from combustion on the vehicle. It is of no value to reduce CO_2 emissions from the vehicle if these are more than offset by increases in CO_2 (or other GHG) emissions during fuel production and/or distribution. It is also important to assess the potential of a given fuel / vehicle combination to substitute a significant portion of the existing transport market in order to focus research efforts on options that can really make a difference.

5.3 Biofuels

In the context of the EU Commission's proposed Directive on biofuels, CONCAWE undertook a review of the literature concerning the energy and greenhouse gas balance of biofuels. This study was reported in CONCAWE report 2/02 [41]. In summary, it concluded that while biofuels can contribute to energy and greenhouse gas savings, (**Figures 10 and 11**), the amount of land likely to be available to grow the crops means that the total contribution to greenhouse gas emissions reduction and security of energy supply is minimal.

The report highlighted that the energy and GHG emissions balance of biofuels are highly dependent on the assumed use of by-products as well on the assumptions on the agricultural N_2O emissions from fertilisers. Also, that sequestration and release of carbon in/from soil leads to a large uncertainty over global CO_2 emissions if a major change in land use is envisaged.

The report further suggested that there may be more CO_2-efficient ways to use land than for transport fuels. For example, growing high yielding crops for direct use in combined heat and power units would lead to a greater net CO_2 saving per hectare of land. The most effective use of available land deserves further study.

5.4 Other alternative fuel / vehicle options

A number of well-to-wheels studies on alternative fuel / vehicle options have already been published. These studies generally agree on some issues e.g. that hydrogen fuel cells and Fischer-Tropsch diesel are not CO_2-efficient compared to conventional fuels/engines when natural gas is the primary energy source, and that hybrid systems have high potential (e.g. **Figure 12**). However, the precise results of these studies have varied widely, since they differ in the detail of the assumptions on the efficiencies of the vehicles and the scenarios chosen for the fuel production pathways. These details can markedly impact the conclusions for a number of fuel / vehicle options.

In an attempt to overcome these difficulties, CONCAWE joined forces with EUCAR and JRC (Joint Research Centre of the EU Commission) with the objective to produce a well documented, soundly based, transparent, well-to-wheels analysis, which could form an agreed technical basis for future rational decision making in Europe. Assistance is being provided by experts from IFP[1] for the tank-to-wheels part and LBST[2] for the well-to-tank part.

This joint CONCAWE/EUCAR/JRC study builds on previous studies, in particular the recent studies of TES (Transport Energy Strategy) and the GM-LBST European well-to-wheels study [43]. It includes a wide range of fuel production pathways from resources e.g. oil, gas, land, wind, to products e.g. gasoline, diesel, Fischer-Tropsch diesel, CNG, hydrogen, and vehicle options, including gasoline and diesel vehicles, natural gas vehicles, hybrids and fuel cell options [44].

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If any of the above options are to be sustainable long term, they need to be technically feasible on a large scale and economically competitive. This study therefore goes a step beyond previous studies in also attempting an assessment of the scale potential and cost of the various options. First results from this study should be available early in 2003.

6 CONCLUSIONS

- Improving European air quality and reducing global greenhouse gas emissions requires consideration of all emitting sources in a common approach.
- Air quality modelling should continue to be the basic tool to identify problem areas and possible abatement measures, on a cost-effective basis.
- Major reductions of pollutant emissions from road transport (HC, CO, NOx and PM) will have been achieved by 2010.
- Progress is being made in the ability to measure automotive particle emissions by size and number, but guidance is still needed from the health and atmospheric science communities. More research is required, especially on nucleation mode particles.
- Improvements in fuel quality are contributing to environmental improvements by enabling new engine and after-treatment technologies.
- EU 2005 specification sulphur-free fuels fully satisfy the requirements of expected near term developments on engine technologies and after-treatment systems, including hybrid concepts.
- Further changes to other fuel properties are unlikely to provide any significant air quality benefits and would increase refinery CO_2 emissions.
- Novel combustion concepts such as HCCI may have new and different fuel requirements and these need to be assessed as the technologies develop.
- A "wells to wheels" approach, also accounting for technical feasibility, scale potential and costs, is required when considering alternative fuel / vehicle options. CONCAWE is actively engaged in this area through a collaborative study with EUCAR and JRC.

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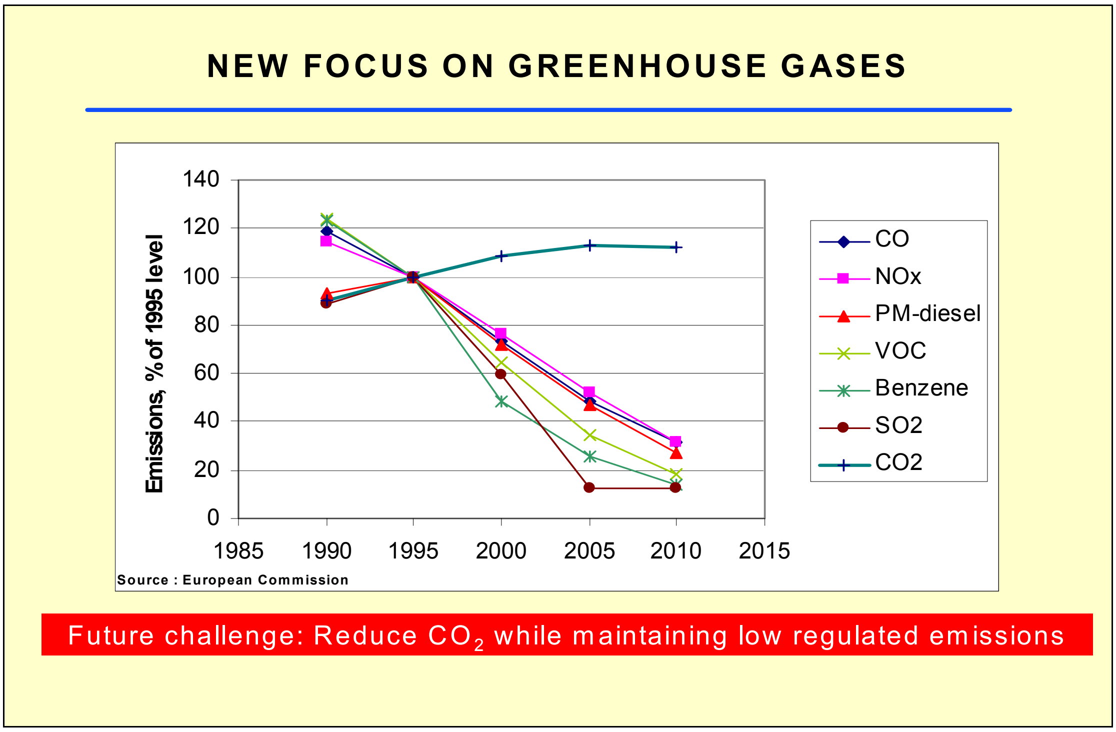
Figure 1 EU-15 predictions of developments in emissions from Road Transport (Auto-Oil II).

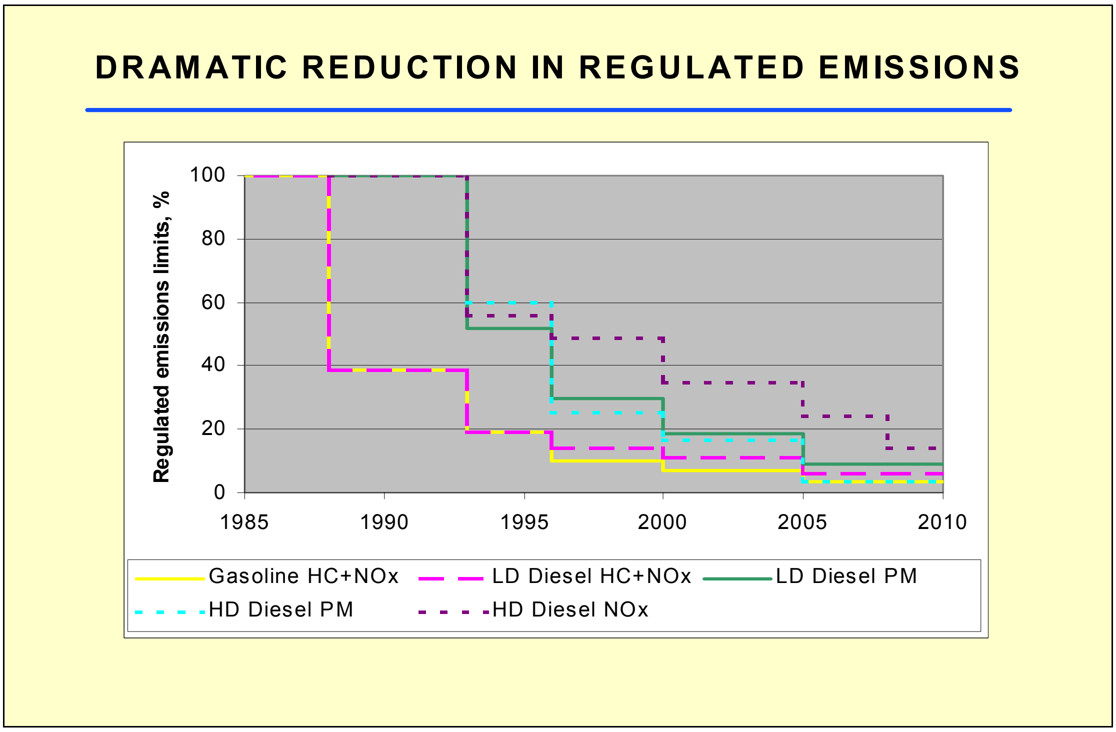


NEW FOCUS ON GREENHOUSE GASES

Source : European Commission

Future challenge: Reduce CO_2 while maintaining low regulated emissions

Figure 2 Developments in European emissions legislation for road transport



DRAMATIC REDUCTION IN REGULATED EMISSIONS

Figure 3 Typical particle size and number distribution profiles from an HD diesel engine

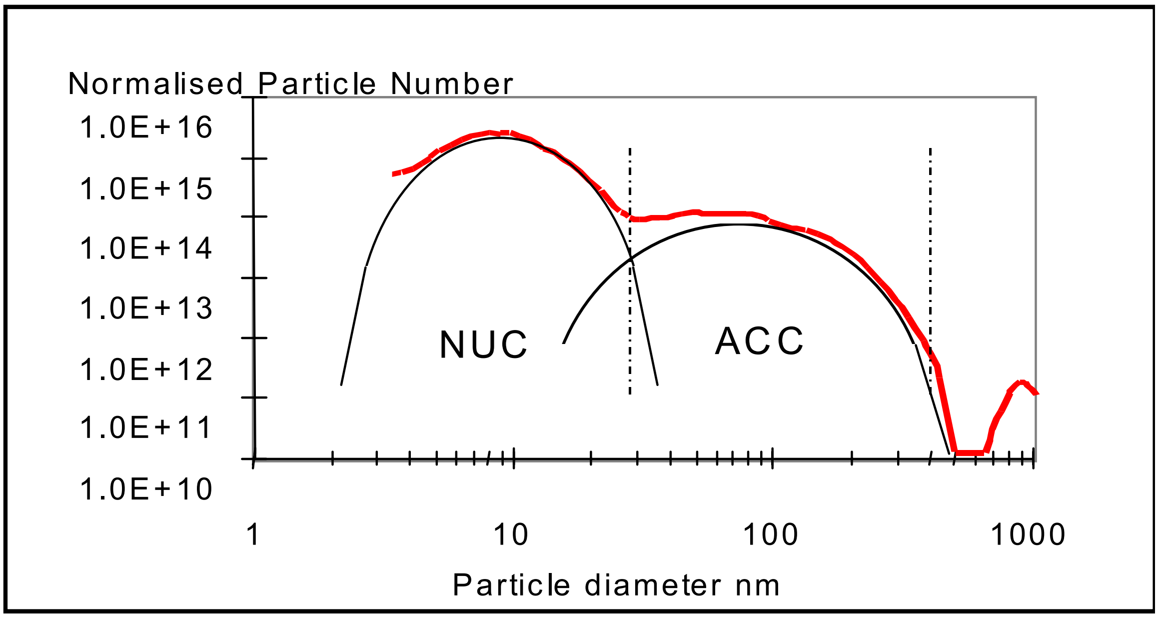


Figure 4 LD vehicle particle size and number emissions, Steady State 50 km/h [17].

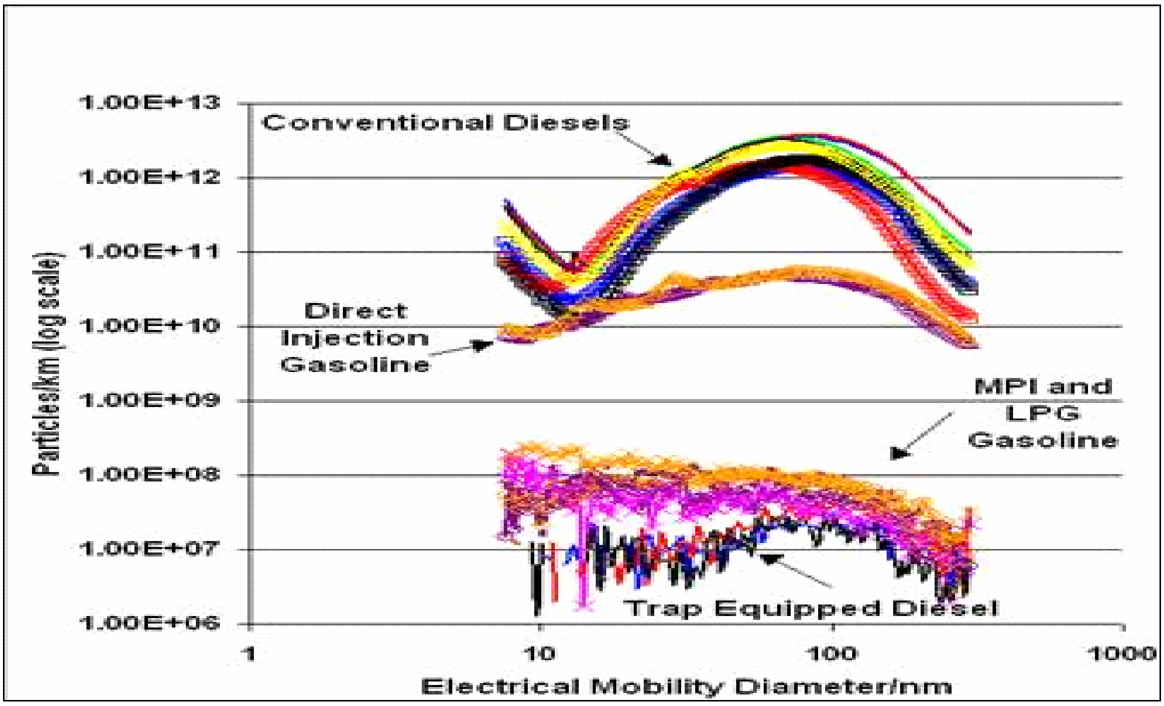


Figure 5 Effect of dilution temperature on production of nucleation mode particles - Source DG TREN Particulates Consortium [18]

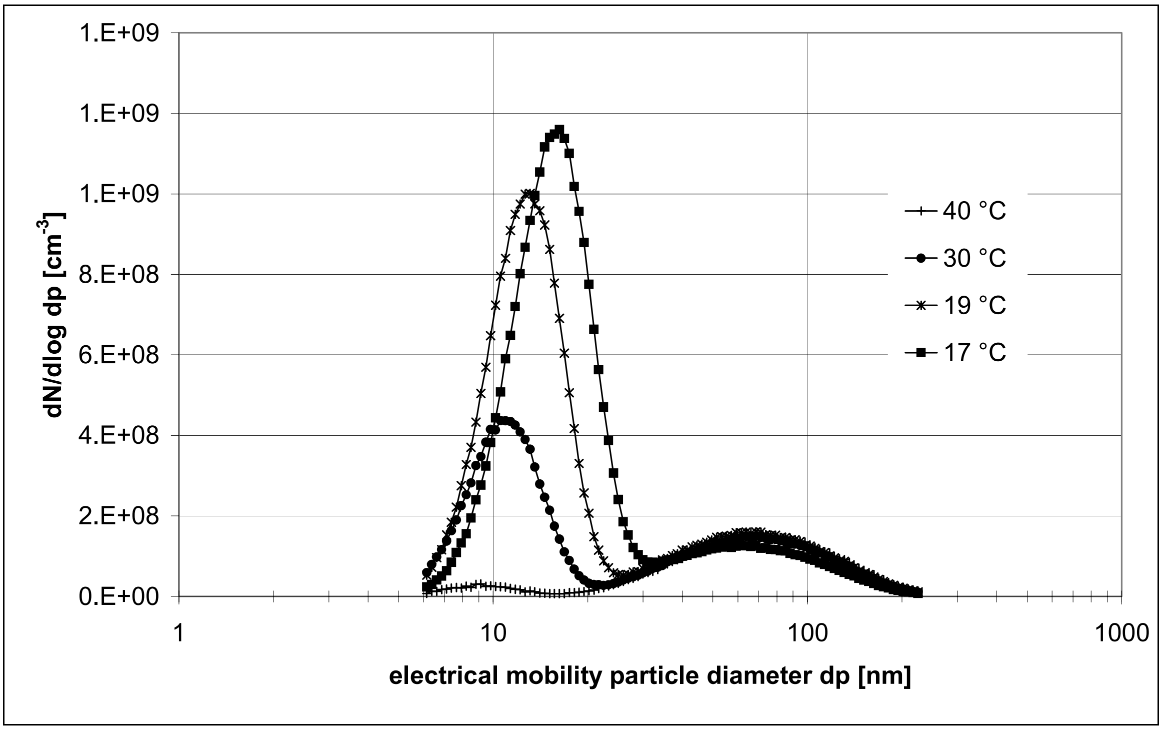


Figure 6 Effect of dilution ratio on production of nucleation mode particles - Source DG TREN Particulates Consortium [18]

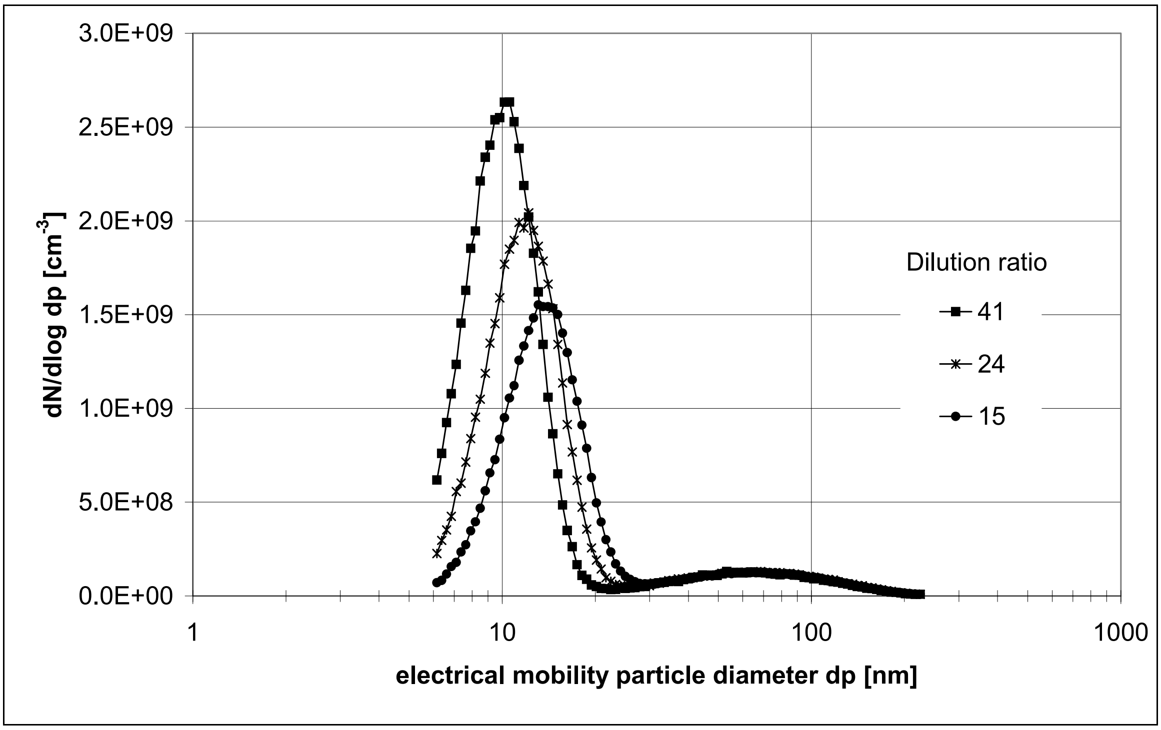


Figure 7 Summary of the development of EU road fuel specifications

Year			**1993**	**1995**	**1996**	**2000**	**2005**	**2009**[1]	**WWFC**[3]
Gasoline Unleaded 95/85			**EN228**						
Sulphur	ppm m/m	**Max**	1000	500		**150**	**50/10**	**10**	**5-10**
Benzene	% v/v	**Max**	5			**1**			
Aromatics	% v/v	**Max**				**42**	**35**		
Olefins	% v/v	**Max**				**18**			**10**
Oxygen	% m/m	**Max**	2.5[2]			**2.7**			
RVP (summer)	kPa	**Max**	up to 80			**60**			
E100	% v/v	**min**	40(s)/43(w)			**46**			**50**
FBP	°C	**max**	215			**210**			**195**
Year			**1993**	**1995**	**1996**	**2000**	**2005**	**2009**	**WWFC**
Diesel (standard grade)			**EN590**						
CI		**min**	46						**52**
CN		**min**	49			**51**			**55**
Sulphur	ppm m/m	**Max**	2000		500	**350**	**50/10**	**10**	**5-10**
Density	kg/m^3	**min**	820						
		Max	860			**845**			**840**
T95	deg C	**Max**	370			**360**			**340**
Aromatics	% v/v	**Max**							**15**
PAH	% m/m	**Max**				**11**			**2**
Lubricity	μm @ 60°	**Max**			**460**				**400**

(1) The final date is still under debate (2008-9)

(2) Up to 3.7% at Member State discretion. Individual limits apply to specific compounds

(3) WWFC = Engine/vehicle manufacturers World-Wide Fuels Charter; Category 4 fuel requirements

Figure 8 CONCAWE Euro-3 engines study
Heavy-Duty Fleet Average PM emissions vs. CN

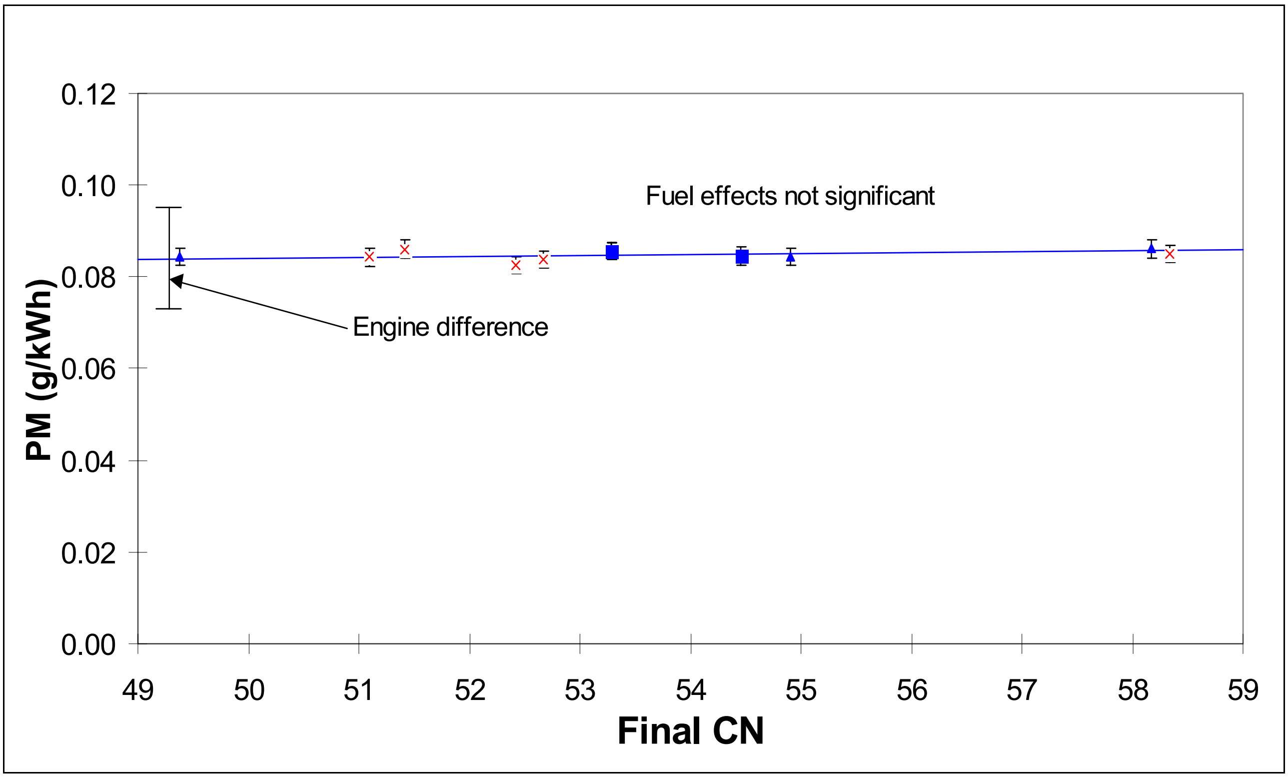


Figure 9 CONCAWE Euro-3 vehicles study
Light-Duty Fleet Average PM emissions vs. aromatics

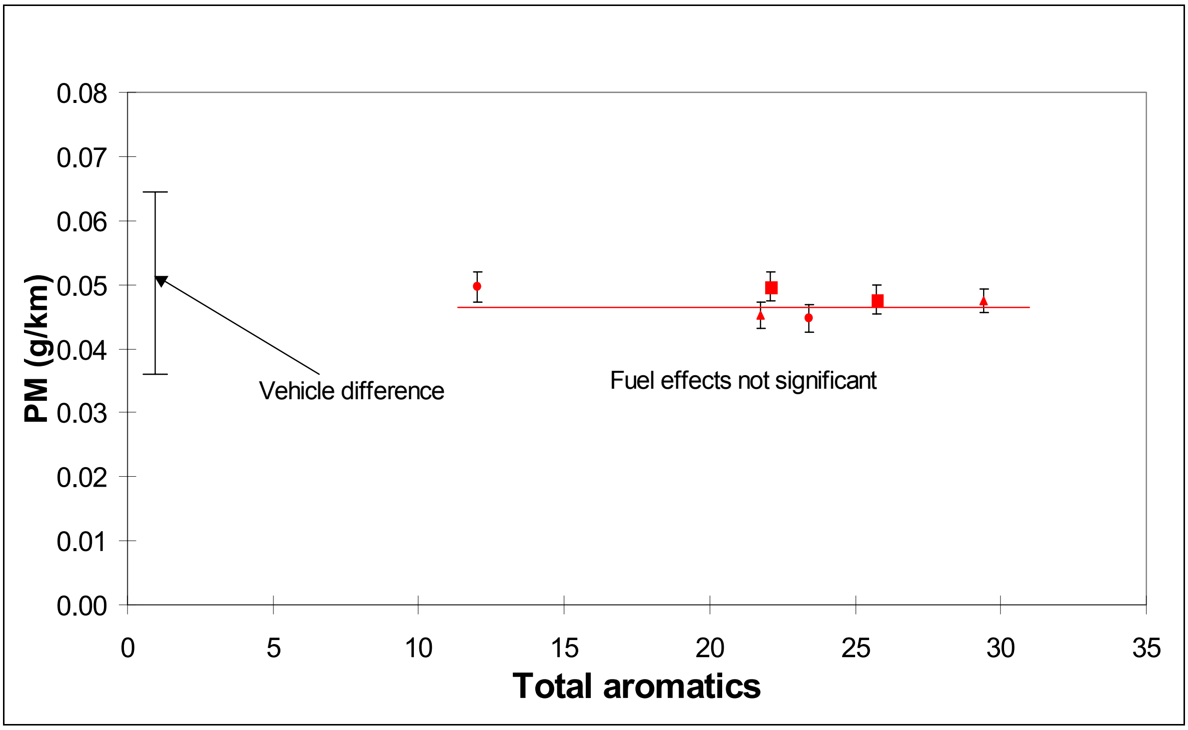
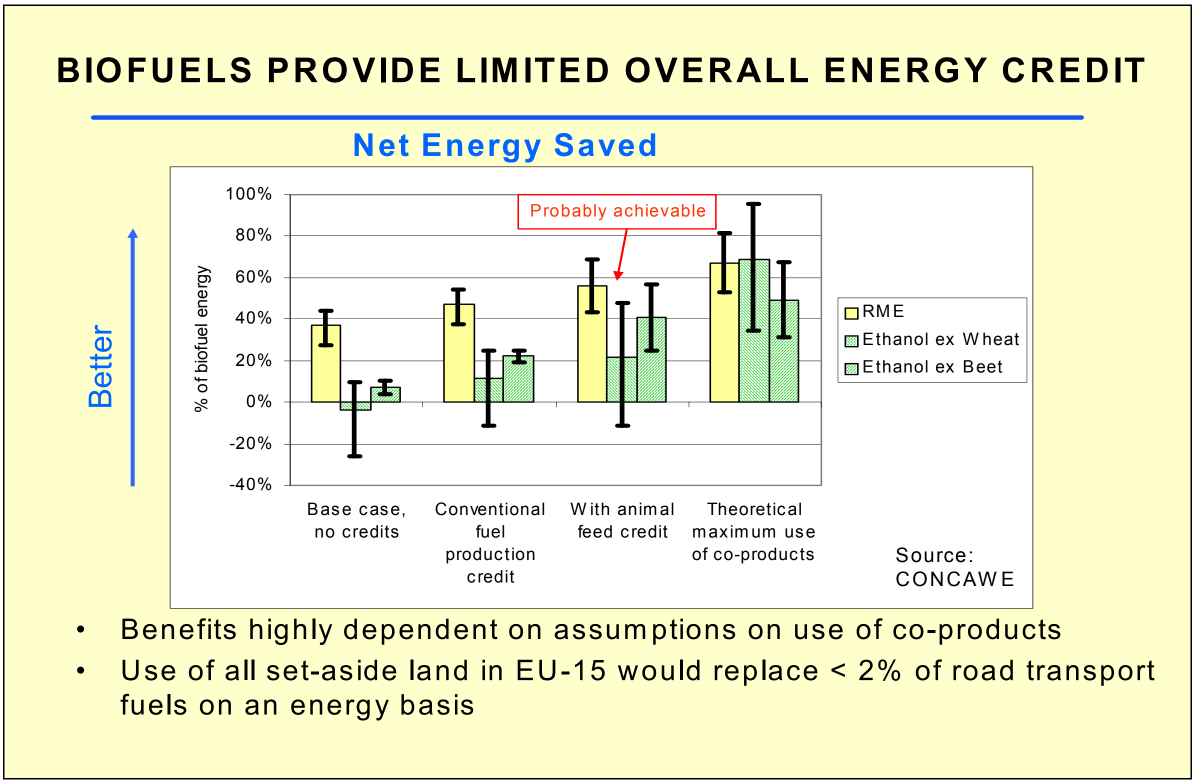


Figure 10 Energy Balance of Biofuels



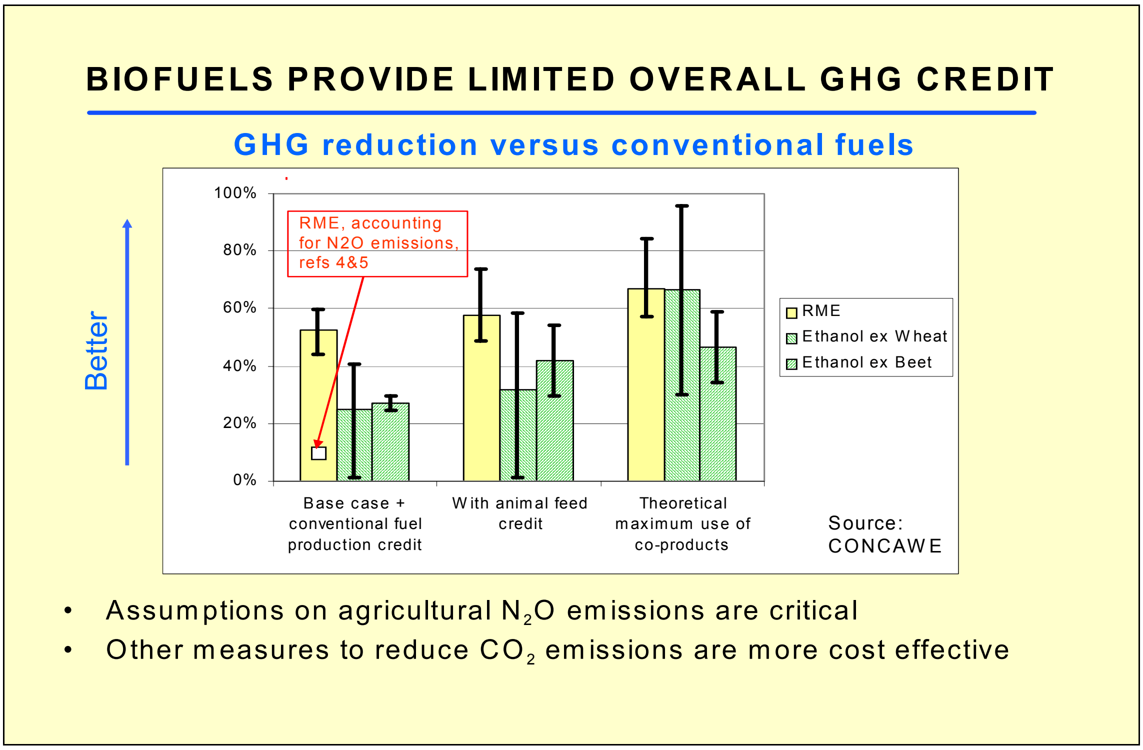
BIOFUELS PROVIDE LIMITED OVERALL ENERGY CREDIT

Net Energy Saved

Source: CONCAWE

- Benefits highly dependent on assumptions on use of co-products
- Use of all set-aside land in EU-15 would replace < 2% of road transport fuels on an energy basis

Figure 11 Greenhouse gas balance of biofuels



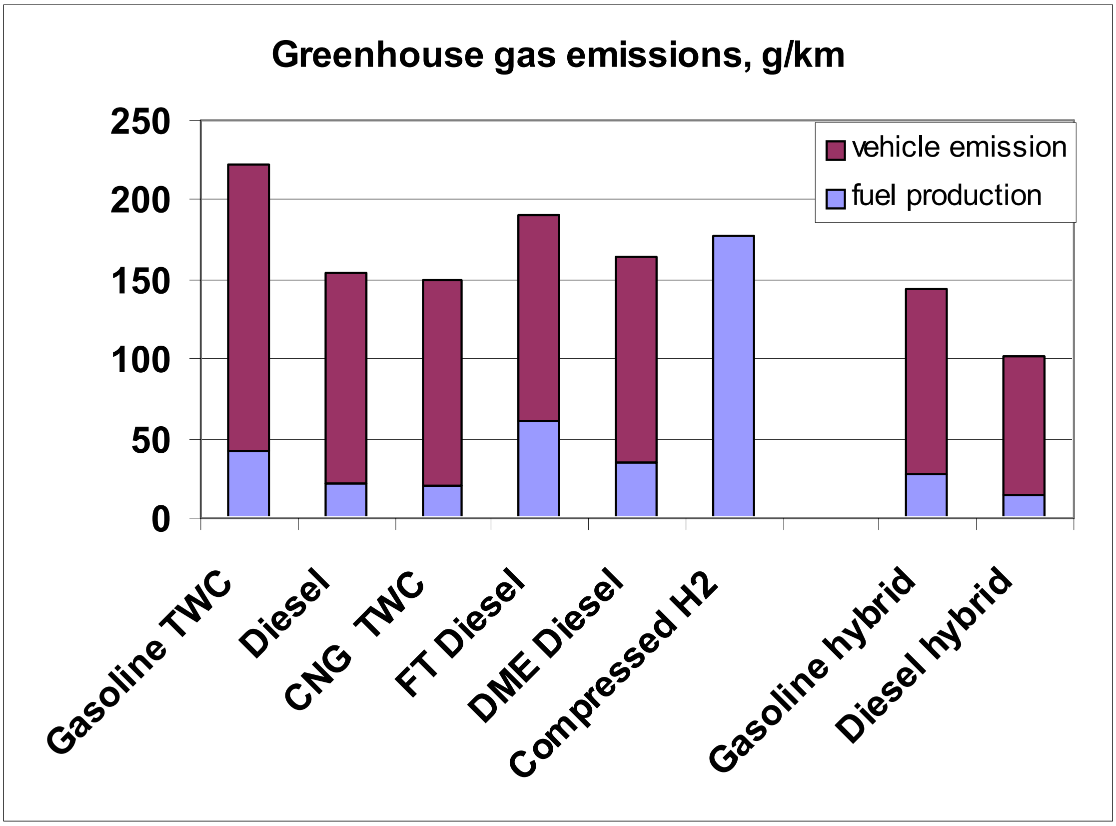
BIOFUELS PROVIDE LIMITED OVERALL GHG CREDIT

GHG reduction versus conventional fuels

Source: CONCAWE

- Assumptions on agricultural N_2O emissions are critical
- Other measures to reduce CO_2 emissions are more cost effective

Figure 12: Example of well-to-wheels analysis results
Source: Shell SAE 2001-01-1343, [42]



Appendix 1 Year 2000/2005 EU Emissions Limits for Passenger Cars and Light Commercial Vehicles

Category		Class	Reference Mass "RW" (kg)	Fuel	Limit Values (g/km)				
					CO	HC	NOx	HC+NOx	PM (1)
Euro 3 A (2000) (2)	M (3)	-	All (3)	Gasoline	2.3	0.20	0.15	-	-
				Diesel	0.64	-	0.50	0.56	0.050
	N_1 (4)	I	RW ≤1305	Gasoline	2.3	0.20	0.15	-	-
				Diesel	0.64	-	0.50	0.56	0.050
		II	1305 <RW ≤1760	Gasoline	4.17	0.25	0.18	-	-
				Diesel	0.80	-	0.65	0.72	0.070
		III	RW >1760	Gasoline	5.22	0.29	0.21	-	-
				Diesel	0.95	-	0.78	0.86	0.100
Euro 4 B (2005) (5)	M (3)	-	All (3)	Gasoline	1.0	0.10	0.08	-	-
				Diesel	0.50	-	0.25	0.30	0.025
	N_1 (4)	I	RW ≤1305	Gasoline	1.0	0.10	0.08	-	-
				Diesel	0.50	-	0.25	0.30	0.025
		II	1305 <RW ≤1760	Gasoline	1.81	0.13	0.10	-	-
				Diesel	0.63	-	0.33	0.39	0.040
		III	RW >1760	Gasoline	2.27	0.16	0.11	-	-
				Diesel	0.74	-	0.39	0.46	0.06

(1) For compression ignition engines only.

(2) Dates for "Year 2000" implementation are as follows:

Category/Class	Date
M (3); N_1 Class I – New types	01/01/00
N_1 Classes II & III – New types	01/01/01
M (3); N_1 Class I – All models	01/01/01
N_1 Classes II & III – All models	01/01/02

(3) Category M vehicles in excess of 2500 kg are treated as Category N1, Class 1 vehicles. Until 01/01/03, M1 diesel vehicles weighing more than 2000 kg, designed to carry more than 6 occupants (including the driver) or classed as off-road vehicles will be considered as Category N1 vehicles.

(4) Plus those Category M vehicles specified in Note (3), above.

(5) Dates for "Year 2005" implementation are as follows:

Category/Class	Date
M (3); N_1 Class I – New types	01/01/05
N_1 Classes II & III – New types	01/01/06
M (3); N_1 Class I – All models	01/01/06
N_1 Classes II & III – All models	01/01/07

Appendix 2 HD Emission Limits – Diesel Engines over the ESC/ELR Test Cycles (Steady-state & Dynamic Load Response Smoke Tests)

Implementation Date (1)	**Gaseous and PM Emissions (g/kWh)**				**Smoke (m^{-1})** (3)
	CO	**HC**	**NOx** (2)	**PM**	
A – 2000 (**Euro 3**)	2.1	0.66	5.0	0.10 (4)	0.80
B1 – 2005 (**Euro 4**)	1.5	0.46	3.5	0.02	0.50
B2 – 2008 (5) (**Euro 5**)	1.5	0.46	2.0	0.02	0.50
C (EEV) – 1999 (6)	1.5	0.25	2.0	0.02	0.15

(1) All implementation dates are 1 October in the designated year.

(2) The specific mass of the oxides of nitrogen measured at the random check points within the control area of the ESC test must not exceed by more than 10 % the values interpolated from the adjacent test modes.

(3) The smoke value on the random test speed of the ELR must not exceed the highest smoke value of the two adjacent test speeds by more than 20 %, or by more than 5% of the limit value, whichever is greater.

(4) A derogation to 0.13 g/kWh applies for small engines having a swept volume of less than 0.75 dm^3 per cylinder and a rated speed greater than 3000 min^{-1}. This derogation will be terminated in 2005.

(5) The EU Commission shall, not later than 31 December 2002, consider the available technology with a view to confirming the mandatory NOx standard

(6) EEV = “Enhanced Environmental Vehicle”

HD Emission Limits – Diesel and Gas Engines over the ETC (Transient) Test Cycle (1)

Implementation Date (2)	**Gaseous and PM Emissions (g/kWh)**				
	CO	**NMHC** (3)	**CH_4** (4)	**NOx**	**PM** (5)
A – 2000 (**Euro 3**)	5.45	0.78	1.6	5.0	0.16 (6)
B1 – 2005 (**Euro 4**)	4.0	0.55	1.1	3.5	0.03
B2 – 2008 (5) (**Euro 5**)	4.0	0.55	1.1	2.0 (7)	0.03
C (EEV) – 1999	3.0	0.40	0.65	2.0	0.02

(1) The conditions for verifying the acceptability of the ETC tests when measuring the emissions of gas fuelled engines against the limit values applicable in row A shall be re-examined and, where necessary, modified in accordance with the procedure laid down in Article 13 of EU Directive 70/156/ EEC.

(2) All implementation dates are 1 October in the designated year.

(3) A manufacturer may choose to measure the mass of total hydrocarbons (THC) on the ETC test instead of measuring the mass of non-methane hydrocarbons. In this case, the limit for the mass of total hydrocarbons is the same as that shown above for the mass of non-methane hydrocarbons.

(4) Natural gas engines only.

(5) Not applicable to gas fuelled engines under Stages A, B1 and B2.

(6) A derogation to 0.21 g/kWh applies for small engines having a swept volume of less than 0.75 dm^3 per cylinder and a rated speed greater than 3000 min^{-1}. This derogation will be terminated in 2005.

(7) The EU Commission shall, not later than 31 December 2002, consider the available technology with a view to confirming the 2008 NOx standard