Perspectives for post-Euro 4 standards for passenger and light commercial vehicles (Euro 5, Euro 5+, Euro 6)

Resolved upon improving air quality for public health and environmental reasons, the European Union has been progressively stiffening its regulations on polluting motor vehicle emissions. A series of EU standards have helped reduce pollution from new diesel and spark ignition vehicles (passenger cars and light commercial vehicles) by obliging manufacturers to optimize technology and develop new tailpipe emission post-treatment systems. At the same time, improvements in motor fuel quality were made, without which it would have been pointless to install the new emissions reduction systems.

The new Euro 5 and Euro 6 standards, effective 1 September 2009 and 1 September 2014 for new passenger and light commercial vehicles, will set stricter limits on particulate emissions (the same for diesel and gasoline vehicles) and introduce a limit on the number of particles. The latter will be implemented during an intermediate stage: Euro 5+ (2011).

A story of evolving regulatory constraints: Euro 1 to Euro 4

Tailpipe emissions for light vehicles in Category M (passenger vehicles) or Categories N1 or N2 (light commercial vehicles) are defined in Directive 70/220/EEC, which has often been amended and whose most well-known amendments gave rise to Euro 1 (Directives 91/441/EEC and 93/59/EEC), Euro 2 (Directives 94/12/EC and 96/69/EC), Euro 3 (Directive 98/69/EC) and Euro 4 (Directive 2003/76/EC) (Tables 1 and 2).

Since Euro 2, different emission limits have been applied to diesel vehicles and spark ignition vehicles. Diesel vehicles must meet stricter standards for carbon monoxide emissions, but the limits on nitrogen oxide emissions are less strict.

Spark ignition vehicles were not subject to particulate emissions limits until Euro 4. Euro 5 sets a particle mass limit specific to direct injection gasoline engines.

Vehicles that comply with Euro 4, which entered into force in 2005, emit half as many pollutants overall as Euro 3 vehicles. As a general rule, each new set of standards divides emissions levels by two.

For type approval of light vehicles in Europe, emissions are measured on chassis dynanometer t 20°C using a standardized test cycle (New European Drive Cycle, NEDC, also known as MVEG-A) that includes a city driving cycle (ECE 15) and an extra-urban driving cycle (EUDC). Before 2000 (Euro 3), the measurement cycle was such that emissions were only measured 40 seconds after cranking with the engine already at idle speed; starting in 2000, start-up emissions were included.

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Table 1

Evolution of European standards applicable to emissions of passenger vehicles (power-driven vehicles designed and built to carry passengers) for the type I test

Categories reference mass (RM)[a] (kg)	Carbon monoxide (CO) (mg/km)		Total hydrocarbons (THC) (mg/km)		Non-methane hydrocarbons (NMHCs) (mg/km)		Nitrogen oxides (NOx) (mg/km)		Combined mass (THC + NOx) (mg/km)		Particle mass (PM) (mg/km)		Number of particles/km	
	SI	CI	SI	CI	SI	CI	SI	CI	SI	CI	SI	CI	SI	CI
Euro 1 01.07.1992	2,720	2,720							970	970		140		
Euro 2[b] 01.01.1996	2,200	1,000							500	700		80		
Euro 3 01.01.2000	2,300	640	200				150	500		560		50		
Euro 4 01.01.2005	1,000	500	100				80	250		300		25		
Euro 5 01.09.2009	1,000	500	100		68		60	180		230	5.0	5.0		
Euro 5+ 01.09.2011	1,000	500	100		68		60	180		230	4.5	4.5		6.10^{11}
Euro 6 01.09.2014	1,000	500	100		68		60	80		170	4.5	4.5	c	6.10^{11}

SI Spark ignition (gasoline, LPG, Natural Gas).
CI Compression ignition (diesel).
a Effective dates for new vehicle types. For all types of vehicles: one year after the new types.
b Values for IDI engines (from 10.01.1999, DI engines must comply with IDI limits).
c Value to be determined before 2014 based on inter-laboratory testing.

Perspectives for vehicle emissions standards: Euro 5, Euro 5+ and Euro 6

The stages of implementation

The new regulations governed by the Euro 5 and Euro 6 standards concerning type approval of light passenger and commercial vehicles appeared on 29 June 2007 in the Official Journal of the European Union.

For thirty-five years, legislators have been regulating vehicle emissions. At present, there are twenty-five directives which, for simplicity's sake, have been replaced by a single regulation: Regulation (EC) No. 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information.

This regulation entered into force on 2 July 2007 and will take effect on 3 January 2009, except for Article 10, paragraph 1 (type approval of vehicles in compliance with Euro 5 and Euro 6 standards) and Article 12 (financial incentives), which will apply from 2 July 2007.

The Commission should also be empowered to establish specific procedures, tests and requirements for type approval designed to add new non-essential elements (Article 5). The elements concerned are as follows:

- Tailpipe emissions, including test cycles, low ambient temperature emissions, emissions at idling speed, smoke opacity and correct functioning and regeneration of after-treatment systems.
- Evaporative emissions and crankcase emissions.
- OBD systems and in-use performance of pollution control devices.
- Durability of pollution control devices, replacement pollution control devices, in-service conformity, conformity of production and roadworthiness.
- Measurement of greenhouse gas emissions and fuel consumption.
- Hybrid vehicles and alternative fuel vehicles.
- Extension of type approvals and requirements for small volume manufacturers.
- Test equipment.
- Reference fuels, such as petrol, diesel, gaseous fuels and biofuels, such as bioethanol, biodiesel and biogas.

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Table 2

European standards concerning the emissions of light commercial vehicles
(power-driven vehicles designed and built to haul freight)

Categories effective dates (New types)[a]	Carbon monoxide (CO) (mg/km)		Total hydrocarbons (THC) (mg/km)		Non-methane hydrocarbons (NMHCs) (mg/km)		Nitrogen oxides (NOx) (mg/km)		Combined mass (THC + NOx) (mg/km)		Particle mass (PM) (mg/km)		Number of particles/km	
	SI	CI	SI	CI	SI	CI	SI	CI	SI	CI	SI	CI	SI	CI
N1 Classe I RM ≤ 1,305														
Euro 3	2,300	640	200				150	500		560		50		
Euro 4	1,000	500	100				80	250		300		25		
Euro 5	1,000	500	100		68		60	180		230	5.0	5.0		
Euro 5+	1,000	500	100		68		60	180		230	4.5	4.5		
Euro 6	1,000	500	100		68		60	80		170	4.5	4.5		
N1 Classe II 1,305 < RM ≤ 1,760														
Euro 3	4,170	800	250				180	650		720		70		
Euro 4	1,810	630	130				100	330		390		40		
Euro 5	1,810	630	130		90		75	235		295	5.0	5.0		
Euro 5+	1,810	630	130		90		75	105		195	4.5	4.5		
Euro 6	1,810	630	130		90		75	105		195	4.5	4.5		
N1 Classe III 1,760 < RM														
Euro 3	5,220	950	290				210	780		860		100		
Euro 4	2,270	740	160				110	390		460		60		
Euro 5	2,270	740	160		108		82	280		350	5.0	5,0		
Euro 5+	2,270	740	160		108		82	125		215	4.5	4,5		6.10^{11}
Euro 6	2,270	740	160		108		82	125		215	4.5	4,5	b	6.10^{11}
N2														
Euro 5	2,270	740	160		108		82	280		350	5,0	5.0		
Euro 5+	2,270	740	160		108		82	125		215	4,5	4.5		6.10^{11}
Euro 6	2,270	740	160		108		82	125		215	4,5	4.5	b	6.10^{11}

SI Spark ignition (gasoline, LPG, Natural Gas).
CI Compression ignition (diesel).
a RM (reference mass) = mass of the vehicle in running order less the uniform mass of the driver and increased by a uniform mass of 100 kg.
b Value to be determined before 2014 based on inter-laboratory testing

The member States should notify the Commission by 2 January 2009 of provisions concerning penalties applicable for infringement of the provisions of the regulation.

The final draft of the technical portion of the Euro 5 and Euro 6 regulations was approved on 1 October 2007 at a meeting of the CATP (Committee for the adaptation of technical progress).

To ensure implementation of ultra-fine particulate emissions control, the Commission should adopt a new limit based on the number of particles, in addition to the particle mass limit. The particle number limit should be based on the findings of the UNECE Particle Measurement Programme (PMP). To increase the reproductibility of measurements (mass and particle number), the Commission should adopt a new method based on the findings of this program. Within the framework of PMP, a method for sampling, conditioning and counting tailpipe particles emitted by diesel or spark ignition vehicles was developed and is now being validated by circular tests at European level.

This project includes an Euro 5+ stage to introduce PMP procedures for the measurement of particle mass and particle number.

Euro 5+ is to take effect on 1 September 2011 for new vehicle types and 1 January 2013 for new vehicles. The text will be submitted to the European Parliament and to the European Council for a period of examination of

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three months before being published in the Official Journal in early 2008.

Directive 70/220/EEC and its successive amendments (25 directives) will be abrogated from 2 January 2013.

Table 3

Effective dates for Euro 5 and Euro 6 emissions limit values

Passenger vehicles	Euro 5	Euro 5+	Euro 6
EC type approval and national type approval	01/09/2009	01/09/2011	01/09/2014
Registration, sale, entry into service	01/01/2011	01/01/2013	01/09/2015
Light commercial vehicles	Euro 5	Euro 5+	Euro 6
EC type approval and national type approval	01/09/2010	01/09/2011	01/09/2015
Registration, sale, entry into service	01/01/2012	01/01/2013	01/09/2016

Emissions levels

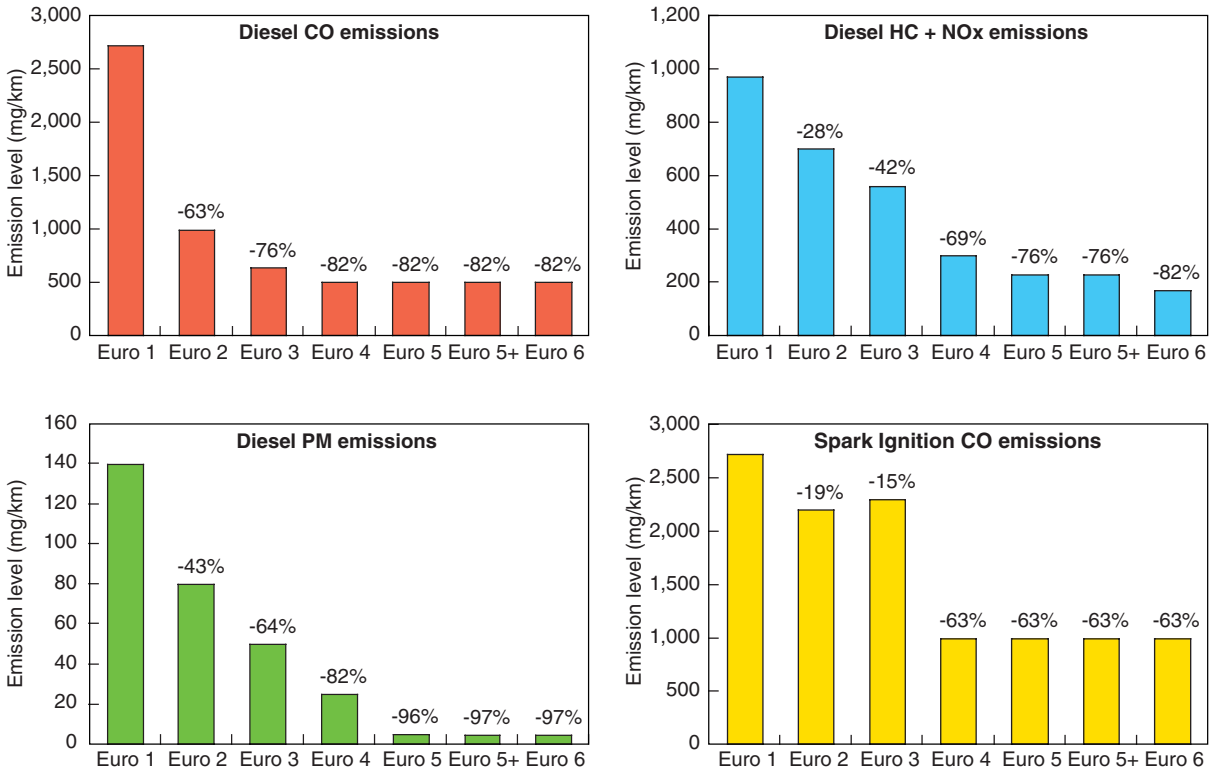
Euro 5 and Euro 6 emission limit values are given in Tables 1 and 2.

As for the reduction of nitrogen oxides from diesel vehicles, the constraints imposed by Euro 5 will be much stricter than those of Euro 4. And the gap between Euro 6 and Euro 5 will be even greater. The Euro 5 nitrogen oxide limit (180 mg) is 28% lower than Euro 4. Euro 6 will represent a sharp decrease in NOx emissions (-55%) from diesel vehicles, compared to Euro 5. For instance, the figures below give the emissions levels imposed by various Euro standards and the difference with the Euro 1 level (expressed as a percentage).

The Euro 5 and Euro 6 standards introduce a drastic reduction (-80%) in particle mass limit values (5 mg/km versus 25 mg/km for a Euro 4 diesel vehicle). In future, gasoline and diesel vehicles will have to comply with the same limits.

As far as hydrocarbon emissions are concerned, the Euro 5 standard proposes for the first time to make a distinction between non-methane hydrocarbons and total hydrocarbons, with a limit of 68 mg/kg for spark ignition vehicles. This is in addition to the total hydrocarbon limit, which remains unchanged at 100 mg/kg.

Fig. 1 - Emissions levels imposed by various Euro standards and the difference with the Euro 1 level (expressed as a percentage)



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With respect to particulate emissions, the Euro 5+ stage imposes a limit of 6.10^{11}/km for the number of particles. A further reduction of particle mass emissions to 4.5 mg/km (versus 5.0 mg/km for Euro 5) is planned.

Besides seeing that type-approval requirements are met with respect to emissions levels, automobile manufacturers must ensure that procedures for verifying conformity of production, the durability of anti-pollution devices and in-use compliance are met. The technical measures adopted by the manufacturer must effectively limit tailpipe emissions and evaporative emissions, in compliance with these regulatory requirements, throughout the normal useful life of the vehicle.

In-use compliance measures shall be checked for a period of up to five years or 100,000 km. Durability testing of pollution control devices shall cover a period of 160,000 km (as opposed to 80,000 previously).

Impact on technologies and motor fuel quality

Emissions standards are always technologically neutral, which means that automobile manufacturers are free to install the emissions reduction systems of their choice. However, substantially reducing vehicle emissions levels means making certain technology choices that must be accompanied by progress in motor fuels.

Euro 1 imposed catalytic converters on gasoline vehicles.

At the same time, progress in optimizing diesel engines led to vehicles that could meet Euro 4 particle limits even without particle filters. The Euro 5 standard, which will take effect in 2009, will nevertheless make this type of filter mandatory.

With the limits on NOx emissions, systems (e.g. Exhaust Gas Recirculation or EGR) have come into general use. New technologies are being or already have been developed, including the NOx trap, selective catalyst reduction (SCR) technology and low NOx emissions engines ("low temperature" combustion).

These technological developments have had to be accompanied by progress in motor fuel quality, to optimize operation of post-treatment systems in place and minimize polluting emissions. In parallel, European directives on motor fuel quality (98/70/EC and 2003/17/EC, relative to Commission decision 2002/159/EC) have been re-evaluated. One notes that:

- There has been a steady and very great reduction in the sulfur content in motor fuels. In 1996, the first limit imposed a maximum content of 500 ppm. When Euro 5 takes effect in 2009, this maximum will be 10 ppm (for gasoline and diesel). This large reduction was necessary to optimize the operation of advanced post-treatment systems (e.g. catalytic converter, NOx trap and particle filter) and reduce particle mass emissions at the source by decreasing particle sulfate content.
- A great deal of attention has been paid to motor fuel composition in the drive to reduce the levels and toxicity of polluting emissions. The following have been limited:
  - Benzene (5% vol. in 1996, 1% vol. since 2000) and aromatics (42% vol. in 2000, 35% vol. in 2005) in gasoline. This is to curb global emissions of hydrocarbon and reduce those of benzene, which is carcinogenic.
  - Olefins in gasoline (18% vol. since 2000). This is to limit the emissions of toxic molecules, such as aldehydes, and help prevent the formation of tropospheric ozone.
  - Polyaromatic hydrocarbons, or PAHs, in diesel (restricted to 11%wt since 2000). This is to limit the soot emissions given off by diesel engines.

Tables 4 and 5

Trend in key diesel specifications

	1993	2000	2005	2009(1) ?
Cetane number, measured/calculated	> 49 / > 46	> 51 / > 46	> 51 / > 46	> 51 / > 46
Sulfur content (mg/kg)	< 2000	< 350	< 50	< 10
PAH content (%wt)	–	< 11	< 11	< 6 ?

Trend in key gasoline specifications

	1993	2000	2005	2009(1) ?
Aromatics content (%vol)	–	< 42	< 35	< 35
Olefins content (%vol)	–	< 18	< 18	< 18
Sulfur content (mg/kg)	< 1 000 / < 500	< 150	< 50	< 10
oxygen (%wt)	–	< 2.7	< 2.7	< 2.7 / < 4 ?(2)

(1) European Parliament draft resolution (December 2007) concerning the revision of Directive 98/70/EC.

(2) The oxygen limit under consideration is 2.7%wt for standard motor fuels and 4%wt for fuels containing 10% ethanol.

The use of biofuels is rising, as the European Union strives to promote alternative fuels. The green paper "Towards a European strategy for the security of energy

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supply" set an objective of replacing 20% of conventional fuels with alternative fuels (using biofuels, natural gas and hydrogen) by 2020. Biofuels were first incorporated into motor fuels in Europe in the early 1980s and a directive on oxygenated compounds was adopted in 1987. This translated into an authorization to add 5% ethanol or 15% ETBE to gasoline. The use of vegetable oil methyl esters (VOMEs) is more recent: France allows the addition of up to 5% VOMEs to diesel for standard distribution. Europe is determined to develop biofuels technology, as evidenced by the ambitious targets specified in Directive 2003/30/EC (5.75% of equivalent energy by 2010). These targets imply that the maximum biofuel concentrations permitted in commercial motor fuels will soon be changing.

Conclusion

The standards applicable to polluting emissions have become increasingly stringent in recent years. The levels of emissions indicated in the draft version of Euro 6 are, in some cases, up to 97% lower than 1996 Euro 1 levels.

Automobile manufacturers have worked hard to comply with these standards and refining companies to supply reformulated motor fuels. The impact on overall air quality has been positive. According to a study of annual average levels of pollution over the last ten years conducted by the association Airparif, which monitors air quality in the Paris area, the situation has improved for air quality in general and for CO, benzene, sulfur dioxide and nitrogen dioxide in particular.

As far as nitrogen oxide emissions are concerned, an emissions inventory by CITEPA (*Centre Interprofessionnel Technique d'Étude de la Pollution Atmosphérique*) show that emissions fell by 694 kt (-37%) between 1991 and 2005. Specifically, transport emissions show a significant decrease since the early 1990s, when the first emissions standards were implemented. The level dropped from 987 kt in 1995 to 524 kt in 2006, despite an increase in the size of the automobile fleet.

With the entry into force of the Euro 5, Euro5+ and Euro 6 standards, the trend towards improved overall air quality can be expected to continue, despite the fact that the fleet is growing and the proportion of diesel vehicles (NOx and particulate emissions) within the fleet is increasing.

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