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MITIGATING THE ENVIRONMENTAL AND HEALTH EFFECTS OF MOTOR VEHICLES AND FUELS IN RUSSIA AND THE CIS

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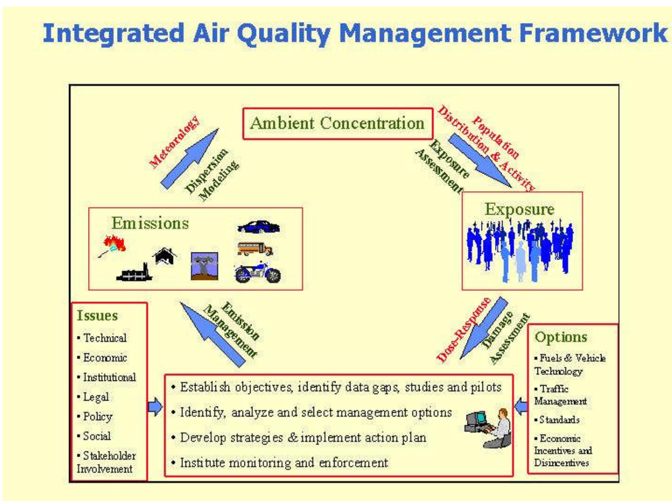
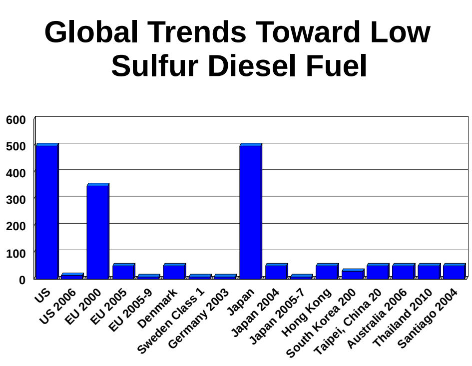
1. Background

Motor vehicles emit large quantities of carbon monoxide, hydrocarbons, nitrogen oxides, and such toxic substances as benzene, formaldehyde, acetylaldehyde, 1,3,butadiene, fine particles, and lead. Each of these, along with secondary by-products such as ozone, can cause serious adverse effects on health and the environment. Because of the growing vehicle population and the high emission rates from many of these vehicles, serious air pollution and health effect problems have been increasingly common phenomena in modern life. (Appendix A contains a brief summary of the adverse effects from air pollution.)



In developing strategies to clean up vehicles, it is necessary to start from a clear understanding of the emissions reductions from vehicles and other sources that will be necessary to achieve healthy air quality. Depending upon the air quality problem and the contribution from vehicles, the degree of control required will differ from location to location. As illustrated in the Figure regarding Integrated Air Quality Management Framework, one should start with a careful assessment of air quality and the sources that are contributing the most to the problem or problems.

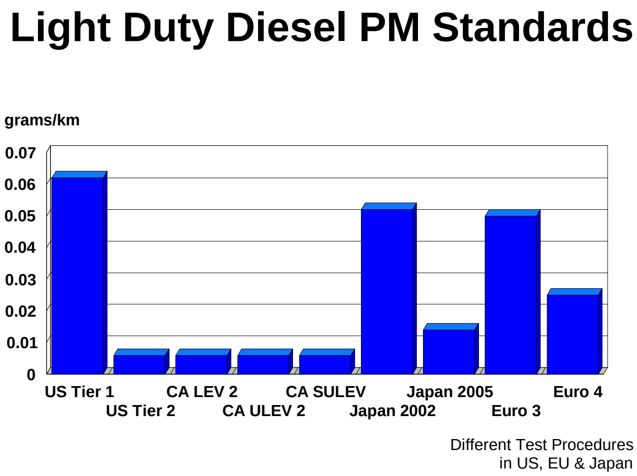
Where vehicles are the major culprits, a broad based approach to the formulation and implementation of policies and actions aimed at reducing their pollution will be needed.



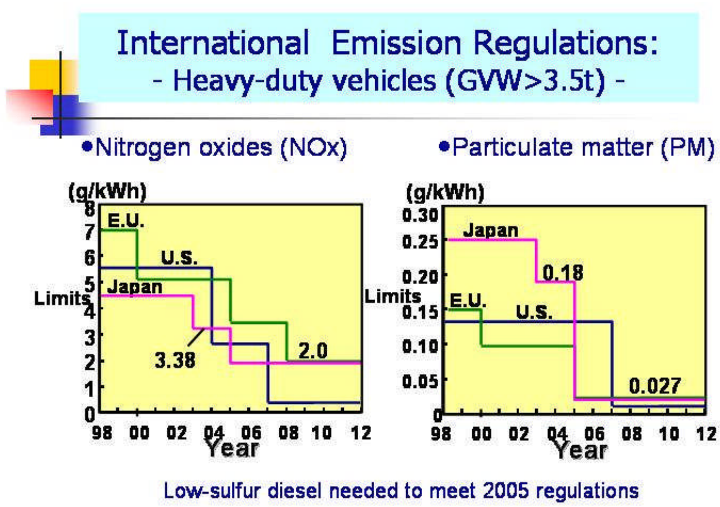
In every corner of the world, for every type of road vehicle, there is a clear trend toward lower and lower emissions levels. Over the next decade, this pattern will move toward similar controls on off road vehicles and fuels and will finally address the last holdouts – aircraft and marine vessels. Driving these trends are several factors:

- Continued growth in the production of vehicles (especially in China and other parts of Asia) and their concentration in urban areas where pollution levels remain unacceptably high,
- The growing accumulation of health studies which show adverse impacts at lower and lower levels and in the case of PM at virtually any level,
- Advances in vehicle technology and clean fuels which are making it possible to achieve lower and lower levels at reasonable costs.

With regard to fuels, one can now foresee the possible elimination of lead from gasoline as African countries, the last large remaining dumping ground are coming to grips with this problem. Most African countries have committed to phase out the use of lead by 2005 or soon thereafter and progress toward this goal is occurring in many countries. Unfortunately, some countries are being seduced into replacing lead with other potentially hazardous substitutes such as MMT. Sulfur levels in both diesel and gasoline are falling rapidly throughout the OECD countries and low sulfur fuels are on the horizon in a number of developing countries as well. (Appendix B contains a brief summary of the impact of fuels on vehicle emissions.)



Diesel technology is advancing rapidly and in addition to virtually saturating the heavy duty commercial vehicle market is increasingly penetrating the light duty sector. Diesel fueled light duty vehicles are gaining a foothold in countries such as China, Taiwan and South Korea where light duty diesels were previously banned. Diesel's superior fuel economy and relatively low carbon dioxide emissions are a principle reason for its increasing market share. With the exception of the US, however, light duty diesel standards remain more lenient than gasoline fueled vehicle standards, a situation which is expected to be corrected, at least in the EU and Japan, before the end of this decade.



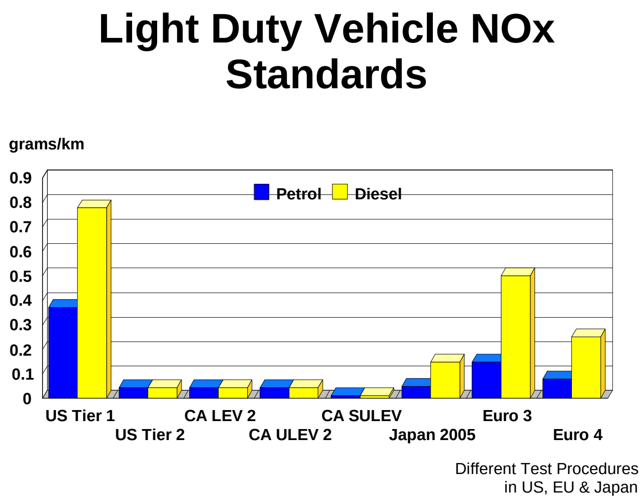
2. Regulatory Developments

The three dominant regulatory programs in the world are the US (including California), the EU and Japan[1]. Each of them is currently in the process of phasing in tighter

1. [1] Emissions regulations in every other country of the world are derivatives of one of these programs, especially the EU program.

standards for both light and heavy duty vehicles. The standards for NOx and PM for light and heavy duty vehicles and engines are illustrated in the figures.

Vehicle emissions standards and fuel requirements continue to be tightened in every corner of the globe. Major developments in the last few years include the following:



- The European Union has mandated the widespread availability of near zero sulfur levels in both gasoline and diesel fuel by 2005 and its universal use by 2009. It is in the process of implementing the already adopted Euro 4 standards for light duty vehicles and the Euro 4 and 5 standards for heavy duty vehicles with many cars already meeting Euro 4 requirements, well ahead of schedule. Finally it is already far along in developing so called Euro 5 standards for light duty vehicles and Euro 6 standards for heavy duty engines with proposals expected from the Commission during 2005. Almost certainly, these new standards will require PM filters on all new diesel vehicles. Whatever Euro 5 standards are adopted will likely go into effect earlier than the mandated date in many countries since several Member States will encourage early introduction through tax incentives. (One example of a tax incentive scheme currently in effect in Denmark is summarized in Appendix C. A full summary of the regulatory situation in the EU is contained in Appendix D.)

- In the US, the Tier 2 and LEV 2 standards are gradually being phased in across the nation and California, respectively. The number of states opting in to the California requirements continues to grow with New Jersey and Rhode Island the most recent additions. In spite of a series of Court challenges and political battles, the 2007-10 heavy duty engine requirements and low sulfur fuel standards remain on track and are expected to go into effect on schedule. EPA has also adopted very stringent requirements for off road diesel engines and fuels which will require the same degree of controls for most size categories as the on road standards.

- The California Air Resources Board (ARB) has voted to make significant modifications and upgrades to the state's zero emission vehicles (ZEV) regulations. The most important modification creates a new ZEV pathway, giving manufacturers a choice of two options for meeting their ZEV requirements.

    - Auto manufacturers can meet their ZEV obligations by meeting standards that are similar to the ZEV rule as it existed in 2001. This means using a formula allowing a vehicle mix of 2 percent pure ZEVs, 2 percent AT-PZEVs (vehicles earning advanced technology partial ZEV credits) and 6 percent PZEVs (extremely clean conventional vehicles). The ZEV obligation is based on the number of passenger cars and small trucks a manufacturer sells in California.

    - Or, manufacturers may chose a new alternative ZEV compliance strategy, meeting part of their ZEV requirement by producing their sales-weighted market share of approximately 250 fuel cell vehicles by 2008. The remainder of their ZEV requirements could be achieved by producing 4 percent AT-PZEVs and 6 percent PZEVs. The required number of fuel cell vehicles will increase to 2,500 from 2009-11, 25,000 from 2012-14 and 50,000 from 2015 through 2017. Automakers can substitute battery electric vehicles for up to 50 percent of their fuel cell vehicle requirements.

- The above requirements will not fully go into effect until 2005. However, automakers can receive credit for any ZEV, PZEV or AT-PZEV vehicles they choose to sell or lease in 2003-04.

- The Japanese Ministry of the Environment has begun drafting new regulations on light and heavy duty vehicle and engine tailpipe emissions that would require reducing nitrogen oxide emissions by as much as 90 percent by fiscal 2010 from the current levels. The Automobile Emission Gas Expert Committee, which advises the Central Environment Council, began drafting a new diesel vehicle emission standard that would reduce NOx by as much as 92 percent and particulate matter by 93 percent from the fiscal 2003 regulations.

In summary, by 2010 it is expected that the stringency of emissions requirements for new vehicles in the US, Japan and the EU will be very similar.

- In other North American developments, Canada has adopted virtually identical standards for vehicles and fuels as the US on the same approximate schedule. Mexico has phased in Tier 1 light duty vehicle standards and is in discussion with industry regarding Tier 2. A key determinant of the outcome from these discussions as well as the prospects for significant tightening of the heavy duty requirements is whether fuel quality will be improved. PEMEX has developed a detailed plan to phase in fuels meeting US sulfur standards in almost the same timeframe as in the US and it is undergoing serious discussion at this time.

- Australia has recently harmonized its requirements with the EU and will largely be on a par with the EU by the end of the decade.

- China’s new vehicle sales are growing more rapidly than in any other country in the world. To deal with this rapid growth, China has already adopted Euro 2 standards for both light and heavy vehicles and will likely introduce Euro 3 standards in Beijing and Shanghai as early as next year. Euro 3 and Euro 4 standards have been drafted with the ultimate schedule for national introduction still under discussion. One proposal calls for Euro 3 in 2008 and Euro 4 between 2010 -2012; SEPA would like to accelerate that schedule and is leaning toward Euro 3 in 2007 and Euro 4 in 2010. The major determinant of progress on emissions standards will be the schedule for improvements in fuel quality, especially sulfur and MMT. Both of these issues are under intense discussion within China at the present time.

- Effective January 1, 2002, China enforced 0.2 percent maximum sulphur content in domestic diesel output, a cut from a previous 0.5 percent. Subsequently, Sinopec announced that it will make available on a voluntary basis a lower sulfur diesel fuel, sulfur less than 0.05%, for cities.

- As illustrated below, most countries across Asia are moving down the trail toward state of the art pollution controls although at a somewhat slower pace than in the highly industrialized countries. Most are following the EU requirements. To highlight a few examples:

Country		95	96	97	98	99	2000	01	02	03	04	05	06	07	08	09	10
European Union	Euro 1		Euro 2					Euro 3				Euro 4			Euro 5		
Bangladesh										Euro 2 (under discussion)							
Hong Kong, China		Euro 1		Euro 2				Euro 3					Euro 4				
India[a]								Euro 1				Euro 2					E3
India[b]						E1	Euro 2					Euro 3					
Indonesia												Euro 2					
Malaysia				Euro 1			Euro 2										
Nepal							Euro 1										
Philippines										Euro 1							
PRC[a]								Euro 1				Euro 2					
PRC[c]								Euro 1		Euro 2		Euro 3					
Singapore[e]	Euro 1							Euro 2									
Singapore[g]	Euro 1							Euro 2					Euro 4				
Sri Lanka										Euro 1							
Taipei,China						US Tier 1								US Tier 2 for diesel[d]			
Thailand	Euro 1							Euro 2			Euro 3					Euro4	
Viet Nam[e]					Euro 1												
Viet Nam[f]												Euro 1					

- Thailand has decided to proceed to Euro 4 standards by the end of the decade. Agreement has been reached with the fuels industry to reduce sulfur levels in both diesel and gasoline to a maximum of 50 ppm by 2010 and discussions are ongoing regarding a possible reduction to 10 ppm maximum.

- South Korea will introduce ULEV standards for gasoline fuelled cars and Euro 4 standards for diesel cars by 2006. Maximum sulfur levels for gasoline and diesel will be reduced to a maximum of 50 ppm and 30 ppm, respectively, in the same timeframe. They intend to tighten emissions standards by an additional 50% by 2010.

- Taiwan will reduce the maximum sulfur levels in both gasoline and diesel to 50 ppm by 2007. At the same time, they will introduce 2004 US heavy duty vehicle standards; Euro 4 standards for heavy duty diesels will be deemed equivalent.

- The New Zealand government, the last OECD country without emissions standards for new vehicles, has adopted a new rule that applies to new and used light and heavy duty vehicles that enter New Zealand from Jan. 1, 2005. The rule requires vehicles imported into New Zealand to be built to the version of the emissions standard that was current in Australia, the United States, Japan, or Europe at the date the vehicle was manufactured. In some cases, the rule allows for a transition period with less stringent emissions standards, depending on the timetable for the introduction of more stringent fuel specifications in New Zealand or required production lead-times for heavy vehicles.

- India has adopted Euro 2 standards for 2005 and Euro 3 by 2010. The major cities will be on a faster schedule, moving to Euro 4 by 2010. Currently, 11 cities are required to meet Euro II norms: New Delhi, Mumbai (Bombay), Kolkata (Calcutta), Bangalore, Chennai, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, and Agra. Under the new policy, vehicles in the 11 cities now operating under Euro II standards will be required to meet Euro III norms by April 1, 2005, and Euro IV standards by 2010.

- Brazil will phase in US Tier 1 standards during the period from 2005-2007 jumping to Tier 2 in 2009. Diesel Cars will continue to be banned throughout the country. With regard to heavy duty trucks and buses, Euro 3 will be phased in during 2004-2006 and Euro 4 in 2009. Fuel quality remains under discussion with 50 ppm sulphur likely to be required in the major cities by 2009 or 2010.

3. The Current Situation in Russia[2]

Russia has one of the most rapidly developing motor vehicle fleets in Europe, increasing by 1.68 times during the decade from 1992 to 2002. Motorization is most pronounced in Russia cities; Moscow, for example, has about 240 cars per 1000 inhabitants. In part as a result of the high growth, vehicles have become one of the main sources of air pollution in Russia's major cities. Other factors contributing to this negative impact include:

- The poor environmental performance of most vehicles and fuels
- Poor vehicle maintenance
- Insufficient development of the road network
- Poor road conditions
- Ineffective traffic engineering

Underlying these problems are more fundamental reasons, including:

- Lack of a strong legislative basis for control of vehicle emissions
- Lack of a strong legislative basis requiring clean fuels
- Lack of effective economic instruments to stimulate the introduction and use of clean vehicles and fuels
- Poor enforcement of existing environmental norms and requirements

Emissions requirements for new vehicles in Russia can lag behind those of the EU by as much as 9 years. In 1992, only 10% of petrol fuelled cars in the Russia fleet met Euro 1

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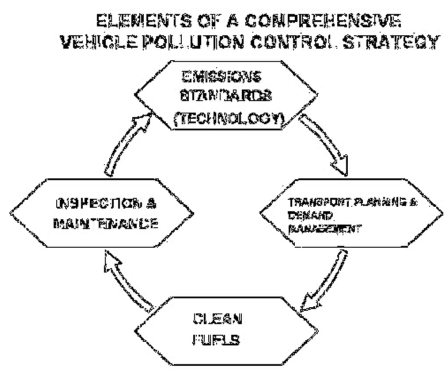
[2] Derived from "Provision of International Road Carriers with Low Sulfur and Sulfur Free Fuels on the Main Routes in the European Part of the Russian Federation", Dr. Vadim Donchenko, The State Scientific and Research Institute of Motor Transport

or Euro 2 standards; only 4% of heavy diesel fuelled trucks and none of the diesel buses met these requirements.[3]

With regard to fuel quality, the situation is equally serious. While lead has been eliminated from gasoline, the use of MMT is widespread. In 2002, about 75% of petrol production had sulfur levels below 500 ppm. Almost all diesel fuel, however, has sulfur levels between 1000 and 2000 ppm. Overall, the gap in the sulfur content requirements for fuels in Russia lags the EU norms by about 3 to 5 years. Looking to the future, the situation appears even more bleak as plans for the introduction of low sulfur fuels (50 ppm or less) and sulfur free fuels (10 ppm of less) are not yet even being considered.

4. A Strategy for Progress in Russia

Reducing the pollution that comes from vehicles will usually require a comprehensive strategy that includes four key components: emissions standards for new vehicles, specifications for clean fuels, programs to assure proper maintenance of in-use vehicles, and transportation planning and demand management. One important lesson that has been learned is that vehicles and fuels should be treated as a system. These emission reduction goals should be achieved in the most cost effective manner available.



It is difficult to proceed through these mitigation measures without several key components however:

A. Institutional Arrangements

At least one organization must be given a clear mandate to reduce the pollution that comes from vehicles and fuels and the **resources** and **authority** to carry out that mandate. In most countries, this includes and Environmental Agency or Ministry but it can also include important roles for Transport and Energy organizations.

B. Action Plan

An action plan should be developed which lays out in detail the short term and longer term measures needed to attain clean air goals. This plan should not be developed in a vacuum but should include input from all important stakeholders. The following groups will each have an important role in the development of the appropriate policies and strategies:

- National government agencies and legislative bodies,
- Local government agencies and legislative bodies,
- Industry (vehicle producers, fuel producers, catalyst suppliers, maintenance industry, etc.),

[3] Euro 1 standards were introduced in the EU in 1992 and Euro 2 in 1996.

- NGOs who can play a role in advocating for and implementation of pollution reduction campaigns, and
- End users. Within the end users group it is important to differentiate between users, such as taxi drivers, who depend on the affected vehicles for a living and users who require the vehicle for personal transportation.
- Breathers

Effective and efficient coordination mechanisms for the management of pollution from vehicles must be established. This should also include a clear allocation of responsibilities for specific functions and tasks to individual agencies and organizations.

C. Enforcement

Whatever standards are adopted for vehicles and fuels should be enforceable and enforced. Sufficient funding for this can come from fees which are levied on either new or used vehicles or fuels or all of the above. Penalties for violations of requirements must be sufficient to deter cheating.

D. Economic Incentives

Beyond mandatory requirements, economic incentives should be used to encourage appropriate behavior. For example, if both low sulfur and high sulfur fuels are simultaneously available in the marketplace, and the high sulfur fuels are much cheaper than the low sulfur fuels, there will be a strong tendency for consumers to use the high sulfur fuels even if the proper operation of their vehicles' pollution controls requires the use of low sulfur fuel. In this example, at a minimum, the two fuels should be priced equally. Ideally as has been demonstrated in several EU countries the cleaner fuel should be priced lower (through the judicious use of tax policies) which would tend to encourage the greater use of the cleaner fuel. (An example of an effective vehicle and fuels tax policy in Europe is shown in Appendix C.)

E. Public Awareness

Cleaner vehicles and cleaner fuels will tend to increase prices to consumers. Inspection and maintenance programs will also tend to be somewhat burdensome. In order for the public to support these efforts, therefore, it is important that they are aware of the benefits of these programs. This will not happen automatically but will require a careful effort involving a variety of tools and participants. Very often NGO's have proven to be very effective in designing and implementing such efforts.

Hopefully the above discussion has highlighted some of the technical tools and policy instruments which can lead to cleaner vehicles and fuels in Russia. Experience has indicated that these can very effectively result in lower emissions and improved air quality with very substantial public health benefits.

5. Appendix A: Adverse Health Effects Associated With Urban Air Pollution

A. Carbon Monoxide (CO)

Carbon monoxide -- an odorless, invisible gas created when fuels containing carbon are burned incompletely -- poses a serious threat to human health. Persons afflicted with heart disease and fetuses are especially at risk. Because the affinity of hemoglobin in the blood is 200 times greater for carbon monoxide than for oxygen, carbon monoxide hinders oxygen transport from blood into tissues. Therefore, more blood must be pumped to deliver the same amount of oxygen. Numerous studies in humans and animals have demonstrated that those individuals with weak hearts are placed under additional strain by the presence of excess CO in the blood. In particular, clinical health studies have shown a decrease in time to onset of angina pain in those individuals suffering from angina pectoris and exposed to elevated levels of ambient CO.[4]

Healthy individuals also are affected, but only at higher levels. Exposure to elevated CO levels is associated with impairment of visual perception, work capacity, manual dexterity, learning ability and performance of complex tasks.[5]

B. Nitrogen Oxides (NOx)

As a class of compounds, the oxides of nitrogen are involved in a host of environmental concerns impacting adversely on human health and welfare. Nitrogen dioxide (NO_2) has been linked with increased susceptibility to respiratory infection, increased airway resistance in asthmatics, and decreased pulmonary function.[6] [7] It has been shown that even short-term exposures to NO_2 have resulted in a wide-ranging group of respiratory problems in school children - cough, runny nose and sore throat are among the most common.[8]

NOx also is a contributor to acid deposition, which can damage trees at high elevations and increases the acidity of lakes and streams, which can severely damage aquatic life. Finally, NOx emissions can contribute to increased levels of particulate matter by changing into nitric acid in the atmosphere and forming particulate nitrate.

4/ "Effect of Carbon Monoxide on Exercise Performance in Chronic Obstructive pulmonary Disease", Aronow, et. al., Am. J. Med., 1977, "Health Effects of Exposure To Low Levels of Regulated Air Pollutants, A Critical Review", Ferris, Journal of The Air Pollution Control Association, May 1978

5/"Air Quality Criteria For Carbon Monoxide", U.S. Environmental Protection Agency, Second External Review Draft, October 1999.

6/USEPA, 1993, Air Quality Criteria for Oxides of Nitrogen, EPA/600/8-91/049aF.

7/U.S. EPA, 1995, Review of National Ambient Air Quality Standards for Nitrogen Dioxide, Assessment of Scientific and Technical Information, OAQPS Staff Paper, EPA-452/R-95-005

8/ "The University Of Akron Study on Air Pollution and Human Health Effects", Mostardi et al, Archives of Environmental Health, September/October 1981.

C. Photochemical Oxidants (Ozone)

Ground-level ozone, the main ingredient in smog, is formed by complex chemical reactions of volatile organic compounds (VOC) and nitrogen oxides (NOx) in the presence of heat and sunlight. Ozone forms readily in the lower 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 also are emitted by natural sources such as vegetation. NOx is emitted largely from motor vehicles, nonroad equipment, power plants, and other sources of combustion.

i. Health Effects

Based on a large number of studies, the US EPA has identified several key health effects caused when people are exposed to levels of ozone found today in many areas.[9] [10] Ozone can cause harmful respiratory effects including chest pain, coughing, and shortness of breath, which affect people with compromised respiratory systems most severely. When inhaled, ozone can cause acute respiratory problems; aggravate asthma; cause significant temporary decreases in lung function of 15 to over 20 percent in some healthy adults; cause inflammation of lung tissue; may increase hospital admissions and emergency room visits; and impair the body's immune system defenses, making people more susceptible to respiratory illnesses. Children and outdoor workers are likely to be exposed to elevated ambient levels of ozone during exercise and, therefore, are at greater risk of experiencing adverse health effects.

ii. Environmental Effects

In addition to the effects on human health, ozone is known to adversely affect the environment in many ways. These effects include reduced yield for commodity crops, for fruits and vegetables, and commercial forests; ecosystem and vegetation effects in such areas as National Parks; damage to urban grass, flowers, shrubs, and trees; reduced yield in tree seedlings and non-commercial forests; increased susceptibility of plants to pests; materials damage; and visibility.

D. Gaseous Air Toxics

In addition to their contribution to ozone levels, emissions of certain hydrocarbons contain toxic air pollutants that may have a significant effect on the public health.

i. Benzene

The EPA has recently reconfirmed that benzene is a known human carcinogen by all

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9/U.S. EPA, 1996, Review of National Ambient Air Quality Standards for Ozone, Assessment of Scientific and Technical Information, OAQPS Staff Paper, EPA-452/R-96-007.

10/U.S. EPA, 1996, Air Quality Criteria for Ozone and Related Photochemical Oxidants, EPA/600/P-93/004aF.

routes of exposure.[11] Respiration is the major source of human exposure. Long-term respiratory exposure to high levels of ambient benzene concentrations has been shown to cause cancer of the tissues that form white blood cells. Leukemias, lymphomas, and other tumor types have been observed in experimental animals exposed to benzene by inhalation or oral administration. Exposure to benzene and/or its metabolites has also been linked with genetic changes in humans and animals[12] and increased proliferation of mouse bone marrow cells.[13] The occurrence of certain chromosomal changes in individuals with known exposure to benzene may serve as a marker for those at risk for contracting leukemia.[14]

ii. Formaldehyde

EPA has classified formaldehyde as a probable human carcinogen based on limited evidence for carcinogenicity in humans and sufficient evidence of carcinogenicity in animal studies, rats, mice, hamsters, and monkeys.[15] Epidemiological studies in occupationally exposed workers suggest that long-term inhalation of formaldehyde may be associated with tumors of the nasopharyngeal cavity (generally the area at the back of the mouth near the nose), nasal cavity, and sinus. Research has demonstrated that formaldehyde produces mutagenic activity in cell cultures.[16]

iii. Acetaldehyde

The atmospheric chemistry of acetaldehyde is similar in many respects to that of formaldehyde.[17] Like formaldehyde, it is produced and destroyed by atmospheric chemical transformation. Acetaldehyde emissions are classified as a probable human carcinogen.

11/U.S. EPA (1998) Environmental Protection Agency, Carcinogenic Effects of Benzene: An Update, National Center for Environmental Assessment, Washington, DC. 1998. EPA/600/P-97/001F.

12/International Agency for Research on Cancer (IARC) (1982) IARC monographs on the evaluation of carcinogenic risk of chemicals to humans, Volume 29, Some industrial chemicals and dyestuffs, International Agency for Research on Cancer, World Health Organization, Lyon, France, p. 345-389.

13/Irons, R.D., W.S. Stillman, D.B. Colagiovanni, and V.A. Henry (1992) Synergistic action of the benzene metabolite hydroquinone on myelopoietic stimulating activity of granulocyte/macrophage colony-stimulating factor *in vitro*, Proc. Natl. Acad. Sci. 89:3691-3695.

14/Lumley, M., H. Barker, and J.A. Murray (1990) Benzene in petrol, *Lancet* 336:1318-1319.

15/U.S. EPA (1987) Environmental Protection Agency, Assessment of health risks to garment workers and certain home residents from exposure to formaldehyde, Office of Pesticides and Toxic Substances, April 1987.

16/U.S. EPA (1993) Motor Vehicle-Related Air Toxics Study, U.S. Environmental Protection Agency, Office of Mobile Sources, Ann Arbor, MI, EPA Report No. EPA 420-R-93-005, April 1993.

17/Ligocki, M.P., G.Z. Whitten (1991) Atmospheric transformation of air toxics: acetaldehyde and polycyclic organic matter, Systems Applications International, San Rafael, CA, (SYSAPP-91/113).

iv. 1,3 Butadiene

1,3-Butadiene is formed in vehicle exhaust by the incomplete combustion of fuel. 1,3-Butadiene was classified by EPA as a Group B2 (probable human) carcinogen in 1985.[18] This classification was based on evidence from two species of rodents and epidemiologic data.

E. Lead

The toxic properties of lead at high concentrations have been known since ancient times as lead has been mined and smelted for more than 40 centuries. Precautions in its use have been widespread for centuries, but it has only been recently that its adverse impacts at very low levels have been fully appreciated. The seminal work in this area is the 1979 report by Dr. Herbert Needleman and his colleagues which showed that children with high levels of lead accumulated in their baby teeth experienced more behavioral problems, lower IQ?s and decreased ability to concentrate.[19] More recent evidence indicates that it is not only the length and severity of exposure to lead that results in the health damage but the age at which exposure occurs. This is especially important because “Of all the persons in the community, the newborn child is the most prone to injury from overexposure to lead for several reasons, and the damage that may be caused then will have the greatest long-term social and economic consequences.”[20]

Over the past century, a range of clinical, epidemiological and toxicological studies have continued to define the nature of lead toxicity, to identify young children as a critically susceptible population, and to investigate mechanisms of action of lead toxicity. A full discussion of lead toxicity, clinical manifestations and mechanisms of action can be found in the 1995 **Environmental Health Criteria Document for Lead**, published by the International Program on Chemical Safety (IPCS). In summary, lead affects many organs and organ systems in the human body with sub cellular changes and neurodevelopmental 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 ?g/deciliter of blood relates to decrements 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 ?g/deciliter 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 ?g/deciliter of blood which can persist well beyond the termination of lead exposure. Other effects that may occur include:

18/U.S. EPA (1985) Mutagenicity and carcinogenicity assessment of 1,3-butadiene. EPA/600/8-85/004F. U.S. Environmental Protection Agency, Office of Health and Environmental Assessment. Washington, DC.

19/ “Deficits In Psychological And Classroom Performance Of Children With Elevated Dentine Lead Levels”, Needleman, et al, The New England Journal Of Medicine, Vol. 300, Number 13, March 29, 1979.

20/ “Exposure to Lead In Childhood: The Persisting Effects”, Moore, Nature Vol. 283, 24 January 1980

? 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 fetal growth and maturation at blood lead levels of 15 ?g/deciliter or more.

F. 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, a significant portion of these additives is 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.[21] Therefore, their removal along with the removal of lead may result in significant benefits to health.

G. Particulate

Particulate matter (PM) represents a broad class of chemically and physically diverse substances that exist as discrete particles (liquid droplets or solids) over a wide range of sizes. Human-generated sources of particles include a variety of stationary and mobile sources. Particles may be emitted directly to the atmosphere or may be formed by transformations of gaseous emissions such as sulfur dioxide or nitrogen oxides. The major chemical and physical properties of PM vary greatly with time, region, meteorology, and source category, thus complicating the assessment of health and welfare effects as related to various indicators of particulate pollution.

The key health effects categories associated with PM include premature death; aggravation of respiratory and cardiovascular disease, as indicated by increased hospital admissions and emergency room visits, school absences, work loss days, and restricted activity days; changes in lung function and increased respiratory symptoms; changes to lung tissues and structure; and altered respiratory defense mechanisms. Most of these effects have been consistently associated with ambient PM concentrations, which have been used as a measure of population exposure, in a large number of community epidemiological studies.

Sensitive populations include the following:

- Individuals with respiratory disease (e.g., chronic obstructive pulmonary disease, acute bronchitis) and cardiovascular disease (e.g., ischemic heart disease) are at greater risk of premature mortality and hospitalization due to exposure to ambient PM.

21 "Automotive Emissions of Ethylene Dibromide", Sigsby, et al, Society of Automotive Engineers, #820786

- Individuals with infectious respiratory disease (e.g., pneumonia) are at greater risk of premature mortality and morbidity (e.g., hospitalization, aggravation of respiratory symptoms) due to exposure to ambient PM. Also, exposure to PM may increase individuals' susceptibility to respiratory infections.
- Elderly individuals are also at greater risk of premature mortality and hospitalization for cardiopulmonary problems due to exposure to ambient PM.
- Children are at greater risk of increased respiratory symptoms and decreased lung function due to exposure to ambient PM.
- Asthmatic individuals are at risk of exacerbation of symptoms associated with asthma, and increased need for medical attention, due to exposure to PM.

The strongest evidence for ambient PM exposure health risks is derived from epidemiologic studies. Many epidemiologic studies have shown statistically significant associations of ambient PM levels with a variety of human health endpoints in sensitive populations, including mortality, hospital admissions and emergency room visits, respiratory illness and symptoms, and physiologic changes in mechanical pulmonary function. The epidemiologic science points to fine PM as being more strongly associated with some health effects, such as premature mortality, than coarse fraction PM, which is associated with other health effects.

Time-series analyses strongly suggest a positive effect on daily mortality across the entire range of ambient PM levels. Relative risk (RR) estimates for daily mortality in relation to daily ambient PM concentration are consistently positive, and statistically significant (at P ? 0.05), across a variety of statistical modeling approaches and methods of adjustment for effects of relevant covariates such as season, weather, and co-pollutants.

Diesel emissions deserve a special discussion because they tend to be a dominant source of mobile source cancer risk. The US EPA determined a reference concentration in 1993 to minimize noncancer health effects resulting from exposure to diesel exhaust. Based on information provided in the draft Health Assessment Document for Diesel Emissions and other sources of information, the US EPA has concluded that diesel particulate is a probable human carcinogen. The most compelling information to suggest a carcinogenic hazard is the consistent association that has been observed between increased lung cancer and diesel exhaust exposure in certain occupationally exposed workers working in the presence of diesel engines. Approximately 30 individual epidemiological studies show increased lung cancer risks of 20 to 89 percent within the study populations depending on the study. Analytical results of pooling the positive study results show that on average the lung cancer risks were increased by 33 to 47 percent. The magnitude of the pooled risk increases is not precise owing to uncertainties in the individual studies, the most important of which is a continuing concern about whether smoking effects have been accounted for adequately. While not all studies have demonstrated an increased risk (six of 34 epidemiological studies summarized by the Health Effects Institute[22] reported relative risks less than 1.0), the fact that an increased risk has been consistently noted in the majority of epidemiological studies strongly supports the determination that exposure to diesel exhaust is likely to pose a carcinogenic hazard to humans.

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[22] Health Effects Institute (1995) Diesel Exhaust: A Critical Analysis of Emissions, Exposure, and Health Effects pp. 253-292. April 1995.

The concern for the carcinogenic health hazard resulting from diesel exhaust exposures is widespread and several national and international agencies have designated diesel exhaust or diesel particulate matter as a 'potential' or 'probable' human carcinogen.[23] [24] The International Agency for Research on Cancer (IARC) in the late 1980s concluded that diesel exhaust is a 'probable' human carcinogen.[25] Based on IARC findings, the State of California identified diesel exhaust in 1990 as a chemical known to the State to cause cancer and after an extensive review in 1998 has listed diesel exhaust as a toxic air contaminant.[26]

Another aspect of diesel particulate that is a cause for concern is its size. Approximately 80-95 percent of diesel particle mass is in the size range from 0.05-1.0 micron with a mean particle diameter of about 0.2 microns. These fine particles have a very large surface area per gram of mass, which make them excellent carriers for adsorbed inorganic and organic compounds that can effectively reach the lowest airways of the lung. Approximately 50-90 percent of the numbers of particles in diesel exhaust are in the ultrafine size range from 0.005-0.05 microns, averaging about 0.02 microns. While accounting for the majority of the number of particles, ultrafine diesel particulate matter accounts for 1-20 percent of the mass of diesel particulate matter.

H. Sulfur Dioxide (SO2)

High concentrations of SO_2 can result in temporary breathing impairment for asthmatic children and adults who are active outdoors. Short-term exposures of asthmatic individuals to elevated SO_2 levels while at moderate exertion may result in reduced lung function that may be accompanied by such symptoms as wheezing, chest tightness, or shortness of breath. Other effects that have been associated with longer-term exposures to high concentrations of SO_2, in conjunction with high levels of PM, include respiratory illness, alterations in the lungs' defenses, and aggravation of existing cardiovascular disease. The subgroups of the population that may be affected under these conditions include individuals with cardiovascular disease or chronic lung disease, as well as children and the elderly.

I. Visibility and Regional Haze

Visibility impairment is the haze that obscures what we see, and is caused by the presence of tiny particles in the air. These particles cause light to be scattered or absorbed, thereby reducing visibility. Visibility impairment, also called regional haze, is a

[23] National Institute for Occupational Safety and Health (1988) Carcinogenic effects of exposure to diesel exhaust. NIOSH Current Intelligence Bulletin 50. DHHS (NIOSH) Publication No. 88-116. Centers for Disease Control, Atlanta, GA.

[24] World Health Organization (1996) Diesel fuel and exhaust emissions: International program on chemical safety. World Health Organization, Geneva, Switzerland.

[25] International Agency for Research on Cancer (1989) Diesel and gasoline engine exhausts and some nitroarenes, Vol. 46. Monographs on the evaluation of carcinogenic risks to humans. World Heath Organization, International Agency for Research on Cancer, Lyon, France.

[26] California EPA (1998) Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant Appendix III Part A: Exposure Assessment. California Environmental Protection Agency. California Air Resources Board April 22, 1998.

complex problem that relates to natural conditions and also several pollutants. Visibility in our national parks and monuments, and many urban areas of the country, continues to be obscured by regional and local haze.

The principle cause of visibility impairment is fine particles, primarily sulfates, but also nitrates, organics, and elemental carbon and crustal matter. Particles between 0.1 and one micrometer in size are most effective at scattering light, in addition to being of greatest concern for human health. Of the pollutant gases, only NO_2 absorbs significant amounts of light; it is partly responsible for the brownish cast of polluted skies. However, it is responsible for less than ten percent of visibility reduction.

6. Appendix B: The Impact of Fuels on Vehicle Emissions

A. Diesel Fuel

Diesel fuel is a complex mixture of hydrocarbons with the main groups being paraffins, napthenes and aromatics. Organic sulfur is also naturally present. Additives are generally used to influence properties such as the flow, storage and combustion characteristics of diesel fuel. The actual properties of commercial automotive diesel depend on the refining practices employed and the nature of the crude oils from which the fuel is produced. The quality and composition of diesel fuel can significantly influence emissions from diesel engines.

Diesel vehicles emit significant quantities of both NOx and particulate. Reducing PM emissions from diesel vehicles tends to be the highest priority because PM emissions in general are very hazardous and diesel PM, especially, is likely to cause cancer. To reduce PM and NOx emissions from a diesel engine, the most important fuel characteristic is sulfur because sulfur in fuel contributes directly to PM emissions and because high sulfur levels preclude the use of the most effective PM and NOx control technologies.

Impact of Diesel Fuel Composition on Vehicle Emissions[27]

The following tables summarize the impacts of various diesel fuel qualities on emissions from light and heavy duty diesel vehicles, respectively.

Impact of Fuels on Light Duty Diesel Vehicles

Diesel Fuel Characteristic	Pre-Euro	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5[28]	Comments
Sulfur↑	SO_2, PM↑		If ox cat, SO_3, SO_2, PM↑		If Filter, 50 ppm maximum, 10-15 ppm better		If NOx adsorber used requires near zero sulfur (<10 ppm) With low S, use lubricity additives
Cetane↑	Lower CO, HC, benzene, 1,3 butadiene, formaldehyde & acetaldehyde						Higher white smoke with low cetane fuels
Density↓	PM, HC, CO, formaldehyde, acetaldehyde & benzene↓, NOx↑						

[27] Most Asian countries have linked their vehicle emissions control programs to the EU or ECE requirements so much of the discussion that follows will relate fuels parameters to different technologies meeting EU standards.

[28] Euro 5 emissions standards for light duty diesel vehicles have not yet been adopted by the EU. However, the EU Commission has indicated that it will propose these standards during 1995 and they will likely become mandatory during the period from 2008-2010. It seems likely that these standards will mandate the use of PM filters on all light duty diesel vehicles.

Volatility (T95 from 370 to 325 C)	NOx, HC increase, PM, CO decrease	
Polyaromatics↓	NOx, PM, formaldehyde & acetaldehyde↓ but HC, benzene & CO ↑	some studies show that total aromatics are important

Impact of Fuels on Heavy Duty Diesel Vehicles

Diesel	Pre-Euro	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5[29]	Comments
Sulfur↑	SO_2, PM↑		If ox cat, SO_3, SO_2, PM↑		If Filter, 50 ppm maximum, 10-15 ppm better		If NOx adsorber used requires near zero sulfur (<10 ppm) With low S, use lubricity additives
Cetane↑	Lower CO, HC, benzene, 1,3 butadiene, formaldehyde & acetaldehyde						Higher white smoke with low cetane fuels
Density↓	HC, CO ↑, NOx↓						
Volatility (T95 from 370 to 325 C)	Slightly lower NOx but increased HC						Too much heavy ends increases smoke and PM
Polyaromatics↓	NOx, PM, HC ↓						Some studies show that total aromatics are important

Higher **sulfur** content will tend to increase sulfur dioxide (SO2) and PM emissions from all vehicle categories, from the least controlled to the most controlled. Sulfur dioxide is an acidic irritant that also leads to acid rain and the formation of sulfate particulate matter. As vehicle emissions standards are tightened to Euro 2 and Euro 3 levels, oxidation catalysts will tend to be introduced to reduce PM emissions but these systems will also tend to convert some of the SO2 into more hazardous SO3 emissions which when combined with water vapor leads to sulfuric acid mist (H2SO4). Further tightening of vehicle emissions standards will tend to require the introduction of PM filters on many vehicles and while these systems can largely eliminate PM emissions they tend to be very sensitive to sulfur levels in fuel. It is generally recommended that maximum sulfur levels with these systems be reduced to 50 ppm or less; many of these systems give optimum performance with fuels having sulfur levels in the range of 10 to 15 ppm or less. NOx control systems for diesel vehicles are still evolving with the two major candidates for Euro 4 and Euro 5 vehicles being Selective Catalytic Reduction (SCR) Systems which are not especially sensitive to sulfur levels in fuel[30] and NOx adsorber systems

[29] The EU Commission has also indicated that it will propose Euro 6 emissions standards for heavy duty engines during 2005, likely mandating the use of PM filters on all heavy duty diesel vehicles from 2010 or 2012.

[30] While SCR systems are not particularly sensitive to sulfur levels, they tend to be combined with an oxidation catalyst to reduce ammonia slip and these oxidation catalysts are sensitive to sulfur levels. They will also tend to increase sulfate emissions levels.

which are extremely sensitive to sulfur and require levels in the range of 10 to 15 ppm or less.

Cetane number is a measure of auto-ignition quality. High cetane number fuels enable an engine to be started more easily at lower air temperatures, reduce white smoke exhaust, and reduce diesel knock. An increase in cetane number generally results in a decrease in carbon monoxide and hydrocarbon emissions, nitrogen oxides emissions (most notably in heavy duty engines), as well as benzene, 1,3 butadiene, formaldehyde and acetaldehyde emissions from light duty engines. For diesel vehicles equipped with oxidation catalysts or catalyzed PM filters, emissions of CO, HC and the toxics, benzene, 1,3 butadiene, formaldehyde and acetaldehyde, will tend to be less sensitive to cetane number. While one major study (the EU EPEFE[31] study) found that particle emissions increased from light duty vehicles as the cetane number increased (no significant effect was seen in heavy duty engines) other research has suggested that an increase in cetane number can lead to lowered particle emissions.

Density relates to the energy content of fuel; the higher the density of the fuel the higher its energy content per unit volume. Too high a fuel density for the engine calibration has the effect of over-fuelling, increasing black smoke and other gaseous emissions. The European EPEFE study found that:

- For light duty vehicles, reducing fuel density decreased emissions of particles, hydrocarbons, carbon monoxide, formaldehyde, acetaldehyde and benzene; increased emissions of NOx; but had no impact on the composition of the particle load.

- For heavy duty vehicles, reducing fuel density decreased emissions of NOx; increased emissions of hydrocarbons and carbon monoxide; but had no impact on particle emissions or the composition of the particle load.

CONCAWE investigations have shown that changes to engine calibration can considerably reduce the impact of changes in density (and viscosity) on emissions. Density effects could therefore be compensated for by changes in engine calibration.

The **distillation** curve of diesel fuel indicates the amount of fuel that will boil off at a given temperature. The curve can be divided into three parts: the light end, which affects startability; the region around the 50% evaporated point, which is linked to other fuel parameters such as viscosity and density; and the heavy end, characterized by the T90,[32] T95 and final boiling points. Investigations have shown that too much ‘heavy ends’ in the fuel’s distillation curve can result in heavier combustion chamber deposits and increased tailpipe emissions of soot, smoke and particulate matter. The effect of T95 on vehicle emissions was examined in the EPEFE study which indicated that exhaust gas emissions from heavy duty diesel engines were not significantly influenced by T95-variations between 375°C and 320°C. However, a tendency for lower NOx and higher hydrocarbon emissions with lower T95 was observed.

Polyaromatic hydrocarbons (PAHs) are increasingly attracting special attention

[31] European Program on Emissions, Fuels and Engine technologies

[32] The temperature at which 90% of the fuel will evaporate.

because many are known human carcinogens. Testing for the EU EPEFE study showed that:

- For light duty vehicles reducing polyaromatics decreased NOx, particles, formaldehyde and acetaldehyde emissions, but increased hydrocarbon, benzene and carbon monoxide emissions.
- for heavy duty vehicles, reducing polyaromatics decreased NOx, particles and hydrocarbon emissions

B. Gasoline

Gasoline is a complex mixture of volatile hydrocarbons used as a fuel in internal combustion engines. The pollutants of greatest concern from gasoline-fuelled vehicles are CO, HC, NOx, lead and certain toxic hydrocarbons such as benzene. Each of these can be influenced by the composition of the gasoline used by the vehicle. The most important characteristics of gasoline with regard to its impact on emissions are – lead content, sulfur concentration, volatility, aromatics, olefins, oxygenates, and benzene level.

Impact of Gasoline Composition on Vehicle Emissions.

The following tables summarize the impacts of various fuel qualities on emissions from light duty gasoline vehicles.

Impact of Gasoline Composition on Emissions from Light Duty Vehicles

<table>
<tr><th>Gasoline</th><th>No Catalyst</th><th>Euro 1</th><th>Euro 2</th><th>Euro 3</th><th>Euro 4</th><th>Euro 5</th><th>Comments</th></tr>
<tr><td>Lead ↑</td><td>Pb, HC↑</td><td colspan="5">CO, HC, NOx all increase dramatically as catalyst destroyed</td><td></td></tr>
<tr><td>Sulfur ↑ (50 to 450 ppm)</td><td>SO_2 ↑</td><td colspan="5">CO, HC, NOx all increase ~15-20%
SO_2 and SO_3 increase</td><td>MIL light may come on incorrectly</td></tr>
<tr><td>Olefins ↑</td><td colspan="6">Increased 1,3 butadiene, increased HC reactivity, NOx, small increases in HC for Euro 3 and cleaner</td><td>Potential deposit buildup</td></tr>
<tr><td rowspan="2">Aromatics ↑</td><td colspan="6">Increased benzene in exhaust</td><td rowspan="2">Deposits on intake valves and combustion chamber tend to increase</td></tr>
<tr><td>potential increases in HC, NOx</td><td colspan="2">HC↑, NOx↓, CO↑</td><td colspan="3">HC, NOx, CO ↑</td></tr>
<tr><td>Benzene ↑</td><td colspan="6">Increased benzene exhaust and evaporative emissions</td><td></td></tr>
<tr><td>Ethanol ↑ up to 3.5% O_2</td><td>Lower CO, HC, slight NOx increase(when above 2% oxygen content),</td><td colspan="5">Minimal effect with new vehicles equipped with oxygen sensors, adaptive learning systems</td><td>Increased evaporative emissions unless RVP adjusted, potential effects on fuel</td></tr>
</table>

	Higher aldehydes					system components, potential deposit issues, small fuel economy penalty
MTBE ↑ up to 2.7% O_2	Lower CO, HC, higher aldehydes	Minimal effect with new vehicles equipped with oxygen sensors, adaptive learning systems				Concerns over Water Contamination
Distillation Characteristics T50, T90↑	Probably HC↑	HC↑				
MMT ↑	Increased Manganese Emissions			Possible Catalyst Plugging	Likely Catalyst Plugging	O_2 sensor and OBD may be damaged, MIL light may come on incorrectly
RVP ↑	Increased evaporative HC Emissions					Most critical parameter for Asian countries because of high ambient Temperatures
Deposit control additives ↑		Potential HC, NOx emissions benefits				Help to reduce deposits on fuel injectors, carburetors, intake valves, combustion chamber

Lead additives have been blended with gasoline, primarily to boost octane levels, since the 1920s but there is now a clear worldwide trend to eliminate their use and most Asian countries have done so. Lead emissions from all vehicles using leaded gasoline increase in direct proportion to the amount of lead consumed. This lead is toxic and has long been recognized as posing a serious health risk especially for children. In addition, vehicles using leaded gasoline cannot use a catalytic converter (required to comply with Euro 1 emissions standards or tighter) and therefore have much higher levels of CO, HC and NOx emissions.

Sulfur dioxide emissions increase from all categories of gasoline fueled vehicles in direct proportion to the amount of **sulfur** in fuel. Sulfur dioxide is an acidic irritant that also leads to acid rain and the formation of sulfate particulate matter. Its greatest impact, however, is in vehicles equipped with catalytic converter technology, required for compliance with Euro 1 or tighter vehicle emissions standards. Testing of catalysts has demonstrated reductions in efficiency resulting from higher sulfur levels across a full range of air/fuel ratios. The effect is greater in percentage for lower emission vehicles (Euro 3, 4 and 5) than for less controlled vehicles (Euro 1 or 2). The durability of catalysts is also impacted by sulfur levels in fuels as active catalyst sites tend to get coated with sulfur compounds. Studies have also shown that sulfur adversely affects heated exhaust gas oxygen sensors; slows the lean-to-rich transition, thereby introducing an unintended rich bias into the emission calibration; and may affect the durability of advanced on-board diagnostic (OBD) systems.

The lean-burn gasoline engine with direct fuel injection which is emerging makes possible a 15% decrease in fuel consumption compared with conventional gasoline engines thereby reducing greenhouse emissions. In Europe, there is a clear recognition that to be able to comply with future 'severe emissions limit values', the use of NOx accumulator DeNOx catalytic converters will be necessary. Even low levels of sulfur in fuel lead to deterioration in the accumulation capacity of this catalytic converter and make more frequent regeneration intervals necessary, which causes an increase in fuel consumption. A reduction of the fuel sulfur content from 50 to 10 ppm lowers the frequency of the regeneration intervals, and decreases fuel consumption; with sulfur levels above 50 ppm, DeNOx catalysts are not feasible.

The EU EPEFE study found that reducing sulfur from 382 to 18 ppm reduced exhaust emissions of HC, CO and NOx (the effects were generally linear at around 8-10% in urban driving and 20 to 50% in high speed driving). In the case of air toxins, benzene and C3-12 alkanes were in line with overall hydrocarbon reductions, with larger reductions (around 18%) for methane and ethane.

Gasoline **volatility** is an indication of how readily a fuel evaporates and is characterized by two measurements – vapor pressure and distillation. High gasoline **vapor pressure** causes high evaporative hydrocarbon emissions which can comprise a large part of total hydrocarbon emissions. Their release may occur during the delivery and transfer of gasoline to storage, vehicle refueling, the diurnal breathing of vehicle fuel tanks (as they heat up and cool down with normal daily temperature variations), and the fugitive losses that occur from carburetors and other equipment during normal vehicle operation. Reductions in fuel volatility will significantly reduce evaporative emissions from vehicles. A reduction in vapor pressure is one of the more cost effective of the fuel-related approaches available to reduce hydrocarbon emissions.

Vapor pressure is most effectively managed on a regional and seasonal basis to allow for the different volatility needs of gasoline at different temperatures. The reduction of evaporative emissions is most effectively achieved when RVP is controlled when ambient temperatures are high – i.e. the summer period. Any associated cold weather driveability-related problems can be addressed by either restricting limits to the summer period, or by shortening the summer period and/or setting regional volatility limits to take into account both climatic and seasonal temperature profiles.

Distillation is a second method for measuring the volatility of gasoline. The EPEFE study found that increasing E100 in gasoline (the percentage of gasoline evaporated at 100°C) reduces emissions of hydrocarbons but increases NOx emissions. Increasing E100 from 35% to 50% by volume showed a decrease in mass emissions of both formaldehyde and acetaldehyde but increasing E100 from 50 % to 65 % by volume showed no clear effect.

Olefins are good high octane components of gasoline but they can lead to the build up of engine deposits and increased emissions of highly reactive ozone-forming hydrocarbons and toxic compounds. They tend to be chemically more reactive than other hydrocarbon types. A study by the US Auto/Oil program concluded that reducing total olefins from 20% to 5% would significantly decrease ozone-forming potential. Reduction of low molecular weight olefins accounts for about 70% of the ozone reduction effect. In addition, 1,3-butadiene, a known carcinogen, is formed during the combustion of olefin compounds in gasoline and is therefore reduced by lowering the olefin fraction in gasoline.

Aromatics are hydrocarbon fuel molecules based on the ringed six-carbon benzene series or related organic groups. Combustion of aromatics can lead to the formation of benzene in exhaust gas, a human carcinogen that can cause leukemia in exposed persons. Lowering aromatic levels in gasoline significantly reduces toxic benzene emissions from vehicle exhausts. In the EU EPEFE study, benzene emissions were found to vary between 3.6% and 7.65 % of total volatile organic compounds for fuel aromatic contents ranging from 19.5% to 51.1% by volume.

Benzene is a six-carbon, colorless aromatic that occurs naturally in gasoline and is also a product of catalytic reforming used to boost octane levels. Benzene in gasoline leads to both evaporative and exhaust emissions of benzene.

Oxygen is added to gasoline to improve combustion, to limit emissions of ozone precursors and carbon monoxide, and/or to raise octane levels. The principal oxygenates which are used today are ethanol and MTBE. Where ethanol is used, evaporative HC emissions can increase significantly if the RVP of the fuel is allowed to increase. Increases in NOx exhaust emissions can occur with either oxygenate when the oxygen content is higher than 2 weight %. (There is some debate regarding the NOx effect for newer technology vehicles.) The magnitude of the reductions in HC exhaust emissions depends upon the vehicle technology; while older (pre Euro 1) vehicles would experience some reductions in exhaust emissions, newer vehicles (Euro 1 and newer) with oxygen sensors and adaptive learning systems will experience little or no effects. HC emissions during storage and transportation depend upon the presence or absence of Stage I and Stage II vapor recovery systems. Carbon monoxide emissions can decrease by around 10% following an increase in gasoline oxygen content from 0 to 2% (by weight).

Certain other **additives** which are put into gasoline can also affect vehicle emissions. Methylcyclopentadienyl manganese tricarbonyl (**MMT**) when added to gasoline will increase manganese emissions from all categories of vehicles. Vehicle manufacturers have expressed concerns regarding catalyst plugging and oxygen sensor damage with MMT use which could lead to higher in use vehicle emissions especially at higher mileage. The impact seems greatest with vehicles meeting tight emissions standards and using high cell density catalyst substrates.

Deposit control additives can reduce the build up of deposits on various engine components including fuel injectors and carburetors thereby maintaining low emissions from vehicles.

7. Appendix C: Denmark's Tax System for Vehicles and Fuels

A. Vehicle tax

From 1 July 1997 the *yearly tax* has been based on energy consumption, measured according to Directive 93/116. Before that date it was based on weight. Twenty-four classes are defined for both gasoline and diesel cars. Examples of selected classes (basis 2000) are given below (the figures will be increased with inflation plus 1.5% every year):

Examples of Danish Tax Incentive System (year 2000)

Vehicle Class		Fuel Consumption (km/l)	Annual Tax (DKK)
Gasoline	1	> 20.0	460
	11	10.0 – 10.5	5,040
	24	< 4.5	16,920
Diesel	1	25> 22.5	1,860
	12	10.2 – 11.3	9,000
	24	< 5.1	23,340

From 1st January 2000 three new classes for diesel passenger cars were defined. The annual tax (DKK) is:

	2000	2001	2002
> 32.1 km/l	140	200	280
28.1-32.1 km/l	700	780	860
25-28.1 km/l	1280	1380	1460

From 1st of January 2000 a supplementary reduction in *purchase tax* for energy efficient passenger cars was introduced:

Diesel	gasoline	2000-2005	2006-2010
> 45 km/l	> 40 km/	4/6	3/5
37.5-45 km/l	33.3-40 km/l	3/6	2/5
32.1-37.5 km/l	28.6-33.3 km/l	2/6	1/5
28.1-32.1 km/l	25-28.6 km/l	1/6	-

This means that a diesel car running more than 45 km/l in the period 2000-2005 will have to pay a purchase tax which is 2/6 of the normal tax - and so on.

B. Light commercial vehicles

In the new system incentives were given to light commercial vehicles for which it can be demonstrated that they meet the future EURO 3 (2000) or EURO 4 (2005) standards, before they became mandatory. The reference is the figures given in the Commission proposal COM (97) 61, dated 20th of February 1997 (directive 98/69).

The Danish system operates with 4 classes based on gross vehicle weight. Examples on the reduction in the yearly taxes for class 1 and 4 are given below:

Class		EURO 3 (Dkr)	EURO 4 (Dkr)
1 (below 1,000 kg)	1998-2000	350	450
	2001	0	100
	2002-2005	0	100
4 (2,500-3,500 kg)	1998-2000	1,150	1,600
	2001	1,150	1,600
	2002-2005	0	450

The system entered into force 1st of January 1998.

C. Fuels

i. Gasoline

Since 1995 incentives (Dkr 0.03 pr liter) have been given to gasoline delivered from stations equipped with vapor recovery systems (even if it has become mandatory for stations with a yearly capacity 500 m3 or more from 2000).

A benzene limit of 1% was introduced from 2000 (directive 98/70)

ii. Diesel fuel

From 1st of June 1999 a tax incentive was introduced in order to promote auto diesel with low sulphur content (defined as sulphur below 50 ppm). The incentive is 0.18 DKK pr liter. As a result all auto diesel sold on the Danish market from that date has met the low sulphur spec.

8. Appendix D: The Current Status of Vehicle Pollution Control in the EU

A. Passenger Cars

Since the early 1990s, the emission standards for new passenger cars equipped with gasoline and diesel engines have been reduced significantly.

i. Euro 3 and Euro 4 Standards

The First Auto-Oil program started in the early 1990s led to the adoption, in 1998, of the Euro 3 emission standards for new passenger cars and light commercial vehicles. These standards have been mandatory since January 2000.

The European Commission intended to use the second Auto-Oil program to investigate and confirm the Euro 4 emission standards, taking into account the likely improvements in emission control technology between 1998 and 2005, when Euro 4 was intended to become mandatory for new vehicles. However, the European Parliament and the Council decided to fix the Euro 4 emission standards at the same time as Euro 3 with the result that the second Auto-Oil program did little more than suggest a range of additional measures that Member States might wish to apply where air quality problems due to road transport persisted.

In addition, Euro 3 introduced new requirements covering:

- a cold start emission test carried out at –7 Celsius with specific limits for hydrocarbons and carbon monoxide;
- in-use compliance checking to ensure that vehicles continue to achieve their type-approved emissions performance up to 100,000 km in the case of Euro 4;
- a revised test procedure for evaporative emissions to better reflect a 24-hour daily temperature profile;
- requirements for on-board diagnostic systems;

There are many models of cars on the EU roads that are already type-approved as meeting the Euro 4 emission limits - both gasoline and diesel cars. The use of tax incentives by some of the Member States (see Danish example above) has stimulated manufacturers to provide Euro 4 cars earlier than the mandatory date of 2005;

ii. Additional Technical Work

Presently, the Commission is working on a revision of the OBD requirements, including the OBD threshold values, in Directive 70/220, which is the base Directive for the type-approval of light-duty vehicles with respect to emissions and other technical requirements. They were intending to introduce revised OBD threshold limits for gasoline passenger cars that would be applicable in the Euro 4 stage. However, delays have occurred and they have yet to decide when such new OBD limits would become mandatory. Pushing back the date of application beyond 2005 brings direct injection gasoline engines and diesel engines into the picture. The Commission will decide if a date between Euro 4 and Euro 5 is necessary, or whether to wait and include revised

OBD thresholds in the Euro 5 package.

They will also look to include new measures for the type-approval of diesel engines equipped with regenerating particulate filters and hybrid vehicles, essentially aligning with the requirements already developed for UN-ECE Regulation No.83;

B. Existing and Near Term Measures for HDV

The emission standards for new heavy-duty vehicles have been reduced significantly over the recent years. The Euro 3, Euro 4 and Euro 5 emission limits were again a result of the first Auto-Oil program and finalized through political decision. Euro 3 has been in force since October 2000 and provides a 30% reduction in emission over Euro 2. Euro 3 also introduced two new testing procedures to improve the representativity of the test cycle with respect to actual real-world driving – the ESC (European Steady-state Cycle) and the ETC (European Transient Cycle). Euro 4 comes into force from October 2005 and will provide an additional 30% reduction over Euro 3 except in the case of particulates where a reduction of 80% is foreseen.

Euro 3 also introduced a permissive Environmentally Friendly Vehicle (EFV) concept that would allow Member States to encourage, through the use of tax incentives, the introduction of new vehicles meeting more stringent emission limits than required even by Euro 5. However, there have been very few EFV type-approvals in the EU, just gas-fuelled engines which have achieved the EFV limits.

i. Euro 5 limits (2008):

Euro 5 was also set in stone apart from the NOx limit of 2 grams per kilowatt-hour (g/kWh) which was subject to review based on the capability of technology. The Commission undertook an independent study and internet consultation on the Euro 5 NOx standard; in short, the Euro 5 NOx limit of 2 g/kWh was shown to be eminently achievable in the 2008 timeframe but future technical developments in exhaust treatment technology will enable a lower NOx limit to be set dependant on the demonstration of the efficiency of such technology over long periods of use or durability. The Commission has publicly stated that the 2008 NOx limit will be unchanged but Euro 6 will look closely at a more stringent NOx standard.

ii. Additional issues in Euro 4:

Directive 99/96 which laid down the Euro 3, 4 and 5 emission limits also tasked the Commission to come forward with proposals regarding the durability of emission control systems, on-board diagnostics and in-use conformity checking that would apply in the Euro 4 stage. Some members of the European Parliament involved in EU legislation affecting the automotive sector had asked the Commission to find a way of proposing legislation for scrutiny and debate that allowed the European Parliament to concentrate their time on the fundamental elements of legislation (e.g. emission limit values or performance requirements for vehicle crash protection) and not be burdened with scrutinizing 200 pages of technical annexes explaining how an emission test had to be carried out. Therefore, the Commission decided to develop a new style of making proposals to the European Parliament and the Council. This is known as the "split-level" proposal and is in two complementary parts.

a) Split-level approach

The Directive that will compose the first part of the split-level approach as a result of proposal COM(2003)522 will recast Directive 88/77, as part of the clean up of the Community body of rules, and introduce the new fundamental requirements of durability distances and OBD threshold limits. When adopted, this Directive will repeal 88/77 and become the new base Directive covering emission from heavy-duty vehicles.

The second part of the "split-level" will provide the detailed technical annexes, i.e. how to test exhaust emissions against the durability requirements and how to test the performance of OBD systems in relation to the OBD threshold values;

At the end there will be a new base Directive through co-decision and a first, rather immediate, amendment through the regulatory committee. Obviously both Directives will be applied by the Member States from the same time as one can not operate without the other.

b) Durability:

The first part of the "split-level" was agreed between the European Parliament and the Council in March and so it should be published in the Official Journal in the forthcoming months. The "split-level" process will be used for other legislative proposals in the automotive sector.

This table shows the agreed durability periods for various classes of vehicles used for carrying goods (category N) and used for carrying passengers (category M). Category N3 covers the larger heavy-duty vehicles while category M3 covers the larger urban buses and coaches. The various classes of M3 [33] vehicles shown here specify the number of standing and sitting passengers.

Vehicle Category	Date applicable
N1	100,000 km or 6 years

[33] **Category M3** are vehicles used for the carriage of passengers and comprising more than 8 seats in addition to the driver's seat and a maximum mass exceeding 5 tonnes.

Category M3 class I are vehicles used for the carriage of passengers, comprising more than 22 seats including the driver's seat with areas for standing passengers to allow frequent passenger movement.

Category M3 class II are vehicles used primarily for the carriage of seated passengers, comprising more than 22 seats including the driver's seat with areas for standing passengers in the gangway and/or in an area which does not exceed the space provided for two double seats.

Category M3 class A are vehicles used for the carriage of passengers, comprising less than 22 seats including the driver's seat, designed to carry standing passengers; a vehicle of this class has seats and shall have provisions for standing passengers.

Category M3 class B are vehicles used for the carriage of passengers, comprising less than 22 seats including the driver's seat, not designed to carry standing passengers; a vehicle of this class has no provision for standing passengers.

Category M3 class III are vehicles used primarily for the carriage of seated passengers, comprising more than 22 seats including the driver's seat constructed exclusively for the carriage of seated passengers.

N2	200,000 km or 6 years
N3 ≤ 16 tons	200,000 km or 6 years
N3> 16 tons	500,000 km or 7 years
M2	100,000 km or 6 years
M3 class I, II, A & B ≤ 7.5 tons	200,000 km or 6 years
M3 class III & B > 7.5 tons	500,000 km or 7 years

These durability requirements will be applicable for type-approval to the Euro 4 stage (i.e. approval against the Euro 4 emission limits) when the new Directive enters into force later this year.

c) On-board diagnostics (OBD):

The general OBD requirements will be applicable in 2 stages:

Stage I OBD will be applicable for type-approval to the Euro 4 stage (i.e. approval against the Euro 4 emission limits) when the new Directive enters into force later this year;

- Stage I OBD requires monitoring of the emission control system against the OBD threshold limits, in this case 7.0 g/kWh for NOx and 0.1 g/kWh for particulates. However, due to the present non-availability of necessary sensors, the exhaust emission control system, e.g. particulate filter, NOx reducing system or combined systems may be monitored for *major functional failure*;
- In the case of an engine equipped with a NOx reducing system, examples of monitoring for major functional failure includes complete removal of the system or replacement of the system by a bogus system (both intentional major functional failure), lack of reagent for a selective catalytic reduction (SCR) system, use of a chemical reagent having a specification that is outside the quality requirements declared by the manufacturer, failure of any SCR electrical component, major breakdown of a DeNOx system;
- In the case of an engine equipped with a diesel particulate filter, examples of monitoring for major functional failure are for major melting of the trap substrate or a clogged trap resulting in a differential pressure out of the range declared by the manufacturer.

Stage II OBD will be applicable for type-approval to the Euro 5 stage (i.e. approval against the Euro 5 emission limits) when the new Directive enters into force later this year;

Stage II OBD requires monitoring only against the OBD threshold limits. However, due to the present non-availability of necessary sensors, the Stage II OBD thresholds will be subject to technical review by the Commission in the next few years.

d) Other issues for HDV:

At the same time, the Commission is working on several complementary issues which it aims to include in the Commission Directive providing the technical annexes as the second part of the split-level proposal. These are:

a) In-Use Conformity Checking:

Here the major issue is how to test heavy-duty vehicles to ensure their emission control systems are meeting the emission limits against which the vehicle was type-approved. Unlike cars, there are few heavy-duty vehicle chassis dynamometers available and the cost of taking engines out of heavy-duty vehicles to test is prohibitive. Heavy-duty vehicles are the livelihood of commercial operators and getting hold of heavy-duty vehicles to test can be rather complicated.

The Commission is therefore seeking to set up a basic requirement for manufacturers to provide information from in-service vehicles to demonstrate compliance. Such information would be audited by the type-approval authority. The issue of confirmatory testing of heavy-duty vehicles if the information does not demonstrate compliance has still to be resolved in the short term. However, in the longer term, the Commission is putting great emphasis on the use of portable emission measurement systems (PEMS) which will be discussed below.

b) Improved Particulate Measuring For Euro 4:

Here the issue is to improve the accuracy of the procedures for measuring particulate mass. ISO standard 16183 was developed through the Worldwide Heavy Duty Cycle (WHDC) program and industry is pushing for the acceptance of the partial flow measurement systems in ISO 16183 for measuring particulate mass from the Euro 4 stage.

c) Regenerative Particulate Filter Systems:

The test procedures for heavy-duty vehicles will be adapted from those already developed for light-duty vehicles in UN-ECE Regulation 83.

d) Multi-Setting Engines:

Some type-approval authorities have recently been requested to grant a type-approval for a type of engine that contains two or more calibration maps. For example, one manufacturer has introduced a new auto-shift transmission concept to optimize fuel consumption and driving comfort. The concept provides for what is known as two “virtual engines” within one engine specification. Take a bus, for example, having one engine setting for urban operations and another setting for rural operations.

While type-approvals have been granted to such multi-setting engines, concerns remain as to whether the Directive contains the right tools to 100% determine compliance of multi-map engines. The Commission is looking to provide the right tools to enable the authorities to approve engines where there is a clear differentiation between two engine settings – the engine control strategy should be the same and the European Steady-state Cycle control area (i.e. the speed range A-B-C) should be the same for the two engine settings. Compliance could then be demonstrated on the two engine settings (or perhaps only for the primary setting if the other setting is a sub-set of the primary setting).

The Commission is still looking at the issue of multi-setting engines where the switch point between settings is not defined or the switching takes place automatically. However, it is certainly obvious that there are some sensitive competitive issues here between vehicle manufacturers. A type-approval procedure would have real difficulties to test multi-setting engines where the switch points are not clear. Therefore, a new procedure such as PEMS would provide a better testing solution.

e) Off-Cycle Emissions:

Some engines with multiple settings could reasonably be described as having an 'irrational strategy' that may result in emissions being unacceptably high in driving events that do not normally occur within the legislative test cycle. The US consent decree and the implementation of the "not-too exceed" or "NTE" concept came about as a result of off-cycle emissions. In 2000 the Commission became aware that some Euro 3 approved heavy-duty engines showed evidence of utilizing defeat devices to improve fuel consumption at the expense of emissions. The more stringent defeat device requirements of Directive 2001/27 were the result. There is now also international activity through the UN-ECE to develop a Global Technical Regulation (GTR) covering off-cycle emissions from heavy-duty vehicles but also being extended to other vehicle categories.

At this time, the Commission will strengthen the requirements against off-cycle emissions while taking into account international work and harmonized requirements for off-cycle emissions.

iii. MEMS – Mobile Emission Measuring Systems:

The Commission recognizes the possibilities for measuring real world emission that exist when using PEMS equipment. The US EPA and heavy-duty vehicle manufacturers have invested heavily in the development of procedures for the use of PEMS and the Commission is also keen to establish the use of such procedures in the EU for in-use conformity checking.

The Commission has established a cooperative PEMS project with heavy-duty vehicle manufacturers and manufacturers of portable emission measurement equipment. The PEMS project consists of a number of phases:

- assessment of instrumentation – where tests will be conducted on an engine dynamometer test bench to select devices or sets of instruments to be used for on-road tests;
- vehicle road-testing with on-board instrumentation on a representative range of heavy-duty vehicles;
- Engine dynamometer testing and in case of availability heavy-duty chassis dynamometer testing on at least two engines removed from the vehicles used in the road tests to measure emissions simultaneously using PEMS and laboratory-grade analyzers.

This first phase is expected to be finished in mid-2005 and further development trials will follow.

C. "The SCR issue"

i. Meeting Low NOx:

There are different ways of meeting future low NOx emission limits. In the EU, manufacturers of heavy-duty vehicles have all indicated that they will use Selective Catalytic Reduction (SCR) and will introduce this technology on new heavy-duty vehicles to meet Euro 4. By using SCR, engine combustion and control measures can focus on reducing particulate emissions with the trade-off of higher engine-out NOx emissions and SCR will then clean-up the NOx emissions to meet the limits at the tailpipe. In this way, a beneficial recovery of fuel efficiency of some 3 to 5% can be achieved, compared to Euro 3 engines. Fuel efficiency is a very high operating cost for fleet operators and is therefore one of the main factors in deciding which vehicle to purchase. The Commission expects heavy-duty vehicles equipped with SCR to start appearing on the EU market in early 2005.

ii. SCR systems:

While SCR offers the potential to achieve very low NOx emissions, perhaps lower than 0.5 g/kWh, and is not unduly affected by fuel quality, the long-term durability of SCR has to be established. However, SCR can be used to gain type-approval against the Euro 4 and even the Euro 5 emission standards.

Early SCR systems will rely on the engine's NOx map to determine urea dosing rates. Under-dosing would result in higher NOx emissions, over-dosing could result in ammonia emissions unless the SCR system includes a catalyst to scrub off this ammonia slippage. The market availability of NOx sensors for heavy-duty applications later this year will enable a positive feedback of NOx emissions after the SCR catalyst to more accurately control urea dosing.

SCR depends on the use of a chemical reagent generally known as "urea" but operating also under the trade names "AdBlue" and "NOxCare". If urea is not injected into the SCR catalyst the engine out NOx emissions will not be treated and tailpipe NOx from a Euro 4 or even a Euro 5 type-approved heavy-duty vehicle could be higher than a Euro 2 engine.

iii. SCR Controls:

There seems to be a need to encourage the driver to ensure the urea tank is never empty. When he fuels with diesel he should be reminded to fill-up also with urea. Stage I OBD requires monitoring for lack of necessary chemical reagent.

All in all, the Commission believes that vehicle manufacturers have an obligation to ensure that their products will be used on the road as they were designed to.

D. Euro 5 for Light Duty Vehicles

i. Already Stated In Council:

Future emission standards for road vehicles will form an important part of the overall Clean Air for Europe (CAFE)[34] strategy that is being developed to help achieve future EU air quality. Several other industrial sectors are included in the CAFE program and a range of emission reducing scenarios that may be applicable in those sectors will be assessed in terms of their overall cost-effectiveness;

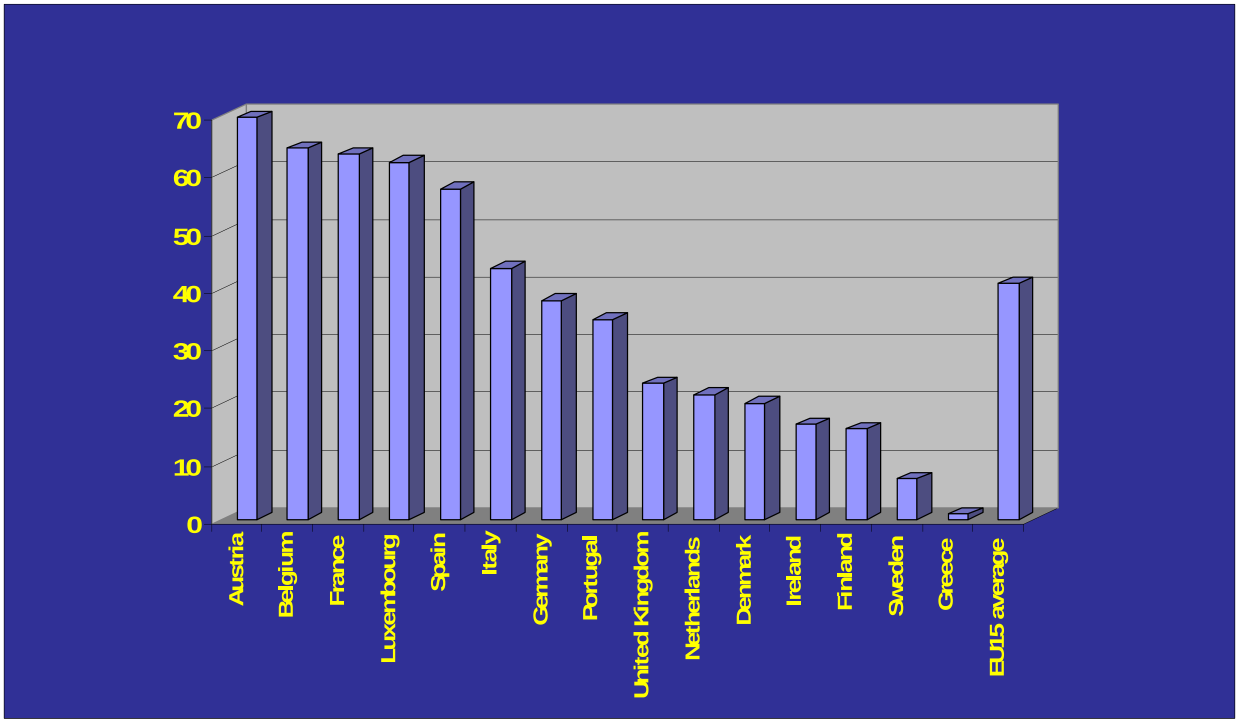
For cars, the Environment Council of 18-19 December 2000 reported its conclusions on the second Auto-Oil program and noted the following:

> “The Council supports the opinion put forward in the Commission communication concerning the need for **further action on particulate matter, nitrogen oxides and tropospheric ozone**.
>
> The Council invited the Commission to:
>
> - Encourage the **progressive and harmonized introduction of fuels** whose characteristics allow for the **optimization of new technologies** for the post-treatment of emissions and of new engine types;
> - Make continued efforts to significantly **reduce nano-particle emissions**;
> - Bring the provisions on limit values for diesel engines – for example, on emissions of **nitrogen oxides (NOx)** – closer to the provisions for petrol engines;
> - Start technical work and the necessary studies to assess the feasibility of a **new phase in the reduction of limit values for emissions which could come into force** by 2010;
> - **Review the latest developments of the new propulsion technologies**, and to submit a report to the Council as soon as possible.

In short the Council asked the Commission to continue the work of further reducing emission from motor vehicles, **in particular NOx and nano-particle emissions.**

The diesel car sector is particularly important to the EU where several Member States show new registrations of diesel cars exceeding 60% of all new car registrations (see Figure below). There are many reasons for the high market share of diesel cars, e.g. new car registration tax and annual circulation tax, but the increasing penetration of diesel cars into the market has led to calls for more stringent measures to reduce emissions from new diesel cars, notably emissions of NOx and particulates.

[34] The details of the Commission’s Clean Air for Europe (CAFE) program can be found on the web-page of the Commission’s DG Environment.



ii. Council - Car Emissions:

As noted earlier, the European Parliament and the Council had decided to set the Euro 4 emission standards back in 1998. The political aim of Euro 4 had been to require the use of particulate filters on new diesel cars. However, engine controls improved, and high pressure common rail diesel systems became commonplace with the result that the Euro 4 emission limits can be met without the use of a particulate filter. Such vehicles would also qualify for tax incentives in those Member States offering such incentives.

Some manufacturers have of course chosen to take a “green line” and equip at least their larger diesel cars with particulate filters of one type or another.

To push the use of particulate filters, some Member States have called on the Commission to take action to either introduce Euro 5 standards as soon as possible so they can be used for tax incentives when Euro 4 becomes mandatory, or provide an interim standard (Euro 4+) on which tax incentives can be based. The Commission has resisted proposing a Euro 4+ standard since it believes there are other ways of offering incentives to new vehicles or even disincentives to encourage the replacement of older more polluting vehicles. Discussions on this point are ongoing.

However, the recent discussions about Euro 4+ and tax incentives have encouraged several manufacturers to offer diesel particulate filters, as announced at the last Frankfurt motor show. Such vehicles can today obtain Euro 4 type-approval and thereby qualify for a tax incentive.

iii. Comments From Member States

Germany and France presented a united front in March 2003 stressing the need for the Commission to take action to ensure the reduction of particulate mass emissions through the widespread use of particulate filters and also to push for further reductions in NOx emissions together with simultaneous reductions in CO2 emissions. More recently, the united German-French front has crumbled somewhat in the level of aspirations of what the Euro 5 emission standards should be. Germany has proposed a limit of 8.5 milligram per kilometer (mg/km) for particulates and 200 mg/km for NOx and more recently indicated that those limits would suffice for a Euro 4+ stage only and be more stringent for Euro 5. France has indicated its support of emission limits of 12.5 mg/km for particulates and 200 mg/km for NOx. Denmark and Sweden have proposed a limit of 2.5 mg/km for particulates.

Other Member States have indicated their preference for a scientific result from CAFE before deciding on Euro 5.

iv. Important Factors:

The Commission has heard the calls for a Euro 4+ standard but it takes the view that technical capability and the costs of measures need to be fully assessed. One also has to recognize the importance of other regulatory actions on the automotive sector:

- CO2 is high on the agenda of the EU. An industry average of 140 g/km of CO2 has to be achieved by 2008 and the EU is presently looking with the motor industry associations representing the EU, Japanese and Korean manufacturers to see what can be achieved beyond 2008. The achievement of lower pollutant emissions in Euro 5 from 2010 will have a direct effect on what can be achieved for CO2 towards 2012, and vice-versa;
- There are also other legislative initiatives in the area of vehicle safety that impose a difficult burden on the motor industry;
- The issue of fuel quality remains important but the availability of zero-sulphur gasoline (less than 10 parts per million sulphur) from 2009 and the expected confirmation of the same date for zero-sulphur diesel help in realizing the technology to achieve lower pollutant emissions and improvements in CO2.

v. Issues for Euro 5:

The Commission has identified the priority issues for Euro 5 as being:

- reduction in tailpipe emission limits based on a cost-effective assessment;
- introduction of new measurement methods for ultra-fine particle emissions based on the work being carried out in the UN-ECE in Geneva – the PMP group;
- reduction in diesel particulate mass emissions and new controls on ultra-fine particle emissions;
- consideration of measures on direct injection gasoline engines with respect to ultra-fine particle emissions;
- attention to HC species and limits appropriate to the use of new alternative fuels;

- Consideration of the effects of such measures on CO_2 emissions.

In addition, there are several complimentary measures being looked at:

- Extension of the durability requirements beyond 160,000 km (it is 100,000 km in Euro 4);
- The need for additional evaporative emission controls;
- Revision to test procedures, in particular to take account of the effect of the increasing use of mobile air conditioning equipment (MAC). In fact, revision of test procedures to include the use of MAC will not be properly addressed in the timeframe of a Euro 5 proposal but it will be studied further to determine if it can fit into the Euro 5 stage through a proposal at a later date. Any Euro 5 emission limits may have to be adapted to account for changes to the test cycle;
- To determine whether there could be a role for EFV in Euro 5 if the mandatory Euro 5 standards achieve what is needed to help meet future air quality from passenger cars;
- Improved measures on off-cycle emissions, aligning with a global approach developed through the UN-ECE.

vi. Euro 5 Questionnaire Aims:

In order to help provide the necessary data on the costs and effects of technology to meet possible Euro 5 limits and to provide for a transparent process involving the stakeholders, the Commission has set-up a specific working group within the Motor Vehicle Emission Group (MVEG) looking at Euro 5 (and Euro 6). A questionnaire on Euro 5 was sent to the stakeholders in the Euro 5 process in mid-February in order to collect information on the costs and effects of achieving certain emission limit scenarios for Euro 5.

In the case of diesel light-duty vehicles, these scenarios range from a 50% to a 90% reduction in particulate emissions over Euro 4 (12.5 to 2.5 mg/km) and from a 40% to 70% reduction in NOx emissions over Euro 4 (150 to 75 mg/km). In the case of gasoline light-duty vehicles, these scenarios range from a 40% to 70% reduction in NOx emissions over Euro 4 (48 to 24 mg/km).

On the basis of the responses to the questionnaire (that were due by the end of April), the Commission will assemble a range of Euro 5 scenarios and their respective costs that will be used in the CAFE modeling process. This process is anticipated to be completed by mid-June.

Following the CAFE process, a proposal for Euro 5 is likely to be adopted by the Commission in mid-2005.

E. Euro 6 for Heavy Duty Vehicles

i. Already Said On Euro 6:

The need for further reductions in emissions from heavy-duty vehicles was already recognized in Directive 99/96 where it drew attention to:

- development of diesel and gas engine control and aftertreatment technology and influence of fuel quality;
- improvements in accuracy and repeatability of measurement and sampling procedures for very low levels of particulates;
- The adoption of a worldwide harmonized test procedure for heavy-duty vehicles (WHDC) should be included in a Euro 6 stage;
- limits for pollutants currently non-regulated by virtue of introduction of new alternative fuels;

In addition, the recent first reading agreement on heavy-duty vehicles mentioned earlier has included statements to reinforce the need for a Euro 6 stage concentrating on reducing NOx and particulate mass emissions and focusing also on ultra-fine particles.

ii. Issues for Euro 6

The priority issues for Euro 6 will be:

- Significant reduction in NOx beyond 2.0 g/kWh;
- introduction of new measurement methods ultra-fine particle emissions based on the work being carried out in the UN-ECE in Geneva – the PMP group;
- reduction in diesel particulate mass emissions and new controls on ultra-fine particle emissions;
- control of crankcase emissions through closed crankcase ventilation;
- the introduction of the WHDC test procedure concurrent with its agreement as a Global Technical Regulation;
- review the need for increased durability;
- Improved measures on OBD & off-cycle emissions, aligning with the adoption of Global Technical Regulations in these areas.

A Euro 6 questionnaire is in the final stages of preparation and, like Euro 5, the data collected will provide an important input to the CAFE program. Again, following the CAFE process, a proposal for Euro 6 is likely to be adopted by the Commission in the autumn of 2005.

F. Conclusions:

1. Proposals for Euro 5 and Euro 6 are in preparation;
2. As a result of the CAFE program, a Euro 5 proposal for light duty vehicles is due in mid-2005 and a proposal for Euro 6 for heavy duty engines in autumn 2005;
3. The priority issues for both Euro 5 and Euro 6 are further NOx and particulate mass reductions and controls on ultra-fine particles;
4. SCR for heavy-duty vehicles remains an issue that needs addressing in the near term;
5. Zero-sulphur gasoline and diesel fuels will be available in the EU in time for Euro 5 for light-duty vehicles. Zero sulphur fuels are critical to the efficient operation of future emission control systems. Other fuel characteristics are being looked at by the Commission in an overall review of fuel quality and it is expected that attention will be paid to issues such as detergents which can certainly help in the efficient operation of emission control systems.