Vehicle Emission Reductions

ECMT

EUROPEAN CONFERENCE
OF MINISTERS OF TRANSPORT

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The European Conference of Ministers of Transport (ECMT) is an inter-governmental organisation established by a Protocol signed in Brussels on 17 October 1953. It is a forum in which Ministers responsible for transport, and more specifically the inland transport sector, can co-operate on policy. Within this forum, Ministers can openly discuss current problems and agree upon joint approaches aimed at improving the utilisation and at ensuring the rational development of European transport systems of international importance.

At present, the ECMT's role primarily consists of:

– helping to create an integrated transport system throughout the enlarged Europe that is economically and technically efficient, meets the highest possible safety and environmental standards and takes full account of the social dimension;

– helping also to build a bridge between the European Union and the rest of the continent at a political level.

The Council of the Conference comprises the Ministers of Transport of 40 full Member countries: Albania, Austria, Azerbaijan, Belarus, Belgium, Bosnia-Herzegovina, Bulgaria, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, FYR Macedonia, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Moldova, Netherlands, Norway, Poland, Portugal, Romania, the Russian Federation, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine and the United Kingdom. There are six Associate member countries (Australia, Canada, Japan, New Zealand, Republic of Korea and the United States) and two Observer countries (Armenia and Morocco).

A Committee of Deputies, composed of senior civil servants representing Ministers, prepares proposals for consideration by the Council of Ministers. The Committee is assisted by working groups, each of which has a specific mandate.

The issues currently being studied – on which policy decisions by Ministers will be required – include the development and implementation of a pan-European transport policy; the integration of Central and Eastern European Countries into the European transport market; specific issues relating to transport by rail, road and waterway; combined transport; transport and the environment; the social costs of transport; trends in international transport and infrastructure needs; transport for people with mobility handicaps; road safety; traffic management; road traffic information and new communications technologies.

Statistical analyses of trends in traffic and investment are published regularly by the ECMT and provide a clear indication of the situation, on a trimestrial or annual basis, in the transport sector in different European countries.

As part of its research activities, the ECMT holds regular Symposia, Seminars and Round Tables on transport economics issues. Their conclusions serve as a basis for formulating proposals for policy decisions to be submitted to Ministers.

The ECMT's Documentation Service has extensive information available concerning the transport sector. This information is accessible on the ECMT Internet site.

For administrative purposes the ECMT's Secretariat is attached to the Organisation for Economic Co-operation and Development (OECD).

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Further information about the ECMT is available on Internet at the following address:
www.oecd.org/cem

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ECMT remains responsible for any errors in this publication.

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EXECUTIVE SUMMARY

This report provides an overview and comparison of vehicle emissions standards in Europe, Japan, the USA and California. Its purpose is to provide an international context for assessing the outlook for vehicle emissions trends and standards. It describes the impact of vehicle emissions on health and the environment, assesses the adequacy of emissions limits adopted for new passenger car engines and for heavy duty diesel engines, describes emissions control technologies and examines the potential role of removing fuel sulphur in reducing air emissions including carbon dioxide.

The publication draws together three reports approved by the ECMT Council of Ministers: Vehicle Emissions Trends; Monitoring of CO_2 Emissions from New Passenger Cars; and Sulphur Free Fuels.

Air quality problems from vehicle related pollution continue to stimulate innovative pollution control approaches around the world. As these approaches are implemented, steady progress in reducing urban air pollution problems is occurring. An example is the experience in Southern California's Los Angeles Basin, which has had the most aggressive motor vehicle pollution control programme in the world over the past forty years. From 1955 to 1993, peak ozone concentrations were cut in half. The average annual number of days above the Federal carbon monoxide standard fell from 30 to 4.3 between 1977 and 1992 and lead levels are now 98% lower than in the early 1970's. Most remarkably, this achievement occurred while the regional economy out-paced the national economy in total job growth, manufacturing job growth, wage levels and average household income. In short, a strong focus on environmental protection can be compatible with strong economic development.

However, the vehicle population and kilometres travelled by vehicles continues to increase, especially in the rapidly industrialising developing countries of the world. To keep pace with this growth while lowering vehicle pollution even more, the US, Europe and Japan are continuing to develop even tighter controls for coming years. Controls initially introduced in these countries are gradually also being adopted by other countries.

With the recently adopted US national Tier 2 standards and California Low Emissions Vehicle 2 standards, it appears unlikely that any further tightening of light duty vehicle emissions standards will be needed in the USA in the future. The one possible area for additional control of these vehicles is with regard to toxic emissions. US heavy duty engine emissions controls are not yet completed, however, and the Environmental Protection Agency has indicated its intention to substantially tighten requirements during 2000 with the new requirements to be introduced in 2007 approximately. Gasoline fuel sulphur levels have been reduced to an average of 30 ppm but auto manufacturers have indicated that this will not be sufficient and pressure will continue in future years to lower these levels even more. Diesel fuel sulphur levels will likely be reduced in the future; EPA has indicated its intention to propose maximum levels of 15 ppm during the coming year.

While Japan has recently tightened standards, it is expected that additional controls at least for heavy duty engines and fuels will be introduced in approximately 2002 for the 2007 Model Year.

Gasoline sulphur levels are already low but it is expected that efforts to reduce diesel fuel sulphur levels will gain momentum in the next two years.

In Europe, European Union light and heavy duty vehicle and engine standards have been substantially tightened over the past few years and further tightening is not likely in the near future. There has been a conscious decision to set less stringent standards for diesel fuelled cars than for gasoline fuelled cars in recognition of the superior fuel economy potential of diesel vehicles. Gasoline and diesel fuel sulphur levels have been capped at a maximum of 50 ppm by 2005 in the European Union but Germany has indicated that it will seek a maximum diesel fuel sulphur level of 10 ppm by 2007 and the European Commission is expected to make proposals on measures to promote sulphur free fuels during the course of 2001.

One response to reducing greenhouse gases has been to increase the use of highly efficient diesels in the passenger car and light truck sectors. However, these vehicles emit higher amounts of NOx and particulate matter than the gasoline fuelled alternatives and have been linked to increased cancer risks[1]. Further, some evidence indicates that currently applied technologies which reduce the mass of PM emitted may result in an increase in the number of very small particles. Since smaller particles have the potential to be ingested more deeply into the lung than larger particles, they may actually be more hazardous. To offset both the increased cancer risk and the concern with small, ultrafine particles, particle filters will likely be used in the future. Peugeot introduced such filters on certain new car models in 2000. The EU particulate matter standards for 2005 are expected to be met by the use of particle filters on all diesel passenger cars. If it turns out that manufacturers can and do meet the standards without filters, however, it is possible that standards will be tightened further in the future.

No country has adequately addressed the vehicle contribution to carbon dioxide emissions with the result that the fraction of global CO_2 emissions arising from the transport sector is increasing. Europe has taken the lead with a voluntary commitment to reduce new car fuel consumption by 25% over the next decade and Japan is closely following suit. In the US there has been substantial focus on developing advanced vehicle technologies in the laboratory but in reality new car fuel economy continues to decline.

Finally, today's vehicles depend on properly functioning emission controls to keep pollution levels low. Malfunctions in the emission control system can sharply increase emissions. A relatively small number of vehicles with serious malfunctions frequently cause the majority of the vehicle-related pollution problems. Effective inspection and maintenance programmes can identify these problem cars and assure their repair. By assuring good maintenance practices and discouraging tampering and misfueling, inspection and maintenance remains the best demonstrated means for protecting a national investment in emission control technology and achieving the air quality gains which are needed. On-board diagnostics have been introduced in the USA to help ensure better maintenance. On-board diagnostic requirements are being progressively introduced from 2000 in Europe as well. Substantially expanded durability requirements and continued improvements in onboard diagnostic technology are being pushed in the US to shift more of the in use emissions burden to vehicle and engine manufacturers.

Fuel sulphur content has an important bearing on all of these issues. Sulphur affects the performance and durability of many exhaust treatment and on-board diagnostic systems on petrol and diesel vehicles, both cars and trucks. Reducing fuel sulphur cuts emissions of nitrogen oxides, hydrocarbons, particulate matter and carbon monoxide from all vehicles and emissions of ultra fine particles and especially benzene are particularly sensitive to fuel sulphur content.

For new vehicle models, sulphur free fuel will help ensure the latest European emissions standards can be met. For future petrol cars, sulphur free fuel will help ensure significant reductions in CO_2 emissions can be made without exceeding 2005 EURO4 NOx emissions limits. For heavy duty vehicles, sulphur free diesel will improve the prospects of meeting 2005 EURO4 particulate matter emissions standards and expected 2008 EURO5 NOx emissions limits. For light trucks and large diesel passenger cars sulphur free diesel will improve the prospects of meeting EURO4 particulate and NOx emissions standards.

Tax incentives or regulations could play an important role in providing signals to the refining industry to make the investments needed to produce sufficient quantities of sulphur free fuels in good time for markets throughout Europe. Early decisions on providing incentives, or on mandatory fuel sulphur limits, would help refiners contain costs by enabling them to plan investments and plant outages for refurbishment on an optimal path and in conjunction with preparations for meeting intermediate standards already mandated.

This report ends by recommending that all governments examine the value of taking measures for ensuring widespread availability of sulphur free fuels in step with the entry into the market of vehicles that are dependent on sulphur free fuels for compliance with mandatory emissions standards, and recommends promoting the production and distribution of low sulphur and sulphur free fuels as a means to achieve immediate cuts in all the main classes of air emissions from all vehicles, both old and new.

Note

1. The German UBA has carried out a study which concludes that currently produced new diesel cars have more than 10 times higher cancer risk than new gasoline fuelled cars.

Part I.

Vehicle Emission Trends

1. BACKGROUND AND INTRODUCTION

Steady progress in reducing certain air pollution problems is occurring in the US, Europe and Japan. Globally, the use of advanced pollution control technology, especially catalysts has been spreading, as has the use of unleaded gasoline. However, spurred by continued growth in the traffic and lingering air quality problems, in conjunction with newly emerging problems such as toxic emissions and climate modification, the US, Europe, Japan and other countries are introducing tighter emissions controls over the coming years.

The purpose of this report is to review the concerns associated with vehicle emissions, the trends in regulations to address these concerns, the progress made and the likely areas of future concern over public health.

Trends in World Motor Vehicle Fleets

Production of motor vehicles since the end of World War II has risen from about 5 million motor vehicles per year to almost 50 million. Growth in production has been at a rate of 1 million additional vehicles each year. Beyond cars and trucks, motorcycle production has also grown rapidly, especially in Asia.

Since motor vehicle production is increasing at a more rapid rate than vehicle scrappage, worldwide vehicle registrations are growing rapidly and are accelerating. Europe (including Eastern Europe and the USSR) and North America each have about 35% of the world's motor vehicle population with the remainder now divided among Asia, South America, Africa, and Oceania, in that order.

In terms of per capita motor vehicle registration, the United States, Japan, and Europe also account for much the largest share of the ownership and use of motor vehicles. Non-OECD countries in Africa, Asia and Latin America — home to more than four fifths of the world's population — account for only one fifth of world motor vehicle registrations. It is clear that future growth is likely to occur in Asia and Latin America.

"Drivers" Behind Vehicle Fleet Growth

The three primary drivers leading to increases in the world's vehicle fleets are population growth, increased urbanisation and economic improvement.

According to the United Nations, the global population increased from approximately 2.5 billion people in 1950 to 6 billion people in late 1999 and it is projected to increase by an additional 50% to 9 billion by 2050. As illustrated in the table below, this growth will not be evenly distributed but will be concentrated outside of the OECD, in Asia, Africa and Latin America.

Table 1. **Population growth (millions)**

	1950	1998	2050
World	2 521	5 901	8 909
More developed regions	813	1 182	1 155
Less developed regions	1 709	4 719	7 754
Africa	221	749	1 766
Asia	1 402	3 585	5 268
Europe	547	729	628
Latin America and the Caribbean	167	504	809
Northern America	172	305	392
Oceania	13	30	46

Simultaneously, all regions of the world continue to urbanise with the greatest increases expected in Southeast Asia, and South and South West Asia. This is significant since per capita vehicle populations are greater in urban than in rural areas.

Table 2. **Vehicle population per capita**

	% Urban 1999	Annual Growth Rate %
East and North-East Asia	40	2.7
South-East Asia	38	3.4
South and South-West Asia	31	3.1
North and Central Asia	68	0.4
Pacific	70	1.3

According to the OECD, annual GDP growth rates over the next two decades will be highest in China, East Asia, Central and Eastern Europe and the former Soviet Union which will stimulate growth in vehicle populations in these regions.

Table 3. **Annual GDP growth rates**

	1995-2000	2000-2005	2005-2010	2010-2015	2015-2020
Canada, Mexico and United States	2.9	2.5	2	1.6	1.6
Western Europe	2.4	2.6	1.5	1.2	1.2
Central and Eastern Europe	3.6	4.5	4.1	3.6	3.6
Japan and Korea	0.75	2.25	1.5	1	1
Australia and New Zealand	3	3.1	2.2	1.75	1.75
Former Soviet Union	-2.5	3.5	4.5	4	4
China	7.6	5.6	5	4.8	4.8
East Asia	2.4	4.8	4.8	4.5	4.2
Latin America	1.75	3.1	2.9	2.8	2.8
Rest of the World	2.75	3.2	3	3	3

As a result of these factors, one can anticipate a global vehicle population of approximately 2.65 billion by 2020.

Motor Vehicles are a Dominant Pollution Source

Worldwide, cars, trucks, buses, and other motor vehicles continue to play a dominant role in causing air pollution. They are major sources of volatile organic compounds (VOCs) and nitrogen oxides, the precursors to both tropospheric ozone and acid rain; carbon monoxide (CO); toxic air pollutants such as diesel particulate; and chlorofluorocarbons (CFCs).

In the European Union as a whole, on and off road vehicles are the largest source of CO, NOx and non-methane hydrocarbons[1]. Prior to the adoption of the Euro 3/4 requirements, forecasts indicated that vehicles would remain a major emissions source out to 2010. In densely populated urban areas, vehicles can be a major source of exposure to particulates as well. Currently, road vehicles account for 74% of nitrogen oxides and 94% of black smoke emissions in London. On their own, diesels account for 32% and 87% of total emissions (43% and 92% of vehicle emissions) for these two pollutants respectively[2].

Motor vehicles are also major emissions sources in the United States and Japan. In the densely populated North-eastern United States where the air pollution problem is especially severe, the Environment Protection Agency (EPA) has projected that highway vehicles will account for approximately 38% of the total NOx inventory and 22% of the total VOC inventory in 2005, in spite of the introduction of tighter motor vehicle standards in the 1990 Clean Air Act[3]. Further, when focusing on emissions in congested city centres, the importance of vehicle emissions is even greater. One recent study used a chemical mass balance technique to determine the source of the particulate in a midtown Manhattan Street. In this instance, diesel bus emissions appeared to be the primary source.

While not as well documented, it is increasingly clear that motor vehicles are also the major source of pollution problems in the developing world.

2. ENVIRONMENTAL PROBLEMS ASSOCIATED WITH MOTOR VEHICLE EMISSIONS

Cars, trucks, motorcycles, scooters and buses emit significant quantities of carbon monoxide, hydrocarbons, nitrogen oxides and fine particles. Where leaded gasoline is used, vehicles are also a significant source of lead in urban air. The adverse environmental consequences resulting from these pollutants are summarised in the following paragraphs.

Particulate (PM)

Particulate matter is the general term for the mixture of solid particles and liquid droplets found in the air. Particulate matter includes dust, dirt, soot, smoke and liquid droplets. It can be emitted into the air from natural and manmade sources, such as windblown dust, motor vehicles, construction sites, factories, and fires. Particles are also formed in the atmosphere by condensation or the transformation of emitted gases such as sulphur dioxide, nitrogen oxides, and volatile organic compounds.

Scientific studies show a link between particulate matter (alone or in combination with other pollutants in the air) and a series of health effects. Studies of human populations and laboratory studies of animals and humans have established linkages to major human health impacts including respiratory symptoms; aggravation of existing respiratory and cardiovascular disease; alterations in the body's defence systems against foreign materials; damage to lung tissue; carcinogenesis, and premature mortality.

PM also causes damage to materials and soiling; it is a major cause of substantial visibility impairment in many parts of the world.

Motor vehicle particle emissions and the particles formed by the transformation of motor vehicle gaseous emissions tend to be in the fine particle range. Fine particles (those less than 2.5 micrometers in diameter) are of health concern because they easily reach the deepest recesses of the lungs. Scientific studies have linked fine particles (alone or in combination with other air pollutants), with a series of significant health problems, including premature death; respiratory related hospital admissions and emergency room visits; aggravated asthma; acute respiratory symptoms, including aggravated coughing and difficult or painful breathing; chronic bronchitis; and decreased lung function that can be experienced as shortness of breath.

The US Environment Protection Agency (EPA) recently tightened the air quality standards for particulates. The standard for coarse particles (10 microns or less) remains essentially unchanged, while a new standard for fine particles (2.5 microns or less) was set at an annual limit of 15 micrograms per cubic meter and a 24-hour limit of 65 micrograms per cubic meter.

The California Air Resources Board (CARB) has evaluated diesel exhaust as a candidate toxic air contaminant under the State's air toxics identification programme. To evaluate whether or not diesel exhaust causes cancer, the Office of Environmental Health Hazard Assessment (OEHHA) reviewed all controlled animal and mutagenicity studies as well as studies of worker populations exposed to diesel exhaust. They analysed over 30 human studies concerning lung cancer risk and workplace exposure to diesel exhaust. They found that workers who were exposed to diesel exhaust were consistently more likely than others to develop lung cancer. The consistent results are unlikely to be due to chance, confounding, or bias, according to CARB.

As a result, CARB concluded that a reasonable and likely explanation for the increased rates of lung cancer observed in the epidemiological studies is a causal association between diesel exhaust exposure and lung cancer.

Carbon Monoxide (CO)

Carbon monoxide (CO) is a tasteless, odourless, and colourless gas produced though the incomplete combustion of carbon-based fuels. CO enters the bloodstream through the lungs and reduces the delivery of oxygen to the body's organs and tissues. The health threat from exposure to low concentrations of CO is most serious for those who suffer from cardiovascular disease, particularly those with angina or peripheral vascular disease. Healthy individuals also are affected, but only at higher exposure levels. Exposure to elevated CO levels is associated with impairment of visual perception, work capacity, manual dexterity, learning ability and performance of complex tasks.

Nitrogen Oxides (NOx)

NOx emissions produce a wide variety of health and welfare effects. Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infection (such as influenza). NOx emissions are an important precursor to acid rain that may affect both terrestrial and aquatic ecosystems. Atmospheric deposition of nitrogen leads to excess nutrient enrichment problems ("eutrophication") a problem, for example, in the Chesapeake Bay and several other nationally important estuaries along the East and Gulf Coasts of the USA. Eutrophication can produce multiple adverse effects on water quality and the aquatic environment, including increased nuisance and toxic algal blooms, excessive phytoplankton growth, low or no dissolved oxygen in bottom waters, and reduced sunlight causing losses in submerged aquatic vegetation critical for healthy estuarine ecosystems. Nitrogen dioxide and airborne nitrate also contribute to pollutant haze, which impairs visibility and can reduce residential property values and revenues from tourism.

Photochemical Oxidants (Ozone)

Ozone is not emitted directly into the atmosphere, but is formed by a reaction of volatile organic compounds (VOC) — for vehicles mainly hydrocarbons (HC) — and NOx in the presence of heat and sunlight. Ground-level ozone forms readily in the atmosphere, usually during hot summer weather. VOCs are emitted from a variety of sources, including motor vehicles, chemical plants, refineries, factories, consumer and commercial products, and other industrial sources. VOCs are also emitted by natural sources such as vegetation. NOx is emitted from motor vehicles, power plants and other source of combustion. Changing weather patterns contribute to yearly differences in ozone concentrations and differences from city to city. Ozone can also be transported into an area from pollution sources found hundreds of miles upwind.

Ground-level ozone is the prime ingredient of smog, the pollution that blankets many areas during the summer[4]. Short-term exposures (1-3 hours) to high ambient ozone concentrations have been linked to increased hospital admissions and emergency room visits for respiratory problems. Repeated exposures to ozone can exacerbate symptoms and the frequency of episodes for people with respiratory diseases such as asthma. Other health effects attributed to short-term exposures include significant decreases in lung function and increased respiratory symptoms such as chest pain and cough. These effects are generally associated with moderate or heavy exercise or exertion. Those most at risk include children who are active outdoors during the summer, outdoor workers, and people with pre-existing respiratory diseases like asthma. In addition, long-term exposures to ozone may cause irreversible changes in the lungs, which can lead to chronic ageing of the lungs or chronic respiratory disease.

Ambient ozone also affects crop yield, forest growth, and the durability of materials. Because ground-level ozone interferes with the ability of a plant to produce and store food, plants become more susceptible to disease, insect attack, harsh weather and other environmental stresses. Ozone chemically attacks elastomers (natural rubber and certain synthetic polymers), textile fibres and dyes, and, to a lesser extent, paints. For example, elastomers become brittle and crack, and dyes fade after exposure to ozone.

Ozone is also an effective greenhouse gas, both in the stratosphere and the troposphere[5]. That is, ozone absorbs infrared radiation emitting from the earth, captures it before it escapes into space, and re-emits a portion of it back toward the earth's surface. The specific role of ozone in climate change is very complex and not yet well understood. Ozone concentrations in the atmosphere vary spatially, both regionally and vertically, and are most significant in urban areas where precursor gases are abundant. This variability makes assessment of global, long-term trends difficult.

Lead

Over the past century, a range of clinical, epidemiological and toxicological studies have defined the nature of lead toxicity and investigated its mechanisms of action, identifying young children as a critically susceptible population. As noted by the 1995 Environmental Health Criteria Document for Lead, published by the International Programme on Chemical Safety (IPCS), lead affects many organs and organ systems in the human body with sub-cellular changes and neuro-developmental effects appearing to be the most sensitive. The most substantial evidence from cross sectional and prospective studies of populations with lead levels generally below 25 µg/decilitre of blood relates to reductions in intelligence quotient (IQ).

As noted by the IPCS, existing epidemiological studies do not provide definitive evidence of a threshold. Below the range of about 10-15 µg /decilitre of blood, the effects of confounding variables and limits in the precision in analytical and psychometric measurements increase the uncertainty attached to any estimate of effect. However, there is some evidence of an association below this range. Animal studies provide support for a causal relationship between lead and nervous system effects, reporting deficits in cognitive functions at lead levels as low as 11-15 µg/decilitre of blood which can persist well beyond the termination of lead exposure. Other effects, which may occur, include:

- impaired sensory motor function;
- impaired renal function;
- a small increase in blood pressure has been associated with lead exposure;
- some but not all epidemiological studies show a dose dependent association of pre-term delivery and some indices of foetal growth and maturation at blood lead levels of 15 µg/decilitre or more.

Lead and its compounds may enter the environment at any point during mining, smelting, processing, use, recycling or disposal. In countries where leaded gasoline is still used, the major air emission is from mobile and stationary combustion of gasoline. Areas in the vicinity of lead mines and smelters are subject to high levels of air emissions.

Airborne lead can be deposited on soil and water, thus reaching humans through the food chain and in drinking water. Atmospheric lead is also a major source of lead in household dust.

Because of the concerns highlighted above, a global consensus has emerged to phase out the use of lead in gasoline[6].

In December 1994, at the Summit of the Americas, heads of state from a number of countries pledged to develop national action plans for the phase out of leaded gasoline in the Western Hemisphere.

In May 1996, the World Bank called for a global phase out of leaded gasoline and offered to help countries design feasible phase out schedules and incentive frameworks.

A key recommendation of the Third "Environment for Europe" Ministerial Conference held in Sofia, Bulgaria in October 1995 called for the reduction and ultimate phase out of lead in gasoline.

In June 1996, the second United Nations Conference on Human Settlements, called Habitat II, included the elimination of lead from gasoline as a goal in its agenda.

In May 1997, environmental ministers from the Group of Seven plus Russia endorsed the phase out of leaded gasoline in the 1997 Declaration of Environmental Leaders of the Eight on Children's Environmental Health.

Lead Scavengers

When lead additives were first discovered to improve gasoline octane quality, they were also found to cause many problems with vehicles. Notable among these was a very significant build up of deposits in the combustion chamber and on spark plugs, which caused durability problems. To relieve these problems, lead scavengers were added to gasoline at the same time as the lead to encourage greater volatility in the lead combustion by-products so they would be exhausted from the vehicle. These scavengers continue to be used today with leaded gasoline.

Ultimately, significant portions of these additives are emitted from vehicles. This is important because, unfortunately, the National Cancer Institute has found these lead scavengers, most notably ethylene dibromide, to be carcinogenic in animals and have been identified as potential human carcinogens[7]. Therefore, their removal along with the removal of lead may result in significant benefits to health.

Other Toxic Emissions

The 1990 Clean Air Act (CAA) directed the US EPA to complete a study of emissions of toxic air pollutants associated with motor vehicles and motor vehicle fuels. The study identified an aggregate cancer risk from exposure to vehicle emissions. It found that in 1990, the aggregate risk is 720 cancer cases in the US. For all years, 1.3-butadiene is responsible for the majority of the cancer incidence, ranging from 58 to 72% of the total risk from exposure to toxic motor vehicle emissions. This is due to the high unit risk of exposure to 1.3-butadiene.

Polycyclic organic matter (POM) accounts for the second largest cancer risk from exposure to vehicle emissions. Particulate matter emissions correlate with POM emissions and gasoline and diesel motor vehicles have roughly equal risk profiles in respect of POMs. The combined risk from gasoline and diesel particulate matter ranged from 16 to 28% of the total risk from exposure to toxic motor vehicle emissions, depending on the year examined. Benzene is responsible for roughly 10% of the total for all years. Aldehydes, predominately formaldehyde, are responsible for roughly 4% of the total for all years.

Within the last several months, two reports have become available that characterise the actual and projected exposures for a large number of chemicals found in ambient air and compare these ambient air levels with health-derived guidance levels. Toxic air pollutants typically associated with mobile sources were found at elevated levels exceeding a one-in-ten-thousand cancer risk. These new monitoring studies indicate that EPA's Motor Vehicle-Related Air Toxics Study may understate the problem.

In February 1998 the Vermont Agency of Natural Resources issued a report that included a comparison of the state's health-based ambient air standards with findings from state monitoring sites measured from 1993-1998. The comparison showed that monitored levels of some contaminants greatly exceeded health based air standards. Contaminants from mobile sources were significantly higher in urban sites than in rural areas.

In April and May 1998, EPA scientists published two peer-reviewed articles based on EPA's Cumulative Exposure Project, which found that in 1990, twenty million people in the United States were exposed to concentrations of air toxics in excess of a one in ten thousand cancer risk level. These findings were based on modelled emissions data of hazardous air pollutants that were then verified by ambient air quality monitoring data. The EPA study showed findings similar to those in Vermont.

The table below provides a comparison of the Vermont and EPA findings for six contaminants associated with mobile sources. In most cases, actual measured ambient air levels in Vermont (a state with relatively few sources) are within an order of magnitude of the highest modelled census tracts nationally. The health based standards determined by the Vermont Department of Health and peer reviewed by public health scientists are virtually the same as the health standards estimated by EPA scientists.

Table 4. **Comparison of ambient toxics and public health standards (micrograms/cubic meter)**

Air toxic	**Air levels monitored or modelled**		**Health standards**	
	Vermont (Max. annual average)	EPA (Modelled max. census tract)	Vermont health standard	EPA Bench mark estimate
Benzene	4.05	79	0.12	0.12
1.3 butadiene	0.95	6.7	0.0019	0.0036
Formaldehyde	10.2	52	0.078	0.077
Acetaldehyde	4.65	21	0.45	0.45
Xylene	8.09	72	1033	300
Toluene	11.87	89	400	400

The Vermont study and EPA's Cumulative Exposure Project suggest two general conclusions.

- Risks from mobile sources related ambient air toxics are in the range of public health concern.
- Even small urban centres are at risk from mobile source air toxics.

Climate Change

Beyond direct adverse health effects, there are other concerns with vehicle emissions. Among these is global warming or the greenhouse effect. Greenhouse warming occurs when certain gases allow sunlight to penetrate to the earth but partially trap the planet's radiated infrared heat in the atmosphere. Some such warming is natural and necessary. If there were no water vapour, carbon dioxide, methane, and other infrared absorbing (greenhouse) gases in the atmosphere trapping the earth's radiant heat, our planet would be about 60°F (33°C) colder, and life as we know it would not be possible. Naturally occurring greenhouse gases include water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3).

Several classes of halogenated substances that contain fluorine, chlorine, or bromine are also greenhouse gases, but they are, for the most part, solely a product of industrial activities. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are halocarbons that contain chlorine, while halocarbons that contain bromine are referred to as halons. Other fluorine containing halogenated substances include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6).

There are also several gases that, although they do not have a direct global warming effect, do influence the formation and destruction of ozone, which does have such a terrestrial radiation absorbing effect. These gases include carbon monoxide (CO), oxides of nitrogen (NO_X), and nonmethane volatile organic compounds (NMVOCs).

Aerosols, extremely small particles or liquid droplets often produced by emissions of sulphur dioxide (SO_2), can also affect the absorptive characteristics of the atmosphere.

Although CO_2, CH_4, and N_2O occur naturally in the atmosphere, the atmospheric concentration of each of them has risen, largely as a result of human activities. Since 1800, atmospheric concentrations of these greenhouse gases have increased by 30, 145, and 15%, respectively (IPCC 1996). This build-up has altered the composition of the earth’s atmosphere, and may affect the global climate system.

Beginning in the 1950s, the use of CFCs and other ozone depleting substances (ODSs) increased by nearly 10% a year, until the mid-1980s when international concern about ozone depletion led to the signing of the Montreal Protocol. Since then, the consumption of ODSs has rapidly declined, as they are phased-out. In contrast, use of ODS substitutes such as HFCs, PFCs, and SF_6 has grown significantly and all have strong greenhouse forcing effects.

Over the past few centuries, however, human activities have increased atmospheric concentrations of naturally occurring greenhouse gases and added new and very powerful infrared absorbing gases to the mixture. Even more disturbing, in recent decades the atmosphere has begun to change through human activities at dramatically accelerated rates. According to a growing scientific consensus, if current emissions trends continue, the atmospheric build up of greenhouse gases released by fossil fuel burning, as well as industrial, agricultural, and forestry activities, is likely to turn our benign atmospheric "greenhouse" into a progressively warmer "heat trap", as Norway’s former Prime Minister, Ms. Gro Harlem Brundtland, has termed this overheating.

In late November 1995, the IPCC Working Group 1 concluded, “the balance of evidence suggests that there is a discernible human influence on global climate.” In December 1997, acting on this consensus, countries around the world approved the Kyoto Protocol to the 1992 Climate Change Treaty. Key aspects of the agreement include:

REDUCTIONS: Thirty-eight industrialised nations are required to reduce their “greenhouse” gas emissions from 1990 levels between 2008 and 2012. The European Union would reduce them by 8%, the United States by 7% and Japan by 6%. Some would face smaller reductions, and a few would not face any now. As a group, the industrialised nations would cut back on the emissions of such gases by just more than 5%.

GASES INVOLVED: Emissions of six gases would be affected: carbon dioxide, methane, nitrous oxide, and three halocarbons used as substitutes for ozone-damaging chlorofluorocarbons.

'**OFFSHORE' REDUCTIONS:** Countries that do not meet their own emission targets can strike deals with nations that do better than required, to buy the excess "quota". This may encourage reductions to be made where most cost-effective.

ENFORCEMENT: A later meeting of the treaty parties will decide on "appropriate and effective" ways to deal with non-compliance.

DEVELOPING COUNTRIES: Developing countries, including major greenhouse gas emitters such as China and India, are asked to set voluntary reduction targets.

NEXT STEP: The accord approved by the Kyoto conference takes effect once it is ratified by 55 nations, representing 55% of 1990 carbon dioxide emissions. It is binding on individual countries only after their governments' complete ratification.

Implementing this agreement will require significant improvements in fuel economy and carbon dioxide emissions from vehicles.

3. EU, US AND JAPANESE EMISSIONS CONTROL PROGRAMMES

Rapid progress in emissions controls

Legislators in most regions of the world have been significantly tightening their motor vehicle regulations to address the environment and health concerns described above. Major recent developments are summarised below.

European Union

The European Commission set up the European Auto-Oil Programme in 1994 with the European associations for the car industry (ACEA) and the oil industry (Europia), to provide the technical basis for the development of EU policy towards road vehicle emissions. The first phase of the programme was completed in 1996 and following two years of refinement, a three-part dossier to further reduce pollution from road transport in the Community was agreed, in 1998, by the European Parliament and the Council of Environment Ministers. The three dossiers cover:

- measures to be taken against air pollution by emissions from passenger cars (amendment of Directive 70/220/EEC);
- measures to be taken against air pollution by emissions from light commercial vehicles (pick up trucks, delivery vans etc.), amending the same Directive;
- the quality of petrol and diesel fuels (amendment to Directive 93/12/EC).

Overall the Auto Oil programme has five sections:

- fuel quality;
- emissions from private cars;
- emissions from light commercial vehicles;
- emissions from heavy goods vehicles;
- adaptation of provisions relating to roadworthiness testing.

More specifically, the directives aim at:

- Controlling those parameters in the composition of petrol and diesel that influence the level of atmospheric emissions, in particular sulphur, benzene, aromatics and lead;

- Reducing the limit values for certain pollutants in new vehicle models being brought onto the market.

- In addition, improved control of the day-to-day emissions of vehicles in use is to be achieved by the mandatory fitting of on-board diagnostic systems, the introduction of a new testing procedure and a new test to limit evaporative emissions.

The resulting directives are interlinked, as the quality of fuel has a significant impact on emissions, in particular as regards the use of catalysts. They will therefore enter into force simultaneously on 1 January 2000.

The standards for passenger cars and Class 1 light commercial vehicles are identical. However, heavier light trucks in classes 2 and 3 have more lenient standards in relation to their weight.

With regard to heavy goods vehicles, the initial Commission proposal was modified by the Council and in November 1999 was approved by the Parliament; the proposal from the Commission regarding roadworthiness testing is still pending.

Annex A provides an overview of the recent European decisions regarding vehicles and fuels.

United States

The Clean Air Act Amendments of 1990 largely determined current vehicle emissions requirements in the US with the major highlights summarised in Annex B. The US EPA has recently adopted the so-called Tier 2 requirements for cars and light trucks, which reduce emissions limits, and lowered the sulphur content of gasoline to an average of 30 ppm.

Most notable has been the decisions to require both cars and light trucks (up to 10 000 lbs. GVW) to ultimately achieve the same emissions standards and to require gasoline and diesel fuelled vehicles to achieve the same standards.

The US EPA has also announced its intention to substantially tighten heavy-duty truck and bus standards and diesel fuel sulphur levels in the coming year.

California

Because it has traditionally had the most serious air pollution problem in the United States, and because it began to regulate vehicle emissions earlier than the Federal government, California has been treated differently than other states in the US Clean Air Act and authorised to adopt its own unique vehicle emissions control programme as long as this programme is at least as protective of public health as the national programme. Other states have the option of adopting either the California or the Federal programmes but are not permitted to set their own unique requirements. Both New York and Massachusetts have in recent years chosen to implement the California requirements.

With regard to controlling emissions from light duty vehicles, California has traditionally been several years ahead of the US EPA, especially with regard to nitrogen oxides and hydrocarbons. Its Low Emissions Vehicle (LEV) programme and recently adopted LEV2 programme have included not only stringent emissions standards but also specific requirements for sales of advanced technology vehicles such as battery electric and fuel cell powered cars. Details of the California programme are contained in Annex C.

Japan

Japanese standards for passenger cars fuelled by gasoline or LPG were stable for approximately 20 years until they were recently tightened. Diesel vehicle controls tended to lag both Europe and the United States until the mid 1990's when tighter regulations began to be phased in. Further restrictions on heavy-duty diesels were adopted in late 1998. Details of the Japanese vehicle emissions regulations are summarised in Annex D.

Rest of the World

Many developing countries around the world have taken advantage of the technologies developed in the developed world. One measure of this is that almost 80% of all new cars produced last year were equipped with catalytic converters. About 80% of all gasoline sold worldwide was unleaded.

Comparison of EU, US and Japanese Programmes

Clearly substantial reductions in emissions are occurring from new vehicles in the major OECD countries of the world. However, because each region uses different test procedures, it is difficult to make precise comparisons regarding their relative stringency. Ignoring the test procedure question, the Tables and Figures below summarise the passenger car and heavy truck requirements in each region for nitrogen oxides and particulate.

Table 5. **Passenger car emissions' standards**
Nitrogen oxides (gasoline)

		Year of introduction	g/km	Useful life (km)
US national	**Tier 1**	1994	0.373	160 000
	NLEV [a]	2001	0.186	160 000
	Tier 2 [b]	2004	0.043	193 080
California	**TLEV** [c]	1994	0.373	160 000
	LEV	1994	0.186	160 000
	ULEV	1994	0.186	160 000
	LEV2 [d]	2004	0.043	193 080
	ULEV2	2004	0.043	193 080
	SULEV	2004	0.012	193 080
Japan	**Japan 2000**	2000	0.080	80 000
EU	**Euro 3**	2000	0.150	80 000
	Euro 4	2005	0.080	100 000

a. The National Low Emission Vehicle standards will be phased in in a few north-east states starting in 1999; nationally they go into effect in 2001.

b. Tier 2 standards will be phased in beginning in 2004 in order to comply with EPA's declining fleet average NOx standard as described in Annex B. 100% of the passenger car and light truck fleet operating on both diesel and gasoline will be required to comply on average by 2007; 100% of heavier trucks up to 10.000 lbs. will comply by 2009.

c. California's TLEV, LEV and ULEV standards are phased in by each manufacturer in a manner sufficient to comply with the fleet average NMOG standard described in Annex C.

d. California's LEV2, ULEV2 and SULEV will be phased in beginning in 2004 by each manufacturer in a manner sufficient to comply with the declining fleet average NMOG standard described in Annex C.

This table indicates that the NOx standards for passenger cars will become quite low in all three regions by 2005. However, the durability requirements in Europe and Japan appear to still be substantially lower than the actual lifetime of new cars.

Table 6. **Passenger Car Emissions Standards**
Nitrogen Oxides (Diesel)

		Year of Introduction	g/km	Useful Life (km)
US national	**Tier 1**	1994	0.777	160 000
	NLEV [a]	2001	0.186	160 000
	Tier 2 [b]	2004	0.043	193 080
California	**TLEV** [c]	1994	0.373	160 000
	LEV	1994	0.186	160 000
	ULEV	1994	0.186	160 000
	LEV2 [d]	2004	0.043	193 080
	ULEV2	2004	0.043	193 080
	SULEV	2004	0.012	193 080
Japan	**Japan 2002**	2002	0.280	80 000
E.U.	**Euro 3**	2000	0.500	80 000
	Euro 4	2005	0.250	100 000

a. These will be phased in a few Northeast states starting in 1999; nationally they go into effect in 2001.
b. Tier 2 standards will be phased in beginning in 2004 in order to comply with EPA's declining fleet average NOx standard as described in Annex B. 100% of the passenger car and light truck fleet operating on both diesel and gasoline will be required to comply on average by 2007; 100% of heavier trucks up to 10.000 lbs. will comply by 2009.
c. California's TLEV, LEV and ULEV standards are phased in by each manufacturer in a manner sufficient to comply with the fleet average NMOG standard described in Annex C.
d. California's LEV2, ULEV2 and SULEV will be phased in beginning in 2004 by each manufacturer in a manner sufficient to comply with the declining fleet average NMOG standard described in Annex C.

With regard to diesel powered passenger cars, it is clear that the EU and Japan, while substantially tightening their requirements over the next several years, will maintain substantially weaker NOx requirements than for petrol fuelled vehicles, unlike the USA. The same is true for particulate requirements as summarised in the table below.

Table 7. **Passenger Car Emission Standards**
Particulate Matter (Diesel)

		Year of Introduction	g/km	Useful Life (km)
US national	**Tier 1**	1994	0.062	160 000
	NLEV [a]	2001	0.050	160 000
	Tier 2 [b]	2004	0.006	193 080
California	**TLEV** [c]	1994	0.050	160 000
	LEV	1994	0.050	160 000
	ULEV	1994	0.025	160 000
	LEV2 [d]	2004	0.006	193 080
	ULEV2	2004	0.006	193 080
	SULEV	2004	0.006	193 080
Japan	**Japan 2002**	2002	0.052	80 000
E.U.	**Euro 3**	2000	0.050	80 000
	Euro 4	2005	0.025	100 000

a. These will be phased in a few Northeast states starting in 1999; nationally they go into effect in 2001.
b. Tier 2 standards will be phased in beginning in 2004 in order to comply with EPA's declining fleet average NOx standard as described in Annex B. 100% of the passenger car and light truck fleet operating on both diesel and gasoline will be required to comply on average by 2007; 100% of heavier trucks up to 10.000 lbs. will comply by 2009.
c. California's TLEV, LEV and ULEV standards are phased in by each manufacturer in a manner sufficient to comply with the fleet average NMOG standard described in Annex C.
d. California's LEV2, ULEV2 and SULEV will be phased in beginning in 2004 by each manufacturer in a manner sufficient to comply with the declining fleet average NMOG standard described in Annex C.

Great progress in reducing heavy-duty vehicle and engine emissions is also occurring as is illustrated in the tables below.

It seems clear that in contrast to auto standards, the EU has adopted the most stringent heavy-duty requirements in the world. The US EPA has indicated its intention to adopt an additional round of heavy-duty requirements during the next year but until it does so it will lag the EU requirements significantly.

Table 8. **Heavy-duty diesel NOx standards**
(g/kw-hr)

Model Year	US	Likely US proposal	EU[a]	Japan
1990	8.2		15.8	
1991	7.2		15.8	
1992	7.2		15.8	
1993	7.2		9	
1994	7.2		9	6
1995	7.2		9	6
1996	7.2		7	6
1997	7.2		7	6
1998	5.8		7	4.5
1999	5.8		7	4.5
2000	5.8		5	4.5
2001	5.8		5	4.5
2002	5.8		5	4.5
2003	2.9		5	3.38
2004	2.9		5	3.38
2005	2.9		3.5	3.38
2006	2.9		3.5	3.38
2007		0.16	3.5	3.38
2008		0.16	2	3.38
2009		0.16	2	3.38
2010		0.16	2	3.38

a. Euro 3 from 2005 and Euro 4 from 2008.

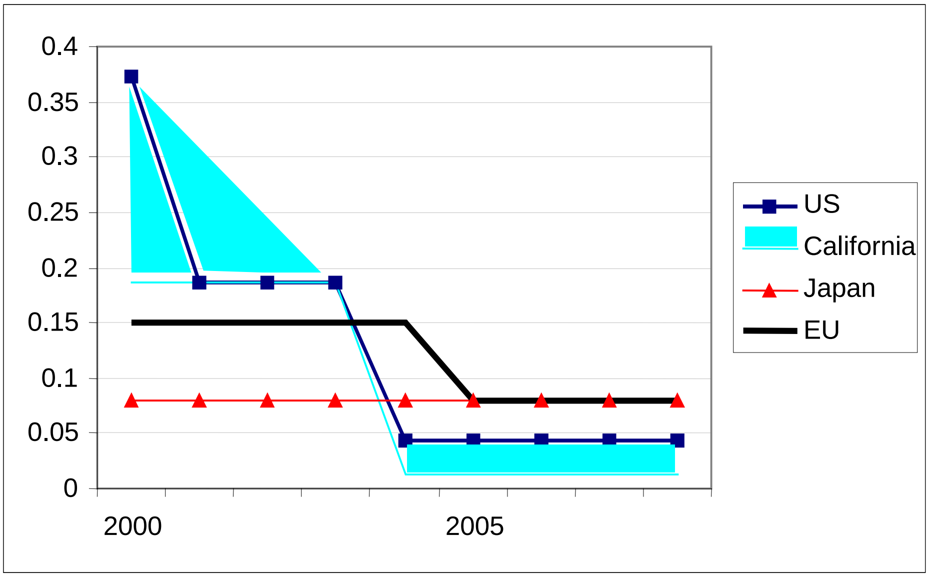
Table 9. **Heavy-duty diesel PM standards**
(g/kw-hr)

Model Year	US Trucks	Likely US proposal	US Buses	EU[a]	Japan
1993	0.3		0.15	0.4	
1994	0.15		0.105	0.4	
1995	0.15		0.105	0.4	
1996	0.15		0.075	0.15	0.25
1997	0.15		0.075	0.15	0.25
1998	0.15		0.075	0.15	0.25
1999	0.15		0.075	0.15	0.25
2000	0.15		0.075	0.1	0.25
2001	0.15		0.075	0.1	0.25
2002	0.15		0.075	0.1	0.25
2003	0.15		0.075	0.1	0.18
2004	0.15		0.075	0.1	0.18
2005	0.15		0.075	0.02	0.18
2006	0.15		0.075	0.02	0.18
2007		0.075	0.0075	0.02	0.18
2008		0.075	0.0075	0.02	0.18
2009		0.075	0.0075	0.02	0.18
2010		0.075	0.0075	0.02	0.18

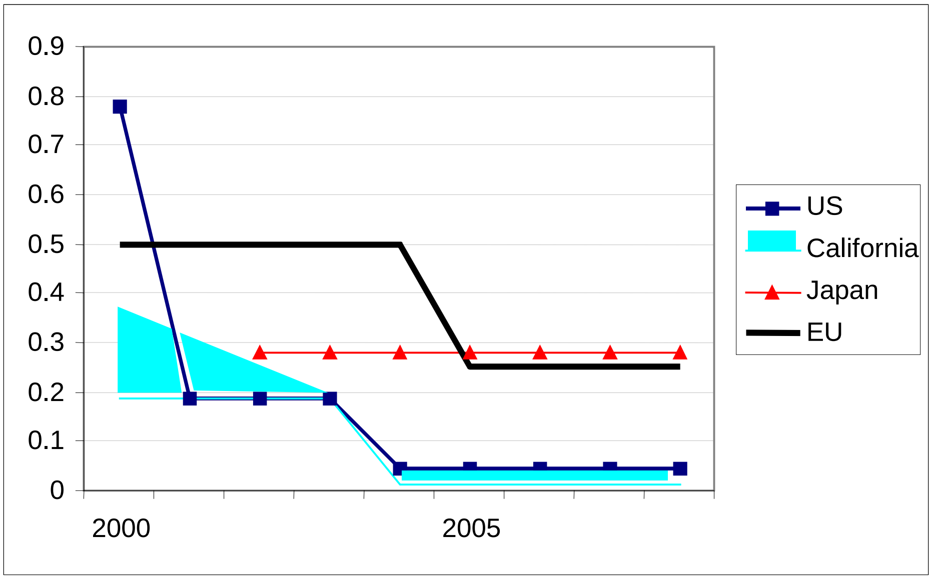
a. Euro 3 from 2005 and Euro 4 from 2008.

Figure 1. **Comparison of passenger car emissions standards in the EU, USA and Japan**

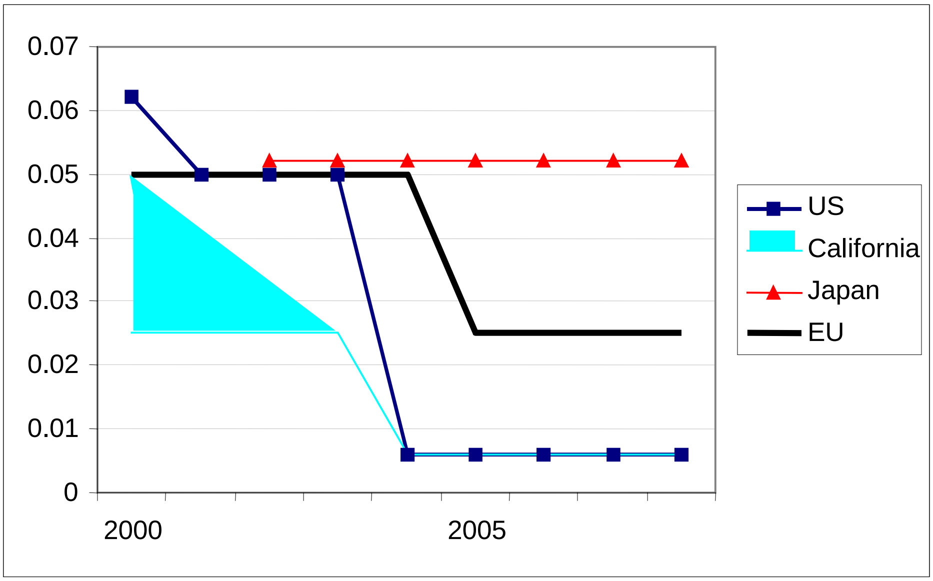
Nitrogen oxide limits
(g/km for petrol engine)



Nitrogen oxide limits
g/km for diesel engines



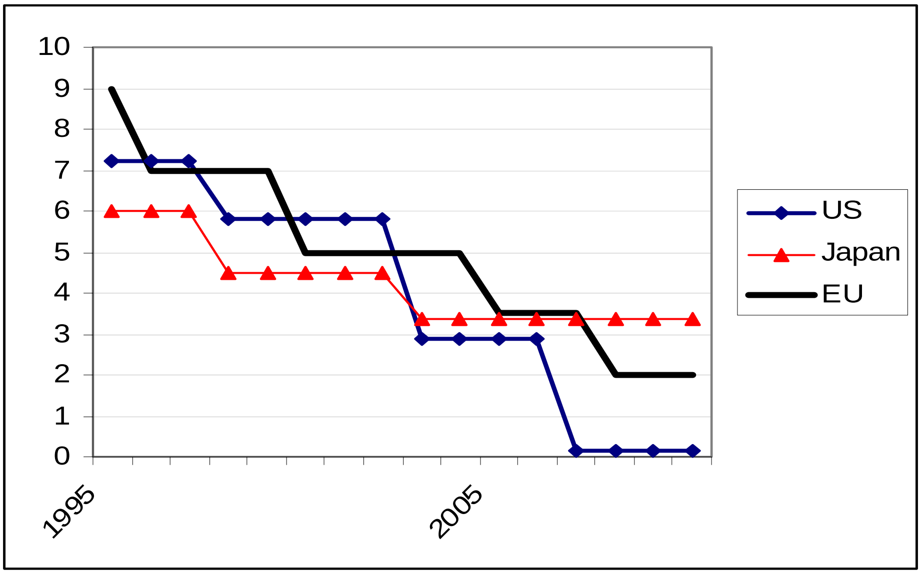
Particulate matter limits
g/km for diesel engines



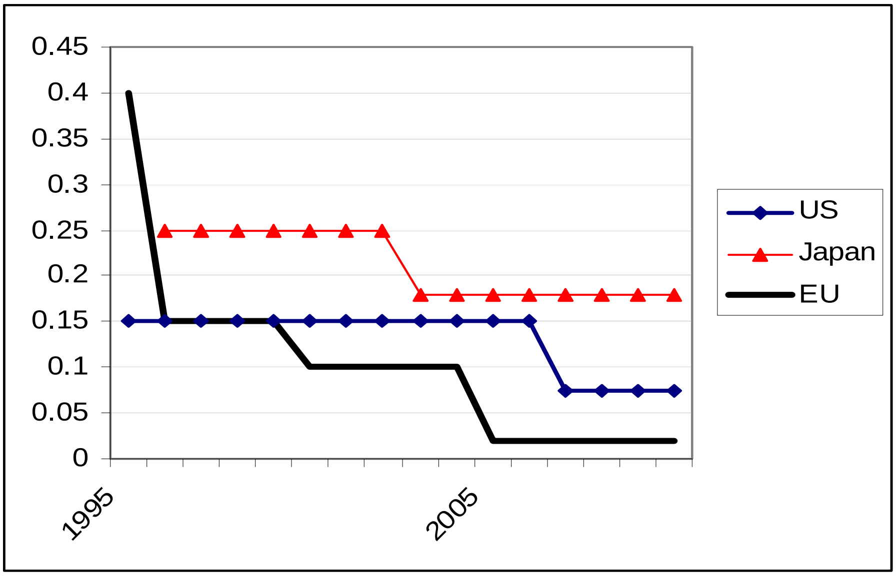
Source: ECMT, 2001.

Figure 2. **Comparison of heavy-duty diesel emissions standards in the EU, USA and Japan**

Nitrogen oxide limits
g/kWh



Particulate matter limits
g/kWh



Source: ECMT, 2001.

Note: Californian passenger car regulations set two emissions limit levels. All vehicles must meet the upper limit, with a series of quotas that increase over time for the proportion of vehicles that must meet the lower limit.

4. PROGRESS IN REDUCING EMISSIONS AND IMPROVING AIR QUALITY

As these approaches are implemented, steady progress in reducing certain air pollution problems is occurring. An example is the experience in Southern California's Los Angeles Basin, which has had the most aggressive motor vehicle pollution control programme in the world over the past forty years[8]. From 1955 to 1993, peak ozone concentrations were cut in half. The number of days on which Federal ozone standards were exceeded fell by 50% from the 1976-78 time frame to the 1991-1993 interval. The average annual number of days above the Federal carbon monoxide standard fell from 30 to 4.3 during this same period and lead levels are now 98% lower than in the early 1970's. Most remarkably, this achievement occurred while the regional economy out-paced the national economy in total job growth, manufacturing job growth, wage levels and average household income. In short, a strong focus on environmental protection is not only not incompatible with strong economic development, they seem to be mutually reinforcing.

On a US national level, emissions of almost all pollutants are down significantly over a similar time frame in spite of a more than doubling in vehicle miles travelled and gross domestic product (GDP).

Similar reductions are beginning to occur in Europe and forecasts indicate much lower levels in the future in spite of continued growth. For example, the German Umweltbundesamt has developed an emissions model reflecting the in use performance of vehicles in Germany. Using this model, Dr. Ulrich Hoepfner has developed emissions estimates for the country as shown in the Table below.

Table 10. **Emissions from cars in Germany**

	1980 Emissions	**1995 Emissions with Catalysts**	**1995 Emissions without Catalysts**
CO	100%	39%	82%
HC	100%	45%	113%
NOx	100%	57%	119%
Km	100%	148%	148%

Based on this analysis, the following conclusions seem appropriate:

– In spite of an approximately 50% increase in kilometres driven since 1980, emissions of CO, HC and NOx from cars have been cut approximately in half.

– Especially striking has been the improvement due to catalytic converters since 1985. Without catalysts, i.e. by retaining the ECE 15-04 requirements only, CO emissions would have declined slightly but HC and NOx emissions would have actually increased.

5. REMAINING CHALLENGES

While substantial progress has occurred in reducing vehicle emissions and further improvements in air quality are expected in coming years in most major industrialised countries, significant problems remain which require additional action beyond that noted above. Three of these problems will be discussed below.

Particulate emissions

While all regulation of diesel particulate emissions from vehicles is based on the mass of particulate matter emitted, several studies in recent years in the United Kingdom, Switzerland and the US have increased concern with the number of very small ultrafine particles emitted[9]. Modern engines, which produce a smaller mass of particulate emissions, may actually emit larger numbers of particles (of smaller size) than older designs. This raises concerns that the form of future regulations should focus more on the number of particles emitted, in addition to or as an alternative to their mass. Additional studies indicate that large numbers of ultrafine particles may also be emitted by gasoline and CNG fuelled vehicles, at least at high speeds and loads, and especially from the more fuel-efficient direct injection technology[10].

Studies are underway to characterise the size distribution of particles in ambient air as well as to understand the health consequences of these particles. Depending on the results of these studies, future vehicle regulation may focus more on particle numbers. In practice, however, this may not be necessary if the agreed mass based standards result in the use of particulate filters or traps. Studies consistently show that these devices successfully reduce both the mass and the number of particles.

Beyond the size concerns, studies indicate that diesel PM may be carcinogenic. Increased sales of light duty diesel vehicles, which is occurring in much of Europe, may therefore exacerbate the overall cancer risk. The German UBA has carried out a study which concludes that currently produced new diesel cars have more than 10 times higher cancer risk than new gasoline fuelled cars and the difference in relative risk factors will be even greater when Euro 3 standards go into effect next year. However, according to UBA, diesel cars complying with the Euro 4 (2005) vehicle emissions standards **if equipped with a particulate filter system** would have almost the equivalent cancer risk as a gasoline fuelled car meeting the same standards. As summarised below, they conclude that the relative cancer risk would be only approximately twice as high as from the gasoline-fuelled car.

Otto w/o Catalyst 1992	4.5
Euro 2	11.3
Euro 3	17.5
Euro 4	14.7
Euro 4 with Particle Filter	1.9

Similarly, new heavy-duty diesel equipped with PM filters and meeting Euro 4 standards would be four times higher carcinogenic potential compared to a CNG fuelled vehicle as summarised below, compared to almost 40 times higher today.

Conventional	117
Euro 2	38
Euro 3	24
Euro 4	13
Euro 4 with Particle Filter	3.8

It appears that at least some diesel cars could comply with the Euro 4 emissions standards without the use of particle filters but one manufacturer, Peugeot has indicated that it will voluntarily introduce PM filters on some models next year. If other manufacturers follow suit, the concerns with ultrafine PM and increased cancer risks may be resolved; however, if they do not it is likely that additional diesel regulation will follow.

Global warming

The greenhouse gases most closely identified with the transportation sector include carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). Relative to CO_2, N_2O and CH_4 have the following global warming potentials relative to carbon dioxide.

Table 11. **Global warming potentials relative to CO_2**

IPCC GWP	Methane (CH_4)	Nitrous Oxide (N_2O)
20 Year Horizon	56	280
100 Year Horizon	21	310
500 Year Horizon	6.5	170

However, it is important to note that other vehicle related pollutants contribute to global warming although their quantification has been more difficult. These include CO, NMHC and NO_2. According to the original (1990) IPCC report, the following global warming potentials were attributed to these gases. Because of difficulty reaching agreement on the appropriate quantification, specific GWPs for these gases were not contained in the most recent IPCC report.

Table 12. **Global warming potentials attributed to CO, NMHC and NO_2**

GWP	CO	NMHC	NO_2
20 Year Horizon	7	31	30
100 Year Horizon	3	11	7
500 Year Horizon	2	6	2

Another approach to quantifying the relative importance of the different greenhouse gases is based on an economic damage index (EDI) for each pollutant. Using this approach, the relative ranking of the various gases as determined by Delucchi is summarised in the table below.

Table 13. **Economic damage index (EDI) of greenhouse gases**

CO_2	CH4	N2O	CO	NMHC	NO_2
1	22	355	2.0	3.67/1.5	2.8

In most countries, over 90% of the global warming potential of the direct acting greenhouse gases from the transportation sector come from carbon dioxide. The transportation sector is responsible for approximately 17% of global carbon dioxide emissions and these emissions are increasing in virtually every part of the world.

European Efforts

CO_2 from passenger cars accounts for about half of CO_2 emissions from Transport, and about 12% of total CO_2 emissions in the European Union[11]. Under a "business as usual" scenario, CO_2 emissions from cars are expected to increase over 1990 levels by about 20% by 2000 and by about 36% by 2010. In one year, an average medium size car in the European Union emits some 3 tons of CO_2[12]. The road transport sector has stood out in recent years as one of the few sectors in the Union experiencing CO_2 emissions growth.

The European vehicle industry has recently adopted voluntary reductions in vehicle CO_2 emissions. ACEA's board of directors adopted an emissions reduction target of 140 g/km of CO_2 for new cars by 2008, a 25% reduction from 1995 levels.

ACEA also vowed to debut new cars emitting 120 g/km of CO_2 or less by the year 2000, review by 2003 the feasibility of further reduction by 2012 towards 120 g/km of CO_2 for all new cars, set a estimated target range of 165-170 g/km of CO_2 for 2003 and establish a joint European Union/industry monitoring system for sharing achievements in CO_2 reduction.

US Efforts

The trends in U.S. greenhouse gas emissions and sinks for 1990 through 1996 are summarised in Annex E. Total U.S. greenhouse gas emissions rose 9.5% in 1996 from 1990 baseline levels, to 1 788.0 MMTCE. The largest single year increase in emissions over this time period was registered in 1996 (57 MMTCE or 3.3%).

Emissions of CO_2 from fossil fuel combustion grew by 9% (118.9 MMTCE) over the seven year period and were responsible for over two-thirds of the increase in national emissions. The largest annual increase in emissions from this source was also registered in 1996, when increased fuel consumption drove CO_2 emissions up by 3.7%. The primary factors for this single year increase were (a) fuel switching by electric utilities from natural gas to more carbon intensive coal as gas prices rose sharply, (b) higher petroleum consumption in the transportation end-use sector as travel increased and fuel efficiency stagnated, (c) greater natural gas consumption for heating in the residential end-use sector due to colder weather, and (d) overall robust domestic economic growth.

Other significant trends in emissions over the seven year period of 1990 through 1996 included:

- Combined N_2O and CH_4 emissions from mobile source fossil fuel combustion rose 3.2 MMTCE (22%), primarily due to increased rates of N_2O generation in highway vehicles.

- Aggregate HFC and PFC emissions resulting from the substitution of ozone depleting substances (e.g. CFCs) increased dramatically (by 11.6 MMTCE); however PFC emissions from aluminium production decreased significantly (41%) as a result of both voluntary industry emission reduction efforts and falling domestic aluminium production.

- Methane emissions from the decomposition of waste in municipal and industrial landfills rose by 8.9 MMTCE (16%) as the amount of organic matter in landfills steadily accumulated.

- Emissions from coal mining dropped by 5.1 MMTCE (21%) as the use of methane from degasification systems increased significantly.

- Nitrous oxide emissions from agricultural soil management increased by 6.2 MMTCE (10 per cent) as fertiliser consumption and cultivation of nitrogen fixing crops rose.

Overall, from 1990 to 1996 total emissions of CO_2, CH_4, and N_2O increased by 122.8 (9%), 8.6 (5%), and 11.4 MMTCE (12%), respectively. During the same period, weighted emissions of HFCs, PFCs, and SF_6 rose by 12.5 MMTCE (56%). Despite being emitted in smaller quantities, emissions of HFCs, PFCs, and SF_6 are significant because of their extremely high global warming potentials and, in the cases of PFCs and SF_6, long atmospheric lifetimes.

Overall, transportation activities accounted for an almost constant 26% of total U.S. greenhouse gas emissions from 1990 to 1996. These emissions were primarily CO_2 from fuel combustion, which increased by 8.8% from 1990 to 1996. However, because of larger increases in N_2O and HFC emissions during this period, overall emissions from transportation activities actually increased by 10.1%.

The average fuel economy for all model year 1999 light vehicles is 23.8 miles per gallon (MPG) or 11.9 l/100km. Within this category, average fuel economy is 28.1 MPG (10.1 l/100km) for passenger cars and 20.3 MPG (14.0 l/100km) for light-duty trucks. The 1999 fuel economy average is the lowest value since 1980 and is 2.1 MPG (1.5 l/100km) less than the peak value of 25.9 MPG (13.4 l/100km) achieved in both 1987 and 1988. Average fuel economy for new light vehicles has dropped 1.0 MPG (0.7 l/100km) since 1996.

The Big Three automakers and the U.S. government have been sharing high-tech information and manufacturing know-how since 1993 in an effort to serve mutually beneficial purposes. The programme is called the Partnership for a New Generation of Vehicles (PNGV) and matches engineers from the auto industry with government researchers from national laboratories, renowned in the past for their work on military technologies.

The goal is to create technology that will lead to a working model of a super-car by the year 2004 -- a car capable of getting 80 miles to the gallon while meeting Tier 2 emissions levels or better.

Japan Fuel Economy Agreement

MITI and MOT jointly drafted energy saving standards for automobiles and electric appliances on 13 October, 1998 in compliance with the energy saving law. The draft standards were then adopted earlier this year.

The standards were drafted based on the "top runner method" or best-in-class method and are as follows.

- For gasoline passenger cars: average improvement of 23%, set by weight class, and for gasoline trucks: average 13%; resulting in a 21% improvement for all gasoline vehicles.

- For diesel passenger cars: average 15%, and for diesel trucks: average 7%; resulting in a 13% improvement for all diesel vehicles.

Details of the programme are contained in Annex F.

High emitting vehicles

Today's vehicles are absolutely dependent on properly functioning emission controls to keep pollution levels low. Minor malfunctions in the emission control system can increase emissions significantly. Major malfunctions in the emission control system can cause emissions to skyrocket. A relatively small number of vehicles with serious malfunctions frequently cause the majority of the vehicle-related pollution problem. Unfortunately, it is rarely obvious which vehicles fall into this category, as the emissions themselves may not be noticeable and emission control malfunctions do not necessarily affect vehicle driveability. Effective I/M programmes, however, can identify these problem cars and assure their repair. By assuring good maintenance practices and discouraging tampering and misruling, I/M remains the best demonstrated means for protecting a national investment in emission control technology and achieving the air quality gains which are needed.

Over many years, the real world experience has consistently shown that centralised, test only inspections have advantages compared to combined test and repair programmes. As far back as the late 1970's in the US, the programmes in Portland, Oregon, Phoenix, Arizona and New Jersey stood out as superior to private garage systems in terms of test accuracy and quality control. Over the course of the years, there have been many changes and improvements in both test only and combined test and repair systems but the centralised systems usually continue to excel.

In the most recent demonstration of centralised I/M capability, in 1992, the province of British Columbia implemented an emissions inspection and maintenance (I/M) programme in the Lower Fraser Valley (LFV) area which incorporated then state of the art inspection procedures[13]. It was the first I/M programme to measure hydrocarbons (HC), carbon monoxide (CO) and the oxides of nitrogen (NOx) using the acceleration simulation mode (ASM) test, which is a loaded mode test simulating vehicle acceleration. The inspection also included an idle test and an anti tampering check to further assure that high emitting vehicles were identified and repaired.

Table 14. **Acceleration simulation mode (ASM) test**

Model year	HC (g/km)		CO		NOx	
	Before repair	**After repair**	**Before repair**	**After repair**	**Before repair**	**After repair**
Pre-1981	3.5	1.9	33	17	3.3	1.4
1981-1987	2.2	1.2	29	12	2.8	2.1
Post-1987	0.49	0.24	8.6	2.9	3.0	1.7

The above Table summarises the emissions reductions following repairs for HC, CO and NOx for each of the model year groups and illustrates that repairs significantly reduced HC, CO and NOx of the failed vehicles in all model year groups[14]. Overall, about 88% of the repairs were effective in reducing emissions[15].

Based on the audit results, overall emissions were reduced by approximately 20% for HC, 24% for CO and 2.7% for NOx[16].

In addition to the emissions reductions, the audit programme found that fuel economy for the failed vehicles improved by approximately 5.5% for an estimated annual savings of $72 per year per vehicle.

The audit programme also demonstrated that the centralised programme was resulting in a very high quality test programme. For example, after reviewing over 2 million tests, the auditor concluded that in only 1.1% were incorrect emissions standards applied. Not one instance was found where a vehicle was given a conditional pass or waiver inappropriately[17]. About 1% of the failed vehicles were found to be receiving waivers even though their emissions are excessive, i.e. they exceed either 10% CO, 2 000 ppm HC or 4 000 ppm NOx. If the cost limits were increased such that this percentage were halved, the auditor concluded that HC and CO reductions from the programme would each increase by about 5%.

Available data also indicates that many vehicles are repaired sufficiently that they remain low emitting. For example, almost 53 000 vehicles which failed the test the first year were repaired well enough to pass the following year.

Overall these data confirm the conclusions that I/M programmes when properly performed in a centralised facility using a loaded mode test are achieving a substantial reduction in emissions. These reductions are approximately equal to those predicted by EPA’s mobile emissions model and are accompanied by substantial fuel savings. According to the auditor, improvements to the programme such as including evaporative testing, reducing or eliminating cost waivers[18], adding the IM240 test or tightening the standards could all increase the overall benefits significantly.

An extensive European study of Inspection and Maintenance programmes for in use cars, carried out under the auspices of DGs XI, VII and XVII was completed in 1998[19]. In carrying out the effort, a relatively large sample of passenger cars was tested including:

- 192 TWC equipped cars designed to meet 91/441/EEC requirements, including 17 LPG fuelled vehicles.
- 41 conventional and oxidation catalyst equipped cars.
- 28 diesel cars.

Most of the vehicles tested were randomly selected although a few were chosen specifically because they were “high emitters”. Results were similar to those in British Columbia but based on a simpler test cycle.

NOTES

1. "The Estimation of the Emissions of Other Mobile Sources and Machinery Subparts Off-Road Road Vehicles and Machines, Railways and Inland Waterways In The European Union", Andrias, Samaras and Zierock, September 1994.

2. "Diesel Vehicle Emissions and Urban Air Quality", Second Report of the Quality of Urban Air Review Group, prepared at the request of the Department of the Environment, December 1993.

3. These emissions estimates are based on the most accurate data currently available. The Agency continues to analyse emissions data and modelling assumptions. Consequently, these estimates could be subject to change.

4. Ozone occurs naturally in the stratosphere and provides a protective layer high above the earth.

5. Intergovernmental Panel on Climate Change (IPCC), Working Group I, "Climate Change 1992 - The Supplementary Report to the IPCC Scientific Assessment," supplement to.

6. US Environmental Protection Agency (US EPA) (1986) Ambient Air Quality Criteria Document for Lead. Research Triangle Park NC: EPA ORD; US Centers for Disease Control (CDC) (1991) Preventing Lead Poisoning in Young children. Atlanta: US DHHS, October 1991; Howson, C., and Hernandez, Avila M. (1996) Lead in the Americas. Washington: NAS Press; International Program on Chemical Safety (IPCS) (1995) Environmental Health Criteria Document: Lead. Geneva: IPCS, WHO; National Research Council (NRC) (1993). Measuring Lead exposures in Infants, Children and Other Sensitive Populations. Washington: NAS Press.

7. "Automotive Emissions of Ethylene Dibromide", Sigsby, *et al*., Society of Automotive Engineers, #820786.

8. "The Automobile, Air Pollution Regulation and the Economy of Southern California, 1965-1990", Jane Hall *et al*., Institute for Economic and Environmental Studies, California State University, April 1995.

9. "First International ETH Workshop On Nanoparticle Measurement", ETH Zurich, A. Mayer, 7 August 1997, "Characterization of Fuel and Aftertreatment Device Effects on Diesel Emissions", Bagley, Baumgard, Gratz, Johnson and Leddy, HEI Research Report Number 76, September 1996, "UK Research Programme on the Characterization of Vehicle Particulate Emissions", (ETSU, September 1997).

10. "Characterization of Exhaust Particulate Emissions from a Spark Ignition Engine", Graskow, Kittleson, Abdul-Khalek, Ahmadi and Morris, SAE#980528, "A study of the number, size and mass of exhaust particles emitted from European diesel and gasoline vehicles under steady state and European driving conditions", CONCAWE report No. 98/51, February 1998.

11. Derived from "A Community strategy to reduce CO_2 emissions from passenger cars and improve fuel economy", COM(95)689, Communication from the Commission to the Council and the European Parliament, Adopted by the Commission on December 20, 1995.

12. Assuming 12 600 km per year and an average on road fuel consumption of 9.6 liters per 100 kilometers.

13. When the BC program was designed, EPA had not yet finalized its rule calling for the use of the IM240 test procedure.

14. "Audit Results: Air Care I/M Program", Prepared For B.C. Ministry of Environment, Lands and Parks and B.C. Ministry of Transportation and Highways, Radian, December 9, 1994.

15. In its recent evaluation of its I/M program, which is probably the most advanced but certainly the most intensely enforced decentralized I/M program in the world, California found that only about 50% of the repairs were effective in reducing emissions, as measured by the full federal test procedure.

16. These reductions are almost identical to those predicted by the US EPA Mobile 5a Emissions Model, 20%, 20% and 1%, respectively for HC, CO and NOx.

17. If the vehicle is taken to an authorized technician and spends at least $200 on repairs, it can receive a conditional pass or waiver even if it does not meet the emissions standards.

18. Cost waivers refer to situations where authorities allow vehicles which fail an emissions test to continue to operate even if they fail a subsequent retest as long as the driver can demonstrate that he spent at least a certain amount of money to try to fix the vehicle. If the vehicle has a faulty catalyst for example which would cost over $100 to replace but the state has a 75$ cost waiver limit, the owner can get by just by showing documentation that he tried to fix the vehicle but it would cost more than the waiver limit.

19. The Inspection of In Use Cars in Order to Attain Minimum Emissions of Pollutants and Optimum Energy Efficiency", May 1998.

ANNEX A. EUROPEAN EMISSIONS REGULATIONS

Passenger Cars

The limit values in grams per kilometre - (g/km) set out in the table represent the final Conciliation values agreed by the European Council of Ministers and the Parliament in 1998 (present step 2 limit values which were introduced in 1996 are indicated in brackets).

Table 15. **Limit values (g/km)**

TYPE OF POLLUTANT					
g/km	**Carbon monoxide (CO)**	**Hydrocarbons (HC)**	**Oxides of nitrogen (NOx)**	**Combined Hydrocarbons and Oxides of nitrogen (HC + NOx)**	**Particulate (PM)**
2000	P: 2.3 (2.2) D: 0.64 (1)	P: 0.20 D: -	P: 0.15 D: 0.50	P: - (0.5) D: 0.56 (0.7)	P: - D: 0.05 (0.08)
2005	P: 1.00 D: 0.50	P: 0.10 D: -	P: 0.08 D: 0.25	P: - D: 0.30	P: - D: 0.025

P = Petrol
D = Diesel

Light-Duty Trucks

Table 16. **New gasoline light truck standards**

Reference mass (RW) Kg	**CO g/km**		**HC g/km**		**NOx g/km**	
Class	**2000**	**2005**	**2000**	**2005**	**2000**	**2005**
I RW <1305	2.3	1	0.2	0.1	0.15	0.08
II 1305 < RW <1760	4.17	1.81	0.25	0.13	0.18	0.1
III 1760 <RW	5.22	2.27	0.29	0.16	0.21	0.11

Table 17. **New diesel light truck standards**

Reference Mass (RW) Kg	CO g/km		HC + NOx g/km		NOx g/km		PM g/km	
Class	**2000**	**2005**	**2000**	**2005**	**2000**	**2005**	**2000**	**2005**
I RW <1305	0.64	0.5	0.56	0.3	0.5	0.25	0.05	0.03
II 1305 < RW <1760	0.8	0.63	0.72	0.39	0.65	0.33	0.07	0.04
III 1760 <RW	0.95	0.74	0.86	0.46	0.78	0.39	0.1	0.06

As indicated in the tables, Euro 3 and 4 standards, for passenger cars and light commercial vehicles (Class 1) will go into effect in 2000 and 2005, respectively. Euro 3 and 4 standards for other light commercial vehicles (Class 2 and Class 3) will go into effect in 2001 and 2006, respectively.

Several other requirements were also agreed to in 1998:

- OBD systems will be required for all new gasoline vehicles from 2000 and all new diesel vehicles from 2003; Class 2 and 3 light commercial vehicles will be delayed until 2005.

- Gasoline fuelled passenger cars and light commercial vehicles must comply with a low temperature test (7 degrees C) from 2002.

- Fiscal measures can be used to promote the early introduction of 2005 compliant technologies ahead of 2005.

- The Commission must come forward by the end of 1999 with a proposal confirming or complementing the Directive but in particular addressing low temperature tests for heavier light commercial vehicles and threshold limit values for OBD for 2005, among other items, and

- The Commission must come forward with additional proposals beyond 1999 addressing longer-term Community air quality objectives.

Table 18. **Fuels**

	Unit	Average in 1999	Proposed average	Maximum from 2000	Maximum from 2005
Petrol					
RVP	KPa	68	58	60	-
Summer					
Aromatics	% (v/v)	40	37	42	35
Benzene	% (v/v)	2.3	1.6	1	-
Sulphur	ppm	300	150	150	50
Olefins	% (v/v)			18	-
Oxygen	% (m/m)			2.7	-
Diesel					
Polyaromatics	% (v/v)	9	6	11	
Sulphur	ppm	450	300	350	50
Cetane Number				51 (Min)	-
Density 15°C	Kg/m3			845	-
Distillation 95%	°C			360	-

- Derogation for a Member State from the sulphur limits because of severe socio-economic problems may be authorised by the Commission for no more than three years starting from 2000 or for two years from 2005.

- The Commission will be required to make a proposal **no later the end of 1999** with proposals to complement the above specifications.

- The marketing of leaded gasoline is prohibited in the Community from 1 January 2000; however, a Member State could request a derogation until 2005 if it demonstrates that the introduction of a ban would result in severe socio-economic problems or would not lead to overall environmental or health benefits because, *inter alia*, of the climatic situation in that Member State. The lead content of such leaded gasoline must not exceed 0.15 gr/l.

Leaded gasoline to be used by old vehicles and distributed through special interest groups would not be affected by the ban (but sales could not exceed 0.5% of total gasoline sales).

- In order to protect human health and/or the environment in specific agglomerations or ecologically sensitive areas with special problems of air quality, Member States would be permitted - subject to a derogation requested in advance and backed up by evidence - to require that fuels sold in these areas comply with more stringent environmental specifications than those established under the Directive.

Heavy-Duty Vehicles

On December 21, 1998, in response to amendments approved by the Parliament during their first reading, the Council of Ministers amended the initial proposal submitted by the Commission.

In summary the Ministers agreed to the following:

– 2000 (Euro 3) - as the Commission proposed (see tables below), an overall 30% reduction from current levels but with the derogation for small high speed diesel engines extended from a cylinder swept volume of 0.70 litres to 0.75 litres.

– 2005 (Euro 4) - mandatory CO, HC and NOx limits that can probably be achieved by engine improvements but mandatory particulate limits that reflect the need for particulate traps. All engines are to be tested on both cycles except gas engines, which are only tested on the ETC cycle. This means a 50% reduction in CO, HC and NOx and an 80% reduction in PM from current limit values.

– A further stage in 2008 with a NO_X standard of 2.0 g/kWh on both cycles (reflecting the need for DeNOx or SCR catalysts). This is a 70% reduction in NOx from current limit values. At the insistence of the Commission and several other Member States the Commission has to report by the end of 2002 and "consider the available technology with a view to confirming the mandatory NOx standard for 2008 in a report to the Council and the Parliament, accompanied, if necessary, by appropriate proposals."

– The limit values for Enhanced Environmentally Friendly Vehicles (EEV's) are 2.0 g/kWh NOx and 0.02 g/kWh PM on both cycles. These standards should serve as the basis for voluntary purchases of urban vehicles such as buses.

Table 19. **Limit values for diesel engines on ESC and ELR tests (Conventional Engines +/- oxidation catalyst)**

Date of implementation	**CO**	**HC**	**NOx**	**PM**	**Smoke**
	Grams/Kilowatt-Hr (g/kWh)				m^{-1}
2000/01	2.1	0.66	5	0.10 0.13 [a]	0.8
2005/06	1.5	0.46	3.5	0.02	0.5
2008/09	1.5	0.46	2	0.02	0.5

a = For engines having a swept volume of less than 0.75 dm^3 per cylinder and a rated power speed of more than 3 000 min^{-1}.

Table 20. **Limit values for diesel and gas engines on ETC test**
(Diesel engines with advanced after treatment including PM Traps and DeNOx catalysts)

Date of Implementation	CO	NMHC	Methane [a]	NOx	PM [b]
	Grams/Kilowatt-Hr (g/kWh)				
2000/01	5.45	0.78	1.6	5	0.16 0.21
2005/06	4	0.55	1.1	3.5	0.03
2008/09	4	0.55	1.1	2	0.03

a = For natural gas engines only.
b = For diesel engines only.

In November 1999, the European Parliament approved the Common Position of the Council of Ministers, summarised above.

ANNEX B. US EMISSIONS REGULATIONS

Current light-duty vehicle standards

These are known as Tier 1 standards under the national Clean Air Act of 1990.

Table 21. **Emission standards for light-duty vehicles (passenger cars) and light-duty trucks of up to 6 000 lbs GVWR**

	5 Years or 50 000 Miles					10 Years or 100 000 Miles			
g/mile	NMHC	CO	Cold CO	NOx	PM	NMHC	CO	NOx	PM
Non-Diesel									
LDTs (0-3.750 lbs. LVW) and light-duty vehicles	0.25	3.4	10	0.4	-	0.31	4.2	0.6	-
LDTs (3.751-5.750 lbs. LVW)	0.32	4.4	12.5	0.7	-	0.4	5.5	0.97	-
Diesel									
LDTs (0-3.750 lbs. LVW) and light-duty vehicles	0.25	3.4	-	1	0.1	0.31	4.2	1.25	0.1
LDTs (3.751-5.750 lbs. LVW)	0.32	4.4	-	-	0.1	0.4	5	0.97	0.1

Table 22. **Emission standards for light-duty trucks of more than 6 000 lbs GVWR**

g/mile	5 Years or 50 000 Miles			10 Years or 120 000 Miles			
LDT Test Weight	NMHC	CO	NOx	NMHC	CO	NOx	PM
3 751 - 5 750	0.32	4.4	0.7*	0.46	6.4	0.98	0.1
Over 5 750	0.39	5	1.1*	0.56	7.3	1.53	0.12

* Not applicable to diesel-fuelled LDTs.

National low emission vehicle programme

On December 16, 1997, EPA finalised the regulations for the National Low Emission Vehicle (LEV) programme. Because it is a voluntary programme, it could only come into effect if agreed upon by the north-eastern states and the auto manufacturers. EPA subsequently received notifications from all the auto manufacturers and the relevant states lawfully opting into the programme. As a result, starting in the north-eastern states in model year 1999 and nationally in model year 2001, new cars and light light-duty trucks will meet tailpipe standards that are more stringent than EPA can mandate prior to model year 2004. Now that the programme is agreed upon, these standards will be enforceable in the same manner as any other federal new motor vehicle programme.

Table 23. **NLEV exhaust emission standards (g/mi) for LDV's and LLDTs (50 000 miles)**

Vehicle Type	Model Year	Fleet Average NMOG	Nox g/mile	CO g/mile
LDV and LDT	1999*	0.148	0.2	3.4
(0-3750 LVW)	2000*	0.095	0.2	3.4
	2001 and later**	0.075	0.2	3.4
LDT	1999*	0.19	0.4	4.4
(3751-5750 LVW)	2000*	0.124	0.4	4.4
	2001 and later**	0.1	0.4	4.4

* 9 North-eastern States and DC, except New York and Massachusetts.

** All states except California, New York, Massachusetts, Vermont and Maine, which have the California standards.

Tier 2

In drafting the Clean Air Act, as amended in 1990, Congress envisioned that it may be necessary to require additional emission reductions from new passenger vehicles in the beginning of the 21st Century to provide needed protection of public health and outlined a process for assessing whether to do so. Congress identified specific standards[1] that EPA must consider in making this assessment, but stated that the study should also consider other possible standards. These standards, referred to as the "Tier 2 standards", would be more stringent than the standards required for LDVs and LDTs in the CAA beginning in model year 1994, but could not be implemented prior to the 2004 model year.

In May 1999, EPA issued a proposal, which would ultimately require each manufacturer's average NOx emissions over all of its Tier 2 vehicles each model year to meet a NOx standard of 0.07 g/mile. In late December the proposal was finalised.

Vehicle requirements

The Rule sets new federal emission standards ("Tier 2 standards") for passenger cars, light trucks, and larger passenger vehicles. The programme will also, for the first time, apply the same set of federal standards to all passenger cars, light trucks, and medium-duty passenger vehicles. Light trucks include "light light-duty trucks" (or LLDTs), rated at less than 6 000 pounds gross vehicle weight and "heavy light-duty trucks" (or HLDTs), rated at more than 6 000 pounds gross vehicle weight[2]. "Medium-duty passenger vehicles" (or MDPVs) form a new class of vehicles introduced by this rule that includes SUVs and passenger vans rated at between 8 500 and 10 000 GVWR. The programme thus ensures that essentially all vehicles designed for passenger use in the future will be very clean vehicles.

The Tier 2 standards will reduce new vehicle NOx levels to an average of 0.07 grams per mile (g/mi). For new passenger cars and light LDTs, these standards will phase in beginning in 2004, with the standards to be fully phased in by 2007[3]. For heavy LDTs and MDPVs, the Tier 2 standards will be phased in beginning in 2008, with full compliance in 2009.

During the phase-in period from 2004-2007, all passenger cars and light LDTs not certified to the primary Tier 2 standards will have to meet an interim average standard of 0.30 g/mi NOx, equivalent to the current NLEV standards for LDVs and more stringent than NLEV for LDT2s (e.g. minivans)[4]. During the period 2004-2008, heavy LDTs and MDPVs not certified to the final Tier 2 standards will phase in to an interim programme with an average standard of 0.20 g/mi NOx, with those not covered by the phase-in meeting a per-vehicle standard (i.e. an emissions "cap") of 0.60 g/mi NOx (for HLDTs) and 0.09 g/mi NOx (for MDPVs).

The final programme is very similar to the proposed programme in all major respects including the general structure, stringency, and emissions benefits. And by creating a new category of vehicles subject to the Tier 2 standards, medium-duty passenger vehicles, the final rule will ensure that all passenger vehicles expected to be on the road in the foreseeable future will be very clean.

Vehicle categories

The light-duty category of motor vehicles includes all vehicles and trucks at or below 8 500 pounds gross vehicle weight rating, or GVWR (i.e. vehicle weight plus rated cargo capacity).

Table 24 shows the various light-duty categories and also shows the new medium-duty passenger vehicle (MDPV) category.

Table 24. **Light-duty vehicles and trucks and medium-duty passenger vehicles: category characteristics**

LDV	A passenger car or passenger car derivative seating 12 passengers or less.
Light LDT (LLDT)	Any LDT rated at up through 6 000 lbs GVWR. Includes LDT1 and LDT2.
Heavy LDT (HLDT)	Any LDT rated at greater than 6 000 lbs GVWR. Includes LDT3 and LDT4s.
MDPV	A heavy-duty passenger vehicle rated at less than 10 000 lbs GVWR.

Corporate average NOx standard

The programme will ultimately require each manufacturer's average full life NOx emissions over all of its Tier 2 vehicles to meet a NOx standard of 0.07 g/mi each model year. Manufacturers will have the flexibility to certify Tier 2 vehicles to different sets of exhaust standards that we refer to as "bins", but will have to choose the bins so that their corporate sales weighted average full life NOx level for their Tier 2 vehicles is no more than the 0.07 g/mi. The manufacturer will be in compliance with the standard if its corporate average NOx emissions for its Tier 2 vehicles meets or falls below 0.07 g/mi. In years when a manufacturer's corporate average is below 0.07 g/mi, it can generate credits. It can trade (sell) those credits to other manufacturers or use them in years when its average exceeds the standard (i.e. when the manufacturer runs a deficit).

Tier 2 exhaust emission standard "Bins"

The final Tier 2 bin structure has eight emission standards bins (bins 1-8), each one a set of standards to which manufacturers can certify their vehicles. Table 25 shows the full useful life standards that will apply for each bin in the final Tier 2 programme, i.e. after full phase-in occurs for all LDVs and LDTs. Two additional bins, bins 9 and 10, will be available only during the interim programme and will be deleted before final phase-in of the Tier 2 programme. An eleventh bin is available but only for MDPVs (see below). Many bins have the same values as bins in the California LEV2 programme as a means to increase the economic efficiency of the transition, as well as model availability. The two highest of the ten bins shown in Table 25 are designed to provide flexibility only during the phase-in years and will terminate after the standards are fully phased in, leaving eight bins in place for the duration of the Tier 2 programme.

Table 25. **Tier 2 light-duty full useful life exhaust emission standards (grams per mile)**

Bin number	Nox	NMOG	CO	HCHO	PM	Comments
10	0.6	0.156/0.230	4.2/6.4	0.018/0.027	0.08	a,b,c,d
9	0.3	0.090/0.180	4.2	0.018	0.06	a,b,e
The above temporary bins expire in 2006 (for LDVs and LLDTs) and 2008 (for HLDTs)						
8	0.20	0.125/0.156	4.2	0.018	0.02	b,f
7	0.15	0.090	4.2	0.018	0.02	
6	0.10	0.090	4.2	0.018	0.01	
5	0.07	0.090	4.2	0.018	0.01	
4	0.04	0.070	2.1	0.011	0.01	
3	0.03	0.055	2.1	0.011	0.01	
2	0.02	0.010	2.1	0.004	0.01	
1	0.00	0.000	0.0	0.000	0.00	

Notes:

a. Bin deleted at end of 2006 model year (2008 for HLDTs).
b. The higher of the two temporary NMOG, CO and HCHO values apply only to HLDTs.
c. An additional higher temporary bin restricted to MDPVs is discussed below.
d. Optional temporary NMOG standard of 0.280 g/mi applies for qualifying LDT4s and MDPVs only.
e. Optional temporary NMOG standard of 0.130 g/mi applies for qualifying LDT2s only.
f. Higher temporary NMOG value of 0.156g/mi deleted at end of 2008 model year.

Table 26. **Light-duty intermediate useful life (50 000 mile) exhaust emission standards (grams per mile)**

Bin number	NOx	NMOG	CO	HCHO	PM	Comments
10	0.4	0.125/0.160	3.4/4.4	0.015/0.018	--	a,b,c,d,f,h
9	0.2	0.075/0.140	3.4	0.015	--	a,b,e,h
The above temporary bins expire in 2006 (for LDVs and LLDTs) and 2008 (for HLDTs)						
8	0.14	0.100/0.125	3.4	0.015	--	b,g,h
7	0.11	0.075	3.4	0.015	--	h
6	0.08	0.075	3.4	0.015	--	h
5	0.05	0.075	3.4	0.015	--	h

Notes:

a. Bin deleted at end of 2006 model year (2008 for HLDTs).
b. The higher temporary NMOG, CO and HCHO values apply only to HLDTs and expire in 2008.
c. An additional higher temporary bin restricted to MDPVs is available.
d. Optional temporary NMOG standard of 0.195 g/mi applies for qualifying LDT4s and MDPVs only.
e. Optional temporary NMOG standard of 0.100 g/mi applies for qualifying LDT2s only.
f. Intermediate life standards are optional for diesels certified to bin 10.
g. Higher temporary NMOG value deleted at end of 2008 model year.
h. Intermediate life standards are optional for any test group certified to a 150 000 mile useful life (if credits are not claimed).

Any combination of vehicles meeting the 0.07 g/mi average NO_X standard will have average NMOG levels below 0.09 g/mi. The actual value will vary by manufacturer depending on the sales mix of the vehicles used to meet the 0.07 g/mi average NO_X standard. In addition, there will be overall improvements in NMOG since Tier 2 incorporates HLDTs, which are not covered by the NLEV programme. Tier 2 also imposes tighter standards on LDT2s than the NLEV programme by making them average with the LDVs and LDT1s. NLEV has separate, higher standards for LDT2s.

Schedules for Implementation

Table 27 provides a graphical representation of how the phase-in of the Tier 2 programme will work for all vehicles.

Interim standards

The interim standards discussed below are a major source of emission reductions in the early years of the vehicle control programme. The NOx emission standards for LDT2s and LDT4s, which comprise about 40% of the fleet, are more stringent than the corresponding standards in the NLEV and CAL LEV I programmes.

The two groups of vehicles (LDV/LLDTs and HLDTs) will be approaching the Tier 2 standards from quite different emission “backgrounds”. LDV/LLDTs will be at NLEV levels, which require NOx emissions of either 0.3 or 0.5 g/mi on average[5], while HLDTs will be at Tier 1 levels facing NOx standards of either 0.98 or 1.53 g/mi, depending on truck size. These Tier 1 NOx levels for HLDTs are very high (by a factor of 14-22) relative to the 0.07 g/mi Tier 2 NOx average.

Table 27. **Tier 2 and interim non-tier 2 phase-in**
(Shaded areas indicate averaging sets)

	2001	**2002**	**2003**	**2004 %**	**2005 %**	**2006 %**	**2007 %**	**2008 %**	**2009+ later %**	**NOx (g/mi)**
LDV/LLDT (Interim)	NLEV	NLEV	NLEV	75 max	50 max	25 max				0.30 avg.
LDV/LLDT (TIER 2 +evap)	b	*early banking* b	b	25	50	75	100	100	100	0.07 avg.
HLDT (TIER 2 +evap)	b	b	b	*early banking* b	b	b	b	50	100	0.07[d] avg.
HLDT (Interim)	TIER 1 b	TIER 1 b	TIER 1 b	25 c,e	50 e	75 e	100 e	50 max		0.20[a],[d] avg.
MDPVs (Interim)	HDE	HDE	HDE							
MDPVs (TIER 2 +evap)	b	b	b	*early banking* b	b	b	b	50	100	0.07[d] avg.

Notes:

a. 0.60 NOx cap applies to balance of LDT3s/LDT4s, respectively, during the 2004-2006 phase-in years.

b. Alternative phase-in provisions permit manufacturers to deviate from the 25/50/75% 2004-2006 and 50% 2008 phase-in requirements and provide credit for phasing in some vehicles during one or more of these model years.

c. Required only for manufacturers electing to use optional NMOG values for LDT2s or LDT4s and MDPV flexibilities during the applicable interim programme and for vehicles whose model year commences on or after the fourth anniversary date of the signature of this rule.

d. HLDTs and MDPVs must be averaged together.

e. Diesels may be engine-certified through the 2007 model year.

Interim exhaust emission standards for LDV/LLDTs

Beginning with the 2004 model year, all new LDVs, LDT1s and LDT2s not incorporated under the Tier 2 phase-in will be subject to an interim corporate average NOx standard of 0.30 g/mi. This is effectively the LEV NOx emission standard for LDVs and LDT1s under the NLEV programme[6]. This interim programme will hold LDVs and LLDTs to NLEV levels if they are not yet subject to Tier 2 standards during the phase-in. LDT2s will be held to a 0.3 g/mi NOx average in contrast to a 0.5 g/mi average in the NLEV programme.

The proposal to bring LDT2s into line with the LDVs and LDT1s during the interim programme by requiring all LDVs, LDT1s and LDT2s to meet the same average NOx standard (0.30) g/mi is retained, but EPA is providing an optional NMOG standard of 0.130 for LDT2s certified to bin 9 when the manufacturers of those LDT2s elect to bring all of their 2004 model year HLDTs under the interim programme and phase 25% of those HLDTs into the 0.20 g/mi average NOx standard.

Interim exhaust emission standards for HLDTs

The interim standards for HLDTs will begin in the 2004 model year similar to the proposal in the NPRM. The Interim Programme for HLDTs will require compliance with a corporate average NOx standard of 0.20 g/mi that will be phased in between 2004 and 2007. The interim HLDT standards like those for LDV/LLDTs will make use of the bins in Table 25.

Due to statutory lead time considerations, EPA was not able to finalise the HLDT standards to be in effect by the time the 2004 model year begins. For this reason, it is providing incentives for HLDTs to comply with the Tier 2 standards for all 2004 model year HLDTs.

Generating, banking, and trading NOx Credits

As proposed in the NPRM and finalised in the Rule, manufacturers will be permitted to average the NOx emissions of their Tier 2 vehicles and comply with a corporate average NOx standard. In addition, when a manufacturer’s average NOx emissions fall below the corporate average NOx standard, it can generate NOx credits for later use (banking) or to sell to another manufacturer (trading). NOx credits will be available under the Tier 2 standards, the interim standards for LDVs and LLDTs, and the interim standards for HLDTs.

Banking and trading of NOx credits under the interim non-Tier 2 standards will be similar to that under the Tier 2 standards, except that a manufacturer must determine its credits based upon the 0.30 or 0.20 gram per mile corporate average NOx standard applicable to vehicles in the interim programmes. As proposed in the NPRM, interim credits from LDVs/LLDTs and interim credits from HLDTs will not be permitted to be used interchangeably due to the differences in the interim corporate average NOx standards. As proposed in the NPRM, there will be no provisions for early banking under the interim standards and manufacturers will not be allowed to use interim credits to address the Tier 2 NOx average standard.

EPA believes it is appropriate to provide inducements to manufacturers to certify vehicles to very low levels and that these inducements may help pave the way for greater and/or more cost effective emission reductions from future vehicles. We believe it is important in a rule of this nature to provide extra incentives to encourage manufacturers to produce and market very clean vehicles. This is especially important in the earliest years of the programme when manufacturers must make resource commitments to technologies and vehicle designs that will have multi-year life spans. EPA believes this programme provides a strong incentive for manufacturers to maximise their development and introduction of the best available vehicle/engine emission control technology, and this in turn provides a stepping stone to the broader introduction of this technology soon thereafter. Early production of cleaner vehicles enhances the early benefits of the programme and vehicles certified to these lowest bins produce not just lower NOx but also lower NMOG, CO and HCHO emissions. If a manufacturer can be induced to certify to a lower bin by the promise of reasonable extra credits, the benefits of that decision to the programme may last for many years.

EPA is finalising provisions to permit manufacturers, at the beginning of the programme, to weight LDV/Ts certified to the lowest two bins more heavily when calculating their fleet average NOx emissions. Under this provision, which applies through the 2005 model year, manufacturers may apply a multiplier to the number of LDV/Ts sold that are certified to bins 1 and 2 (ZEVs and SULEVs in California terms). This adjusted number will be used in the calculation of fleet average NOx emissions for a given model year and will allow manufacturers having vehicles certified to these bins to generate additional credits (or use fewer credits) that year.

The multipliers that manufacturers may use are found in Table 28 below.

Table 28. **Multipliers for additional credits for bin 1 and 2 LDV/Ts**

Bin	Model year	Multiplier
2	2001, 2002, 2003, 2004, 2005	1.5
1	2001, 2002, 2003, 2004, 2005	2.0

Light-duty evaporative emission standards

More stringent evaporative emission standards are adopted for all Tier 2 light-duty vehicles and light-duty trucks. The standards are shown in Table 29 and represent, for most vehicles, more than a 50% reduction in diurnal plus hot soak standards from those that will be in effect in the years immediately preceding Tier 2 implementation. The higher standards for HLDTs provide allowance for greater non-fuel emissions related to larger vehicle size.

Table 29. **Final evaporative emission standards (grams per test)**

Vehicle class	3 day diurnal +hot soak	Supplemental 2 day diurnal +hot soak
LDVs and LLDTs	0.95	1.2
HLDTs	1.2	1.5

Passenger vehicles above 8 500 pounds GVWR

Historically, all vehicles above 8 500 pounds GVWR have been categorised as heavy-duty vehicles regardless of their application and they have been subject to standards and test procedures designed for vehicles used in heavier work applications[7]. In the Final Rule, EPA is finalising Tier 2 standards for passenger vehicles above 8.500 pounds GVWR. These vehicles are included in the Tier 2 programme beginning in 2004 and are required to meet the final Tier 2 standards in 2009 and later. These vehicles will generally be subject to the same requirements as HLDTs.

The Rule creates a new category of heavy-duty vehicles termed "medium-duty passenger vehicles" (MDPVs). These vehicles will generally be grouped with and treated as HLDTs in the Tier 2 programme. The MDPV category is defined as any complete heavy-duty vehicle less than 10 000 pounds GVWR designed primarily for the transportation of persons including conversion vans (i.e. vans that are intended to be converted to vans primarily intended for the transportation of persons. The conversion from cargo to passenger use usually includes the installation of rear seating, windows, carpet, and other amenities). EPA is not including any vehicle that (1) has a capacity of more than 12 persons total or, (2) that is designed to accommodate more than 9 persons in seating rearward of the driver's seat or, (3) has a cargo box (e.g., a pick-up box or bed) of six feet or more in interior length.

As noted above, the MDPVs and HLDTs must meet the final Tier 2 standards by 2009 at the latest. Prior to 2009, HLDTs and MDPVs are required to meet interim standards. The interim standards are based on a corporate average full life NOx standard of 0.20 g/mile, which is phased in 25/50/75/100% in 2004-2007. MDPVs must be grouped with HLDTs for the interim standards phase-in.

EPA is providing an additional upper bin for MDPVs for the interim programme (effective in model years 2004 through 2008). This bin would only be available for MDPVs. The bin, shown in Table 30, is equivalent to the California LEV I standards that are applicable to these vehicles prior to 2004. Vehicles certified to this bin must be tested at adjusted loaded vehicle weight (ALVW), consistent with California programme testing requirements[8]. Including this upper bin provides manufacturers with the ability to carry over their California vehicles to the federal programme prior to their phase-in to the interim and final Tier 2 standards. Once phased in to the interim standards manufacturers may continue to use the upper bin but the vehicles must be included in the 0.20 g NOx average. The upper bin is not available to manufacturers for the final Tier 2 programme.

Table 30. **Temporary interim exhaust emission standards bin for MDPVs [a]**

	NOx	NMOG	CO	HCHO	PM
Full useful life (120 000 mile)	0.9	0.280	7.3	0.032	0.12

a. Bin expires after model year 2008.

For diesel MDPVs prior to 2008, EPA is allowing manufacturers the option of meeting the heavy-duty engine standards in place for the coinciding model year. Diesels meeting the engine-based standards would be excluded from the interim programme averaging pool. In 2008, the manufacturers must chassis certify diesel vehicles and include them either in the interim programme or in the final Tier 2 programme. In 2009 and later, all MDPVs, including diesels, must be brought into the final Tier 2 programme. As with the higher bin of chassis-based standards, the purpose of this diesel provision is to provide the option of carry-over of vehicles until they are brought into the Tier 2 programme.

For diesel engines that are engine certified and used in MDPVs, as allowed through model year 2007, EPA is requiring those engines to comprise a separate averaging set under the averaging, banking and trading requirements applicable to heavy-duty diesel engines. EPA is permitting engine-based certification for these diesel vehicles to provide time and flexibility for manufacturers who may have limited experience with chassis certifying vehicles containing such engines. However, EPA believes it is appropriate to constrain the application of credits to these engines.

MDPVs placed in bin 10 may also certify to the higher NMOG level of 0.280 g/mile. This provision provides manufacturers with the incentive of selecting the lower NOx bin for MDPVs, since the NMOG level is not an obstacle to compliance.

For legal reasons, EPA cannot force certain vehicles to comply beginning with the 2004 model year. Therefore, EPA tries to encourage manufacturers to do so by offering certain flexibilities in the regulations if they are applied from 2004. If the manufacturer chooses not to start the programme until 2005, the flexible options are not available to him.

EPA requires all non-diesel MDPVs to be OBD II compliant beginning in 2004. California requires OBD II for their LEV I programme and therefore, the new OBD II requirements are consistent with the approach of allowing vehicles to be carried over from California[9]. Diesel vehicles which are carried over from the California programme are required to be equipped with the OBD system as the system is certified in California. Diesel vehicles not carried over from California are not required as part of this rulemaking to be equipped with OBD II. However, EPA has proposed OBD II requirements for heavy-duty diesel engines in its heavy-duty engines NPRM; if OBD II requirements are finalised for heavy-duty engines and vehicles as part of that rulemaking the OBD II requirements would likewise apply to diesels in the MDPV category.

EPA is finalising Cold CO and Certification Short Test requirements for Tier 2 MDPVs. However, they are not finalising SFTP (Supplemental federal Test Procedure which reflects testing under certain high speed and high load driving conditions) standards for MDPVs in this Rule. Currently, SFTP standards do not apply to any vehicles above 8 500 pounds GVWR, including those in the California LEV1 and LEV2 programmes.

Sulphur provisions

The other major part of the Rule will significantly reduce average gasoline sulphur levels nationwide. EPA expects these reductions could begin to phase in as early as 2000, with full compliance for most refiners occurring by 2006. Importers of gasoline will be required to import and market only gasoline meeting the sulphur limits. Temporary, less stringent standards will apply to a few small refiners through 2007. In addition, temporary, less stringent standards will apply to a limited geographic area in the western U.S. for the 2004-2006 period.

The programme requires that most refiners and importers meet a corporate average gasoline sulphur standard of 120 ppm and a cap of 300 ppm beginning in 2004. By 2006, the cap will be reduced to 80 ppm and most refineries must produce gasoline averaging no more than 30 ppm sulphur. The programme includes provisions for trading of sulphur credits.

Table 31 summarises the standards for gasoline refiners and importers. There are three standards which refiners and importers must meet. In 2004 and beyond, every gallon of gasoline produced is limited by a per-gallon maximum or "cap." The cap standard becomes effective January 1, 2004 (and January 1 of subsequent years as the cap standard changes). Also, in 2004 and 2005, each refiner must meet an annual-average standard for its entire corporate gasoline pool. Finally, each individual refinery is subject to a refinery average standard, beginning in 2005. Refineries that do not take advantage of the sulphur ABT programme will have actual sulphur levels averaging 30 ppm beginning in 2005.

Table 31. **Gasoline sulphur standards for refiners, importers, and individual refineries (excluding small refiners and GPA gasoline)**

Compliance as of:	2004 [a]	2005	2006+
Refinery average, ppm [b]	--	30	30
Corporate pool average, ppm [c]	120	90	--
Per-gallon cap [d], ppm	300	300	80

a. We project that the pool averages will actually be below 120 ppm in 2004.
b. The refinery average standard can be met through the use of sulphur credits or allotments from the sulphur ABT programme, as long as the applicable corporate pool average and per-gallon caps are not exceeded.
c. The corporate pool average standard can be met through the use of corporate allotments obtained from other refiners, if necessary.
d. In 2004, exceedences up to 50 ppm beyond the 300 ppm cap are allowed. However, in 2005, the cap for all batches will be reduced by the magnitude of the exceedence.

Heavy-duty vehicles and engines

Currently adopted heavy-duty regulations are summarised below.

Table 32. **Highway heavy-duty emission standards**

Year	HC (g/bhp-hr)	CO (g/bhp-hr)	HC + NOx (g/bhp-hr)	Nox (g/bhp-hr)	Diesel Particulate (g/bhp-hr)
Diesel					
1991-93	1.3	15.5		5.0	0.25
1994-97	1.3	15.5		5.0	0.10
1998	1.3	15.5		4.0	0.10
2004	1.3	15.5	2.4**		
Urban buses					
1991-92	1.3	15.5		5.0	0.25
1993	1.3	15.5		5.0	0.10
1994-95	1.3	15.5		5.0	0.07
1996-97	1.3	15.5		5.0	0.05*
1998	1.3	15.5		4.0	0.05*
Otto-cycle	**HC** (g/bhp-hr)	CO (g/bhp-hr)		**NOx** (g/bhp-hr)	**Evaporative HC** (g/test)
1991-97					3.0
(A)	1.1	14.4		5.0	4.0
(B)	1.9	37.1		5.0	
1998					
(A)	1.1	14.4		4.0	3.0
(B)	1.9	37.1		4.0	4.0

(A) denotes the standard for engines in trucks < 14.000 lbs. Gross Vehicle Weight Rating (GVWR).

(B) denotes the standard for engines in trucks > 14.000 lbs. GVWR.
* 0.07 g/bhp-hr in-use.
** Optional standards of 2.5 are permitted with a NMHC Cap of 0.5.

Table 33. **US Truck definitions**

	GVWR	Curb wt.	Loaded vehicle Wt.	Frontal area
LLDT	0-6000			
LDT	0-8500	>6000		<45
LDT1			0-3750	
LDT2			3750<	
HLDT	6001-8500			
LDT3	6001-8500		0-5750	
LDT4	6001-8500		5750>	
HDV	8500>	6000>		45>

Announcing a total settlement that comprises the largest Clean Air Act enforcement action in US history, the Justice Department and the Environmental Protection Agency recently ordered seven manufacturers of heavy-duty diesel engines to spend more than one billion dollars to settle charges that they illegally poured millions of tons of pollution into the air, including an $83.4 million civil penalty, the largest in environmental enforcement history.

The settlement will resolve charges that the companies - Caterpillar Inc., Cummins Engine Company, Detroit Diesel Corporation, Mack Trucks, Inc., Navistar International Transportation Corporation, Renault Vehicles Industrials and Volvo Truck Corporation - violated the Clean Air Act by installing devices that defeat emission controls. The settlement is expected to prevent 75 million tons of nitrogen oxide (NOx) air pollution over the next 27 years; 75 million is more than the total U.S. NOx emissions for three years. In addition, due to the settlement, the total NOx emissions from diesel engines will be reduced by one-third as of the year 2003. The companies comprise 95% of the U.S. heavy duty diesel engine market.

The complaint alleges that the companies violated the Clean Air Act by selling heavy duty diesel engines equipped with "defeat devices" -- software that alters an engine's pollution control equipment under highway driving conditions. The defeat devices allow engines to meet EPA emission standards during laboratory testing but disable the emission control system during normal highway driving. The Clean Air Act prohibits any manufacturer from selling any new motor vehicle engine equipped with any device designed to defeat the engine's emission control system. The engines meet the emission limits when they run on the EPA's 20-minute Federal Test Procedure, but when the engines are running on the highway, up to three times the limit of NOx emissions result.

The companies are alleged to have sold an estimated 1.3 million of the affected engines, which range from the type used in tractor trailers to large pick-up trucks. The affected engines emitted more than 1.3 million tons of excess NOx in 1998 alone, which is 6% of all NOx emissions from cars, trucks and industrial sources this year. This is equivalent to the NO_X emissions from an additional 65 million cars being on the road. If the companies' use of defeat devices had not been detected and eliminated, more than 20 million tons of excess NOx would have been emitted by the year 2005.

EPA estimates that the companies will spend collectively more than $850 million to introduce cleaner new engines, rebuild older engines to cleaner levels, recall pickup trucks that have defeat devices installed and conduct new emissions testing.

Under the agreements lodged with the U.S. District Court for the District of Columbia, the companies will reduce significantly emissions from new heavy-duty diesel engines by the end of the year and then meet levels beyond what the law requires by October 2002. The companies also will ensure that when older heavy-duty diesel engines are rebuilt, their excess emissions will be reduced. The companies also will move up the date for meeting certain NOx emission standards applicable to non-road engines such as construction equipment.

In addition to reducing NOx emissions from the heavy-duty diesel engines, the companies will undertake a number of projects to lower NOx emissions, including research and development projects to design low-emitting engines that use new technologies and cleaner fuels. Collectively, these projects will cost $109.5 million.

The emission problems were discovered last year when EPA tested one of the company's engines. EPA and DOJ then began an extensive investigation. Settlement discussion began earlier this year.

The manufacturers will be subject to additional heavy penalties if they do not meet the agreement deadlines, and will be required to demonstrate compliance with the settlement on tests, which supplement the Federal Test Procedure to ensure there are no new defeat devices used.

Part of the civil penalties will be paid to the California Air Resources Board, with which the companies have made a related settlement.

As noted in the original rule regarding the 2004 NOx standard for heavy-duty engines, EPA is intending to carry out a careful review in 1999. They intend to propose tightening the gasoline truck standard and requiring OBD on all vehicles and engines. Further, they are inclined to issue an ANPRM that would tighten the PM standard in 2005 and the NOx standard again in 2007. Standards under consideration include 0.2 grams/bhp-hr for NOx and 0.01 for PM.

A driving force for the tighter PM standard is the urban air toxics initiative, which indicates that diesels are the dominant source.

In parallel with the ANPRM Advanced Notice of Proposed Rulemaking[10] for vehicles, EPA appears to be planning a low sulphur diesel fuel Rulemaking to lower sulphur to a maximum of 15 ppm.

NOTES

1. Clean Air Act; Section 202 (i); Table 3: Pending Emission Standards for Gasoline and Diesel Fuelled Light-duty Vehicles and Light-duty Trucks 3 750 lbs LVW or Less.

Pollutant	Emission level in grams per mile
NMHC	0.125 gpm
Nox	0.2 gpm
CO	1.7 gpm

2. A vehicle's "Gross Vehicle Weight Rating", or GVWR, is the curb weight of the vehicle plus its maximum recommended load of passengers and cargo.

3. By comparison, the NOx standards for the National Low Emission Vehicle (NLEV) program, which will be in place nationally in 2001, range from 0.30 g/mi for passenger cars to 0.50 g/mi for medium-sized light trucks (larger light trucks are not covered). For further comparison, the standards met by today's Tier 1 vehicles range from 0.60 g/mi to 1.53 g/mi.

4. There are also NMOG standards associated with both the interim and Tier 2 standards. The NMOG standards vary depending on which of various individual sets of emission standards manufacturers choose to use in complying with the average NOx standard.

5. The NLEV program imposes NMOG average standards that translate into full useful life NOx levels of about 0.3 g/mi for LDV/LDT1s and 0.5 g/mi for LDT2s.

6. The NLEV program does not impose average NOx standards, but the NMOG average standards that it does impose will lead to full useful life NOx levels of about 0.3 g/mi for LDV/LDT1s.

7 The heavy-duty definition also includes vehicles that weigh over 6 000 lbs curb weight regardless of their GVWR.

8. ALVW is the average of curb weight and GVWR. The test weight is sometimes referred to as "half payload".

9. As with HLDTs, the California OBD II compliance option is available for MDPVs.

10. Under the US system, the first formal stage in issuing a rule is the ANPRM to solicit comments on a very preliminary concept. Then EPA will issue an NPRM, a Notice of Proposed Rulemaking, which spells out the measure in great detail for comment. After evaluating these comments, EPA will then issue a FRM or Final Rule Making which reflects the final decisions.

ANNEX C. CALIFORNIA EMISSIONS REGULATIONS

Current light-duty vehicle standards

Table 34. **50 000 mile certification standards for passenger cars operating on gasoline (g/mile)**

G/mile	NMOG [a]	CO	NOx
1993 MY	0.25	3.4	0.4
TLEV	0.125	3.4	0.4
LEV	0.075	3.4	0.2
ULEV	0.04	1.7	0.2

a. NMOG is substituted for conventional hydrocarbons because the constituents in the exhaust could change as fuels change in the future; these emissions will be reactivity adjusted[1] for cleaner burning fuels.

Table 35. **Implementation rates for conventional vehicles, TLEVs, LEVs, ULEVs, and ZEVs used to calculate fleet average standards for passenger cars**

Model			TLEV	LEV	ULEV	ZEV [a]	Fleet Average
Year	0.39	0.25	0.125	0.075	0.040	0.00	NMOG Standard
1994	10%	80%	10%				0.250
1995		85%	15%				0.231
1996		80%	20%				0.225
1997		73%		25%	2%		0.202
1998		48%		48%	2%	2%	0.157
1999		23%		73%	2%	2%	0.113
2000				96%	2%	2%	0.073
2001				90%	5%	5%	0.070
2002				85%	10%	5%	0.068
2003				75%	15%	10%	0.062

a. The percentage requirements for ZEVs are mandatory starting in 2003.

Motorcycles

At its December 10, 1998 public meeting, California's Air Resources Board tightened the emission standards for 2004 and later model year Class III on-road motorcycles (280 cc and greater). The Tier 1 HC+ NOx standard for 2004 is 1.4 g/km and the Tier 2 HC+ NOx standard, which takes effect in 2008, will be 0.8 g/km. Small-volume manufacturers (sales no greater than 300 units) will be required to meet the Tier 1 standards in 2008. Manufacturers could comply using an HC+ NOx corporate average approach. Also, manufacturers will get extra emission credit for the early introduction of motorcycles meeting the Tier 2 HC+ NOx standard. The Motorcycle Industry Council opposed the Tier 2 standard. However, Harley-Davidson testified that it did not oppose the Tier 2 standard and would make every effort to comply.

New "LEV2" standards

On November 5, 1998 CARB adopted a plan to require passenger cars and certain sport utility vehicles (SUVs), mini-vans and large pickup trucks to meet tighter emission standards beginning in 2004.

These amendments include the following primary elements:

Restructuring vehicle weight classifications so that all current light-duty trucks, and all current medium-duty vehicles having a gross vehicle weight (GVW) of less than 8.500 lbs., would generally be subject to the same LEV and ULEV standards as passenger cars; only the very heaviest SUVs and pick-up trucks would remain subject to separate medium-duty vehicle standards;

New more stringent "LEV2" exhaust emission standards for the current LEV, ULEV and SULEV categories, which would be phased in from the 2004 to 2007 model years; the changes include reducing the NOx standard for passenger cars and light-duty trucks certified to the LEV and ULEV standards to 0.05 g/mi from the current 0.2 g/mi level, equivalent NOx reductions for medium-duty vehicles, more stringent particulate emission standards for diesel vehicles, increasing the useful life for passenger cars and light-duty trucks from the current 100 000 miles to 120 000 miles, a new light-duty SULEV category would be created with an NMOG standard less than one-fourth of the level for ULEVs, and a manufacturer option of certifying any LEV, ULEV or SULEV to a 150 000 mile certification standard, resulting in greater NMOG credits as long as the manufacturer provides an 8-year/100 000-mile warranty for high-cost parts rather than for the normal 7-years/70 000 miles;

Continuing yearly reductions in the fleet average NMOG requirements from model years 2004 through 2010, when the fleet average NMOG requirement for passenger cars would be 0.035 g/mi; there would be a separate phase-in schedule for the heavier light-duty trucks in the new LDT2 class, and for medium-duty vehicles the requirement of a 60/40 mix of LEVs and ULEVs in 2004 and subsequent model years would be changed to 40/60;

A new "partial ZEV allowance" mechanism under which advanced technology vehicles could provide partial credits towards satisfying a manufacturer's ZEV requirement; in order to receive any ZEV allowance, a vehicle would have to qualify for the "baseline ZEV allowance" of 0.2 by meeting the SULEV standard at 150 000 miles, satisfying applicable second generation on-board diagnostics requirements (OBD II), having "zero" evaporative emissions, and carrying an emission warranty covering all malfunctions identified by the OBD II system for 15 years or 150 000 miles; an additional allowance would be provided based on the potential for realising zero-emission vehicle miles travelled (e.g. capable of some all-electric operation traceable to energy from off-vehicle charging), up to a maximum of 0.6; and a vehicle that uses fuel with very low fuel-cycle emissions could receive a ZEV allowance of up to 0.2; a large volume manufacturer would have to meet at least 40% of its ZEV requirement with true ZEVs or vehicles with a 1.0 ZEV allowance;

More stringent evaporative emission standards for the 3-day diurnal-plus-hot-soak test and the 2-day diurnal-plus-hot-soak test, applicable to both fuel and non-fuel vehicle emissions and for a useful-life of 15 years or 150 000 miles, whichever first occurs; certification to the new standards would be required for 40% of a manufacturer's vehicles in the 2004 model year, 80% in the 2005 model year, and 100% in the 2006 model year; and

"CAP 2000" amendments which would significantly reduce the emission testing and reporting requirements for new vehicle certification, and substitute new requirements that manufacturers conduct more extensive compliance tests of in-use vehicles that have accumulated substantial mileage;

The four basic strategies to achieve the stringent exhaust emission standards are more precise fuel control, improved fuel delivery, better catalytic converter performance, and reduced base engine-out levels[2].

An element of the approved amendments allows a manufacturer to certify up to 4% of its truck sales in the LDT2 category to a marginally higher NOx emission standard (0.07 for 50 000 miles and 0.10 for 120 000 and 150 000 miles); this will satisfy a manufacturer's need to engineer some of its heavier trucks for more rigorous duty.

The CAP 2000 elements of the approved amendments will allow manufacturers to divert significant resources presently devoted to vehicle certification and redirect them toward in-use compliance in order to provide greater assurance that vehicles are actually complying with the standards in-use; the amendments will also result in cost savings for manufacturers of from $36 million to $57 million per year;

The projected costs to comply with the amendments are expected to range from about $100 to $200 per vehicle, with an-average of about $107; the estimated cost-effectiveness ranges from $0.50 to $1.39 per pound of reactive organic gas (ROG) + NOx reduced (about $1 per pound overall), which compares very favourably to the typical cost-effectiveness values for current air pollution control measures.

New standards

Table 36. **Standards effective in 2004**

Vehicle type	Mileage for compliance	Vehicle emission category	NMOG (g/mi)	Carbon monoxide (g/mi)	Oxides of nitrogen (g/mi)	Formaldehyde (mg/mi)	Diesel particulate (g/mi)
All PCS; LDTs<8 500 lbs. GVW	50 000	LEV	0.075	3.4	0.05	15	N/a
		LEV [a]	0.075	3.4	0.07	15	N/a
		ULEV	0.04	1.7	0.05	8	N/a
	120 000	LEV	0.09	4.2	0.07	18	0.01
		LEV [a]	0.09	4.2	0.1	18	0.01
		ULEV	0.055	2.1	0.07	11	0.01
		SULEV	0.01	1	0.02	4	0.01
	150 000	LEV	0.09	4.2	0.07	18	0.01
		LEV [a]	0.09	4.2	0.1	18	0.01
		ULEV	0.055	2.1	0.07	11	0.01
		SULEV	0.01	1	0.02	4	0.01
MDVs 8.500-10.000 lbs. GVWR	120 000	LEV	0.195	6.4	0.2	32	0.12
		ULEV	0.143	6.4	0.2	16	0.06
		SULEV	0.1	3.2	0.1	8	0.06
MDVs 10.001-14.000 lbs. GVWR	120 000	LEV	0.23	7.3	0.4	40	0.12
		ULEV	0.167	7.3	0.4	21	0.06
		SULEV	0.117	3.7	0.2	10	0.06

a. This optional LEV standard applies to up to 4% of a manufacturer's LDT2 fleet with a maximum base payload in excess of 2 500 lbs.

After the 2003 model year, Tier 1 standards (0.25 grams per mile NMHC) and TLEV standards would be eliminated as available emissions categories. The 50^{o}F multiplier for SULEVs would be 2.0 and the cold temperature carbon monoxide standard would be 10.0.

Fleet Average Requirements

Prior to the elimination of the TLEV category, CARB staff identified the following possible implementation rate to comply with the NMOG requirement.

Table 37. **Implementation rates for TLEVs, LEVs, ULEVs, SULEVs, and ZEVs used to calculate fleet average standards for passenger cars and light-duty trucks 0-3750 lb LVW**

Model year	TLEV	LEV	ULEV	SULEV	ZEV	Fleet average NMOG requirement
2004	2	48	35	5	10	0.053
2005	2	40	38	10	10	0.049
2006	2	35	41	12	10	0.046
2007	1	30	44	15	10	0.043
2008	1	25	44	20	10	0.040
2009	1	20	49	20	10	0.038
2010	1	15	49	25	10	0.035

Because trucks in the new LDT2 category are not as far along in meeting the proposed emission standards as PCs, and because there is no zero-emission vehicle (ZEV) requirement for LDTs (3 751 - 5 750 lb LVW or medium-duty vehicles 0-8 500 lb). The fleet average requirement being proposed would be slightly higher than those for PCS.

Table 38. **Implementation rates for TLEVs, LEVs, ULEVs, SULEVs, and ZEVs used to calculate fleet average standards for light-duty trucks 3751-7300 lb LVW**

Year	TLEV	LEV	ULEV	SULEV	Fleet Average NMOG Requirement
2004	2	75	21	2	0.067
2005	2	65	31	2	0.064
2006	2	55	38	5	0.059
2007	1	45	49	5	0.055
2008	1	35	54	10	0.050
2009	1	25	64	10	0.047
2010	1	20	64	15	0.043

The new Low-Emission Vehicle (LEV2) regulatory package could be the “death knell” for diesel use in California unless industry is able to produce "breakthrough" technology along that front. The NOx requirements are considered especially difficult.

Table 39. **California truck definitions**

	GVWR	LVW
LDT	0 - 6 000	
LDT1		0 - 3 750
LDT2		3 750 <
HDV	6 000<	
MDV [a]	6 001-8 500	
MDV [b]	<14 000	

a. Any pre 1995 heavy-duty vehicle.
b. Post 1992 LEV, ULEV, SULEV, ZEV.

NOTES

1. Different hydrocarbons react differently in the presence of sunlight to form smog. For example, methane has very low reactivity whereas the aldehydes have very high reactivity. A scale has been developed which assigns a reactivity weighting to different hydrocarbons and when this scale is applied, the hydrocarbons are reactivity adjusted.

2. Levels of pollutants coming directly from the engine upstream of the catalytic converter.

ANNEX D. JAPANESE EMISSIONS REGULATIONS

Current light-duty vehicle standards

Japanese standards for passenger cars fuelled by gasoline or LPG have been stable for many years. Applicable regulations are summarised below.

Table 40. **Current Japanese exhaust emission standards for passenger cars**

Spark ignition engines [1] (1978 standards [2, 3])					**Mean [4]**	**Max. [5, 6]**
10-15 Mode [2]	HC	g/km			0.25	0.39
Hot Start Test	CO	g/km			2.1	2.7
	NOx	g/km			0.25	0.48
11-Mode	HC	g/test			7.0	9.5
Cold Start Test	CO	g/test			60.0	85.0
	NOx	g/test			4.4	5.0
	Evap.	g/test			2.0	
	CC EM				0	
Idle	HC	Ppm			1 200	
Idle	CO	% vol.			4.5	
Diesel Engines			**Until 31/3/2000**		**After 1/4/2000**	
Smoke Test[7] 3-Mode Free Accel.	Blackness of filter paper		40 %		25 %	
10-15 Mode [2]	Ref. Mass (kg)		Mean [4, 8]	Max. [6, 8]	Mean [4]	Max. [5, 6]
HotG Start Test	<1 265					
	HC					
	CO	g/km	0.40	0.62	0.40	0.62
	NOx	g/km	2.10	2.70	2.10	2.70
	PM	g/km	0.50 [a]	0.72 [a]	0.40[b]	0.55[b]
			0.20 [a]	0.34 [a]	0.08[b]	0.14[b]
	>1 265					
	HC					
	CO	g/km	0.40	0.62	0.40	0.62
	NOx	g/km	2.10	2.70	2.10	2.70
	PM	g/km	0.60[a]	0.84[a]	0.40[c]	0.55[c]
			0.20[a]	0.34[a]	0.08[c]	0.14[c]

CC-EM = Crankcase Emission.

Notes for Table 40

1. Covers vehicles [no mass limitation] that serve exclusively for the transport of passengers [maximum 10 people].

2. New Hot Start Test (10-15-Mode) superseded the 10-mode test with effect from 1.11.91 for new models. 1.4.93 for importers. The exhaust emission limits remain unchanged.

3. 80 000 km durability run optional; acceptance of US durability run possible. Advantage: if standards are met over 80 000 km, the mandatory periodic catalyst change does not apply. Alternatively certification is allowed with a 30 000 km durability run and demonstration of compliance over 45 000 km [by extrapolation].

4. To be met as a type approval limit and as a production average (for production control 1% of production has to be tested). If sales exceed 2000 per vehicle model per calendar year, the NOx standards are only applicable if reference mass >1000 kg.

5. To be met as a type approval limit if sales are less than 2000 per vehicle model per calendar year and generally as an individual limit in series production. For gasoline and diesel engines (Hot Start Test only) deterioration factors from the durability runs have to be applied.

6. Applicable for simplified certification procedure if sales are less than 1000 per vehicle model per calendar year without durability run. Exhaust emission testing is necessary for every 50th production example per vehicle model.

7. 3 Mode: Full load smoke test at three specified engine speeds.
   Free Acceleration: Start from idle, integrated smoke measurement over a 15 second cycle, (4 sec. maximum acceleration, followed by 11 sec. coast).

8. Effective Dates
   Domestic Manufacturers: 1.10.86 (Manual transmission); 1.10.87 (Automatic transmission)
   Importers: 1.04.88 (Manual transmission); 1.10.89 (Automatic transmission)

a. Effective Dates
   Domestic Manufacturers
      Reference Mass <1265 kg): 1.10.94 - New models; 1.4.95 - Existing models
      Reference Mass> 1265 kg):1.10.94 - New Models; 1.4.95 Existing models
   Importers:
      Reference Mass < 1265 kg - 1.4.96 > 1265 kg. - 1.4.96; Effective Date for PM limit: 1.4.96.

b. Effective Dates
      Domestic Manufacturers - 1.10.98 (New models); 1.9.99 (Existing models)
      Importers 1.4.00

c. Effective Dates
      Domestic Manufacturers - 1.10.97 (New models); 1.7.99 (Existing models)
      Importers 1.4.00

New Light-Duty Standards

In spite of the efforts to date, the NO_2, O_3 and particulate problems in major Japanese cities remain serious. Therefore, the emissions standards for gasoline and LPG fuelled vehicles will be tightened. Quite remarkably, this reflects the first change for passenger cars since the enforcement of the Japanese version Muskie [1] law in 1978.

For passenger vehicles and trucks, CO, HC and NO will be reduced approximately 70% compared to today's levels. Further, the GVW upper limit for medium sized trucks will be increased to 3.5 tons.

For mini-sized trucks, CO, HC and NOx emissions will be reduced by approximately 50%.

Table 41. **New target values for permissible limits for gasoline and LPG motor vehicles (Exhaust emissions)**

Category of motor vehicles		**Target values of permissible limits (Mean values)**			**Measurement method**
		Nitrogen Oxides	Hydro Carbons	Carbon Monoxide	
Ordinary-sized, small-sized and mini-sized motor vehicles fuelled by gasoline or LPG and used exclusively for carriage of passengers with a passenger capacity of 10 persons or less (excluding two-wheeled motor vehicles)		0.08	0.08	0.67	10-15 Mode (g/km)
		1.4	2.2	19	11-Mode (g/test)
Mini-sized motor vehicles fuelled by gasoline or LPG (excluding those used exclusively for carriage of passengers, those with 2-stroke engine, and two-wheeled motor vehicles)		0.13	0.13	3.3	10-15 Mode (g/km)
		2.2	3.5	38	11 - Mode (g/test)
Ordinary-sized and small-sized motor vehicles fuelled by gasoline or LPG (excluding those used exclusively for carriage of passengers with a passenger capacity of 10 persons or less and two-wheeled motor vehicles)	Those with a gross vehicle weight of 1700 kg or less	0.08	0.08	0.67	10-15 Mode (g/km)
		1.4	2.2	19	11- Mode (g/test)
	Those with a gross vehicle weight in excess of 1700 kg but 3500 kg or less	0.13	0.08	2.1	10-15 Mode (g/km)
		1.6	2.2	24	11-Mode (g/test)
	Those with a gross vehicle weight in excess of 3500 kg	1.4	0.58	16	Gasoline 13 - Mode (g/kWh)

Implementation Schedule:

Light-Duty Vehicles - 2000.

Medium & Heavy-Duty Vehicles - 2001.

Mini Vehicles - 2002.

Table 42. **Durability running distance for gasoline and LPG motor vehicles**

Category of Motor Vehicles	Durability running distance
Ordinary-sized and small-sized motor vehicles fuelled by gasoline or LPG (excluding those with a gross vehicle weight in excess of 3500 kg except for those used exclusively for carriage of passengers with a passenger capacity of 10 persons or less) and two-wheeled motor vehicles)	80 000 km
Ordinary-sized and small-sized motor vehicles fuelled by gasoline or LPG with a gross vehicle weight in excess of 3500 kg (excluding those used exclusively for carriage of passengers with a passenger capacity of 10 persons or less and two-wheeled motor vehicles)	180 000 km
Mini-sized motor vehicles fuelled by gasoline or LPG (excluding two wheeled motor vehicles)	60 000 km

Diesel Vehicles

The Japanese EPA also continues to move forward with their regulation of diesel vehicles. The Long Term Targets identified in 1989 are being phased in over the period from 1997 to 1999 as follows:

Table 43. **Long term targets phased in from 1997 to 1999 for the regulation of diesel vehicles**

Vehicle category	NOx	Particulate	Year of implementation
GVW< 1.7 Tons	0.4 g/km	0.08 g/km	1997
1.7<GVW< 2.5 Tons (M)	0.7 g/km	0.09 g/km	1997
1.7<GVW< 2.5 Tons (A)	0.7 g/km	0.09 g/km	1998
2.5<GVW<3.5 Tons	4.5 g/kWh	0.25 g/kWh	1997
3.5<GVW<12 Tons	4.5 g/kWh	0.25 g/kWh	1998
Above 12 Tons	4.5 g/kWh	0.25 g/kWh	1999

On December 14, 1998, the Air Quality Committee, Central Council for Environmental Pollution Control issued the new Short Term Targets[2] for diesel vehicle pollution control. The new limits are as follows.

Table 44. **Short term targets for diesel vehicle pollution control**

Vehicle category	Test procedure (Unit)	Component	Current Limit		New short term target	
			Enforcement year	Limit value	Enforcement year	Target value
Small-sized cars < 1.25 tons [1]	10-15 mode (g/km)	NOx	1997	0.4	2002	0.28
		PM		0.08		0.052
		HC	1986	0.4		0.12
		CO		2.1		0.63
Medium-sized cars 1.25 tons > [1]		NOx	1998	0.4		0.3
		PM		0.08		0.56
		HC	1986	0.4		0.12
		CO		2.1		0.63
Light-duty trucks, buses < 1.7 tons [2]		NOx	1997	0.4		0.28
		PM		0.08		0.052
		HC	1988	0.4		0.12
		CO		2.1		0.63
Light-duty trucks, buses 1.7 – 2.5 tons [2]		NOx	1997 & 1998	0.7	2003	0.49
		PM		0.09		0.06
		HC	1993	0.4		0.12
		CO		2.1		0.63
Heavy-duty trucks, buses 2.5 – 12 tons [2, 3]	D 13 mode (g/kWh)	NOx	1998	4.5	2003	3.38
		PM		0.25		0.18
		HC	1994	2.9		0.87
		CO		7.4		2.22
Heavy-duty trucks, buses 12 tons > [2, 4]		NOx	1994	6.00 (DI) 5.00 (IDI)	2004	3.38
			1999	4.5		
		PM	1994	0.7		0.18
			1999	0.25		
		HC	1994	2.9		0.87
		CO	1999	7.4		2.22

1. Division is made according to the equivalent inertia weight (EIW).
2. Division is made according to gross vehicle weight (GVW).
3. Year 1997: GVW 2.5 ~ 3.5 tons; Year 1998: GVW 3.5 ~ 12 tons.
4. DI: Direct Injection; IDI: Indirect Injection.

With these short-term targets, NOx emissions will be reduced by 25 to 30% and particulate matter by 28 to 35% over a period from the year 2002 to 2004. Moreover, with a view to maintaining adequate performance of exhaust emissions controls in use, the durability requirements will be extended (see Table below) and the installation of OBD systems will become mandatory.

Expected control technologies include oxidation catalysts, cool EGR, high pressure fuel injection, intercooling and Turbocharging.

Consideration was also given to modification to diesel fuel quality needs for new technologies such as NOx reduction catalysts but no decision was made to reduce sulphur levels (from 500 ppm) or to modify Cetane number, aromatics content, density, etc. at this time. Also, additional review will be needed before changes to the existing test procedures can be recommended.

Table 45.

Vehicle category		**Passenger cars**	**Trucks and Buses (Gross Vehicle Weight)**				
			~ 2.5 tons	~ 3.5 tons	~ 8 tons	~ 12 tons	12 tons [a]
Durability Running Distance	Current	30 000 km	20 000 km	30 000 km			
	After revision	80 000 km			250 000 km	450 000 km	650 000 km

a. Current 12 Tons~: To be enforced after year 1999

In addition, automobile manufacturers and petroleum refiners are to carry out technical development so that further reduction of the emissions by an additional 50% beyond the short-term targets can be achieved by around 2007. The specific limits and fuel requirements will be determined by the end of 2002.

NOTES

1. These standards are frequently referred to as the Muskie standards since they were adopted following a highly publicized visit to Japan by Senator Edmund Muskie, the principal author of the landmark 1970 US Clean Air Act.

2. Short-term targets are those which the Central Council believes are technologically feasible in a short time frame, generally 2 to 4 years. Longer term targets are considered necessary to achieve the environmental goals but will generally require additional technological development.

ANNEX E. US FUEL EFFICIENCY EFFORTS

The Table below summarises the US EPA estimate of the trends in U.S. greenhouse gas emissions and sinks for 1990 through 1996. Estimates are presented in units of millions of metric tons of carbon equivalents (MMTCE), which weights each gas by its GWP value, or global warming potential.

Table 46. **Recent trends in U.S. greenhouse gas emissions and sinks (MMTCE)**

Gas/Source	1990	1991	1992	1993	1994	1995	1996
CO_2	1 348.3	1 333.2	1 353.4	1 385.6	1 408.5	1 419.2	1 471.1
Fossil Fuel Combustion [a]	1 331.4	1 316.4	1 336.6	1 367.5	1 389.6	1 398.7	1 450.3
Natural Gas Flaring	2.0	2.2	2.2	3.0	3.0	3.7	3.5
Cement Manufacture	8.9	8.7	8.8	9.3	9.6	9.9	10.1
Lime Manufacture	3.3	3.2	3.3	3.4	3.5	3.7	3.8
Limestone and Dolomite Use	1.4	1.3	1.2	1.1	1.5	1.8	1.8
Soda Ash Manufacture and Consumption	1.1	1.1	1.1	1.1	1.1	1.2	1.2
Carbon Dioxide Manufacture	0.2	0.2	0.2	0.2	0.2	0.3	0.3
Land-Use Change and Forestry (Sink) [b]	(311.5)	(311.5)	(311.5)	(208.6)	(208.6)	(208.6)	(208.6)
CH_4	169.9	171.1	172.5	171.9	175.9	179.2	178.6
Stationary Sources	2.3	2.3	2.4	2.3	2.3	2.4	2.5
Mobile Sources	1.5	1.4	1.4	1.4	1.4	1.4	1.4
Coal Mining	24.0	22.8	22.0	19.2	19.4	20.3	18.9
Natural Gas Systems	32.9	33.3	33.9	34.1	33.9	33.8	34.1
Petroleum Systems	1.6	1.6	1.6	1.6	1.6	1.6	1.5
Petrochemical Production	0.3	0.3	0.3	0.4	0.4	0.4	0.4
Silicon Carbide Production	[c]	[c]	[c]	[c]	[c]	[c]	
Enteric Fermentation	32.7	32.8	33.2	33.6	34.5	34.9	34.5
Manure Management	14.9	15.4	16.0	16.1	16.7	16.9	16.6
Rice Cultivation	2.5	2.5	2.8	2.5	3.0	2.8	2.5
Agricultural Residue Burning	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Landfills	56.2	57.6	57.8	59.7	61.6	63.6	65.1
Wastewater Treatment	0.9	0.9	0.9	0.9	0.9	0.9	0.9

Gas/Source	1990	1991	1992	1993	1994	1995	1996
N2O	92.3	94.4	96.8	97.1	104.9	101.9	103.7
Stationary Sources	3.7	3.7	3.7	3.8	3.8	3.8	4.0
Mobile Sources	13.2	13.9	14.8	15.6	16.3	16.6	16.5
Adipic Acid	4.7	4.9	4.6	4.9	5.2	5.2	5.4
Nitric Acid	3.4	3.3	3.4	3.5	3.7	3.7	3.8
Manure Management	2.6	2.8	2.8	2.9	2.9	2.9	3.0
Agricultural Soil Management	62.4	63.4	65.2	64.1	70.4	67.2	68.6
Agricultural Residue Burning	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Human Sewage	2.1	2.1	2.2	2.2	2.3	2.2	2.3
Waste Combustion	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HFCs, PFCs, and SF_6	22.2	21.6	23.0	23.4	25.9	30.8	34.7
Substitution of Ozone Depleting Substances	0.3	0.2	0.4	1.4	4.0	9.5	11.9
Aluminium Production	4.9	4.7	4.1	3.5	2.8	2.7	2.9
HCFC-22 Production	9.5	8.4	9.5	8.7	8.6	7.4	8.5
Semiconductor Manufacture	0.2	0.4	0.6	0.8	1.0	1.2	1.4
Electrical Transmission and Distribution	5.6	5.9	6.2	6.4	6.7	7.0	7.0
Magnesium Production and Processing	1.7	2.0	2.2	2.5	2.7	3.0	3.0
Total Emissions	1 632.7	1 620.2	1 645.7	1 678.0	1 715.3	1 731.1	1 788.0
Net Emission (Sources and Sinks)	1 321.2	1 308.7	1 334.2	1 469.4	1 506.7	1 522.5	1 579.5

a. See the following table for the mobile source contribution to the total.
b. Sinks are only included in net emissions total. Estimates of net carbon sequestration due to land-use change and forestry activities exclude non-forest soils, and are based partially upon projections of forest carbon stocks.
c. Does not exceed 0.05 MMTCE.
Note: Totals may not sum due to independent rounding.

The largest source of CO_2 and of overall GHG emissions in the United States was fossil fuel combustion. Methane emissions resulted primarily from decomposition of wastes in landfills, manure and enteric fermentation associated with domestic livestock, natural gas systems, and coal mining. Emissions of nitrous oxide were dominated by agricultural soil management and mobile source fossil fuel combustion. The substitution of ozone depleting substances and emissions of HFC-23 during the production of HCFC-22 were the primary contributors to aggregate HFC emissions. PFC emissions came mainly from primary aluminium production, while electrical transmission and distribution systems emitted the majority of SF_6.

Total U.S. greenhouse gas emissions rose 9.5% in 1996 from 1990 baseline levels, to 1 788.0 MMTCE. The largest single year increase in emissions over this time period was registered in 1996 (57.0 MMTCE or 3.3%).

The Table below summarises greenhouse gas emissions from all transportation related activities. Overall, transportation activities accounted for an almost constant 26% of total U.S. greenhouse gas emissions from 1990 to 1996. These emissions were primarily CO_2 from fuel combustion, which increased by 8.8% from 1990 to 1996. However, because of larger increases in N_2O and HFC emissions during this period, overall emissions from transportation activities actually increased by 10.1%.

Table 47. **Transportation Related Greenhouse Gas Emissions (MMTCE)**

Gas/Vehicle Type	1990	1991	1992	1993	1994	1995	1996
CO_2	409.6	400.8	406.7	414.1	427.4	432.8	445.5
Passenger Cars [a]	169.3	167.8	172.0	173.5	172.5	160.0	163.2
Light-Duty Trucks [a]	77.5	77.2	77.2	80.5	87.2	104.9	107.1
Other Trucks	56.8	54.7	56.6	59.7	62.4	64.0	67.0
Buses	2.7	2.9	2.9	3.0	3.3	3.5	3.7
Aircraft	55.9	53.8	53.0	53.5	55.6	55.0	57.4
Boats and Vessels	16.3	15.0	15.3	13.4	13.7	12.5	13.2
Locomotives	7.4	6.9	7.4	6.7	8.0	8.1	8.5
Other [b]	23.7	22.4	22.4	23.7	24.8	24.9	25.5
CH_4	1.5	1.4	1.4	1.4	1.4	1.4	1.4
Passenger Cars	0.8	0.7	0.7	0.7	0.7	0.7	0.6
Light-Duty Trucks	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Other Trucks and Buses	0.1	0.1	0.1	0.2	0.2	0.2	0.2
Aircraft	+	+	+	+	+	+	+
Boats and Vessels	0.1	0.1	0.1	+	+	+	+
Locomotives	+	+	+	+	+	+	+
Other [c]	0.1	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	13.2	13.9	14.8	15.6	16.3	16.6	16.5
Passenger Cars	8.7	9.1	9.7	10.1	10.0	10.1	10.1
Light-Duty Trucks	3.4	3.7	3.9	4.2	5.1	5.2	5.1
Other Trucks and Buses	0.7	0.7	0.7	0.7	0.8	0.8	0.9
Aircraft [d]	+	+	+	+	+	+	+
Boats and Vessels	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Locomotives	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Other [c]	0.2	0.2	0.2	0.2	0.2	0.2	0.2
HFCs	+	+	0.2	0.7	1.3	2.5	3.6
Mobile Air Conditioners [e]	+	+	0.2	0.7	1.3	2.5	3.6
Total	424.3	416.1	423.2	431.7	446.4	453.3	467.0

+ Does not exceed 0.05 MMTCE

Note: Totals may not sum due to independent rounding.

a. In 1995, the U.S. Federal Highway Administration modified the definition of light-duty trucks to include minivans and sport utility vehicles. Previously, these vehicles were included under the passenger cars category. Hence the sharp drop in CO_2 emissions for passenger cars from 1994 to 1995 was observed. This gap, however, was offset by an equivalent rise in CO_2 emissions from light-duty trucks.

b. "Other" CO_2 emissions includes motorcycles, construction equipment, agricultural machinery, pipelines, and lubricants.

c. "Other" CH4 and N_2O emissions includes motorcycles, construction equipment, agricultural machinery, gasoline-powered recreational, industrial, lawn and garden, light commercial, logging, airport service, other equipment; and diesel-powered recreational, industrial, lawn and garden, light construction, airport service.

d. Aircraft N_2O emissions include aviation gasoline combustion but exclude jet fuel combustion due to insufficient data availability.

e. Includes primarily HFC-134a.

The United States has had a mandatory fuel efficiency programme since 1975. The Energy Policy and Conservation Act, passed that year to come into effect in model year 1978, amended the Motor Vehicle Information and Cost Saving Act to require new passenger cars to get at least 27.5 miles per U.S. gallon (8.55 liters/100 km) by 1985, as measured by EPA test procedures.

Vehicle manufacturers are required to test some percentage of all vehicles destined to be sold in the United States so that a fuel - consumption rating can be assigned to each product line. The test involves both city and highway driving cycles. From these figures, a sales-weighted average fuel-consumption figure is calculated for all the passenger cars produced by each manufacturer. Fuel efficiency (in mpg) calculated this way must exceed the Corporate Average Fuel Economy (CAFÉ) standard specified for the appropriate model year. Since the 1979 model year, the CAFÉ programme, as it is called, has been expanded to cover light-duty trucks as well as passenger cars.

Failure to meet the CAFÉ requirements can result in substantial financial penalties. For each vehicle produced, a manufacturer whose fleet-average fuel consumption does not meet the CAFÉ standard is fined $5 per vehicle for every 0.1 miles/U.S. gallon by which the standard is not met. These fines may be offset by credits accrued in other model years, however.

Table 48. **US New-Car fuel efficiency standards (CAFÉ)**
(Miles per US gallon)

Model year	**Passenger cars**	**Light trucks**	
		2 WD	**4 WD**
1978	18.0	-	-
1979	19.0	17.2	15.8
1980	20.0	16.0	14.0
1981	22.0	16.7	15.0
1982	24.0	18.0	16.0
1983	26.0	19.5	17.5
1984	27.0	20.3	18.5
1985	27.5	19.7	18.9
1986	26.0	20.5	19.5
1987	26.0	21.0	19.5
1988	26.0	21.0	19.5
1989	26.5	21.5	19.0
1990	27.5	20.5	19.0
1991	27.5	20.7	19.1

Light-duty trucks, including jeeps and mini-vans had to meet a corporate fuel economy standard of 20.6 miles per gallon starting with their 1995 model year vehicles according to the National Highway Traffic Safety Administration.

In recent years, as fuel prices have dropped and the CAFÉ pressures to improve fuel efficiency have diminished, U.S. new-car fuel efficiency has begun to slip.

The average fuel economy for all model year 1999 light vehicles is 23.8 miles per gallon (MPG). Within this category, average fuel economy is 28.1 MPG for passenger cars and 20.3 MPG for light-duty trucks. The 1999 fuel economy average is the lowest value since 1980 and is 2.1 MPG less than the peak value of 25.9 MPG achieved in both 1987 and 1988. Average fuel economy for new light vehicles has dropped 1.0 MPG since 1996.

All of the fleet-wide improvement in new light vehicle fuel economy occurred from the middle 1970s through the late 1980s, but it has been consistently falling since the late 1980s. Viewed separately, the average fuel economy for new cars has been essentially flat over the last 14 years, varying only from 27.6 MPG to 28.6 MPG. Similarly, the average fuel economy for new light trucks has been largely unchanged for the past 19 years, ranging from 20.1 MPG to 21.6 MPG. The increasing market share of light-duty trucks, which have lower average fuel economy than cars, is the primary reason for the decline in fuel economy of the overall new light vehicle fleet.

Sales of light-duty trucks, which include sport utility vehicles (SUVs), minivans, and pickup trucks, have risen steadily for 20 years and now make up 46% of the U.S. market, more than twice their market share as recently as 1983.

Growth in the light-duty truck market has been led recently by the explosive popularity of SUVs, which rose in sales from less than 200 000 in 1975 (less than 2% of the overall new light vehicle market) to almost 3 million in 1999 (20% of the market). Over the same period, market share for minivans and full-size vans doubled from 5 to 10% and for pickup trucks grew from 13 to 16%. Between 1975 and 1999, market share for new passenger cars and wagons has fallen from 81 to 54%. Based on lower average fuel economies and projected longer useful lives, EPA estimates that the new light-duty trucks sold in 1999 will consume, over their lifetimes, almost 60% of the fuel used by all of the new light vehicles sold in 1999.

More efficient technologies have continued to enter the new light vehicle fleet and are being used to increase light vehicle weight and performance rather than fuel economy. Based on accepted engineering relationships, if the new 1999 light vehicle fleet had the same average weight and performance as in 1986, it could have achieved 5 MPG higher fuel economy.

More efficient technologies, such as engines with more valves and more sophisticated fuel injection systems, and transmissions with extra gears, have continued to penetrate the new light vehicle fleet. The trend has clearly been to apply these new technologies to increase average new vehicle weight, power, and performance while maintaining fuel economy. This is reflected by heavier average vehicle weight (up 20% for new light vehicles since 1986), rising average horsepower (up 58% for new light vehicles since 1986), and lower 0 to 60 mile-per-hour acceleration time (19% faster for new light vehicles since 1986). During this same time, average new light vehicle fuel economy fell by 7%.

The Big Three automakers and the U.S. government have been sharing high-tech information and manufacturing know-how since 1993 in an effort to serve mutually beneficial purposes. The programme is called the Partnership for a New Generation of Vehicles (PNGV) and matches engineers from the auto industry with government researchers from national laboratories, renowned in the past for their work on military technologies.

The goal is to create technology that will lead to a working model of a super-car by the year 2004 -- a car capable of getting 80 miles to the gallon while meeting Tier 2 emissions levels or better.

ANNEX F. JAPANESE PROGRAMME TO REDUCE FUEL CONSUMPTION

MITI and MOT jointly drafted energy saving standards for automobiles and electric appliances on 13 October 1998 in compliance with the energy saving law. The draft standards were then adopted earlier this year.

Manufacturers which cannot meet the standards are to be penalised.

The standards will apply to the vehicle categories indicated below.

- Gasoline-fuelled passenger vehicles
- Gasoline-fuelled light trucks less than 2.5 tons GVW
- Diesel powered passenger vehicles
- Diesel powered light trucks less than 2.5 tons GVW

Target fiscal year

- Gasoline-fuelled vehicles - 2010
- Diesel powered vehicles - 2005

Measurement Method

The value, expressed in kilometres per litre of fuel, will be based on the 10 - 15 mode method.

Categories and target standard values

The average energy efficiency ratio for each category in the following table must not fall below the target standard values.

Table 49. **Gasoline-fuelled passenger vehicles**

Category (vehicle weight kg)	- 702	703-827	828-1015	1016-1265	1266-1515	1516-1765	1766-2015	2016-2265	2266-
Target standard value (km/l)	21.2	18.8	17.9	16.0	13.0	10.5	8.9	7.8	6.4

Table 50. **Gasoline-fuelled light trucks less than 2.5 tonnes GVW**

Category	Light Freight					Light Weight Freight		Medium Weight Freight			
Vehicle weight	- 702		703 - 827		828-1015	1016 - 1265	1266 -	- 1265		1266 - 1515	1516 -
	Passenger vehicle derivative	Other	Passenger vehicle derivative	Other				Passenger vehicle derivative	Other		
Automatic trans-mission	18.9	16.2	16.5	15.5	14.9	14.9	13.8	12.5	11.2	10.3	
Manual trans-mission	20.2	17.0	18.0	16.7	15.5	17.8	15.7	14.5	12.3	10.7	9.3

Table 51. **Diesel-powered passenger vehicles**

Category (vehicle weight kg)	- 1015	1016-1265	1266-1515	1516-1765	1766-2015	2016-2265	2266-
Target standard value (km/l)	18.9	16.2	13.2	11.9	10.8	9.8	8.7

Table 52. **Diesel-powered light trucks less than 2.5 tonnes GVW**

Category	**Light weight freight**	**Medium-weight freight**				
Vehicle weight kg		- 1265		1266 - 1515	1516 - 1765	1766 -
		Passenger vehicle derivative	Other			
Automatic transmission	15.1	14.5	12.6	12.3	10.8	9.9
Manual transmission	17.7	17.4	14.6	14.1	12.5	

Light-weight freight: Freight vehicle 1.7 tons or below in gross vehicle weight.
Medium-weight freight: Freight vehicle over 1.7 tons and less than 2.5 tons GVW.

If it is assumed that the percentage of exported vehicles is the same as in 1995, the rates of improvement in consumption efficiency over the actual 1995 values are as given below.

Table 53. **Gasoline-fuelled vehicles**

	Actual values in fiscal 1995	**Estimated value for fiscal 2010**	**Rate of improvement**
Passenger vehicles	12.3 km/l	15.1 km/l	22.8 %
Light trucks 2.5 tons or below in gross weight	14.4 km/l	16.3 km/l	13.2 %
Total	12.6 km/l	15.3 km/l	21.4 %

Table 54. **Diesel-powered vehicles**

	Actual values in fiscal 1995	**Estimated value for fiscal 2005**	**Rate of improvement**
Passenger vehicles	10.1 km/l	11.6 km/l	14.9 %
Light trucks 2.5 tons or below in gross weight	13.8 km/l	14.7 km/l	6.5 %
Total	10.7 km/l	12.1 km/l	13.1 %

ANNEX G. VOLUNTARY AGREEMENTS TO REDUCE CO_2 EMISSIONS AND MONITORING OF CO_2 EMISSIONS FROM NEW CARS IN EUROPE

Background

In the 1995 Joint Declaration on reducing CO_2 emissions from passenger cars, ECMT agreed with the vehicle manufacturing industry, represented by ACEA and OICA, on a number of joint actions, including the establishment of a new car fuel consumption monitoring system.

After examining available options for establishing the most appropriate monitoring system, governments and industry agreed on a pragmatic and cost-effective approach, based on data from an existing high-quality source, the AAA (*Association Auxiliaire Automobile*) database maintained by the CCFA (*Comité des Constructeurs Francais d'Automobiles*). In 1996, a first report under the Declaration was presented, covering monitoring data and analysis for the period 1980 to 1995. A progress report, based on the same data source and covering developments in 1996 and 1997 was presented to Ministers in 1999. At the Warsaw Council in 1999, Ministers:

Agreed to continue monitoring the CO_2 emissions of new passenger cars under the Joint Declaration with Industry until such time as the monitoring system under development by the European Commission is operational;

Requested Deputies to:

- continue work under the Joint Declaration with Industry;
- report in 2000 on some of the policy issues arising from the monitoring of new passenger vehicles and on issues related to emissions of vehicles in use;
- and to report again on monitoring, if necessary, in 2001.

The present report provides additional data for the years 1998 and 1999, first published in graph form in *Sustainable Transport Policies, ECMT, June 2000*.

It should be noted that almost identical data is reported in the Communication from the European Commission to the European Council and the European Parliament on Implementing the Community Strategy to Reduce CO_2 Emissions from Cars: First annual report on the effectiveness of the strategy, October 2000 (see http://europa.eu.int/comm/environment/co2/co2_home.htm). As the official EU data reporting system is not yet operational, the Commission and ECMT monitoring reports draw data mainly from the same source. The present report uses data from the AAA database for all vehicles sold in Europe, regardless of manufacturer. For the European Commission, ACEA provided data from the AAA database for vehicles manufactured by its members only. The Korean manufacturers association, KAMA, also provided data from the AAA database for vehicles manufactured by its members. The Japanese manufacturers association, JAMA, provided figures from Marketing Systems Data for vehicles manufactured by its members. These minor differences in sources result in small differences in the results in some years and are noted in this report where they occur.

Recent Trends

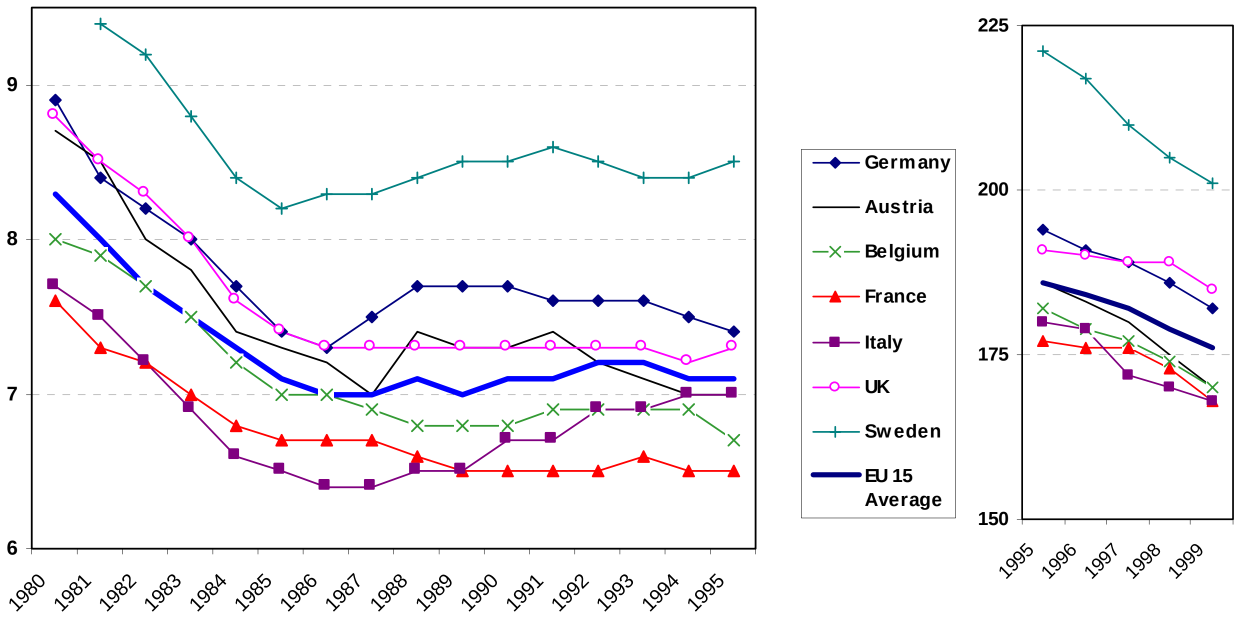
The first ECMT monitoring report showed 1995 average fuel consumption of new cars in 15 European markets at 7.1 litres per 100km (measured according to the "old" 80/1268/EEC cycle). As noted in the first report, data is affected by the change in the official test-cycle for fuel consumption. CO_2 emissions data is now being estimated in accordance with Directive 93/116/EC, which replaced Directive 80/1268/EEC. The "new" test cycle was implemented in large part as of 1.1.1997 and remains applicable for the years under review. Amongst other changes, the "new" cycle includes for the first time a cold start period, and consequently higher fuel consumption/CO_2 emissions are recorded. In the prior report it was expected that the impact of the new cycle would be higher values for fuel consumption of the order of 10%. Subsequent comparisons (by industry) indicate an increase of some 9% in average car CO_2 emissions. This latter figure has been used, where necessary, in the following analysis; this has enabled trends to be identified which would not be otherwise possible. It is important to realise that the change in Directive has created an artificial increase in recorded CO_2 emissions which is not reflected in the real world.

The need to make this adjustment was anticipated and the conversion indicates that in 1995 the average fuel consumption of new cars in the 15 European markets equated to emissions of 186g CO_2 per km under the new test cycle. This figure forms the basis for the review of more recent trends. As can be seen in the table below, from a 1995 base of 186g CO_2 per km, average European (EU 15 minus Greece for which data is not available and Finland for which data is only available for 1995) new car CO_2 emissions reduced to 184g/km in 1996, 182g/km in 1997, 179g/km in 1998 (179.6 with the data reported to the EC) and 176g/km in 1999 — with falls occurring in all countries. Thus over the 1995 to 1999 period new car CO_2 emissions in Europe as a whole maintained the steady and continuous path of reduction evident since 1993.

The trend in average emissions from new passenger cars is currently on course to meet the target of 140g of CO_2 per km in 2008 (a 25% reduction compared to 1995) set under the ACEA voluntary agreement, (2009 under the JAMA and KAMA voluntary agreements) concluded with the European Commission. This represents much the largest contribution in the transport sector to measures taken so far towards meeting the commitments to reduce CO_2 emissions made under the 1997 UN Kyoto protocol.

Figure 3. **Weighted average fuel consumption and CO_2 emissions, all new cars**

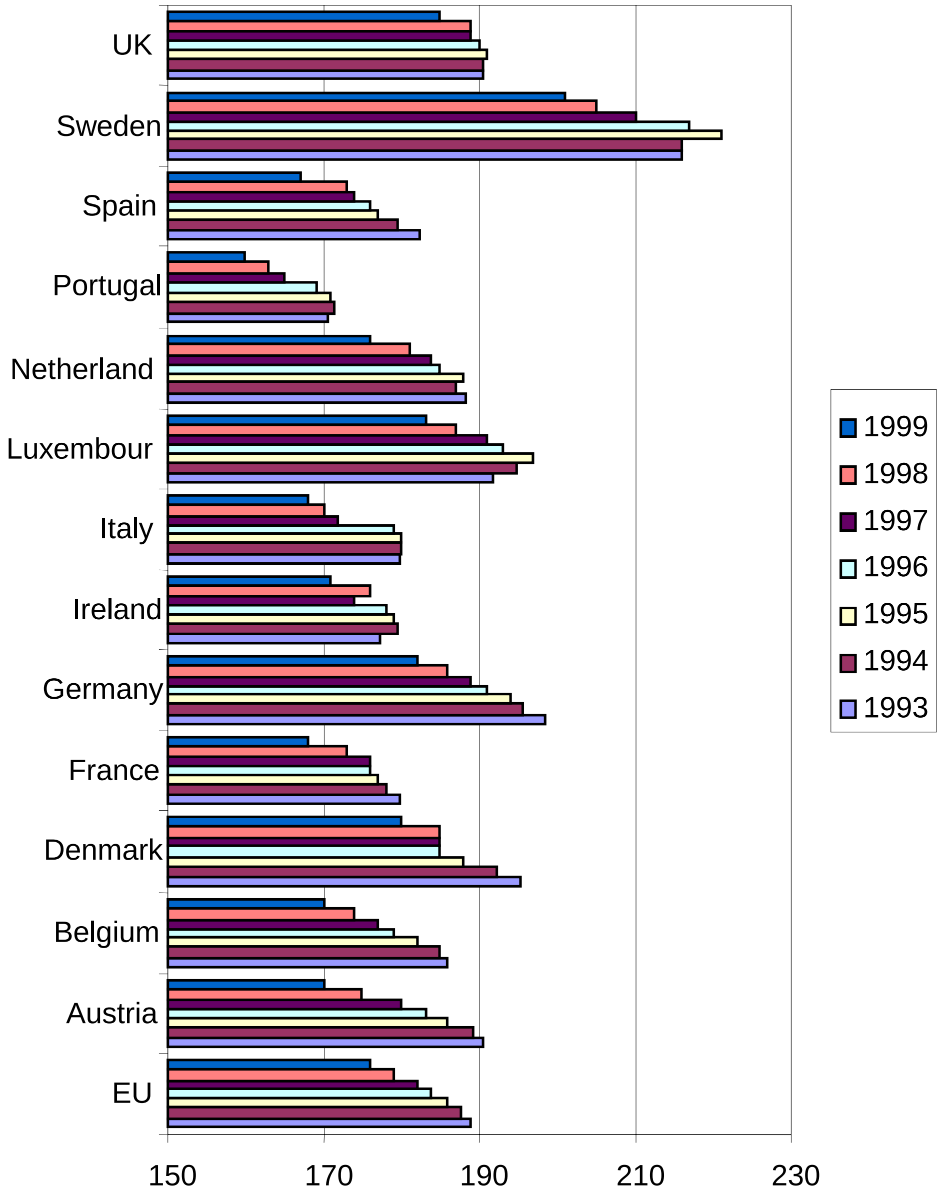
Test cycle - 80/1268/EEC (Litres / 100 km) Test cycle - 93/116/EC (Grams CO_2/km)



Note: Bold line shows the weighted average for the 7 countries (selected according to data availability and accounting for 85% of EU sales) for the period to 1995; and the weighted average for 13 EU member countries from 1995 onwards (excluding Finland and Greece).

Source: ACEA/OICA/ECMT, 2000, drawn from AAA database for all manufacturers.

Figure 4. **Average CO_2 emissions of new passenger cars weighted by registrations**
(grammes CO_2/km measured according to norm 93/116/EC)



Source: ACEA/OICA/ECMT, 2000, drawn from AAA database for all manufacturers.

Table 55. **Average specific CO_2 emissions of new cars weighted by registrations**
(Grammes CO_2/km - test cycle 93/116/EC)

	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
EU13	189	188	186	184	182	179*	176
Austria	191	189	186	183	180	175	170
Belgium	186	185	182	179	177	174	170
Denmark	195	192	188	185	185	185	180
France	180	178	177	176	176	173	168
Germany	198	196	194	191	189	186	182
Ireland	177	179	179	178	174	176	171
Italy	180	180	180	179	172	170	168
Luxembourg	192	195	197	193	191	187	183
Netherlands	188	187	188	185	184	181	176
Portugal	171	171	171	169	165	163	160
Spain	182	180	177	176	174	173	167
Sweden	216	216	221	217	210	205	201
UK	190	191	191	190	189	189	185
Norway			196	191	192		
Switzerland			216	212	211		

* 179.6 according to data reported to the European Commission.
Source: ACEA/OICA/ECMT, 2000, drawn from AAA database for all manufacturers.

The reduction in new car CO_2 emissions observed can also be viewed in the context of developments in the physical characteristics of cars sold in Europe. Key trends are:

– **diesel penetration** in Europe has risen through the monitoring period to reach 29%[1] of registrations in the 15 EU countries in 1999. The temporary stabilisation of penetration noted in the last monitoring exercise has been overtaken by a resumption in growth in the share of diesel car sales. In 1998-99 the market share for diesel showed some expansion as technically advanced new direct injection (DI) diesels came to market. However dieselisation varies considerably across Europe with certain countries at diesel shares above 40% (such as: Austria, Belgium, Spain and France), and other countries with very low diesel penetration (such as: Denmark, Norway, Sweden and Switzerland).

– **average cylinder capacity and power** of car engines varies considerably from one country to another – reflecting the differing economic and geographic conditions in the various markets. Engine power has grown steadily throughout the monitoring period, whilst engine capacity declined slightly in 1995 and then remained stable until a long term trend for gradual increase reappeared in 1998 and 1999.

Note

1. 28% from the figures reported to the European Commission.

Table 56. **Average fuel consumption, all new cars weighted by registrations**
(Litres/100km test cycle 80/1268/EEC)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Germany	8.9	8.4	8.2	8	7.7	7.4	7.3	7.5	7.7	7.7	7.7	7.6	7.6	7.6	7.5	7.4
Austria	8.7	8.5	8	7.8	7.4	7.3	7.2	7	7.4	7.3	7.3	7.4	7.2	7.1	7	7
Belgium	8	7.9	7.7	7.5	7.2	7	7	6.9	6.8	6.8	6.8	6.9	6.9	6.9	6.9	6.7
France	7.6	7.3	7.2	7	6.8	6.7	6.7	6.7	6.6	6.5	6.5	6.5	6.5	6.6	6.5	6.5
Italy	7.7	7.5	7.2	6.9	6.6	6.5	6.4	6.4	6.5	6.5	6.7	6.7	6.9	6.9	7	7
UK	8.8	8.5	8.3	8	7.6	7.4	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.2	7.3
Sweden	-	9.4	9.2	8.8	8.4	8.2	8.3	8.3	8.4	8.5	8.5	8.6	8.5	8.4	8.4	8.5
EU 7 Average	**8.3**	**8**	**7.7**	**7.5**	**7.3**	**7.1**	**7**	**7**	**7.1**	**7**	**7.1**	**7.1**	**7.2**	**7.2**	**7.1**	**7.1**

Source: ACEA/OICA/ECMT, 2000, drawn from AAA database for all manufacturers.

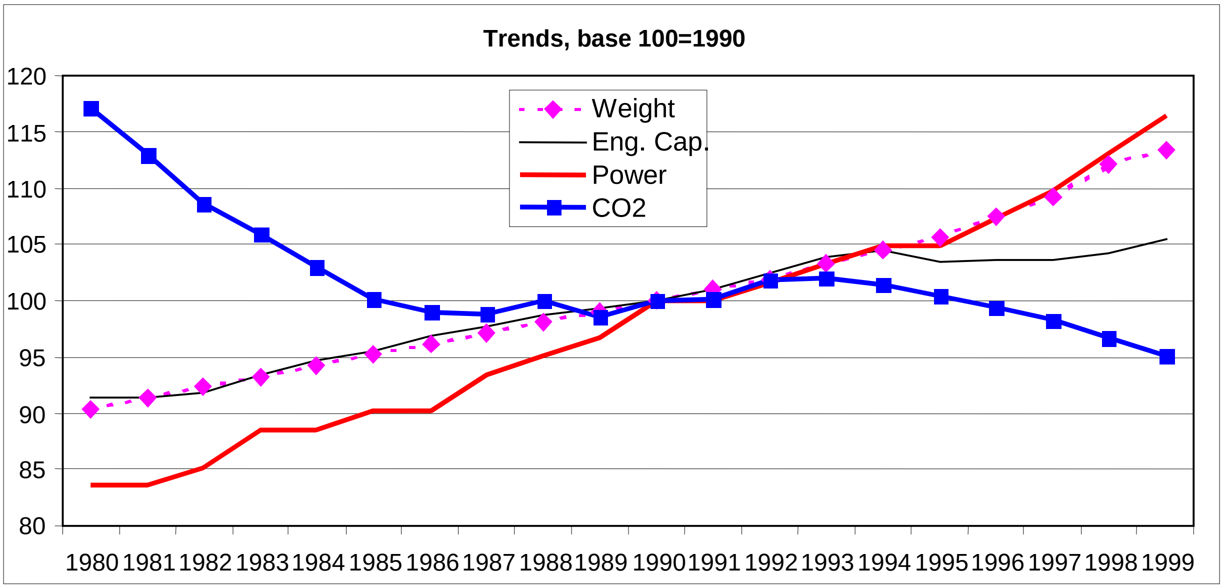
Table 57. **Average weight, engine capacity, power and CO_2 emissions, all new cars by registration in countries for which data was available**
(8 countries in 1980, 13 from 1995)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Weight (kg)	944	954	964	974	984	994	1 004	1 014	1 024	1 034	1 044	1 054	1 064	1 078	1 090.5	1 103
Engine Cap	1457	1 458	1 465	1 490	1 509	1 523	1 544	1 558	1 575	1 584	1 595	1 610	1 634	1 657	1 666	1 650
Power (kW)	51	51	52	54	54	55	55	57	58	59	61	61	62	63	64	64
CO_2 (g/km)	217	209	201	196	191	185	183	183	185	183	185	185	188	189	188	186

	1996	1997	1998	1999
Weight (kg)	1 122	1 140	1 170	1 184
Engine Cap	1 652	1 653	1 662	1 682
Power (kW)	65.5	67	69	71
CO_2 (g/km)	184	182	179	176

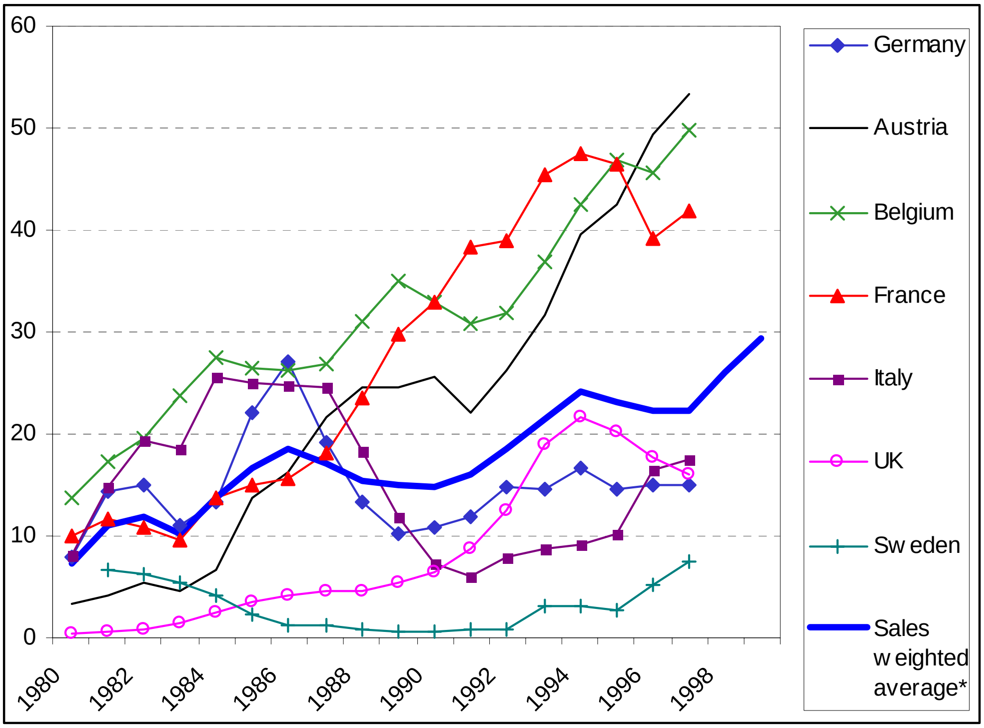
Source: ACEA/OICA/ECMT, 2000, drawn from AAA database for all manufacturers.

Figure 5. **Trends in average CO_2 emissions, power, weight and engine capacity for all new cars in EU**



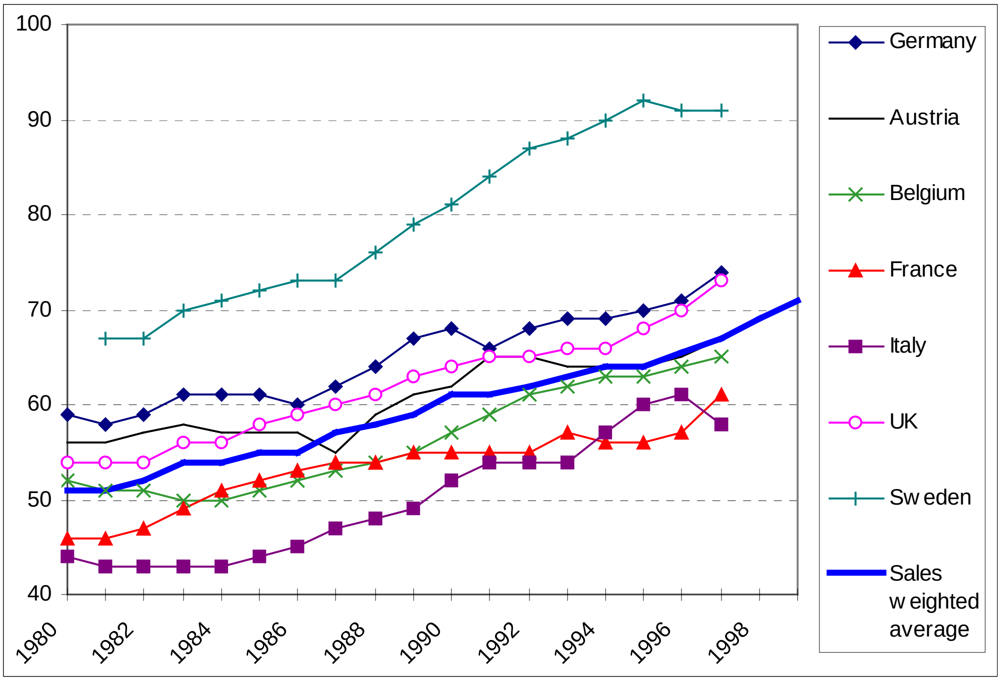
Note: Average of registrations in countries for which data was available (8 countries in 1980, 13 from 1995).
Source: ACEA/OICA/ECMT, 2000, drawn from AAA database for all manufacturers.

Figure 6. **Penetration of Diesel Cars (% of new sales)**



Note: *All Europe for which data recorded (8 countries in 1980, 13 countries in 1999).
Source: ACEA/OICA/ECMT 2000, drawn from AAA database for all manufacturers.

Figure 7. **Sales Weighted Average Power** (kW)



Source: ACEA/OICA/ECMT 2000, drawn from AAA database for all manufacturers..

Industry's Commitments

The world vehicle manufacturer's association, OICA, and European vehicle manufacturer's association, ACEA, agreed to substantially and continuously reduce the fuel consumption of new cars sold in ECMT countries in their 1995 Joint Declaration with ECMT Transport Ministers.

ACEA, made a Commitment on CO_2 emissions reductions to the European Commission in July 1998. This self-commitment was approved by the EU Council in October that year, with an agreement between ACEA and the Commission finalised in early 1999. The Commission estimates that the agreement with ACEA will contribute more than 15% of the total emission savings (CO_2 equivalent for the 6 controlled greenhouse gases) required from the EU under the Kyoto Protocol.

ACEA's collective commitments are extremely ambitious, both technically and economically, and go far beyond any "business as usual" scenario. Specifically, ACEA has committed itself to:

- bring to the market individual car models with CO_2 emissions of 120 g/km or less by 2000;

- achieve an average CO_2 emission figure of 140 g/km by 2008 for all its new cars sold in the EU -- this translates into an average CO_2 reduction of 25% compared to 1995;

- an estimated target range of 165–170 g/km in 2003 -- a 9-11% reduction compared to 1995;

- review in 2003 the potential for additional improvements with a view to moving the new car fleet average further towards 120 g/km by 2012;

- a joint ACEA/Commission monitoring of all the relevant factors related to the commitments.

It is to be noted that the profile of CO_2 emissions reduction is not expected to be linear; the pace will be relatively slow initially, and gather momentum later. The profile will notably depend on the timing of availability of improved quality fuels on the market as well as on the lead-time for new technologies and products, and their market penetration.

Subsequent to the ACEA voluntary agreement, the European Commission negotiated similar agreements with the Japanese and Korean vehicle manufacturer's associations.

APPENDIX

Additional National Data

Data in this appendix is provided by Ministries of Transport under their authority. The original source of the data may differ from that of the data included in the main report, and complete conformity has yet to be verified.

Poland

Poland is the biggest car market in central and eastern Europe and the Government monitors the CO_2 emissions of new cars in accordance with the 1995 Joint Declaration. In November 2000 the Ministry of Transport reported results for 1998 and 1999 provided by the Motor Transport Institute of Poland. The figures are summarised in the table below and cover 98% to 99% of new car sales.

Table 58.

	1998	**1999**
Average specific CO_2 emissions, g/km	177	174
Average fuel consumption, litres/100 km	7.4	7.1
Diesel market share, %	1.4	2.5
Average engine power, kW	51.4	53.0
Average engine displacement (cm^3)	1 277	1 264

Methodology

The methodology followed in monitoring CO_2 emissions from new cars can be summarised as follows.

1. The new vehicle population is divided into types with the same:
   - Manufacturer;
   - Fuel type (gasoline, diesel, gas);
   - Rated power;
   - Engine displacement;
   - CO_2 emissions;
   - Fuel consumption.

2. Numbers of vehicles falling into a given type is determined on the basis of annual sales rather than registrations as a centralised database for vehicle registrations does not exist. Sales information is supplied by vehicle manufacturers and their representatives.

3. Average specific CO_2 emissions and fuel consumption for a given vehicle type are taken from the type approval documentation.

4. CO_2 emissions and fuel consumption are measured according to UN/ECE Regulation 101 (equivalent to EU Directive 93 116/EC) For some vehicle types only fuel consumption figures measured according to UN/ECE Regulation 84 (equivalent to EU Directive 80/1268/EEC) are available. In these cases fuel consumption figures under the earlier regulation are converted to approximate conformity with the new regulation using a constant coefficient of 1.1 as the basis for calculating CO_2 emissions.

Part II.

Sulphur free fuels

TABLE OF CONTENTS

REFERENCES

This paper draws, amongst other sources, from the following key reports:

- ACEA, the Alliance of Automobile Manufacturers, EMA, JAMA and OICA, *The World-Wide Fuel Charter*, April 2000;
- ACEA, *ACEA data of the sulphur effect on advanced emission control technologies*, July 2000;
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1. FUEL QUALITY

Sulphur is present to a greater or lesser degree in all crude oils. Much of it has to be removed during refining to produce commercial fuels. The term low sulphur is applied to fuels with different sulphur contents in different countries and can be misleading. This report uses *low sulphur* to indicate fuels with less than 50 ppm sulphur. Fuels containing under 10 ppm are generally referred to as *sulphur free*.

EU Directive 98/70/EC relating to the quality of petrol and diesel fuels sets the following two stage maximum allowable sulphur content limits for auto fuels[1]:

Table 59. **EU maximum sulphur content limits**

	EURO3 1 January 2000	**EURO4 1 January 2005**
Diesel	350 ppm	50 ppm
Gasoline	150 ppm	50 ppm

Low sulphur and sulphur free petrol and diesel are already available in a number of European countries.

The World Wide Fuel Charter[2] recommends 30 ppm sulphur as the limit for petrol and diesel for markets with advanced requirements for emissions control such as EURO3 and EURO4 standards. It recommends a limit of less than 5 to 10 ppm sulphur for markets where EURO4 or equivalent emissions standards are combined with stringent fuel efficiency constraints, to enable sophisticated NOx and particulate matter after-treatment technologies to be used.

The European Commission launched a consultation in 2000 to collect evidence on the impact of sulphur free fuels on CO_2 and air emissions reductions strategies. Proposals for levels of sulphur in fuels beyond 2005 will be made on the basis of its findings.

2. ADVANTAGES OF LOW SULPHUR FUELS

Lowering fuel sulphur content contributes directly to reducing vehicle emissions of both sulphur oxides and particulate matter and indirectly to reducing emissions of NOx, carbon monoxide and hydrocarbons. It also enables enhanced and maintained conversion efficiency for catalytic conversion systems. Current interest in sulphur free fuels is mainly driven by pressure to improve the fuel efficiency of internal combustion engines in the interests of reducing CO_2 emissions whilst respecting agreed emission limits for other exhaust gases. It should also be noted that test procedures for Type Approval of new model cars in the EU were modified in conjunction with the adoption of EURO4 emissions limits. Previously the specifications for fuels used in emissions tests were not prescribed in detail. Tests must now be made using fuels typical of those on the market. This has sharpened interest in fuel quality for both vehicle manufacturers and emissions regulators.

Petrol Engines

Conventional engine/catalyser configurations

In general, reducing the sulphur content of petrol provides immediate reductions in exhaust emissions from all catalyst equipped vehicles on the road. Results from recent testing reported in the World Wide Fuel Charter are reproduced in the following table. As well as reducing all major emission types across a range of vehicle technologies and fuel qualities, lowering fuel sulphur content improves the durability of emissions control systems. Sulphur also has an impact on on-board diagnostic systems. Research in the USA reported in the Charter suggests reduced catalyst efficiency in the presence of sulphur can result in OBD systems giving false indications of malfunctioning catalysers and can also result in the OBD system failing to identify real catalyst failures.

Table 60. **Recent testing on conventional engines equipped with catalysers**

Study	**Vehicle Technology (emissions limits)**	**Sulphur Range (ppm)**		**Emissions Reduction % (high to low sulphur)**		
		high	low	HC	CO	NOx
AQIRP 1997	Tier 0	450	50	18	19	8
EPEFE 1996	EURO2+	382	18	9 (43*)	9 (52*)	10 (20*)
AAMA/AIAM	LEV & ULEV	600	30	32	55	48
CRC	LEV	630	30	32	46	61
JARI	1978 regs.	197	21	55	51	77

* Reduction achieved during hot extra-urban portion of test.
Source: World-Wide Fuel Charter, 2000.

More recently a study commissioned from the German testing laboratory ADAC by the FIA confirmed these results with tests on three contemporary petrol cars equipped with 3-way catalytic converters[3]. Each was subjected to the New European Driving Cycle test as used for Type Approval of new cars under EU Directive 98/69/EC using fuels with three different levels of sulphur: 102/106 ppm; 42 ppm and 10 ppm. Current Type Approval emissions testing measures hydrocarbon and NOx emissions together, and these were reduced on average13% with low sulphur fuel and 20% with sulphur free fuel, as shown in the following table.

Table 61. **Tests on petrol cars equipped with 3-way catalytic converters**

Petrol sulphur content (ppm)	Emissions (g/km)				Emissions reduction
	CO	HC	NOx	HC+NOx	HC+NOx
Opel Corsa 1.0					
102/106	0.412	0.090	0.024	0.114	
42	0.424	0.083	0.023	0.106	7 %
10	0.431	0.078	0.021	0.099	13 %
Mercedes C180					
102/106	0.133	0.040	0.050	0.090	
42	0.122	0.025	0.044	0.069	23 %
10	0.107	0.024	0.039	0.063	30 %
Ford Puma 1.6					
102/106	0.331	0.057	0.023	0.080	
42	0.279	0.043	0.022	0.065	19 %
10	0.261	0.040	0.020	0.060	25 %

Source: ADAC.

Three way catalytic converters are fitted to all new petrol vehicles in Europe to conform with EURO1 standards under EU emissions legislation. For efficient operation of a three way catalytic converter the amount of air available to burn fuel in the engine must match the requirements of the chemical reactions in the catalytic converter. The correct input mix to achieve a complete reaction is known as the stoichiometric ratio. The stoichiometric value for the proportion of air required by the reactions in the catalytic converter[4] unfortunately does not match the air/fuel ratio for complete combustion of fuel in an internal combustion engine. In order to meet emissions regulations the air/fuel mix burnt in vehicle engines has currently to be optimised for the catalysers used rather than the engine, leading to losses in fuel efficiency.

In practice stoichiometric conditions can not be maintained for catalytic converters at all points in the driving cycle — acceleration changes the air fuel ratio. Smoothing fluctuations in air/fuel ratios through electronic control of throttles is one route being pursued to meet EURO3 and 4 regulations. This will increase the adverse impact of emissions controls on fuel efficiency. Some other approaches to reducing emissions also have fuel efficiency penalties, such as exhaust gas recirculation if used at high driving speeds. Some, however, could improve fuel efficiency, such as improved fuel atomisation and improved air flow round fuel injectors, along with changes in the design of inlet ports and piston heads.

Lean burn engines

Commercialisation of lean burn engines is seen by European vehicle manufacturers as an essential part of the strategy to meet ACEA’s commitments to reducing CO_2 emissions. Lean burn engine operation[5] uses a higher air to fuel ratio to improve fuel efficiency, cutting CO_2 emissions. The highest air to fuel ratios are achieved by direct injection engines, but the further from stoichiometric conditions they operate the more difficult it is for conventional catalysers to reduce NOx emissions.

Under lean burn conditions an oxidation catalyst can be used to reduce HC and CO emissions but a conventional three way catalytic converter to reduce NOx will not function. At the same time 90% reductions in NOx emissions are possible with the present generation of de-NOx catalysts under partial[6] lean burn operation. This implies EURO2 standards could be met with this technology and it may be possible to meet EURO3 standards with improved versions.

Lean burn multipoint injection engines are currently marketed in Japan by Toyota, Nissan and Mitsubishi. Mitsubishi launched a version of its direct injection lean burn engined Carisma G-DI in Europe equipped with an iridium based de-NOx catalyst upstream of a conventional three way catalytic converter to meet EURO3 standards and tolerate a sulphur content up to 150 ppm. The iridium catalyst system has since been withdrawn because of durability problems. The system was not in any case able to meet EURO4 standards and at high power loads the engine switched to a stochiometric fuel/air ratio with a significant fuel efficiency penalty.

Advanced NOx Emissions Control

Regenerative NOx storage catalysers (also known as NOx traps or NOx adsorber catalysts) are already in commercial use on a range of Toyota's petrol engine vehicles[7]. These tolerate fuel sulphur content of up to 50 ppm in Japanese driving conditions. The catalysers work in conjunction with an advanced engine management system which periodically produces fuel rich combustion conditions to allow regeneration of the catalyst. They incorporate barium oxide into a conventional three way catalyser. When the engine runs lean, NO (nitric oxide) reacts over the catalyst to form barium nitrate. When the engine management system evaluates that the catalyst is close to saturation it triggers a very short fuel rich pulse (0.3 seconds) which generates carbon monoxide and unburnt hydrocarbons in the exhaust gas. This decomposes the nitrates to NO_2 which reacts over the reductant in the catalyser to form nitrogen.

The activity of catalysers deteriorates if the sulphur content in the petrol burnt exceeds 50 ppm even for a short period. Sulphur blocks the NOx storage sites. Sulphur oxides are more strongly adsorbed than nitrates and as a competitor to NOx reduce the capacity of the catalyser to remove NOx. More frequent NOx purges are required and sulphur removal requires more prolonged fuel rich combustion periods, penalising the fuel efficiency of the system. This can lose 1 to 5% on the vehicles fuel efficiency (i.e. negating the efficiency gain from using a lean burn engine). Moreover the original NOx conversion capacity of the catalyser is never fully recovered. Sulphur at 150 ppm has been found to have irreversible effects on the catalysers used by Toyota. Even at low levels, the long term effect of sulphur on NOx trap technology is not fully understood and may not be fully reversible.

The thermal conditions to which the catalysers are subjected also affects their performance. Road ageing tests have revealed that catalyst activity is severely degraded after 5 000 km using 30 ppm sulphur fuel suggesting current NOx storage catalyser systems are not thermally durable under European driving conditions (European conditions have higher speed limits and less congestion than in Japan and this is reflected in the test cycles for emissions controls). Vehicle manufacturers are currently investigating improved thermal management of these systems to reduce sensitivity to sulphur and the possible use of sulphur traps upstream of the NOx trap to improve performance with 10 ppm sulphur petrol. Catalyst manufacturers are also researching more sulphur tolerant catalysts but NOx storage technology is unlikely ever to be able to tolerate higher fuel sulphur levels because of the similar chemistry of sulphur and nitrogen oxides, with the sulphur oxides always out-competing NOx for adsorption sites in catalysers.

Thus all currently available advanced catalyst systems require EURO4 petrol (50 ppm) to meet EURO4 NOx emissions standards, and there is doubt that these systems will operate satisfactorily in European driving conditions. To meet EURO4 emissions standards and at the same time maximise fuel efficiency, sulphur free petrol will be required. Sulphur free petrol is required for taking full advantage of the fuel efficiency of lean burn engines (necessary for ACEA to achieve its CO_2 commitment) equipped with adsorber catalysers.

Diesel Engines

Sulphur in diesel contributes significantly to emissions of fine particulate matter through the formation of sulphates, both in the exhaust stream and later in the atmosphere. At the same time, diesel engines effectively operate on a lean burn regime and consequently require lean burn after-treatment technology to comply with future emissions requirements for NOx. The efficiency of diesel exhaust after-treatment systems for both particulates and NOx is impaired by sulphur and in some cases they are rendered completely ineffective.

The study commissioned from the German testing laboratory ADAC by the FIA demonstrated the, albeit modest, emissions reductions obtainable from diesel vehicles already in the car fleet by reducing fuel sulphur content. It tested two contemporary diesel cars equipped with oxidation catalysts. Each was subjected to the New European Driving Cycle test as used for Type Approval of new cars under EU Directive 98/69/EC using fuels with three different levels of sulphur: 330 ppm, 50 ppm and 4 ppm. Hydrocarbon and NOx emissions together were reduced 3% with low sulphur fuel and 6% with sulphur free fuel. Particulate emissions were not significantly reduced with low sulphur fuel but fell 7% with sulphur free diesel, as shown in the following table. Earlier work under the Auto Oil Programme suggested that reducing diesel sulphur from 500 ppm to 30 ppm cuts the mass of particulate emissions 7% in light duty vehicles and 4% or more in heavy duty vehicles.

Table 62. **Hydrocarbon emissions according to diesel sulphur content**

Diesel sulphur content (ppm)	**Emissions (g/km)**				
	CO	HC	NOx	HC+NOx	PM
Citroen Xsara HDI					
330	0.228	0.034	0.341	0.375	0.025
50	0.275	0.035	0.340	0.375	0.024
4	0.207	0.031	0.333	0.364	0.024
Toyota Avensis D-4D					
330	0.423	0.025	0.508	0.533	0.023
50	0.374	0.022	0.508	0.530	0.025
4	0.392	0.022	0.488	0.510	0.021

Source: ADAC.

Particulate emission controls

Sulphur in fuel is oxidised in combustion to form SO_2, the main sulphur compound emitted in the exhaust. Some is further oxidised to SO_3 which together with water vapour forms sulphuric acid (H_2SO_4 also referred to as sulphate aerosol or SO_4=) which coalesces around carbon cores in particulate matter, increasing the mass of the particles[8]. The conversion rate of SO_2 to SO_4 is only around 1% in the exhaust leaving the engine but after-treatment with an oxidation catalyst can increase the rate up to 100% — since 1996 all European diesel cars have been equipped with diesel oxidation catalysts to control carbon monoxide and gaseous and liquid[9] hydrocarbon emissions. Increasing the formation of sulphate aerosol not only increases the mass of particulate emissions but has a significant impact on the efficiency of advanced after-treatment systems for CO, HC and NOx. Many diesel cars are fitted with special catalysts that minimise sulphuric acid formation but this in turn reduces their activity for oxidising regulated pollutants.

EURO4 regulations require trucks to be equipped with traps or filters to meet emissions limits for particulate matter. Peugeot has chosen to install particle filters on its passenger cars, beginning with the top of the range model, in anticipation of EURO4 standards and Volkswagen will also shortly announce a vehicle equipped with a particle trap. Filters trap solid and liquid particulate matter emissions whilst allowing exhaust gasses to pass through. The filters become plugged with particulates and have to be regenerated regularly by burning off the trapped particulates. Unaided combustion (oxidation) requires temperatures to increase to 600 to 650 C. Engine-out exhaust usually does not reach these temperatures and combustion has to be assisted in one of four ways:

- The filter can be heated electrically;
- An oxidation catalyst can be incorporated upstream that doubles as a conventional catalyser and, from NO in the exhaust, produces additional NO_2 that acts as an oxidising catalyst in the particle filter;
- The filter can be coated with a catalyst to lower the temperature at which particulate matter burns;
- A catalyst can be added to the fuel to combine with particles on the filter and allow them to burn at lower temperatures.

A combination of techniques can be used together with injecting fuel into cylinders after the main combustion phase in order to raise the temperature of the exhaust.

Continuously regenerating diesel particulate filters have been retrofitted on some vehicles to meet existing regulations with 50 ppm fuel though most experience with this system has been in Scandinavia operating on 10 ppm "city diesel". These filters oxidise and destroy particulate matter using NO_2 produced from NO in the exhaust by an oxidation catalyst placed upstream (NO_2 is a more effective low-temperature oxidising agent for diesel particulate matter than oxygen). The system can remove more than 99% of particulates emitted from the engine. Coincidentally any sulphur in the exhaust gets oxidised to SO_2 and then sulphate aerosol by the system. Not only does this contribute to particulate matter but the SO_2 competes with particulates for oxidisation by the NO_2, making the filter less effective. Tests reported by the AECC in its response to the EC consultation on sulphur in fuel show that once diesel sulphur content reaches 30 ppm EURO4 limits will be exceeded as a result of sulphate aerosol formation.

Catalysed diesel particulate filters achieve regeneration with a catalyst coating on the particle filter that promotes oxidation of particulates using oxygen in the exhaust. Sulphur in the exhaust also gets oxidised by the filter to form sulphates. The impact of sulphur on performance is similar to that with continuously regenerating filters. Results of laboratory tests presented in the World-Wide Fuel

Charter show that removal efficiency drops from 95% with 3 ppm sulphur diesel to around 73% at 30 ppm and zero at 150 ppm for both types of filter. Catalysed diesel particulate filters probably require 10 ppm fuel to perform adequately at low temperatures, such as encountered on low speed inner city buses at low ambient temperatures. In other conditions they function sufficiently with 50 ppm diesel, albeit at reduced efficiency.

Fuel-borne catalysts can be combined with diesel particulate filters to improve performance. Usually very small quantities of a metal (usually cerium oxide, sometimes iron based compounds such as ferrocene or other compounds) are added to fuel. When trapped in the filter as an intimate mixture with particulate matter, the cerium catalyses oxidation, allowing the particulates to burn at temperatures of 350-450 C, regenerating the filters. In urban driving conditions exhaust temperatures may only reach 150 C so some assistance is required to heat the exhaust. Solid residues of the catalyst are retained in the filter. The process is not seriously affected by sulphur but benefits from 10 ppm fuel.

Clogging of filters can be a problem, normally caused by calcium from lubricating oil ashes combining with sulphur to form calcium sulphate. The problem can be solved by eliminating sulphur from fuel or using special ashless engine oils.

NOx emissions control

Small diesel passenger cars will probably not require advanced exhaust after treatment to meet EURO4 NOx standards. Advanced fuel injection, exhaust gas recirculation and conventional oxidation catalysts will be sufficient to meet emissions requirements. Larger cars and light trucks will on the contrary require advanced NOx catalyst systems (and/or particle filters) to comply with EURO4 standards.

Heavy duty diesel vehicles are expected to be able to meet EURO4 NOx standards without advanced exhaust after-treatment. Should future regulations on NOx emissions from diesel vehicles require more advanced exhaust treatment systems fuel, sulphur could be critical to their operation. EURO5 limits under consideration for heavy diesels in 2008, with a NO_X standard of 2.0 g/kWh, would require advanced control systems.

Several systems have been developed. **Catalytic decomposition**, where NO is reduced over a copper substituted zeolite catalyst, initially seemed promising but has proved difficult to engineer and extremely sensitive to sulphur poisoning. **De-NOx (lean-NOx) catalysts** have been developed as passive systems using reducing agents available in the exhaust, usually hydrocarbons, and as active systems where hydrocarbons are injected into the exhaust, usually using diesel fuel. They work by creating a hydrocarbon rich "micro-climate" in the catalytic coating where the exhaust or injected hydrocarbons can reduce nitrogen oxides to nitrogen, while the main exhaust flow remains lean. These systems are sensitive to sulphur and laboratory tests show NOx removal falls from 26% to 14% on the new European test cycle when switching from 6 to 49 ppm fuel[10]. Their relatively low efficiency in removing NOx restricts the potential applications of these systems to smaller passenger cars.

Selective catalytic reduction with ammonia or urea injection has been used for 20 years in fixed installations such as power stations and will be available on trucks produced by several European manufacturers from 2001. The system enables reduction of NOx to nitrogen to take place in the oxidising environment of diesel exhaust as the catalytic reduction of NOx with ammonia occurs preferentially to the oxidation of ammonia with oxygen. Selective catalytic reduction systems perform sufficiently on 50 ppm diesel to meet EURO4 NOx standards, albeit at lower efficiency than with sulphur free fuel. They should also meet the probable EURO5 standard with 50 ppm fuel.

An alternative route to controlling NOx emissions from diesel is to adapt the **adsorber catalyst systems** developed for lean burn petrol engines. The NOx adsorber catalyst systems developed for diesel engines are highly sensitive to fuel sulphur as SO_2 formed in combustion out-competes NOx for sites on the catalyst. Above 10 ppm sulphur significantly impairs the efficiency of these catalyst systems.

Summary of sulphur free fuel benefits

In summary, fuels with a sulphur content under 10 ppm provide for the following benefits:

- Immediate reductions of emissions of NOx, HC, CO from the entire fleet.
- Lower particulate emissions from all diesel vehicles.
- They facilitate the use of particle filters for diesel engines.
- They enable the realisation of reduced CO_2 emissions from gasoline direct injection technology.
- They cut sulphur dioxide emissions to near zero.
- They reduce toxic air emissions.

3. CURRENT AVAILABILITY OF LOW SULPHUR FUELS

Petrol

Sulphur free petrol (10 ppm) is currently (March 2001) available in selected Shell, BP-Amoco, Total-Fina-Elf and Aral service stations in Germany, Scandinavia and France and selected Shell stations in the United Kingdom.

Low sulphur petrol (50 ppm) already accounted for 46% if Euro Super 95 octane sales in Germany at the beginning of 2001. It is available in BP-Amoco stations throughout most of Switzerland and in selected BP-Amoco stations in the United Kingdom (notably around the M25 London ring road). Low sulphur petrol has been available in Sweden since January 2000 under a voluntary agreement with the refining industry.

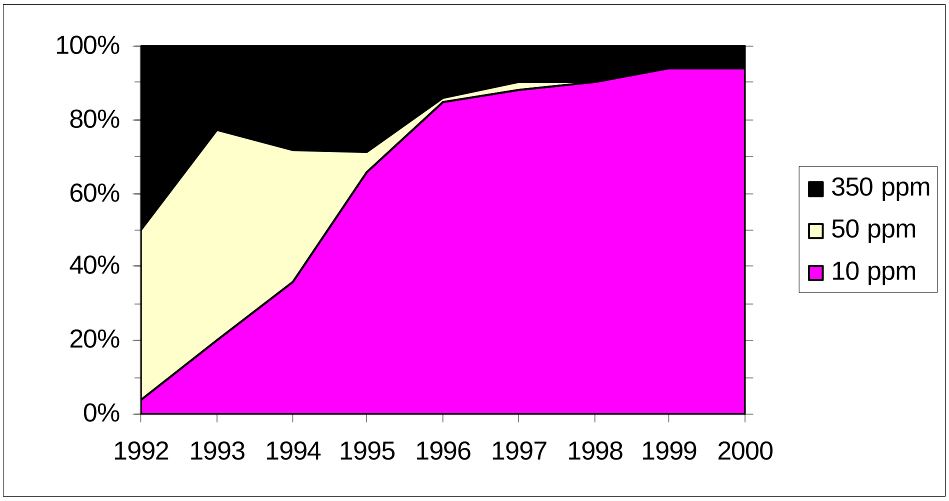
Diesel

An incentive for sulphur free diesel (10 ppm) was first introduced in Sweden on 1 January 1991. Originally intended for city areas, by 1999 it accounted for 94% of the national market. Neste/Fortum, the Finnish refiner produces 0.6 million tonnes a year of sulphur free diesel, 80 % of which is exported to Sweden. In Switzerland Greenergy diesel (< 10 ppm) is produced by Agrola and Greenlife diesel

(< 30 ppm) sold by Migrol. Both account for only small parts of the market. BP supplies sulphur free diesel to public transport and the Swiss army.

Low Sulphur diesel (50 ppm) now accounts 100% of the market in Denmark and Finland and a large part of sales Norway. It is available nation-wide in the United Kingdom and in selected service stations in France, Germany, Switzerland and a number of other European countries. In Sweden low sulphur diesel accounted for over half of diesel sales in 1993 but was almost completely displaced by sulphur free fuel from 1995 onwards.

Figure 8. **Market penetration of low sulphur and sulphur free diesel in Sweden**



Source: Swedish Ministry of Industry.

4. COSTS AND CO_2 BALANCE

Costs of meeting 2005 fuel standard

Concawe has used a sophisticated model to estimate the costs of converting the western European refining industry to producing EU 2005 standard 50 ppm sulphur gasoline and diesel from the 2000 standards of 150 ppm for gasoline and 350 ppm for diesel. Included in the cost estimates are expenditures necessary to adjust gasoline aromatics content to 2005 EU standards. Concawe estimates the net present value of the costs of reformulating gasoline will be Euro 6.5 billion (3.5 attributable to sulphur alone). For Diesel the figure is Euro 3 billion attributable to sulphur alone[11]. The costs vary greatly between refineries.

In the United Kingdom in September 2000, Ultra Low Sulphur Petrol (<50ppm) was on sale at the same price as standard gasoline or up to 2p per litre more expensive. As it benefited from a 1p per litre tax advantage this suggests the additional costs of producing and distributing the new fuel lay between 1 and 3 p (Euro 0.015-0.050) per litre if, as the oil companies report, investment in removing sulphur from fuels shows no return on investment.

The US oil industry associations (National Petrochemical Refiners Association and Petroleum Marketers Association of America) estimate that lowering sulphur content of diesel to 50 ppm will cost $5-6 billion and raise diesel prices by 5 cents per gallon (Euro 0.015 per litre). Australian estimates[12] for reducing diesel sulphur content from a national average 500 ppm to 50 ppm suggest costs would rise by 1.5 cents per litre (Euro 0.009 per litre). These US and Australian cost estimates can not simply be transferred to Europe but are included for information.

Costs of producing sulphur free fuels

Refiners associations in Europe and America have argued that the incremental costs of producing sulphur free fuels make their commercialisation uneconomic. They also argue that the reductions in CO_2 emissions from vehicles that these investments would make possible could be more cost effectively achieved by investments elsewhere in the economy.

However, in September 2000 Shell was selling unsubsidised sulphur free (<10 ppm) gasoline at 640 stations in Germany at a price 4 pfennings (Euro 0.002) per litre higher than standard gasoline.

Concawe and Europia, in their response to the EC consultation, estimated the incremental costs of producing 10 ppm fuels at Euro 11.5 billion for the EU, 4.8 billion for petrol and 6.7 billion for diesel.

The National Petrochemical Refiners Association and Petroleum Marketers Association of America estimate that lowering sulphur content of diesel to 15 ppm as proposed by EPA would raise diesel prices by 10 cents per gallon (Euro 0.030 per litre). According to the American Petroleum Institute reducing the limit to 15 ppm would result in incremental costs of 15 cents per gallon (Euro 0.045 per litre). This value has been judged very pessimistic by an independent consultant (n/e/r/a)[13] who estimate the extra costs at 8 cents per gallon (Euro 0.024 per litre).

The evidence submitted to the European Commission's inquiry into the value of sulphur free fuels to CO_2 and air emissions reductions strategies was summarised by a consultant, AEA Technology, in December 2000. The consultants report concluded that the incremental costs of producing 5-10 ppm fuels over 50 ppm fuels are between Euro 0.001 to 0.043 per litre for petrol and Euro 0.002 to 0.043 for diesel, varying with refinery. The data collected for the EC DG Environment consultation are reported in the following table.

Table 63. **Incremental costs of producing 30 ppm and 5-10 ppm petrol and diesel (Euro per litre)**

Source	Petrol		Diesel	
	30 ppm	5-10 ppm	30 ppm	5-10 ppm
Irish Government for the Irish Republic	Nil	Nil	0.010 - 0.012	0.028 - 0.038
EUROPIA/CONCAWE for EU 15 [(a+b)]	0.0011	0.0035	0.0020	0.0056
Ford for EU 15		0.0026		0.0040
Federal Republic of Germany [(c)]		0.0008 - 0.0015		0.0018 - 0.0026
Netherlands Government for NL		0.0018		0.0067
UKPIA [(d)]		0.043		0.043

a. Calculations based on 15 year plant life and 7% discount rate.
b. Calculations used 1995 figures for EU 15 petrol and diesel consumption in order to calculate costs per litre.
c. As a result of national refining costs only. The FRG indicated that logistical/distribution costs could possibly increase these values substantially in some scenarios.
d. Calculation used UKPIA data for UK petrol and diesel production.

The European Commission also consulted Purvin & Gertz to perform a refinery study on the impact of the sulphur free fuels on European refineries. The resulting extra cost for sulphur free gasoline was estimated to be in the range of Euro 0.001 – 0.003 per litre. For sulphur free diesel fuel the estimation of Purvin & Gertz was Euro 0.003 – 0.009 per litre.

One of the reasons for different cost estimates are assumptions on the rate of technological development in the refining industry. Progress in the development of catalysts for removing sulphur from oil is critical. Submissions from catalyst manufacturers to the EC consultation reported that progress in this area has been rapid and research is now focusing on catalysts for removing the last few ppm of sulphur. Akzo Nobel has equipped refineries with advanced catalyst systems to successfully produce sulphur free fuels in Scotland and Germany and suggested costs would be at the bottom of the range reported to the Commission for most refineries. New catalysts are also able to remove sulphur with less impact on other fuel specifications such as octane rating.

The costs of producing low sulphur fuels varies significantly between refineries depending of the configuration of existing plant. This may raise issues of competition and state aid for compensation in EU member countries where the refineries that face the highest costs are located — mainly in the southern countries of the Union. Many Southern European refineries are also designed to process sour (high sulphur) crude. This could also be an issue in some central eastern Europe refineries supplied by pipeline with Russian sour crudes with no sea access to import other crudes. More generally in central and eastern Europe refineries do not face substantially higher costs than in the EU as major programmes of refurbishment were undertaken during the 1990s.

The timing of the introduction of fuel sulphur limits or incentives could have a major effect on costs. This reflects the ability of refiners to co-ordinate plant upgrades with regular outages for maintenance and co-ordinate investments to produce sulphur free fuels with those necessary to meet the 2005 standards of 50 ppm and other specifications. Setting a target for the production of sulphur free fuels early (although not necessarily with a short lead time), before all refineries embark on investments to meet 2005 specifications, would minimise the costs of switching to sulphur free fuels. At the same time, according to Concawe's estimates a very short transition could cut production capacity 10 to 20%. A longer time frame would avoid the problem. The UK Government's preliminary submission to the EC consultation suggested the final years of the decade would be an appropriate time frame to impose 10 ppm limits for all fuel production. Developments to date suggest that much of the market will already be supplied with sulphur free fuels by the middle of the decade, at least in northern Europe.

CO_2 Balance

Producing sulphur free fuels increases CO_2 emissions from refineries. Akzo Nobel estimates that the extra emissions due to more severe processing and extra hydrogen requirements as a result of changing specifications from 50 ppm to 10 ppm sulphur would be of the order of 5 to 10%. However, some of the extra hydrogen and the energy it represents ends up in the fuel, increasing the hydrogen to carbon ratio and cutting CO_2 emissions on the road. Some investigations for petrol suggest the two effects cancel each other out.

Changes to other fuel specifications are more important in determining CO_2 emissions than sulphur specifications[14]. Changes to the specifications for olefins in gasoline, density/aromatics specifications for diesel and T95% distillation point specifications for diesel mandated by EURO3 and 4 fuel standards are particularly significant. It is important to make any further changes in these fuel specification in conjunction with any new sulphur standards in a co-ordinated manner. Various approaches to processing fuels to meet each specification exist (choice of catalyst, pressure, length of reaction, etc.) with several interactions that can have major impacts on overall CO_2 emissions. The newest sulphur catalysts are highly selective and have a much reduced impact on other fuel components and specifications.

Concawe estimates that for gasoline, reducing sulphur content from 150 to 50 ppm results in a modest increase of 3.3 million tons CO_2 emitted per annum by the refining industry. Lowering aromatic content to the 2005 standard using MTBE manufactured from LPG and natural gas reduces this penalty to 2.5 million tons per annum (as making MTBE produces less carbon dioxide than the gasoline it replaces). For diesel, reducing sulphur content from 350 to 50 ppm also results in a modest increase of 3 million tons CO_2 per annum. These figures compare to around 115 Mt/a from refining in the EU in 1997 and 700 Mt/a of CO_2 emissions from road transport, and to ACEA's commitment on reducing CO_2 emissions which the EC estimates adds up to as much as 85 Mt/a in 2010.

The consultant summary of evidence submitted to the European Commission's consultation into the value of sulphur free fuels reports that estimates of the additional CO_2 produced in refineries when reducing fuel sulphur to 10 ppm from 50 ppm ranges from 0.5 to 78 kt per million tons of fuel produced. The consultant reported on a scoping study that took a mean level of 45 kt of CO_2 per million tons of sulphur free fuel produced and estimated that lean burn engines with NOx storage traps would have to penetrate over 50% of the market for petrol vehicles to gain a net CO_2 benefit from sulphur free petrol production. However the lower estimates for refinery emissions would produce lower penetration requirements for break even. For diesel engines the calculations are more difficult due to uncertainty over which categories of vehicle will require advanced NOx exhaust treatment and or particle filters to meet existing and possible future regulations.

Concawe concluded in its response to the EC consultation that *"in terms of greenhouse gas emissions the benefit of lower sulphur for the after treatment device is of the same order of magnitude as the debit incurred in the production process. The balance would depend on the rate of introduction and final market share of sulphur sensitive technologies but might well remain negative for many years"*.

The conclusion of a panel of three independent experts, who reviewed the data collected by the European Commission in its consultation, indicated that the balance of the CO_2 emissions once sulphur free fuels and new vehicle technologies are generalised is positive. "*In the longer term (probably less than ten years after introduction), when a near steady state condition is reached where most vehicles in service are optimised for use with near zero sulphur fuel, the body of evidence indicates that there will be an annual net reduction in greenhouse gas emissions (including carbon dioxide, nitrous oxide and methane) from vehicles, well to wheel (i.e. including additional refinery emissions), with the use of near zero sulphur fuels compared to the use of fuels containing 50 ppm sulphur.*"

The progress reported above on recent advances in commercial catalysts and refining processes suggests net CO_2 emissions reductions can be achieved more rapidly than this.

5. PROMOTING DISTRIBUTION OF LOW SULPHUR FUELS

Petrol

EU regulation 98/70/EC will limit the sulphur content of both petrol and diesel to 50 ppm from January 2005. A number of governments have introduced or plan to introduce tax incentives to promote low sulphur fuels. National incentives to accelerate the introduction of petrol that meets EURO4 standards ahead of the 2005 deadline have been introduced in the United Kingdom, at Euro 0.017 per litre from October 2000 rising to 0.045 in April 2001. Belgium introduced an incentive of Euro 0.02 per litre for petrol from 1 January 2001. The Netherlands introduced a tax incentive of Euro 0.039 per litre in January 2001 and Germany will raise taxes on petrol with more than 50 ppm by Euro 0.015 from November 2001.

BP-Amoco sells low sulphur petrol <50 ppm throughout most of Switzerland. BP-Amoco, Shell, Total-Fina-Elf and Aral already market sulphur free petrol (<10ppm) in selected stations in France, Germany, Scandinavia and the United Kingdom. Neste/Fortum plans to market sulphur free petrol in Finland from 2002.

Germany plans to shift its tax incentive for low sulphur petrol to sulphur free petrol in January 2003, applying the higher rate of duty on fuels with a sulphur content above 10 ppm. This has been approved by European Community Authorities (Commission Communication to the Council COM(2000)397 final of 27 June 2000, endorsed by the ECOFIN Council in February 2001). Tax incentives for low or sulphur free petrol are under consideration in the Swiss parliament, although if adopted would not enter force until 2003.

Diesel

Sulphur free "City diesel" (10 ppm) began to penetrate the Swedish market in 1991 with the introduction of a tax incentive of SEK 0.35 (Euro 0.039 per litre at the exchange rate of early 2001) applied through a differentiation of fuel category according to environmental characteristics, as part of a strategy to reduce urban air pollution and acid rain. The incentive was designed to cover the additional costs of producing sulphur free diesel. The size of the incentive has since been increased with changes in some of the other specifications for fuels (SEK 0.45 per litre in 1992) and to adjust for changes in the overall package of environmental taxes levied on fuels (SEK 0.54 per litre in 1993). The latest adjustment was made in January 2001 bringing the difference in taxation between environmental class 1 diesel (10 ppm sulphur) and class 3 diesel (350 ppm) to SEK 0.527 per litre (Euro 0.057 per litre).

A tax incentive for low sulphur diesel exists (SEK 0.3 per litre) although there is no longer a market for diesel of this grade as 10 ppm sulphur diesel, benefiting form a higher incentive, accounts for 94% of total sales.

The other Nordic countries employ smaller subsidies (Euro 0.025 per litre) to promote the use of 50 ppm diesel, Finland introduced incentives in 1993 and Denmark followed in 1999. Low sulphur diesel now accounts for 100% of the market in both countries.

The United Kingdom introduced incentives for 50 ppm sulphur diesel of Euro 0.05 per litre in March 1999 and a further Euro 0.045 per litre incentive in April 2001. Belgium will introduce an incentive of Euro 0.02 per litre for diesel from October 2001. The Netherlands introduced a tax incentive for 50 ppm sulphur diesel of Euro 0.039 per litre in January 2001. Germany will introduce a tax incentive for low sulphur diesel in November 2001 equivalent to that for petrol (Euro 0.015 per litre) by raising tax on diesel with more than 50 ppm sulphur content. In January 2003 it plans to shift the incentive to diesel with more than 10 ppm sulphur (approved in European Commission Communication to the Council COM(2000)397 final of 27 June 2000 and endorsed by the ECOFIN Council in February 2001).

Switzerland has followed EC regulations on fuel sulphur limits. Tax incentives for low or sulphur free diesel are under consideration in the Swiss parliament, although if adopted would not enter force until 2003. Low sulphur and sulphur free diesels already account for a small part of the market.

In 1993 Poland already had incentives for the reduction of diesel sulphur content for a range of fuels, with maximum sulphur contents from 1 000 ppm to 3 000 ppm. Incentives have been increased and qualifying sulphur levels lowered in several stages since then with the most recent modifications on 1 January 2001. Incentives now apply to fuels with less than 50 ppm, 50-500 ppm and 500-2 000 ppm sulphur content.

Outside Europe, Hong Kong introduced a large tax incentive (Euro 0.126 per litre) to promote 50 ppm sulphur diesel over 500 ppm diesel in July 2000 and Australia will shortly introduce a tax incentive to reduce sulphur in diesel from the national average of 1300 ppm. In the USA, the Environmental Protection Agency ruled in December 2000 to introduce a diesel sulphur limit of 15 ppm from 1 July 2006 replacing the current limit of 500 ppm. 20% of production will initially be exempt from the limit but 100% compliance will be phased in by 2010. The EPA expects that from mid 2006 over 90% of all diesel will meet the new limit. The main target of the regulation is reducing particulate emissions.

Future developments

The consultation into the merits of sulphur free fuels launched by the European Union's Environment DG in 2000 was followed by a hearing in February 2001 where the Commission set out possible two stage targets for the marketing of sulphur free fuels as follows:

Table 64. **Targets for minimum market penetration rates for <10 ppm fuels**

	2007	2011
Petrol	10 %	100 %
Diesel	10 %	25 %

In several countries in Europe the proposed 2007 targets are already exceeded and most markets are likely to evolve more rapidly than foreseen by the schedule.

The hearing was followed in May 2001 by a proposal from the Commission for a *Directive on the quality of petrol and diesel fuels and amending Directive 98/70/EC* [COM(2001)241]. This proposes to mandate the introduction of zero sulphur petrol and diesel fuels by no later than 1st January 2005 in all countries of the European Union, coinciding with the entry into force of EURO4 vehicle emissions limits. It also proposes that all petrol and diesel should be sulphur free by 1st January 2011. The proposal envisages an interim review of the diesel deadline with respect to minimising overall CO_2 emissions and containing the costs of refining and distribution.

Table 65. **Proposal for Directive COM(2001)241**

	Introduction of <10 ppm fuels in all EU States	**Ending of sales of >10 ppm fuels**
Petrol	2005	2011
Diesel	2005	2011 subject to review

Targets such as those initially proposed by the European Commission may be most appropriate to countries where the costs of refining sulphur free grades of fuel will be highest — Turkey, Russia and some of the other newer members of the ECMT — for ensuring availability of sulphur free fuels throughout Europe. Because the emissions control systems of vehicles designed to operate with sulphur free fuels may be compromised by burning higher sulphur fuels, it will be important for the new fuels to be available throughout the continent so that the cleanest trucks can be used in international trade and car drivers can find fuel that does not damage their vehicles when they cross borders.

6. CONCLUSIONS AND RECOMMENDATIONS

Impacts of fuel sulphur

Fuel sulphur affects the performance and durability of many exhaust treatment and on-board diagnostic systems on petrol and diesel vehicles, both cars and trucks. Reducing fuel sulphur cuts emissions of nitrogen oxides, hydrocarbons, particulate matter and carbon monoxide from all vehicles. Emissions of ultra fine particles and especially benzene, which are the focus of health concerns, are particularly sensitive to fuel sulphur content.

For new models sulphur free fuel will help ensure future emissions standards can be met. For future petrol cars, sulphur free fuel will help ensure significant reductions in CO_2 emissions can be made without exceeding 2005 EURO4 NOx emissions limits. For heavy duty vehicles, sulphur free diesel will improve the prospects of meeting 2005 EURO4 particulate matter emissions standards and expected 2008 EURO5 NOx emissions limits. For light trucks and large diesel passenger cars sulphur free diesel will improve the prospects of meeting EURO4 particulate and NOx emissions standards.

CO_2 and NOx emissions from petrol cars

ACEA's commitment to the European Commission on reducing the CO_2 emissions of passenger cars[15] is subject to appropriate fuels being widely available. ACEA members plan to commercialise lean burn direct injection petrol engines with a fuel efficiency performance similar to the best diesel engines as part of their strategy to reduce CO_2 emissions. The exhaust from this kind of engine is different from conventional exhaust. Oxygen levels are much higher and this prevents standard three way catalytic converters from controlling NOx emissions. Advanced NOx exhaust catalysers have to be used and these are highly sensitive to the presence of sulphur.

Improved versions of advanced NOx catalyst systems in use in Japan since 1996 might meet EURO4 standards with EURO4 petrol (50 ppm sulphur) but road tests suggest that in European driving conditions with higher average speeds, petrol with sulphur content of less than 10 ppm would be required. Even if these catalysers can meet the NOx standards, using fuel with more than 10 ppm sulphur will always carry a fuel efficiency penalty because of the more frequent regeneration of the catalyser to remove sulphur, negating much of the advantage of lean burn engines in reducing CO_2 emissions.

There exists a complex variety of vehicle emissions control systems for the main pollutants, many combining advanced electronic engine management systems with more than one filter and/or catalyst element. Various configurations can achieve similar results and technological advances create new possibilities. Vehicle manufacturers' main concerns are to select durable, relatively low cost configurations that do not require excessive space on the vehicle. Given the range of approaches available for emissions control, problems of sensitivity to sulphur might eventually be overcome. There is, however, no prospect of a solution in the time frame required by existing EU emissions regulations and the ACEA Commitment on CO_2. Improvements in NOx storage catalyst systems are likely — both in the catalysts used and the associated engine management systems — and the use of sulphur traps in combination with NOx traps is the focus of research to improve NOx removal with 10 ppm sulphur fuel. However, ACEA members believe that NOx storage technology is unlikely ever to be able to tolerate higher fuel sulphur levels and the European catalyst manufacturers' association

AECC responded to this effect to the EC consultation. This is because of the similar chemistry of sulphur and nitrogen oxides, with the sulphur oxides always out-competing NOx for adsorption sites in catalysers.

CO_2 emissions from refining

Refineries employ a variety of techniques for removing sulphur from fuels, some involving the production of hydrogen which requires energy and thus results in CO_2 emissions. More energy efficient, catalysed processes for removing sulphur from fuels are under development and are already deployed in some refineries[16]. Producing sulphur free fuels whilst at the same time modifying other fuel parameters to meet EURO3 and 4 specifications produces additional CO_2 emissions from refineries, potentially undermining the CO_2 emissions reductions targeted by ACEA. However, advanced refining processes cut the CO_2 penalty to a maximum of 5-10% and some studies suggest zero net impact. Moreover, matching the supply of sulphur free petrol reasonably closely to the demand for its use in lean-burn engines would limit any impact on the overall CO_2 emissions balance[17]. The EC consultation concluded that once new fuel efficient engines equip around 50% of vehicle sales a net reduction in CO_2 emissions is likely. The financial costs of reducing petrol sulphur content to 10 ppm might be of the same order of magnitude as those incurred in cutting sulphur levels from 2000 to 2005 EU standards and could be less, especially if investments to meet the two specification levels can be co-ordinated.

Particulate and NOx emissions from diesel vehicles

2005 EURO4 particulate emissions limits require the use of particle filters on heavy diesel engines and possibly on light commercial vehicles and larger passenger cars. These filters perform better with sulphur free fuel. Some filter systems require fuel with less than 10 ppm to meet EURO4 limits. Others will tolerate 50 ppm except at low temperatures. 10 ppm fuel would be required to ensure all vehicles could meet EURO4 standards in all operating conditions[18]. Filter systems incorporating a catalyst in the fuel do tolerate 50 ppm diesel but at the cost of increased fuel consumption. For optimal performance all particle filters require diesel limited to 10 ppm.

2005 EURO4 standards for NOx emissions from heavy diesel engines can be met with 2005 EURO4 diesel (50 ppm) but standards under consideration for 2008 could require advanced exhaust treatment systems which are sensitive to sulphur. The smallest diesel passenger cars will probably not require advanced exhaust after-treatment to meet EURO4 NOx emissions standards but bigger cars and light commercial diesel vehicles probably will require advanced NOx catalysers. 10 ppm sulphur fuel would therefore facilitate meeting future NOx emissions limits.

Incentives for 50 ppm sulphur fuels

A number of governments have introduced or plan to introduce tax incentives to accelerate the introduction of fuels that meet EURO4 fuel standards ahead of the 2005 deadline (see summary table at the end of the report). Incentives have been introduced in Denmark, Finland, Norway and Poland for diesel, in the United Kingdom and the Netherlands for petrol and diesel and in Belgium for petrol with an incentive for diesel to follow in October 2001. Germany will introduce incentives in November 2001 for both petrol and diesel, by increasing duty on higher sulphur fuels. 50 ppm sulphur petrol was introduced in Sweden in January 2000 under a voluntary agreement with the refining industry and with a small tax incentive. A tax incentive for low sulphur diesel exists although there is no longer a market for diesel of this grade as 10 ppm sulphur diesel, benefiting form a higher incentive, already accounts for 94% of total sales. Tax incentives for 50 ppm diesel have also been introduced in Norway and Poland.

In the countries where they have been introduced, incentives of the order of Euro 0.015 to 0.045 per litre have been sufficient to cover the costs of refiners in improving fuel quality to the 50 ppm standard and distributing it to filling stations, without increasing the pump price above the price for standard fuels — at least in the northern European countries where incentives have been elaborated. They may not always be sufficient to see low sulphur fuels offered at prices below standard fuels where both are on sale. The incremental cost of producing low sulphur fuels varies significantly from refinery to refinery. Older, less sophisticated plants will face higher costs, and the sulphur content of the crude oil a refinery is designed to process also affects costs. The highest cost refineries are mainly located in the Mediterranean basin. Although these refineries face the highest costs in meeting the EURO4 fuel specifications, the costs of making additional investments to produce 10 ppm fuels are limited and not necessarily greater than in other refineries.

The size of the tax incentive required to promote low sulphur fuels varies between countries according to costs. Tax incentives will be most effective in accelerating the spread of low sulphur fuels when they result in lower prices at the pump for lower sulphur fuels compared to conventional fuels.

Determining how big the incentive needs to be, and ensuring that it is passed on to the consumer to the extent that it exceeds incremental refining costs, requires detailed examination nationally. The timing and detailed design of the incentive can have a significant impact. The tax incentive to be introduced in Germany is only a third that in the United Kingdom although it appears unlikely that British refineries' costs are three times those of German refineries. The German scheme will increase the tax on conventional fuel rather than reducing the tax on new fuels, as in the United Kingdom, and will introduce the differential comparatively late when a large part of the market is already supplied with low sulphur fuels. This may account for some of the difference in the size of the incentives offered.

Incentives for 10 ppm sulphur fuels

Sweden introduced a large incentive for the distribution of 10 ppm "city diesel" on 1 January 1991. Initially intended as a fuel only for city areas, by 1999 it accounted for 94% of the entire market.

Sulphur free diesel supplies a small part of the market in Switzerland without a tax incentive. The Swiss parliament is discussing proposals for incentives for sulphur free fuels that could be introduced in 2003.

Germany plans to shift its tax incentive for low sulphur fuels to sulphur free petrol and diesel in January 2003, by applying the higher rate of duty to fuels containing more than 10 ppm sulphur. The incentive will remain at Euro 0.015 per litre. The programme has received approval from European Community authorities[19].

BP-Amoco, Shell, Neste, Aral and Total-Fina-Elf already market sulphur free petrol in selected stations in France, Germany, Scandinavia and the United Kingdom.

The European Commission launched a consultation in 2000 to collect evidence on the impact of sulphur free fuels on CO_2 and air emissions reductions strategies. Proposals for levels of sulphur in fuels beyond 2005 will be made on the basis of its findings.

The rationale for promoting sulphur free fuels

The case for providing incentives for 50 ppm fuels is relatively clear as the cost effectiveness of mandating these fuels was established under the Auto-oil programme. The incentives already introduced have been highly successful in accelerating the market penetration of low sulphur fuels.

The case for reducing fuel sulphur content to levels approaching zero is less clear from the perspective of cost effectiveness. There is some uncertainty in the financial costs to refiners, not all of the environmental benefits have been quantified in monetary terms and more cost effective opportunities for reducing CO_2 emissions to meet Kyoto targets exist outside the transport sector. Given sufficient time, vehicle emissions control systems might develop sufficiently to overcome the need for sulphur free fuels.

It is the European Union's regulatory schedule for new vehicle emissions limits that makes widespread availability of sulphur free petrol and diesel from 2005 important throughout Europe, together with the binding auto industry commitments on reducing CO_2 emissions.

The benefits of sulphur free fuels

10 ppm sulphur diesel and petrol are valuable fuels for the following reasons.

- Reducing sulphur in both diesel and petrol would provide the simplest method for making further reductions in emissions of all major pollutants from the entire vehicle fleet by increasing the efficiency and especially the durability of exhaust emissions control systems.

- Sulphur free petrol enables the uptake of technologies being developed to cut emissions of CO_2 from new passenger cars. Despite advances in NOx storage catalyst systems, vehicles equipped with fuel efficient lean-burn engines will not be able to meet 2005 EURO4 emissions standards and achieve sufficient fuel efficiency to meet CO_2 targets on time without sulphur free (10 ppm) fuels. Whilst both the emissions standards and CO_2 targets can be met with other engine technologies, lean-burn engines are an important part of the ACEA's strategy to meet its commitment to reduce CO_2 emissions.

- Sulphur free diesel is desirable to ensure that all diesel vehicles can meet 2005 EURO4 particulate emissions limits all of the time. Moreover, an expert review for the EC concluded that "the successful achievement of 2008 EURO5 (NOx) standards for heavy duty diesel vehicles is much more likely with the introduction of near zero sulphur fuels than it is with the use of 50 ppm sulphur diesel".

Conclusions

Tax incentives or regulations could play an important role in providing signals to the refining industry to make the investments needed to produce sufficient quantities of sulphur free fuels in good time for markets throughout Europe.

The summary of submissions to the EC consultation concludes that "taking account of the rate of deployment of new petrol and diesel technologies there is no need for a full transition to sulphur free fuels before 2008-2010". This time frame would also reduce any impact of incremental CO_2 emissions from producing sulphur free fuels in undermining net reductions in CO_2 emissions from vehicles equipped with lean burn engines.

However, early decisions on providing incentives, or on mandatory fuel sulphur limits, would help refiners contain costs by enabling them to plan investments and plant outages for refurbishment on an optimal path and in conjunction with preparations for meeting the 50 ppm standards already mandated for 2005.

Recommendations

Ensuring the owners of vehicles that require sulphur free fuels have adequate information on the importance of using only the right grade of fuel, and ensuring that fuel pumps and service stations are adequately labelled, are important industry responsibilities. Additional steps, beyond the provision of information, may be necessary to stimulate the development of the market for sulphur free fuels, particularly in countries where they are not already available.

It is recommended that all ECMT Member governments should examine the value of taking measures for ensuring widespread availability of sulphur free fuels in step with the entry into the market of vehicles that are dependent on sulphur free fuels for compliance with mandatory emissions standards.

Because the emissions control systems of vehicles designed to operate with sulphur free fuels may be compromised by burning higher sulphur fuels, it will be important for the new fuels to be available throughout Europe, and not just in the European Union, so that the cleanest trucks can be used in international trade and car drivers can find fuel that does not damage their vehicles when they cross borders[20].

Measures for consideration include voluntary agreements with the oil industry and tax incentives to promote sulphur free fuels as well as mandatory fuel quality standards.

It is also recommended that all ECMT Member governments examine the value of taking measures to promote the production and distribution of low sulphur and sulphur free fuels as a means to achieve immediate cuts in emissions of nitrogen oxides, hydrocarbons (including benzene), particulate matter and carbon monoxide from all vehicles, both old and new.

It is recommended that a proliferation of different national mandatory standards for sulphur in fuel should be avoided, through international co-ordination, in order to avoid creating potential barriers to trade in oil markets and increased costs for vehicle manufacturers.

NOTES

1. See table at the end of the report for details of other fuel quality parameters.

2. Produced by ACEA, the Alliance of Automobile Manufacturers, EMA, JAMA and OICA in April 2000.

3. ADAC also tested a VW Lupo equipped with a NOx storage catalyser.

4. Air to fuel ratio of about 14.6:1.

5. Full lean burn operation uses an air to fuel ratio of over 22:1.

6. At high power loads the engine switches to a stochiometric fuel/air ratio with some fuel efficiency penalty.

7. Both multipoint injection and direct injection engines - not yet marketed in Europe.

8. Although current regulations control the mass of particles emitted, the mass of emissions is probably less significant than the number of particles emitted and their size. The smaller the particle the deeper the penetration into the lungs and body. Sulphates formed from fuel account for a large part of the ultra fine particles in typical diesel exhaust. Most particle filters under development remove over 90% of the mass of particles and 99% of the number of ultra fine particles.

9. Liquid HCs are adsorbed on carbon particles and known as the soluble organic fraction of particulate matter. Removing them is particularly important as they include many chemicals of concern to health experts.

10. Lepperhoff et al, FEV/AECC, reported in AECC response to the EC consultation.

11. CONCAWE report no. 99/56.

12. Reported in Life Cycle Costs of Fuels for Heavy Vehicles, CSIRO.

13. Potential Impacts of Environmental Regulations on Diesel Fuel Prices, Report prepared for the Alliance of Automobile Manufacturers, National Research Associates, December 2000.

14. To give an example, in many refineries hydrogen is produced as a by-product in catalytic reformers used to produce high octane aromatics for gasoline. Lowering the aromatics content of petrol (as required by EURO4 standards, albeit slightly from 40 to 35% by volume) reduces the availability of hydrogen needed for desulphurisation. Therefore dedicated hydrogen manufacturing capacity is required, using natural gas and refinery gas or by gasification of refinery liquids and coke. These processes require energy with associated increases in CO_2 emissions. However, new alternative desulphurisation techniques target sulphur containing molecules much more specifically, limit octane loss by avoiding collateral hydrogenation of olefins and other molecules, and require much less hydrogen.

15. Followed by similar commitments from JAMA and KAMA.

16. See Akzo Nobel submissions to EC consultation.

17. This might imply limiting the size of tax incentives for sulphur free petrol to levels that stimulate gradual penetration of the new fuel rather than a rapid rise to 100% of petrol sales.

18. This applies particularly to urban buses operating in a stop-start mode in very cold winter conditions.

19. Commission Communication to the Council COM(2000)397 final of 27 June 2000 endorsed by the ECOFIN Council in 2001.

20 . See for example Russian fuel quality standards in the summary tables at the end of the report.

SUMMARY TABLES

Russian fuel sulphur specifications

Date of entry into force	Regulation	Maximum sulphur content (ppm)		
Petrol				
1978	GOST 2084	1 000		
1 January 1999	GOST 51105-97	500		
Diesel		**Type 1**	**Type 2**	**Type 3**
1984	GOST 305-82	2 000	5 000	Not applicable
Proposal for all NIS from 2002	-	500	1 000	2 000

Fuel Specifications of EU Directive 98/70/EC on petrol and diesel quality

Parameter	Unit	Limits from January 2000 (EURO3)		Limits from January 2005 (EURO4)	
		Minimum	Maximum	Minimum	Maximum
GASOLINE					
Octane		95 / 85	-	95 / 85	-
Reid Vapour Pressure	Kpa	-	60.0	-	
Distillation	%v/v				
Evaporated at 100 C		46.0	-		-
Evaporated at 150 C		75.0	-		-
Hydrocarbons:	% v/v				
Olefins		-	18	-	
Aromatics		-	42	-	35
Benzene		-	1	-	
Oxygen	%m/m	-	2.7	-	
Oxygenates:	%v/v				
Methanol		-	3	-	
Ethanol		-	5	-	
Iso-propyl alcohol		-	10	-	
Butyl-tertiary alcohol		-	7	-	
Iso-butyl alcohol		-	10	-	
Ethers (5 carbon +)		-	15	-	
Other oxygenates		-	10	-	
Sulphur	mg/kg	-	150	-	50
Lead	g/l	-	0.005	-	
DIESEL					
Cetane number		51	-		-
Density at 15C	Kg/m^3	-	845	-	
Distillation point 95%	C	-	360	-	
Polyaromatic hydrocarbons	% m/m	-	11	-	
Sulphur	mg/kg	-	350	-	50

Summary of regulations, incentive programmes and oil company marketing initiatives
(Status in March 2001)

Country	Label	Fuel	Low S fuel max S limit	Conventional fuel limit (and typical content)	Introduced	Tax Incentive (excluding VAT) Euro per litre	Notes
European regulations							
EU	EURO2 regulation	Petrol		500 ppm (300)	1 Jan 1997		
		Diesel		500 ppm (450)			
	98/70/EC regulation	Petrol		150 ppm	1 Jan 2000		
	Stage 1, EURO3	Diesel		350 ppm			
	98/70/EC regulation	Petrol		50 ppm	1 Jan 2005		
	Stage 2, EURO4	Diesel		50 ppm			
European incentive programmes and oil company initiatives				**Limit at time of introduction of incentive**			
Belgium	National incentive	Petrol	50 ppm	150 ppm	1 Jan 2001	0.02	
		Diesel	50 ppm	350 ppm	1 Oct 2001	0.02	
Denmark	National incentive	Diesel	50 ppm	500 ppm	June 1999	0.024 (0.18 DKK/l)	100% penetration by July 1999
Finland	National incentive	Diesel	50 ppm	350 ppm	1993	0.025 (0.15 FIM/l)	100% penetration
	Neste/Fortum initiative	Petrol Diesel	**10 ppm**	150 ppm	2002	-	
			10 ppm	350 ppm	2002		

Country	Label	Fuel	Low S fuel max S limit	Conventional fuel limit (and typical content)	Introduced	Tax Incentive (excluding VAT) Euro per litre	Notes
Germany	Shell & BP Amoco initiative	Petrol	10 ppm	150 ppm	2000	-	Introduced at selected stations
	National incentive	Petrol	50 ppm 10 ppm	150 ppm	1 Nov 2001 Jan 2003	0.015 (3 pfg/l)	In the second stage, from 2003 the incentive
		Diesel	50 ppm 10 ppm	350 ppm	1 Nov 2001 Jan 2003	0.015 (3 pfg/l)	will shift from 50 ppm fuels to 10 ppm fuels
Netherlands	National incentive	Petrol Diesel	50 ppm 50 ppm	150 ppm 350 ppm	Jan 2001	0.039 (0.085 NLG/l)	
	Shell initiative	Petrol	n.a.	150 ppm	Aug 2000	0.040 (0.09 NLG/l)	"Pura" petrol all stations
Poland	National incentive	Diesel	2000 ppm 500 ppm 50 ppm	2000 ppm	Rates as of last change - 1 Jan 2001	0.004 (0.014 PLZ/l) 0.019 (0.075 PLZ/l) 0.031 (0.121 PLZ/l)	Incentives have existed since 1993
Sweden	National incentive	Diesel	**10 ppm**	2000 ppm	1991	0.039 (350 SEK/m^3)	City diesel
	National incentive	Diesel	**10 ppm**	350 ppm	2001	0.057 (527 SEK/m^3)	Current incentive, last adjusted 1 jan 2001
		Diesel	50 ppm	350 ppm	2001	0.033 (300 SEK/m^3)	
	National incentive	Petrol	50 ppm	150 ppm	2001	0.003 (0.03 SEK/l)	Current incentive, last adjusted 1 jan 2001

Country	**Label**	**Fuel**	**Low S fuel max S limit**	**Conventional fuel limit** (and typical content)	**Introduced**	**Tax Incentive (excluding VAT)** Euro per litre	**Notes**
Switzerland	National incentive	Petrol	50 / **10 ppm**	150 ppm	2003		Proposal before parliament
		Diesel	50 / **10 ppm**	350 ppm	2003		
	Agrola initiative	Diesel	**10 ppm**	350 ppm	2000		Small market share
	BP initiative	Diesel	**10 ppm**	350 ppm	2000		Supply to public transport and army
UK	National incentive	Diesel	50 ppm	500 ppm	March 1999	0.045 (3 p/l)	
	Shell initiative	Petrol	**10 ppm**	150 ppm	Fall 2000	-	Some stations
	National incentive	Petrol	50 ppm	150 ppm	Oct 2000 7 Mar 2001	0.015 (1 p/l) 0.030 (2 p/l) [0.045 (3 p/l) in total]	
	National incentive	Diesel	50 ppm	350 ppm	7 Mar 2001	0.045 (3 p/l)	
Rest of world regulations, incentive programmes and oil company initiatives							
Australia	National Regulation	Diesel	50 ppm	1 300 ppm	Jan 2006	-	
	BP initiative, Bulwer Island refinery, Qld.	Diesel	50 ppm	500 ppm for this refinery	End 2000	-	Capacity to supply 12% of national market
Hong Kong	"Ultra low sulphur" national incentive	Diesel	50 ppm	500 ppm	July 2000	0.125 through 2001 (0.89 HK$)	Replaced regular diesel at all filling stations but high sulphur fuel still used by bus fleets as tax free.

Country	**Label**	**Fuel**	**Low S fuel max S limit**	**Conventional fuel limit** (and typical content)	**Introduced**	**Tax Incentive (excluding VAT)** Euro per litre	**Notes**
Japan	National regulatory proposal	Diesel	50 ppm	500 ppm	Before 2005	-	Japan Air Quality Committee has recommended further reduction in the future.
USA	Regulatory proposal	Diesel	**15 ppm**	500 ppm	1 July 2006	-	EPA proposal Initially 20% of sales could continue to be 500 ppm with a phase out to 2009/2010.
Los Angeles	SCAQMD ruling for Los Angeles basin	Diesel	**15 ppm**	500 ppm	2005	-	Car Lines 2000-5

ABBREVIATIONS, SIGNS AND SYMBOLS

AAMA	Alliance of Automobile Manufacturers
ACEA	Association des constructeurs européens d'automobiles / European Automobile Manufacturers' Association
AECC	Association for Emissions Control by Catalyst
AIAM	Association of International Automobile Manufacturers
ALVW	Adjusted Loaded Vehicle Weight
ANPRM	Advanced Notice of Proposed Rulemaking
AQIRP	US Auto/Oil Air Quality Improvement Research Programme
CAA	US Clean Air Act of 1990
CAFE	Corporate Average Fuel Economy (USA) and Clean Air for Europe
CARB	California Air Resources Board
CFC	Chlorofluorocarbons
CH_4	Methane
CNG	Compressed Natural Gas
CO	Carbon monoxide
CO_2	Carbon Dioxide
CONCAWE	Conservation of Clean Air & Water in Europe
CRC	Co-ordinating Research Council of the US auto and oil industries
CSIRO	Commonwealth Scientific and Industrial Research Organisation of Australia
DeNOx	Catalyst that reduces NOx in lean exhaust
DG ENV	Directorate General for the Environment of the European Commission
DI	Direct Injection
EC	European Community (now EU) or European Commission
ECE	United Nations Economic Commission for Europe
EEA	European Environment Agency (EU)
EEV	Enhanced Environmentally-friendly Vehicle
EGR	Exhaust Gas Recirculation
ELR	European Load Response test (Heavy Duty)
EMA	Engine Manufacturers Association
EPA	Environment Protection Agency of the United States Government
EPEFE	European Programme on Emissions, Fuels and Engine Technologies
ESC	European Steady State Cycle (Heavy Duty)
ETC	European Transient Cycle (Heavy Duty)
EU	European Union
EUROPIA	European Petroleum Industry Association
FIA	Fédération Internationale de l'Automobile / Alliance Internationale de Tourisme / International Automobile Federation / International Touring Alliance
GDP	Gross Domestic Product
GVW	Gross Vehicle Weight
GWP	Global Warming Potential
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbons
HDE	Heavy-duty Engine
HDV	Heavy-duty Vehicle
HFC	Hydrofluorocarbons
HLDT	US Light-duty Truck with a Gross Vehicle Weight between 6000-8500 lbs.
I/M	Inspection & Maintenance Programme (US Clean Air Act)

IDI	Indirect Diesel Injection
IPCC	Intergovernmental Panel on Climate Change
IPCS	International Programme on Chemical Safety
JAMA	Japan Automobile Manufacturers Association
JARI	Japan Automobile Research Institute
KAMA	Korean Automobile Manufacturers Association
LDV	Light-duty Vehicle
LEV	Low Emissions Vehicle (CARB standard)
LLDT	US Light Duty Truck with Gross Vehicle Weight Under 6000 lbs.
LPG	Liquefied Petroleum Gas
LTD	Light Duty Truck
MDPV	Medium Duty Passenger Vehicles (from 8 500 to 10 000 lbs. Gross Vehicle Weight)
MDV	Medium Duty Vehicles
MMTCE	Metric Tons of Carbon Equivalents
MPG	Miles per Gallon
MTBE	Methyl-tertiary Butyl Ether
N_2O	Nitrous Oxides
NLEV	National Low Emission Vehicle standard (US)
NMHC	Non-methane Hydrocarbons
NMOG	Non-methane Organic Gases
NOx	Nitrogen oxides
O_3	Ozone
OBD	On-board diagnostic systems
OBD (E)	Onboard Diagnostics (Europe)
ODS	Ozone Depleting Substances
OECD	Organisation for International Co-operation and Development
OEHHA	Office of Environment Health Hazard Assessment
OICA	Organisation internationale des constructeurs d'automobiles / International Organisation of Motor Vehicle Manufacturers
PFC	Perfluorocarbons
PM	Particulate matter
PNGV	Partnership for New Generation of Vehicles (USA)
Ppm	Parts per million (equivalent to mg/kg)
ROG	Reactive Organic Gas
RVP	Reid Vapour Pressure
S	Sulphur
SCAQMD	South California Air Quality Management District (Los Angeles Basin air pollution agency)
SCR	Selective Catalytic Reduction
SF_6	Sulphur hexafluoride
SOx	Sulphur oxides
SULEV	Super Ultra Low Emissions Vehicle
SUV	Sports Utility Vehicle
TLEV	Transitional Low Emissions Vehicle (CARB standard)
TWC	Three Way Catalyst
UBA	Umweltbundesamt (D)
UKPIA	United Kingdom Petroleum Industry Association
ULEV	Ultra Low Emissions Vehicle (CARB standard)
VOC	Volatile Organic Compounds
ZEV	Zero Emissions Vehicle (CARB standard)

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