biofuel cities

A European Partnership

Vehicle warranties and the use of biofuels

An overview of vehicles available within the EU, which have a manufacturers warranty allowing the use of blends of biofuels

Imprint

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An overview of vehicles available within the EU, which have manufacturers warranty allowing the use of blends of biofuels

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Additional information

The Biofuel Cities website can be accessed at: www.biofuel-cities.eu
The Ecotraffic website can be accessed at: www.ecotraffic.se
The Atrax website can be accessed at: www.atrax.se

A great deal of information on the European Union is available on the Internet. It can be accessed through the Europa server: http://europa.eu.int

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Summary

This study gives in first hand an overview of vehicles that are commercially available and that have a manufacturers warranty to drive on the biofuels ethanol or biodiesel neat or in different concentrations.

The survey was made by literature study, studies of relevant web pages and interviews with vehicle manufacturers via telephone and e-mail. Trade organizations such as ACEA, SPI (Swedish Petroleum Institute) and BilSweden as well as other stakeholders (such as ADAC and TÜV Nord) were also contacted, the study covers passenger cars, light duty transport cars busses and heavy duty trucks.

Most of the manufacturers contributed to the study, however a few did not replay.

5 % ethanol in gasoline and 5 % biodiesel in diesel is the highest allowed blend today according to valid fuel specification for gasoline EN 228 and diesel oil EN 590. This was also in line with EU's so called Fuel directive, 98/70/EC. However, 27 March 2009 the European Parliament and the Council of the European Union adopted amendments to the directive that, inter alia makes it possible to blend market gasoline with up to 10 % ethanol and market diesel oil with up to 7 % biodiesel. Most likely that will initiate a work in the European Standardization Organization CEN to redraft the gasoline and diesel oil standards to accept up to 10 % ethanol in gasoline and 7 % biodiesel in diesel oil.

Ethanol can with one exception be used only in vehicles with gasoline engines (spark ignition engines). The only exception is diesel engines (compression ignition engines) fuelled with ethanol with ignition improver (E95) or diesel engines equipped with glow plugs fuelled with neat ethanol. Today there are no European standards on E95 but Sweden has such a national standard (SS 155480).

Most vehicle model that can be fuelled with ethanol are so called Flexible Fuel Vehicles (FFV:s) (passenger cars) that can run on all mixes of gasoline and ethanol from neat gasoline up to 85 % ethanol and 15 % gasoline and as far as possible should be fuelled by E85 (85 % ethanol and 15 % gasoline). However, some manufacturers have since a couple of years accepted up to 10 % ethanol in gasoline with full warranties. Furthermore, Since the new EU directive on fuels as mentioned above and since France in April 2009 introduced E10 as a national standard fuel at the gas stations some vehicle manufacturers have already started a process to accept that their vehicles run on E10 with full warranty. From the 46 car producers in the survey there are 17 who answered that they so far offer Flexi Fuel Vehicles that can run on up to E85 and 22 who allow up to 10 % ethanol in the gasoline.

The E85 vehicles are mostly spread in Sweden but also in Germany, France, Spain, Holland and Great Britain. In Sweden there are today more than 1000 tank stations that offer E85 to the customers. In especially Germany the net of tank stations for E85 is growing and in Spain there are pumps mostly in the area around Madrid.

The E95 heavy duty vehicles (busses) are more or less only market introduced in Sweden where also a close to market introduction is soon to be for heavy duty trucks.

Biodiesel can be used only in diesel engines. Even if there are examples of manufacturers of light duty vehicles who accept biodiesel in some of their models biodiesel today is in first hand used in buses and heavy duty trucks. Just a couple of years ago the situation was different with a number of manufacturers that accepted biodiesel in one or several of their vehicle models in higher blends or even as neat fuel. One reason for the more restricted view on biodiesel in passenger vehicles today might be new EU demands on exhaust gas emission levels and with that the use of more sophisticated engine systems and additional exhaust gas treatment equipments with less tolerance to new fuels.

According to all interviewed representatives for the vehicle manufacturer or their sales organizations, the vehicle warranty is the same over the whole EU-region. If or rather when a manufacturer accepts the use of a fuel what so ever it is with full warranty and the warranty is the same for the whole EU-region. In the instruction manual for the vehicle it should be clearly expressed what fuel or fuels can be used in the vehicle with full warranty. If there is any doubt about this issue the authorised car dealer can be contacted for further information about the specific case.

In some cases manufacturers of heavy duty vehicles are prepared to accept higher blends of biodiesel in their engines with full warranties, but first after a special contract about for example service etc. has been signed between the manufacturer and the owner of the truck.

Sweden is possibly the EU country with the most extensive development of the market so far for so called environmentally friendly vehicles. During January to December 2008 there were in total 250 000 new registrations of passenger vehicles in Sweden. Of these passenger vehicles 33,3 % (83 250) were environmentally friendly cars and of the environmentally friendly cars 68,4 % (56 943) were FFV/E85 vehicles.

If we compare with the rest of the EU-region there were, according to ACEA, 13 788 000 new registered passenger cars from January to December 2008 in Europe. 22,8 % of these cars (68,4 % of 33,3 %) would be the same as 3 143 664 vehicles.

In other words, if the rest of the European countries would start a process with the same success achieved as in Sweden over about 15 years (some are already well away in this process), it might be possible for them to reach a total yearly sales or new registration, in 10 to 15, years of about at least 2 500 000 to 3 000 000 million FFV's. One reason that the progress in the coming 15 years might be slower than it has been for the last 15 year in Sweden is that the age of the vehicle fleet increases. The better high quality vehicles we build the longer they will last and with that will also the age of the vehicle fleet increase; This will have an effect on how fast we can replace old cars with new more environmentally friendly ones.

Concerning heavy duty vehicles today Sweden is probably the only country that has introduced ethanol fuelled buses into the public transportation system on a larger scale. During the first 12 years period with ethanol fuelled buses (1990 – 2002) the number of ethanol buses grew from 0 to approximately 400 buses, which was somewhat lower than 5 % of the total Swedish bus fleet at the time. In all there are currently about 500 buses in operation in a number of fleets of buses in Sweden.

If we assume that the total European bus as well as truck fleets would grow with the same figures the coming 10 – 15 years there would then be around 36 000 ethanol fuelled buses in Europe. However, this estimation might be to optimistic since there are just one producer of ethanol bus engines today (Scania). A more realistic figure could be somewhat around 10 000 to 15 000 ethanol fuelled buses, but still this estimation is much more uncertain than for the FFV's.

Concerning trucks there are some, but still very few ethanol fuelled trucks (Scania) in Sweden, today. The situation of the ethanol fuelled trucks is more on a pre commercial stage than a final commercial market product and the progress seems uncertain, even if there is a clear interest among transportation companies for ethanol fuelled trucks. Since that it seems to be too uncertain to make any estimations of the possible development the coming 10 to 15 years.

Abbreviations, acronyms and glossary

ACEA	European Automobile Manufacturers Association
BCEP	Biofuel Cities European Partnership
BYY	YY = % biodiesel in diesel
CEN	European Standard Organisation
CO	Carbon Monoxide
CI	Compressed Ignition
CWA	CEN Workshop Agreement
DI	Direct Injection
DPF	Diesel Particle Filter
EEV	Enhanced Environmentally Friendly Vehicle
EGR	Exhaust Gas Recirculation
ELR	European Load Response test, a test procedure for determining engine smoke under transient conditions
ESC	European Stationary Cycle
ETC	European Transient Cycle
Euro 1,2,3,4,5	EU emission standards for Light-duty Vehicles
Euro I, II, III, IV, V, VI	EU emission standards for Heavy-duty Vehicles
EXX	XX = % ethanol in gasoline
FAEE	Fatty Acid Ethyl Esters
FAME	Fatty Acid Methyl Esters
FFV	Flexi Fuel Vehicle
FTP-75	The driving cycle used for light-duty vehicles in the USA
GDI	Gasoline Direct Injection
HC	Hydrocarbons
HDV	Heavy-Duty Vehicle
LDV	Light-duty Vehicle
LPG	Liquid Petroleum Gas
LPG	Liquid Petrol Gas
NEDC	New European Driving Cycle
NMHC	Non-Methane Hydrocarbons
NOX	Nitrious Oxides
OBD	On-Board Diagnostics system
OBD	On-Board Diagnosis
PM	Particulate Matter
PMP	Particulate Measurement Program (EU program for new measurement methods=
ppm	parts per million
SAE	Society of Automotive Engineers
SCR	Selective Catalytic Reduction, a NO_X reducing catalyst
SI	Spark Ignition
SOY	Soy Methyl Ester
SPI	Swedish Petroleum Institute
WHTC	World Harmonised Test Cycle
CEN	European Centre for Standardization
CWA	CEN Workshop Agreement
TWC	Three Way Catalyst

Contents

1. Introduction

The following study has been commissioned by SenterNovem on behalf of Biofuel Cities and has been compiled by the Swedish consultancy firms Ecotraffic ERD[3] AB and Atrax Miljö och Energi AB.

Biofuel Cities is a European project - supported by the European Commission - that provides a platform for biofuel stakeholders. SenterNovem is the project coordinator of the Biofuel Cities European Partnership (BCEP).

The Biofuel Cities European Partnership aims to:

- gather and disseminate information on biofuels including scientific, policy, and practical developments;
- encourage networking possibilities to maximise synergies with existing initiatives and to improve co-operation among local, national and international organisations;
- provide mechanisms to facilitate the establishment of partnerships between different organisations; and
- provide other useful tools and information, such as publications, details of events, and training and more to support work on biofuels.

The aim of the study is to develop an overview of vehicles that are commercially available in one or more EU-countries with full manufacturer's warranty to drive on the biofuels bioethanol or biodiesel* in neat form or in different concentrations beyond what today is currently accepted in standard gasoline or standard diesel oil. This kind of information is useful for stakeholders to support their decision making process concerning purchasing of vehicles that could run on biofuels. In particular for personnel working within organisations that own or operate government or commercial vehicle fleets who are considering switching from regular to alternative fuels.

The results of the study are listed in a summary table in chapter 5. Chapter 3. presents a short description of the production and use of bioethanol and biodiesel, along with its benefits and problems. Furthermore in chapter 4. the different types of EU emission standards are listed and explained together with a short description of how different types of exhaust gas equipment works. Chapter 6 provides a rough forecast for the coming 5 to 10 years on the progress of bio fuel technology, the number of vehicles available, which will make use of bio fuels, along with a market forecast on demand for biofuel vehicles. The warranty issue is discussed in chapter 5.6.

* For the rest of the report biodiesel will be used as a synonym to FAME (Fatty Acid Methyl Esters)

2. Research methodology

This study is based on interviews with manufacturers, trade organizations and other stakeholders in the vehicle industry, see references. The interviews were made via telephone and often followed up by questionnaires sent by e-mail.

The people contacted were interviewed in regards to the following items:

- Are there any vehicle models in your fleet with full manufacturer warranty for the use of bioethanol or biodiesel, and if so in which maximum concentrations (E10, E30, E50, E85, E95 or B10, B30, B100)?
- If you have such models what is there EU classification and do they have any form of exhaust after treatment equipment?
- If you have such models are there any differences in the warranty between different EU Member States?
- This information was also searched for in relevant literature and via the internet.

3. Bioethanol and biodiesel fuel

Although there exists a number of bio based alternative vehicle fuels today, bioethanol and biodiesel are the ones that are most commonly used.

- The production technologies are rather well known and also relatively simple.
- Biodiesel can be blended in diesel and bioethanol in gasoline and the blends could, at least when it comes to lower blend levels, be used in modern vehicles without any adaptation of the engines.
- High concentrations of biodiesel and bioethanol can be used in both modern diesel and gasoline engines, with relatively small measures taken to adapt the engine to the fuel.

3.1. Bioethanol

After a short period during the 1960's and 1970's, when methanoll was tested as a vehicle fuel, bioethanol has become the main alcohol fuel when searching for and testing bio based alternative fuels for vehicles.

Bioethanol can be produced from different biomass sources by fermentation, as long as the biomass contains sugar or compounds such as starch that can be hydrolyzed to sugar. This type of biomass is generally in the form of grains or other food stocks. It is also possible to produce bioethanol from gasified biomass. When gasifying the biomass the total supply of biomass for bioethanol production will increase, compared to fermentation, since the only demand on the biomass in this case is that it has to contain carbon. However, this technology is still not fully commercialized.

Even if there is a lot of work going on trying to use cellulosic raw material as a feedstock for bioethanol production, by fermentation, it seems that this technology will not be a reality for the coming 5 to 10 years. Beyond that, and if the technology develops well, cellulosic feedstock might be a possibility for bioethanol production.

Therefore, if we want to produce bioethanol today and for the next coming 5 to 10 years in Europe we most likely have to rely on grain and other farming products as the main feedstock.

When it comes to the use of bioethanol as vehicle fuel the common method at the moment is the blending of low amounts in gasoline. According to the European gasoline standard (EN 228) up to 5 % of anhydrous bioethanol can be blended in gasoline. This also used to be in line with EU's so called Fuel directive, 98/70/EC. However in 27 March 2009 the European Parliament and the Council of the European Union adopted amendments to the directive which, among other things makes it possible to blend market gasoline with up to 10 % bioethanol. Most likely that will initiate a work in the European Standardization Organization CEN to redraft the gasoline standard to accept up to a 10 % bioethanol blend in gasoline.

Low blended gasoline can be used in almost all existing gasoline engines and gasoline vehicles without any adaptation of the engines, storage tanks etc. The only exception might be with very old vehicles but then not due to an impact on the vehicle performance but rather on the exhaust gas emissions.

It is also most likely that higher blends, up to 15 % or 20 % bioethanol can be used in modern gasoline engines without any adaptation, while achieving full engine performance and fulfilling the EU directives on exhaust gas emissions.

Today the highest level for blending bioethanol in gasoline in the U.S.A is 10 % while Brazil accepts blending of more than 20 % bioethanol in gasoline. The main feedstock for ethanol in U.S.A is corn and in Brazil is sugar cane.

One way to use higher blends of bioethanol and gasoline than 10 % bioethanol is by using so called Flexi Fuel Vehicles (FFV). The FFV vehicles can be fuelled by any mix of gasoline and bioethanol from 0 % bioethanol up to 100 % bioethanol, since the engine itself is equipped with technology that adapts the engine and the fuel injection system to the mix. However, since it would be difficult to start a gasoline engine on neat bioethanol, especially in a cold climate, the highest mix of gasoline and bioethanol that is available on the open market is E 85 (85 % bioethanol and 15 % gasoline). When the owner of a FFV vehicle comes to the refuelling station he or she can choose between neat gasoline (currently with 5 % bioethanol and in the future with 10 % bioethanol) and E 85, it doesn't matter in which proportions, the engine automatically adapts to the mix in the tank).

Besides the gasoline standard mentioned above the European standardization organization (CEN) has also started work on a standard on bioethanol for blending in gasoline EN pr15376. So far this pre standard has been published for public enquiry. For the moment this pre standard specifies that the standardized bioethanol can be used for blending up to 5 % in gasoline, If the gasoline standard is changed to accept up to 10 % bioethanol as mentioned above the bioethanol standard will most likely also be changed in the same direction. There is also a so called workshop agreement under CEN specifying some important parameters for E 85, CWA 15293. This CWA has been the base for establishment of national E 85 standards in Sweden and France. In the future it may also be used as a base for a European CEN E 85 standard.

3.2. Bioethanol in diesel engines

It is also possible to use bioethanol in a diesel engine. However, it is difficult to blend alcohol and oil. To overcome that problem you have to use an emulsifier to get a homogeneous mix. Even if possible, this option has not become popular. One reason is that the mix is stable just for a shorter period and if stored for a longer time will start to separate. Another reason is that the bioethanol has a higher risk classification than diesel oil when it comes to the risk of fire and explosions. Because of this a mix of about 10 % bioethanol and 90 % diesel oil has to be treated, stored and distributed with the same safety measures and restrictions taken that is necessary for neat bioethanol and because of this the distribution system for diesel oil can not be used.

One other option of using bioethanol in a diesel engine is to use neat bioethanol. However, since the cetane number, (the willingness to explode when being compressed), is too low for bioethanol, the engine has to be equipped with glow plugs in the cylinder or a cetane improving/boosting additive, has to be added to the bioethanol. However, in the first case the engine will turn from a diesel (compression ignition engine) to a gasoline engine (spark ignition engine). This will result in lower energy efficiency, which is the main strength of a diesel engine. In the other case there has to be logistics for blending the additive, which furthermore is expensive compared to the bioethanol itself.

3.3. Biodiesel

Biodiesel is used as a joint name for a number of fuels which in more formal situations are called Fatty Acid Methyl Esters (FAME). Biodiesel can be produced from different types of oil but most common are vegetable oils such as rapeseed oil, soya oil and sun flower oil. Even waste kitchen/restaurant oil can be used for the production of biodiesel.

The production technology of biodiesel is relatively simple. The oil is mixed with a catalytic compound and methanol in a stirring tank and after a while the biodiesel part can be separated from the top of the tank while glycerol is emptied from the bottom. Biodiesel production is suitable for small farm plants as well as for full scale industrial plants

Since methanol today is made from different fossil feedstock such as natural gas or coal the final product will contain a small fossil part. If bioethanol replaces methanol the product will instead be 100 % bio based Fatty Acid Ethyl Ester (FAEE).

The common biodiesel in Europe today is RME (Rapeseed Methyl Ester) and the European standardization organisation CEN has established a biodiesel (FAME) standard (EN 14214) which includes RME but also other types of FAME.

In the U.S.A. the most common biodiesel is SME (Soy Methyl Ester).

Biodiesel can be used in diesel engines by blending in diesel oil but also as a neat (100 %) fuel and without any major adaptation measures. However, according to the European diesel oil standard (EN 590) the highest level for blending of biodiesel in diesel oil today is 5 %. This also used to be in line with the EU's so called Fuel directive, 98/70/EC. However on the 27th March 2009 the European Parliament and the Council of

the European Union adopted amendments to the directive which, inter alia makes it possible to blend market diesel oil with up to 7 % biodiesel. Most likely this will initiate a work in the European Standardization Organization CEN to redraft the diesel oil standard to accept up to 7 % biodiesel in diesel oil.

Besides the European standards and regulations, higher blends of biodiesel and diesel oil of up to approximately 30 % are used and also standardized on a national/local level. Some years ago a number of vehicle manufacturers of light duty vehicles (passenger vehicles) approved their vehicles for use of up to net (100 %) biodiesel. Examples of companies that approved 100 % biodiesel in their engines were VW, Audi, SEAT and Skoda. These manufacturers approved all their vehicles built between 1996 and 2004 providing that the biodiesel met EN 14214.

The number of manufacturers that accept biodiesel as a fuel beyond what is stipulated in the diesel oil standard has decreased, over recent years. On the heavy duty vehicle side there is still a number of manufacturers that accept biodiesel in their vehicles/engines. However, before accepting biodiesel with full warranty these manufacturers demands a contract with the consumer in which is stipulated what special measures the consumer has to take if he or she wants to fuel it with biodiesel. For example, the biodiesel has to fulfil what is stipulated in the FAME standard EN 14214 and the range of the service intervals has to be decreased compared to if the vehicle is fuelled by diesel oil. These types of contracts are also in most cases restricted to fleet owners and no such contracts are available for private persons and small fleet owners with just one or a few trucks.

One important reason as to why the numbers of manufacturers that accept biodiesel as a fuel has decreased might be the use of "new" and more advanced exhaust gas treatment technology, for example regenerating particulate filters. When regenerating the filters the exhaust gas temperature is increased by late injection of the fuel in the cylinder. Though biodiesel has a higher boiling point than diesel oil a consequence might be that biodiesel is mixed with the engine oil. This dilution can be dealt with when using up to 5 % or even maybe 7 % biodiesel in the diesel oil but with higher blends problems might occur.

Other problems that might occur when using neat biodiesel or higher blends of biodiesel and diesel oil, is increased emission of NO_x compared to neat fossil diesel oil. On the other hand a higher blending of biodiesel in diesel oil will decrease the number of particulates in the exhaust gas. Furthermore the engines has to be adapted to biodiesel when it comes to sealing, gaskets and rubber hoses, otherwise these parts will after a short while be affected and decompose with leakage as a result. But more or less all modern diesel engines are adapted to biodiesel.

Concerning FAEE there is an initial discussion in CEN about drafting a European standard or including FAEE in the existing FAME standard.

Finally there are for the moment no similar solutions like FFV vehicles for diesel engines and blends of diesel oil and FAME.

4. Engine and exhaust gas after treatment technology - with respect to biodiesel and ethanol

This chapter gives a short introduction of some methods used to clean exhaust gas from gasoline and diesel engines. In short the main difference is that diesel engines have a relatively high efficiency but create difficulties in converting and filtering of the exhaust gas. Gasoline engines have the opposite problem; they have relatively low efficiency however the exhaust gas is easier to convert and to filter.

4.1. Gasoline engines

For most of all gasoline engines fuel and air is blended outside the engine in a stoichiometric ratio (balanced chemical reaction) before it is ignited in the cylinder by a spark plug. To reach a correct ratio between air and fuel a so called "oxygen/hydrocarbon sensor" system is used that is placed in the exhaust gas pipes after the engine. After the "sensor" a "three way catalytic converter" (TWC) is placed. It is called a "three way catalytic converter" because three main catalytic reactions take place at the same time in the converter. 1st unburned carbon monoxide (CO) is oxidized to carbon dioxide (CO_2), 2nd unburned hydrocarbons (HC) are oxidized to carbon dioxide and water, 3rd Nitrous oxide (NO_X) is reduced to nitric gas (N_2).

TWC converters in combination with the oxygen/hydrocarbon sensor were introduced in Europe about 20 years ago. Now days this kind of exhaust gas after treatment systems is standard for all gasoline cars. The engine systems with TWC and sensor are not affected in negative ways by using bioethanol as a fuel.

4.2. Diesel Engines

Diesel engines operate by compressing air within the diesel cylinder to a very high pressure. The compressed air becomes very hot and the diesel fuel is then injected into the cylinder where it is ignited by the hot air.

In comparison to the gasoline engine a diesel engine works with a high air to fuel ratio which creates an exhaust gas with a very high surplus of oxygen. The high concentration of oxygen makes it impossible to use a TWC converter. It is relatively easy to burn hydrocarbons (HC) and carbon monoxide (CO) over an oxidation catalyst. However it is not possible to create a reduction of nitrous oxides (NO_X) due to the oxidation atmosphere. One more problem with a diesel engine is that it produces particles and soot.

To handle these problems there are various systems on the market.

- **SCR** (Selective Catalytic Reduction)
  By injecting a reducing agent into the exhaust stream it is possible to reduce NOX. Normally urea is used (trade name adBlue).

- **EGR** (Exhaust Gas Recirculation)
  By taking a part of the exhaust gas and leading it back to the engine it is possible to

reduce NO_X levels. NO_X levels are reduced mainly due to lower combustion temperature and more inert gas in combustion reactions.

- **DPF** (Diesel Particle Filter)
  Particles are trapped in a filter.

Combinations of the described exhaust gas after treatment systems above are also available on the market.

After being used a while particle filters become fully loaded by particles and need to be regenerated. This can be done in two ways, passive or active regeneration.

In passive systems an oxidation catalyst is placed upstream of the filter. The negative aspect of this technology is that NO is oxidized to NO_2 which creates health problems within garages, parking houses, tunnels etc.

In active systems, exhaust gas temperature is often increased by using a late fuel injection. This method sets the particles in the filter on fire. This may give rise to problems for biodiesel, due to different boiling points compared with diesel, and since lubricant oil can be dissolved and cause damage to the filters. It is not fully clear in what concentration biodiesel blended in diesel will be a problem, but some manufactures say that the ratio is relatively low. Until now active systems are only available on light duty vehicles.

4.3. Emission limit values for Light Duty Vehicles, EU 1993 – 2015

Today there are emission limits for most categories of road vehicles in the EU. On July 18 2008, the Regulation 692/2008 for limiting emissions from light passenger cars and commercial vehicles was adopted (EC, 2008). This was an amendment to the previous Regulation 715/2007 published on 20 June 2007 by the European commission (EC, 2007b). In order to provide some backtrack of the progress since early 1990, emission limits from previous EU directives are also included in the table. The emission limit values in the EU for passenger cars (class M1) are presented in **Table 1**, below. Note that there are similar limits for light commercial vehicles (classes N I, II and III) but to simplify the overview, these limits are not shown here.

Table 1 Emission limit values for passenger cars in the European Union.

				EMISSION COMPONENTS AND LIMITS						
Directive		Term[a]	Time[b]	CO (g/km)	HC (g/km)	NMHC[c] (g/km)	NO_X (g/km)	$HC+NO_X$ (g/km)	PM[d] (mg/km)	PN[e] (#/km)
91/441/EEG		Euro 1	6/92 1/93	2,72	---	---	---	0,97	140	---
94/12/EC, petrol		Euro 2	1996-01	2,2	---	---	---	0,5	---	---
94/12/EC, diesel IDI[f]				1,0	---	---	---	0,7	80	---
94/12/EC, diesel DIg[f]			1997-01	1,0	---	---	---	0,9	100	---
98/69/EC, row A petrol[h]		Euro 3	2000-01	2,3	0,20	---	0,15	---	---	---
98/69/EC, row A diesel[i]			2001-01	0,64	---	---	0,50	0,56	50	---
98/69/EC, row B petrol[h]		Euro 4	2005-01	1,0	0,10	---	0,08	---	---	---
98/69/EC, row B diesel[i]			2006-01	0,50	---	---	0,25	0,30	25	---
Euro 5 reg. 692/2008[i]	petrol	Euro 5a	2009-09	1,0	0,10	0,068	0,06	---	5,0[j]	---
	diesel		2011-01	0,5	---		0,18	0,23	5,0[j]	---
Euro 5 reg. 692/2008[i]	petrol	Euro 5b	2011-09	1,0	0,10	0,068	0,06	---	5,0/4,5[j]	---
	diesel		2013-01	0,5	---		0,18	0,23	5,0/4,5[jk]	6×10^{11}
Euro 6 reg. 692/2008[i]	petrol	Euro 6	2014-09	1,0	0,10	0,068	0,06	---	5,0/4,5[jk]	---[l]
	diesel		2015-09	0,5	---	---	0,08	0,17	5,0/4,5[jk]	6×10^{11}

Notes:

a In this column, the regulations have been denoted with the designations (Euro 1, 2, etc.) commonly used by laymen but lately also very often by both officials and the industry.

b The two dates in the table refer to that the implementation is stepwise. The first date is for new type approvals and the latter date is for all type approvals.

c NMHC: non-methane hydrocarbons, valid only from Euro 5 and 6 for engines with positive ignition (otto engines).

d PM: particle emissions. These limits are from only valid for diesel-fuelled vehicles and, from Euro 5 and 6, for petrol vehicles using direct injection.

e P: Particle number emissions. P is regulated only for diesel vehicles in Euro 5 and 6, i.e. no limit is set to petrol-fuelled vehicles although there is a limit for PM emissions (see above) for direct injected petrol cars.

f IDI: indirect injection, i.e. injection in a prechamber (or swirl chamber)

g DI: direct injection, i.e. injection directly in the cylinder (combustion chamber)

h The directive 98/69/EG (2000/2001 and 2005/2006, respectively) are based on the new European driving cycle (NEDC), which uses a modified start procedure (at +20 – +30 °C) compared to the older driving cycle. Therefore, the CO limit (2,3 g/km) in the directive 98/69/EG is actually stricter than the limit in the directive 94/12/EG directive (2,2 g/km) that uses the older European driving cycle (EDC). Since also the HC emissions are higher in the NEDC driving cycle, the reduction in $HC+NO_X$ emissions that can be calculated from the data in the table (from 0,50 till 0,45 g/km) much greater than the levels indicate.

i When this report was written, some details of the regulation for Euro 5 and 6 were not finalised.

j Particle mass standard only apply to positive injection vehicles with direct injection.

k A revised measurement procedure shall be introduced before the application of the 4,5 mg/km standard.

l A number standard for vehicles with positive ignition shall be defined before 1 September 2014.

As **Table 1** above is a simplification, the reader should refer to the EU emission regulations for more details. Some further details in **Table 1** needs clarification:

- The Euro 5a emission standard excludes limits for particle numbers and the revised measurement procedure for particle mass. Furthermore, flexible fuel vehicles are not subject to low-temperature emission testing when tested on biofuel.

- With the introduction of Euro 5b (2011-09-01), a particle number standard is enforced for the first time.

- It is also possible to certify to a Euro 6a standard until the end of 2012, where similar exceptions as for Euro 5a apply for particle mass, number and flexible fuel vehicles tested on biofuel.

- In the "final" Euro 6b standard (not shown in **Table 1**), all the exceptions mentioned above are abolished. Limits on particle mass and number will apply on all vehicle types as well as limits for low temperature on flexible fuel cars.

In conjunction with the emission limit values above, durability standards are also set in order not to allow that the emission limit values are exceeded after vehicle operation over a certain driving distance or time:

- Euro 3, 80 000 km or 5 years (of which comes first). The manufacturer may as an option to a deterioration cycle chose determined factors according to: 1,2 for CO, HC, NO_X (petrol), or 1,1 for CO, NO_X, HC+NO_X, and 1,2 for PM (diesel).

- Euro 4, 100 000 km or 5 years (of which comes first).

- Euro 5 and 6, 160 000 km or 5 years (of which comes first).

- In addition to the requirements above, the 2000/2005 requirements also include:

- The member states in the EU have the right to introduce tax reductions for vehicles introduced prior to 2005 meeting the 2005 requirements.

- Emission limit values for CO and HC for petrol vehicles at -7°C from year 2002.

- Introduction of OBD (on-board diagnosis) for monitoring error codes in the exhaust after treatment system.

With the introduction of Euro 3, all vehicles must be equipped with an OBD-system informing the driver if errors in the exhaust after treatment system occur that may lead to exceeding the emission limit values. Limit values for the OBD are higher as compared to the emission limit values. Requirements for durability were introduced from year 2005 and became fully implemented in year 2006. The manufacturer must confirm that the engine meets the emission limit values for the whole period defined as "useful life" for each category of vehicles. In **Table 2** below, the durability periods for the emissions for each category of vehicle are presented.

Table 2 Durability periods for emissions.

Period*	Category of vehicles†
100 000 km or 5 years	N1 and M2
200 000 km or 6 years	N2 N3 ≤ 16 ton M3 Class I, Class II, Class A, and Class B ≤ 7,5 ton
500 000 km or 7 years	N3 > 16 ton M3 Class III, and Class B > 7,5 ton
N1 = Light duty vehicle < 3.5 ton N2 = Heavy duty vehicle > 3.5 ton < 12 ton N3 = Heavy duty vehicle > 12 ton M1 = Passager car M2 = Bus > 8 passanger, < 5 ton M3 = Bus > 8 passanger, > 5 ton * km or year period, whichever is the sooner † Mass designations (in tons) are "maximum technically permissible mass"	

4.4. Emission limit values for Heavy Duty Vehicles EU 1992 – 2014

Emission limit values for heave duty vehicles have emerged over a longer period of time and the main steps for this process are presented below:

- Euro 1 was introduced in 1992 and was followed by Euro II in 1996. Both truck engines and city buses were covered by this legislation. However, the certification of bus engines was voluntarily.

- Following the directive 1999/96/EG, Euro III was introduced in year 2000, Euro IV in 2005, and Euro V was introduced in October 2008. This directive also introduces voluntary lower emission limit values for EEV[1] vehicles.

- The directive 2001/27/EG was introduced in year 2001 and prohibits the use of "defeat devices" and "irrational emission control strategies" that potentially reduces the function of the emission control system at normal operation as compared to the function obtained by the emission test procedure given by the certification procedure.

- Durability and OBD requirements were introduced with directive 2005/55/EG and the emission limit values for Euro IV and Euro V were confirmed.

- In addition to reduced anticipated emission limit values in the future (Euro VI and later), it is also likely that emission limit values for presently unregulated pollutants will be introduced as an effect of the introduction of new alternative fuels and the use of fuel additives. Furthermore, the requirements for future particle emission limit values are revised in the PMP program in which also the possibility to introduce emission limit values for particle number emissions are examined.

In **Table 3**, the emission limit values for the different certification levels are presented.

[1] EEV: Enhanced Environmental friendly Vehicles

Table 3 Contemporary proposal for Euro VI Emission limit values for heavy duty diesel engines, ESC test.

Level	Date	Test	CO (g/kWh)	HC (g/kWh)	NO_x (g/kWh)	PM (g/kWh)	Smoke (m^{-1})
Euro I	1992, < 85 kW	ECE R-49	4,5	1,1	8,0	0,612	
	1992, > 85 kW		4,5	1,1	8,0	0,36	
Euro II	1996.10		4,0	1,1	7,0	0,25	
	1998.10		4,0	1,1	7,0	0,15	
Euro III	1999.10, EEVs only	ESC & ELR	1,5	0,25	2,0	0,02	0,15
	2000,10	ESC & ELR	2,1	0,66	5,0	0,10 0,13*	0,8
Euro IV	2005.10		1,5	0,46	3,5	0,02	0,5
Euro V	2008.10		1,5	0,46	2,0	0,02	0,5
Euro VI#	2014.01		1,5	0,13	0,5	0,01	0,5

* For engines of less than 0,75 dm^3 swept volume per cylinder and a rated power speed of more than 3000 min^{-1}

Proposal for Euro VI by the European Parliament's Environment Committee on July 15, the final decision on the Euro VI limits is not made.

In **Table 3**, the contemporary proposal for Euro VI is listed. This proposal was made by the European Parliament's Environment Committee on July 15, 2008. The changes made to the previous proposal of the Commission were an increase of the NO_X limit from 0,4 to 0,5 g/kWh and an earlier introduction of Euro VI (1/1 2014 instead of 1/10 2014). One proposal of reducing the limit for particle mass from 10 to 5 mg/kWh was rejected.

With the Euro III regulation new driving cycles were introduced and the older ECE R-49 was replaced by the ESC and ETC cycles. In addition the European load response test ELR was also introduced for measurements of opacity (smoke).

For type approval measurements, the following conditions are required for new engines in Euro III (2000).

- Conventional diesel engines are examined in accordance with ESC/ELR.
- Diesel engines with "advanced exhaust after treatment systems" (e.g. NOx reduction systems or DPF) are examined in accordance with ESC/ELR and ETC.
- Gas engines are examined in accordance with ETC.

For type approval of new engines in Euro IV (2005) and later as for EEV, all diesel engines shall be examined in accordance with ESC/ELR and ETC.

In **Table 4**, the emission limit values for all diesel and gas engines examined in accordance with the ETC are presented.

Table 4 Emission limit values for diesel and gas engines, ETC-test.

Level	Date	Test	CO (g/kWh)	NMHC (g/kWh)	CH_4[a] (g/kWh)	NO_x (g/kWh)	PM[b] (g/kWh)
Euro III	1999.10, EEVs only	ETC	3,0	0,40	0,65	2,0	0,02
	2000.10	ETC	5,45	0,78	1,6	5,0	0,16 0,21
Euro IV	2005.10		4,0	0,55	1,1	3,5	0,03
Euro V	2008.10		4,0	0,55	1,1	2,0	0,03
Euro VI[d]	2014.01		4,0	0,16	0,5	0,5	0,01

a, for natural gas engines only
b, not applicable for gas fuelled engines at the year 2000 and 2005 stages
c, for engines of less than 0,75 dm3 swept volume per cylinder and a rated power speed of more than 3000 min-1
d, Proposal for Euro VI by the European Parliament's Environment Committee on July 15, the final decision on the Euro VI limits is not made.

5. Survey results

Available bioethanol and biodiesel vehicles by manufacturer.

5.1. Passenger cars fuelled by E 10

- 21 of the 49 vehicle manufacurers have replyed that they have vehicle models that can be fuelled by gasoline containing 10 % bioenthanol.
- 19 manufacturers did not replay our request in this issue.
- 9 manufacturers answered that they do not have vehicles that can be fuelled by E10.

Passenger cars E10	Not available	Models fuelled with E10 available with manufacturers warranty	Euro emission standard	Exhaust cleaning system
Alfa Romeo	no reply at present			
Audi		All gasoline fuelled models except: - Audi A2 1.6 FSI, 2002 – 2006 - Audi A3 1.6 FSI, 2001 – 2004 - Audi A3 2.0 FSI, 2001 – 2004 - Audi A4 2.0 FSI, 2001 – 2004 - Audi A4 built until 2007 when the auxiliary heating is used	EURO 3 and EURO 4	TWC
Austin	no reply at present			
BMW	x			
Bufori	x			
Cadillac	no reply at present		EURO 4	TWC
Chevrolet	no reply at present			
Chrysler		All gasoline fuelled models from 1989	Pre EURO 1	TWC
Citroën	no reply at present			
Corvette	no reply at present			
Dacia		All gasoline fuelled models since the Dacian logo in Europe		TWC

Dodge		All models from 1989	Pre EURO 1 and forward	TWC
Ferrari	x			
Fiat	no reply at present			
Ford		All gasoline fuelled models except - Mondeo Sci, 2004 – 2006	Up to EURO 4	TWC
Honda	no reply at present			
HUMMER	no reply at present			
Hyundai		All gasoline fuelled models from 1992	From EURO 1	TWC
Isuzu	x			
Jaguar		All gasoline fuelled models from 1992	From EURO 1	TWC
Jeep		All gasoline fuelled models from 1989	Pre EURO 1	TWC
KIA		All gasoline fuelled models	EURO 4	TWC
Koenigsegg		All gasoline fuelled models		TWC
Lada	no reply at present			
Lancia	no reply at present			
Land Rover		All gasoline fuelled models from 1996	From Euro 1	TWC
Lotus	no reply at present			
Maserati	x			
Mazda	no reply at present			
Mercedes–Smart		All Mercedes-Benz and Smart but: - cars produced without 3-way-catalyst (normally older than 23 years) - cars accepting only Super Plus fuel - cars with 1st generation ottomotors with four cylinder direct injection (C200 CGI – 203 and CLK 200 CGI – 209 produced in 2002 – 2005) fuelled with Super Plus fuel (< 5 % ethanol)	EURO 4 – EURO 6	TWC
Mini		All from 2000	EURO 3	TWC
Mitsubishi		All models except cars with GCI-engine with gasoline direct injection		TWC
Morgan	x			
Nissan		- Micra: from 2000 - Note: from 2006 - Almera: from 2000 - Tiida: from 2007 - Almera Tino: from 2000 - Qashqai: from 2007 - Primera: from 2000 - X-Trail: from 2001 - Terrano II: from 2000 - Pathfinder: from 2000 - Murano: from 2005 - Pick-Up (D22): from 2000	EURO 4	TWC
Opel / Vauxhall		All models except vehicles with 2.2 l direct injection (Motorcode: Z22YH): - Opel/Vauxhall Signum - Opel/Vauxhall Vectra - Opel/Vauxhall Zafira		
Peugeot		All models from January 1st 2000	EURO 4	TWC
Piaggio Porter	x			
Porsche	no reply at present			

Renault		All models from 2000 except: - Vehicles with 2.0l-petrol engine with direct injection (2.016V/F4R) - 2.0l- Turbo (F4Rt) built 2000 - 2002	EURO 3	TWC
Rolls Royce		All models from 2003	EURO 3	TWC
Saab	no reply at present			
Seat	no reply at present			
Skoda		All models except: - models using only Super Plus fuel (< 5 % ethanol) - Felicia with 1,3l-OHV-engine with 40 or 50 kW, Built 1994 - 2001 - previous models (Forman, Favorit etc.)		TWC
Ssang Young	x			
Subaru		All gasoline fuelled models	EURO 4	TWC
Suzuki	no reply at present			
Toyota	x			
Volkswagen	no reply at present			
VOLVO	no reply at present			

5.2. Passenger cars fuelled by E 85

- 19 of the 49 vehicle manufacurers have replyed that they have vehicle models that can be fuelled by E85.
- 2 manufacturers did not yet replay our request in this issue.
- 28 manufacturers answered that they do not have vehicles that can be fuelled by E85.

Passenger cars E85	Not available	Models available with manufacturers warranty	Euro emission standard	Exhaust cleaning system	EU-countries where the E85 vehicles are available
Alfa Romeo	x				
Audi		Audi A3 1.6 MPI		TWC	se
Austin	x				
BMW	x				
Bufori	x				
Cadillac		Cadillac BLS Flexpower	EURO 4	TWC	at, be, de, dk, ee, es, fi, fr, gb, gr, hu, ie, it, lt, lu, lv, mt, nl, pl, pt, se
Chevrolet		Chevrolet Suburban Chevrolet Tahoe	Direct import from USA	TWC	se se
Chrysler		Chrysler Sebring	EURO 4	TWC	nl, se
Citroën		Citroën C4 Citroën C5	EURO 4	TWC	se se
Corvette	x				
Dacia		Dacia Sandero	EURO 4	TWC	se
Dodge		Dodge Journey 2.7 FFV		TWC	be, fi, fr, lu, mt, se
Ferrari	x				
Fiat	x				
Ford		Ford Focus 1.8 Ford Galaxy 2.0 Ford Mondeo 2.0	EURO 4	TWC	be, de, ee, es, fi, fr, hu, lu, pl, se be, de fi, fr, gb, ie, lu, nl pl, se be, de, fi, gb, hu, ie, lu, nl, pl, se

		Ford S-Max 2.0 Ford C-Max 1.8			be, de, es, fi, fr, gb, hu, ie, lu, nl, pl, se ee, es, fi, fr, hu, ie, it, lt, lu, nl, pl, se
Honda	x				
HUMMER					fr, nl
Hyundai	x				
Isuzu	x				
Jaguar	x				
Jeep	x				
KIA	x				
Koenigsegg		All gasoline fuelled models		TWC	All countries
Lada	x				
Lancia	x				
Land Rover	x				
Lotus		Lotus Exige 265E			fr
Maserati	x				
Mazda	x				
Mercedes–Smart	x				
Mini	x				
Mitsubishi		Mitsubishi Colt 5d Plus Cleartech 1.3 l		TWC	nl, se
Morgan	x				
Nissan	x				
Opel / Vauxhall	x				
Peugeot		Peugeot 308 Bioflex Peugeot 407 Bioflex	EURO 5 EURO 5	TWC TWC	fr, nl, se fr, nl, se
Piaggio Porter	x				
Porsche	x				
Renault		Renault Clio III 1.2 16V Eco2 Flex Fuel Renault Mégane 1.6 16 V Eco2 Flex Fuel	EURO 4 EURO 4	TWC TWC	fr, ie, se at, fr, se
Rolls Royce	No replay at present				
Saab		Saab 9-3 BioPower 1,8t Saab 9-5 BioPower 2,0t	EURO 4 EURO 4	TWC TWC	at, be, cz, de, dk, es, fi, fr, gb, hu, ie, it, lu, lv, pl, se, sk, sl at, be, cz, de, dk, es, fi, fr, gr, gr, hu, ie it, lt, lu, lv, pl, se, sk, sl
Seat		Seat Leon Seat Altea	EURO 4 EURO 4	TWC TWC	se se
Skoda		Skoda Octavia GreenLine Multifuel 1,6	EURO 4	TWC	se
Ssang Young	x				
Subaru	x				
Suzuki	No replay at present				
Toyota	x				
Volkswagen		VW Golf 1,6 Multi Fuel VW Golf Plus 1,6 Multi Fuel VW Golf Variant	EURO 4 EURO 4 EURO 4 EURO 4	TWC TWC TWC TWC	se se se se

		1,6 Multi Fuel VW Jetta 1,6 Multi Fuel			
VOLVO		VOLVO C30 Flexifuel VOLVO S40 Flexifuel VOLVO S80 Flexifuel VOLVO V50 Flexifuel VOLVO V70 II Flexifuel	EURO 4 EURO 4 EURO 4 EURO 4 EURO 4	TWC TWC TWC TWC TWC	at, be, bg, cy, cz, de, es, fi, fr, gb, hu, ie, it, lu, mt, nl, ro, se, sk, sl at, be, bg, cy, cz, de, es, fi, fr, gb, hu, ie, it, lu, mt, nl, ro, se, sk, sl at, be, bg, cy, cz, de, es, fi, fr, gb, hu, ie, it, lu, mt, nl, ro, se, sk, sl at, be, bg, cy, cz, de, es, fi, fr, gb, hu, ie, it, lu, mt, nl, ro, se, sk, sl at, be, cy, cz, de, es, fi, fr, gb, hu, ie, it, lu, mt, nl, ro, se, sk, sl
at-Austria, be-Belgium, bg-Bulgaria, cy-Cyprus, cz-Czech Republic, de-Germany, dk-Denmark, ee-Estonia, es-Spain, fi-Finland, fr-France, gb-United Kingdom, gr-Greece, hu-Hungary, ie-Ireland, it-Italy, lt-Lithuania, lu-Luxembourg, lv-Latvia, mt-Malta, nl-Netherlands, pl-Poland, pt-Portugal, ro-Romania, se-Sweden, sk-Slovakia, sl-Slovenia					

5.3. Passenger cars fuelled by biodiesel

- 2 of the 49 vehicle manufacurers have replyed that they have vehicle models that can be fuelled by biodiesel.

- 47 manufacturers answered that they do not have vehicles that can be fuelled by biodiesel.

Passenger cars biodiesel	Not available	Models available with manufacturers warranty	Euro emission standard	Exhaust cleaning system	EU-countries where the biodiesel vehicles are available
Alfa Romeo	x				
Audi	x				
Austin	x				
BMW	x				
Bufori	x				
Cadillac	x				
Chevrolet	x				
Chrysler	x				
Citroën	x				
Corvette	x				
Dacia	x				
Dodge	x				
Ferrari	x				
Fiat	x				
Ford	x				
Honda	x				
HUMMER	x				
Hyundai	x				
Isuzu	x				
Jaguar	x				
Jeep	x				
KIA	x				
Koenigsegg	x				
Lada	x				
Lancia	x				
Land Rover	x				
Lotus	x				
Maserati	x				
Mazda	x				
Mercedes–Smart	x				
Mini	x				
Mitsubishi	x				

Morgan	x				
Nissan	x				
Opel / Vauxhall	x				
Peugeot		All models sold today can be fuelled by up to B30 (30 % FAME EN 14214)			
Piaggio Porter	x				
Porsche	x				
Renault	x				
Rolls Royce	x				
Saab	x				
Seat	x				
Skoda	x				
Ssang Young	x				
Subaru		All models approved for 7 % RME			
Suzuki	x				
Toyota	x				
Volkswagen	x				
VOLVO	x				

5.4. Transport vehicles fuelled by E 85

Only three manufactures supply E85 transport vehicles.

Transport vehicles E85	Not available	Models available with manufacturers warranty	Euro emission standard	Exhaust cleaning system	EU-countries where the E85 vehicles are available
Renault		Renault Kangoo 1.6 16V Expression Ethanol	*EURO 4*	TWC	fr, ie, se, at
Chevrolet		Chevrolet Avalanche Flexifuel Chevrolet Silverado Flexifuel Chevrolet Uplander LT	*Direct import from USA*	TWC	se
Nissan		Nissan Titan Flexifuel	*Direct import*	TWC	*Nissan Titan Flexifuel does not have general agents in Sweden but is available at private distributors in Sweden.*

5.5. Heavy duty vehicles and busses fuelled by E 85 or biodiesel

Heavy duty vehicles and busses	
Scania	**Ethanol:** Scania has no E10 or E30 engines. They have a diesel engine, DC9 E02 that runs on E95 and can be installed in various types of heavy duty vehicles. The warranty is one year in all countries. EURO emission standard is V. **Biodiesel:** Scania accepts 8% biodiesel in the normal diesel fuel with maintained warranty. Without changing the engine they also accept up to 100% biodiesel but with more frequent service and filter exchange. There is one exception, at XPI injection biodiesel is not accepted Exhaust cleaning is SCR or EGR and emission standard EURO V.
IVECO	IVECO has no vehicles that run on ethanol E85 or biodiesel.
MAN / Neoplan	The MAN busses can not run on ethanol but they can use the normal FAME mix. If a higher FAME concentration is wanted, permission from MAN is needed. MAN has a warranty system where additional warranties can be bought. This goes for all

	clients in the European Union. Engines produced for the European market have the emission standard EURO V; some of the engines also have EEV. Exhaust cleaning system is AGR.
Volvo Power Train	Volvo Power Train accepts diesel fuel with up to 30 % FAME in their engines from the 7.0 litre (B7) and upward, whether the engine is a EURO III, IV or V engine. The full warranty is given only for restricted fleets and after a contract about handling, service and maintenance has been signed. All Volvo truck engines are equipped with SCR for exhaust gas emission treatment.
Mercedec/Daimler	no reply at present
Volvo Bus	Volvo Bus accepts up to 100 % FAME in their engines from the 7.0 litre (B7) and upward. Even the smaller engines will be accepted for B 100 but not until 2010. The full warranty is given only for restricted fleets and after a contract about handling, service and maintenance has been signed. All Volvo bus engines are equipped with SCR for exhaust gas emission treatment. When using blends of diesel and FAME even if full warranty is given, they do not guarantee that the emission levels will be the same as with the certification fuel (diesel oil).
DAF	- Fuels for DAF engines must comply with the European standards EN590 or EN14214. Fuel produced from straight vegetable oil (SVO) is not allowed. - Biodiesel and mixtures of diesel oil and biodiesel are allowed for DAF vehicles if all conditions that are mentioned below are met: - Only official produced diesel or blends with alternative fuel up to 7 % biodiesel according to standard EN 590 is allowed. - All EURO III vehicles retrofitted with a passive soot filter unit (released by DAF After Sales dept.): Only official produced diesel or blends with alternative fuel up to 7 % biodiesel according standard EN 590 is allowed. - *LF vehicles with BE or CE engines:* according to EURO III emission class: Only official produced diesel according to EN 590 and mixtures of diesel according to EN 590 with a maximum of 20 % biodiesel according to EN 14214 are allowed. - *LF vehicles with FR, GR engines:* Only official produced diesel or blends with alternative fuels up tp 7 % biodiesel according to standard EN 590 is allowed. - *95XF vehicles with XE engines:* Only official produced diesel or blends with alternative fuel up to 7 % biodiesel according to standard EN 590 is allowed. - *XF95 vehicles with XE engines:* Only official produced diesel according to EN 590 or biodiesel according to EN 14214 and mixtures of these 2 products are allowed. - *CF75/85 vehicles with PE and XE engines chassis number up to OE552890:* Only official produced diesel or blends with alternative fuel up to 7 % biodiesel according to standard EN 590 is allowed. - *CF75/85 vehicles with PE and XE engines chassis number up to OE552890*: Only official produced diesel according to EN 590 or biodiesel according to EN 14214 and mixtures of these 2 products are allowed. - *CF75/85 vehicles with PR and MX engines*: Only official produced diesel according to EN 590 or biodiesel according to EN 14214 and mixtures of these 2 products are allowed. To this has to be added specially to conditions and requirements concerning the sealing, the oil drain, cold weather conditions, service stops etc.

5.6. Vehicle warranty

5.6.1. Biothanol

As shown in the table above all so called FFV models can run on all possible concentrations from neat gasoline up to E 85 (summertime 85 % bioethanol and 15 % gasoline, winter time 75 % bioethanol and 25 % gasoline) with full warranty.

When it comes to low blends all manufacturers today accept up to 5 % bioethanol in market gasoline since this is adopted in the European gasoline standard (EN 228).

Besides the FFV:s and the normal market gasoline there are also manufacturers that accept up to 10 % bioethanol in some or all of their gasoline vehicle models with full warranty. In light of the situation in the EU with the revised fuel directive and the discussion in CEN, Europe will most likely in perhaps a year or two have a revised gasoline standard that includes blending of up to 10 % bioethanol in gasoline. This will probably and in a short time period lead to a situation when more or less all manufacturers will have to accept blends of up to 10 % bioethanol in gasoline. Otherwise, they will take a high risk to lose market shares. In this context, it is also important to bear in mind that a number of manufacturers, as shown in chapter 5.1, already today accept the use of E 10 in their vehicles in the US. Of course the vehicles sold in the US maybe be adapted to E 10 while the vehicles sold in Europe are not, but probably the situation is the opposite and all the vehicle of one type are adapted to the most demanding situation.

5.6.2. Biodiesel

The survey has shown that there exists no FFV model that can run on a varying blend of diesel oil and biodiesel. When it comes to low blending all manufacturers today accept up to 5 % biodiesel (or rather FAME) since this is included in the European diesel oil standard (EN 590). Besides that only two manufacturers (Peugeot and Subaru) accept higher blends than 5 % with full warranty.

5.6.3. Future warranty changes

The EU has accepted a blend of up to 7 % biodiesel in diesel oil and in a year or two we will most likely have a revised European CEN standard on diesel oil that includes up to 7 % biodiesel in diesel oil. Concerning heavy duty trucks and buses there are manufacturers that accept higher blends of diesel oil and biodiesel such as 30 % and up to 100 % biodiesel with full warranty, see chapter 5.5

It is important to note that even if a manufacturer has a vehicle model that can run on E85 or higher blends of gasoline and bioethanol, or diesel oil and biodiesel, it cannot be expected that this model will be sold in all European countries. A manufacturer has no reason to present such a model to the market in every EU country if it not is a request from the market/the consumers. Secondly, there is no reason marketing for example a FFV model if there are no tank stations where you can buy E85. For information in regards to which countries these vehicles and E85 equipped petrol stations are available see **appendix 1**.

It is difficult to gain knowledge about the exact situation in every single EU country, particularly as the situation is changing quickly in close connection to the changes of the price of bioethanol and biodiesel as well as the public and political discussion in favour of or against these fuels. However, the FFV models are currently sold in Sweden and some other countries like Germany, France, Spain, Holland and Great Britain. It is most likely possible to order a FFV in other countries but as long as there are no or very few E85 tank stations there will be no demand for this type of vehicles in these countries. What could change this situation is of course demands from the market to buy FFV:s or other models adapted to low or high blends of bioethanol or biodiesel as well as other fuels. Of course also strong demands from the EU commission (directives) on the use of bioenergy as well as biofuels will have a strong impact on the growth of the biofuel market and the supply of vehicles adapted for biofuels.

According to all interviewed representatives from the vehicle manufacturers or their sales companies/organizations, **see references**, the vehicle warranty is the same over the whole EU-region.

If, or rather when a manufacturer accepts the use of a fuel it is with full warranty. And the warranty is valid across the whole EU-region.

In the instruction manual for the vehicle it should be clearly expressed what fuel or fuels can be used in the vehicle with full warranty. If there is any doubt about this issue the authorised car dealer can be contacted for further information about the specific case.

Furthermore if you buy a vehicle in a European country it is not only in that country it is certified and could be registered. The certification goes for the whole EU-region. So a vehicle possible to fuel with for example B30 in Sweden can also be fuelled with B30 in any other EU country with full warranty. In some cases manufacturers of heavy duty vehicles are prepared to accept higher blends of biodiesel, up to 100%, in their vehicles/engines with full warranties, but only what a special contract specifying for example service frequency and type etc, has been signed between the manufacturer and the owner of the truck.

6. Market forecast

6.1. Passenger vehicles

Concerning the future it is always difficult to foresee what will happen. But with the current standpoint of the EU commission in mind it is difficult to not believe that the use of biofuels will grow rapidly in particular with bioethanol and biodiesel. Mainly this growth will be within low blends of gasoline and diesel oil and to a much lower extent in the use of neat bioethanol or biodiesel. Since low blends can be used in more or less all vehicles while neat fuel only in specially adapted engines or vehicles. Even if there are other biofuels that can be produced and used today, such as biogas, the fuels bioethanol and biodiesel will for at least the next 10 years be the first hand alternatives when looking for biofuels. Two reasons for this are that the production technology is well known and that the feedstock exists and can be expanded. Furthermore the fuels themselves, when low blended in gasoline or diesel oil, easily or with just minor modifications can be used in the existing vehicle fleet.

If we want to use biofuels in higher blends then FFV's that can adapt to different blends will probably be the most popular choice. To get a grip of how the sale of FFV's can be expanded we can compare the situation in Sweden. Around the middle of the 1990'sthe first FFV's were imported to Sweden from the U.S., which were several hundread large family vehicles (Ford Taurus) with a high fuel consumption. In the late 1990's and in the beginning of 2000 one vehicle manufacturer (Ford) promised to present a new middle sized FFV model, Ford Focus Flexi Fuel, as long as they could be guaranteed a sale of at least 2000 vehicles. About two years later around 2000 FFV's (Ford Focus Flexi Fuel) were delivered to the market. The technology with joint technical procurement has been used further in Sweden. In 2000 – 2006 the number of FFV's in Sweden grew from 250 to 49 000 vehicles, 49 000 is about 1,2 % of all passenger cars sold. The interest and the market for FFV:'s has continued to grow further and today there is more than 140 000 FFV:' s on the road, both in captive fleets but most owned by private persons and all of the FFV models that can be found in the table above can be bought in Sweden today.

Table 5 Number of Flexi Fuel Vehicles in Sweden 2000 - 2008

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Number of FFV suitable for E 85	250	890	3 500	7 980	13300	21400	46700	81300	138000

During January to December 2008 there were in total 250 000 new registrations of passenger vehicles in Sweden. Of these passenger vehicles 33,3 % (83 250) were so called environmentally friendly cars and of these environmentally friendly cars 68,4 % (56 943) were FFV/E85 vehicles. This is approximately twice as much as for 2007.

Besides the technical procurement, there have also been a number of actions taken by different actors to establish a net of E85 stations in Sweden. To start with, it was voluntary for the oil companies to set up E85 pumps, and the development of the E85 station network was a result of discussions between possible fleet owners, producers of bioethanol and manufacturers of FFV's. However, after a couple of years the Swedish parliament, by legislation, made it mandatory for oil companies to set up at least one pump with biofuel at every tank station, except the smallest ones. Today Sweden has more than 1000 tank stations where E 85 can be bought.

The combined work on establishing new tank stations for biofuels, in particular bioethanol, in combination with the technical procurement is probably the main reason for the quickly growing market for FFV:'s in Sweden. By doing it this way Sweden has avoided the hen and the egg situation. Using the same line of action it must be possible also for other countries to expand the market for FFV:'s and the number of FFV:'s in their countries.

If we compare with the rest of the EU region there were, according to ACEA, 13 788 000 new registered passenger cars from January to December 2008 in Europe. 22,8 % of these cars (68,4 % of 33,3 %) would be the same as 3 143 664 vehicles.

In other words, if the rest of the European countries would start a process with the same success achieved in Sweden over the past 15 years, it might be possible for the EU to reach a total yearly sales/new registration, in 10 to 15, years of about at least 2 500 000 to 3 000 000 million FFV's. One reason that the progress in the coming 15 years might be slower than it has been for the last 15 years in Sweden is that the age of the vehicle fleet increases. The better high quality vehicles we build the longer they will last and with that will also the age of the vehicle fleet increase. This will have an effect on how fast we can replace old cars with new more environmentally friendly ones.

It is also important to take into account that not all FFV' s will always be fuelled by E85. When the price of gasoline, based on energy content, is low enough compared to the bioethanol (E85) price the customers will prefer gasoline as this is the cheapest fuel. The situation might change and then the E85 is the cheapest alternative. This is often brought up when discussing and criticising FFV's. In the long run the FFV' s will in first hand be fuelled by E85 since the price of oil will most likely continue to increase and the political demand to change from fossil fuel to bio fuels will most likely continue to grow, more so with the help of temporary financial subsidies on biofuels. If we put strong demands on the FFV's to run on E 85 from the very beginning we will probably slow down the development of the FFV market and we will also reduce the benefit with the FFV' s which is the possibility to run on all kinds of blends from neat gasoline up to E85

6.2. Heavy duty vehicles

Concerning heavy duty vehicles Sweden is probably the only country that has introduced bioethanol fuelled buses into the public transportation system on a larger scale. During the 12 year period between 1990 and 2002 the number of bioethanol fuelled buses grew from 0 to approximately 400 buses, which was somewhat lower than 5 % of the total Swedish bus fleet at the time.

In all there are currently about 500 buses in operation in a number of fleets of buses in Sweden.

Table 6 Number of bioethanol fuelled buses in Sweden 2000 - 2008

Year	2003	2004	2005	2006	2007	2008
Number of bioethanol fuelled buses	400	380	370	490	490	510

In the statistics by ACEA and Eurostat the wording, "buses and coaches" has been used for the group of vehicles defined as "buses" used for transportation of people. The number of buses and coaches in the weight class "Over 3.5 tons" registered January to November year 2008 as presented by ACEA for 23 EU countries plus the EFTA countries (countries Iceland, Norway and Switzerland) is 41868

The number of buses and coaches in traffic in the weight class "Over 3.5 tons" are estimated to be somewhat more than 800 000 based on the statistics for the countries mentioned above

In line with the statistics for "New registration" the number of trucks over 3,5 tons registered according to data presented by ACEA for 23 EU countries plus the EFTA countries (countries Iceland, Norway and Switzerland) for year 2007 is about 420 000.

The number of trucks in traffic in the weight class "over 3.5 tons" 2007 are about 6.3 millions for the above-mentioned countries.

If we assume that the total European bus as well as truck fleets would grow with the same figures the coming 10 – 15 years there would then be around 36 000 bioethanol fuelled buses in Europe. However, this estimation might be to optimistic since there is just one producer of bioethanol bus engines today (Scania). A more realistic figure could be somewhat around 10 000 to 15 000 bioethanol fuelled buses, but still this estimation is much more uncertain than for the FFV's.

Concerning trucks there are some, but still very few bioethanol fuelled trucks (Scania) in Sweden, today. The development of bioethanol fuelled trucks is more on a pre commercial stage than a final commercial market product and the progress seems uncertain even if there is a clear interest among transportation companies for bioethanol fuelled trucks. It seems to be too uncertain to make any estimations of the possible development in the coming 10 to 15 years.

7. Conclusions

Even if the progress might seem slow the number of vehicles possible to fuel by bioethanol or biodiesel in neat form or blended with gasoline respectively diesel oil has grown substantially over the last 10 years and will probably grow faster and faster along with new EU directives, growing consumer demand and increasing oil prices.

Even if there are a number of new biobased fuels that could be used it is most likely that the main alternative for the near future will be bioethanol and biodiesel. When talking about biodiesel we mean Fatty acid methyl esters (FAME) or in the future also Fatty Acid Ethyl Esters (FAEE). The main reasons for this are that the production technology for both bioethanol and biodiesel are well known, the feedstock is, and should continue to be reliable for the future and finally both bioethanol and biodiesel can easily be blended with gasoline or dieseloil or used in neat form in existing engines with just minor adaptations.

Already today there are quite a number of manufacturers that have presented so called Flexible Fuel Vehicle models to the market, models that can be fuelled by all mixes of gasoline and ethanol from neat gasoline up to 85 % ethanol and 15 % gasoline. For the future it seems most likely that there will be more and more manufacturers willing to present new FFV models. Nevertheless, even if there already are several FFV models on the market the most successful way to reach substantial volumes of biofuel on the market seems to be by low blending. Today market standard gasoline can be blended with up to 5 % ethanol and in a year or two this figure will probably be 10 %. The figures concerning biodiesel in diesel oil are 5 % today and 7 % tomorrow.

There are a number of manufacturers that already today accept up to 10 % ethanol in gasoline and at least two manufacturers that accept more than 5 % biodiesel in diesel oil with maintained full warranty. For the future it seems most likely that there will be

more and more manufacturers that will accept these new levels of bioethanol in gasoline and biodiesel in diesel oil. Not at least since these new levels probably will be included in the European standards for gasoline (EN 228) and diesel oil (EN 590).

Sweden has been successful in introducing biofuels and FFV's on the Swedish market. One explanation to this might be that the number of vehicles and the net of tank station has been able to grow together and in parallel. To make this possible all involved actors have to work jointly and voluntary measures probably have to be combined with mandatory demands from authorities and the government. With the same approach the rest of Europe might have a yearly registration of perhaps 2 500 00 – 3 000 00 FFV's in 10 years and in 15 years there might be around 36 000 bioethanol fuelled buses in Europe.

References

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