UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

Diesel Engines Exhausts: Myths and Realities

Discussion Paper

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ECE/TRANS/XX

United Nations Economic Commission for Europe

The United Nations Economic Commission for Europe (UNECE) is one of the five United Nations regional commissions, administered by the Economic and Social Council (ECOSOC). It was established in 1947 with the mandate to help rebuild post-war Europe, develop economic activity and strengthen economic relations among European countries, and between Europe and the rest of the world. During the Cold War, UNECE served as a unique forum for economic dialogue and cooperation between East and West. Despite the complexity of this period, significant achievements were made, with consensus reached on numerous harmonization and standardization agreements.

In the post-Cold War era, UNECE acquired not only many new Member States, but also new functions. Since the early 1990s the organization has focused on analyses of the transition process, using its harmonization experience to facilitate the integration of Central and Eastern European countries into the global markets.

UNECE is the forum where the countries of Western, Central and Eastern Europe, Central Asia and North America – 56 countries in all – come together to forge the tools of their economic cooperation. That cooperation concerns economics, statistics, environment, transport, trade, sustainable energy, timber and habitat. The Commission offers a regional framework for the elaboration and harmonization of conventions, norms and standards. The Commission's experts provide technical assistance to the countries of South-East Europe and the Commonwealth of Independent States. This assistance takes the form of advisory services, training seminars and workshops where countries can share their experiences and best practices.

Transport in UNECE

The UNECE Inland Transport Committee (ITC) facilitates the international movement of persons and goods by inland transport modes. It aims to improve competitiveness, safety, energy efficiency and security in the transport sector. At the same time it focuses on reducing the adverse effects of transport activities on the environment and contributing effectively to sustainable development. The ITC is a:

- Centre for multilateral transport standards and agreements in Europe and beyond, e.g. regulations for dangerous goods transport and road vehicle construction at the global level

- Gateway for technical assistance and exchange of best practices

- Promoter of multi-country investment planning

- Substantive partner for transport and trade facilitation initiatives

- Historic center for transport statistics.

For more than six decades, ITC has provided a platform for intergovernmental cooperation to facilitate and develop international transport while improving its safety and environmental performance. The main results of this persevering and important work are reflected in more than 50 international agreements and conventions which provide an international legal framework and technical regulations for the development of international road, rail, inland water and intermodal transport, as well as dangerous goods transport and vehicle construction. Considering the needs of the transport sector and its regulators, UNECE offers a balanced approach to and treatment of facilitation and security issues alike.

Contents

List of Figures

List of Abbreviations

I. Introduction.

1. Every day, millions of diesel-powered vehicles busily move consumer goods and raw materials from ports, distribution centres and rail yards to stores and industrial facilities throughout the world. Diesel-powered ships, trains and trucks are pivotal in the local, regional and global commerce. Most rivers barges, freight trains and ocean-going ships are also powered by diesel, as are the overwhelming majority of trucks and lorries. Furthermore, school buses, buses and garbage collector trucks facilitate our daily lives.

2. Diesel-powered equipment is also a major part of the supply chain that moves crops from the farm to the dinner table. Diesel-powered farm tractors, combines and irrigation pumps are just a few examples of the types of equipment that literally drive the agriculture sector.

3. Diesel engines are not only fundamental in mobile vehicles and machinery, but also widely employed in stationary applications such as pipeline pumps, electric and water plants, industrial machinery, mining tools, factories and oil fields.

4. Unmatched in their reliability, durability, fuel efficiency and mobility, diesel engines play a fundamental role in allowing economic development.

5. However, along with the economically productive role of diesel engines in national economies comes their emissions' harmful effect on human health. Emissions from diesel engines found in trucks, boats, locomotives, buses, agricultural and construction equipment—especially the microscopic soot known as "particulate matter" (PM)—create serious health problems for adults and have extremely harmful effects on children and the elderly.

6. The objective of this Discussion paper is:

(a) to offer a balanced view on the on-going debate about the harmful effects of diesel engine exhaust emissions on human health and the environment;
(b) to take stock of recent studies on the harmful effects of diesel exhausts to public health;
(c) to provide information about diesel emissions by different economic sectors including inland transport;
(d) to overview the recent policy developments on the reduction of pollutant emissions to address health and environmental concerns; and
(e) to overview any technological developments in diesel engines that reduce or even eliminate the harmful effects to public health.

7. The overview includes information of global relevance and focuses, in particular, on the European Union, North America and Japan.

8. Section II contains a list of the main air pollutants from diesel engine exhausts. Section III illustrates the harmful effects of diesel engine exhausts on human health and the environment.

9. Section IV provides information on the main sources of air pollution from diesel engines and, in particular, the role of different economic sectors as well as of inland transport.

10. Section V focuses on the compliance with existing international agreements, as well as EU legislation. A brief report on an assessment of the atmospheric concentration of the PM pollutants in Europe is provided.

11. Section VI provides an overview of regulatory measures undertaken for the reduction of PM pollutant emissions of diesel engines in the framework of the Inland Transport Committee and its subsidiary bodies and particularly by the World Forum for the Harmonization of Vehicle Regulations (WP.29).

12. Section VII provides a set of conclusions and recommendations for consideration by the Governments and relevant international organizations.

II. Analysis of Diesel Engine Exhausts' main air pollutants

II.1. Main air pollutants

13. The incomplete combustion of diesel fuel creates the particulate matter. Particulate matter's composition often includes hundreds of chemical elements, including sulphates, ammonium, nitrates, elemental carbon, condensed organic compounds, and even carcinogenic compounds and heavy metals such as arsenic, selenium, cadmium and zinc. Though just a fraction of the width of a human hair, particulate matter varies in size from coarse particulates (less than 10 microns in diameter) to fine particulates (less than 2.5 microns) to ultrafine particulates (less than 0.1 microns).

14. A recent report from the European Environment Agency (EEA) (EEA, 2012) provides a brief description (summary in Box 1) of particulate matter and other air pollutants and their effects on human health and the environment.

Box 1. Description of the main local air pollutants (gases, particulate matter and heavy metals)

Particulate matter (PM): PM is emitted from many sources and is a complex heterogeneous mixture comprising both primary and secondary PM. Primary PM is the fraction of PM that is emitted directly into the atmosphere, whereas secondary PM forms in the atmosphere following the oxidation and transformation of precursor gases (mainly SO_X, NO_X, NH_3 and some volatile organic compounds (VOCs)). From a regulatory perspective, PM is divided into PM_{10} and $PM_{2.5}$, defined (ISO, 2008) as the size fractions where the median aerodynamic diameter of the particles is respectively 10 and 2.5 microns (this means that 50 per cent of the particles in these fractions have diameters respectively greater, or smaller, than 10 microns and 2.5 microns. Sources of coarse particles include crushing or grinding operations, and dust stirred up by vehicles travelling on roads. Sources of fine particles include all types of combustion, including motor vehicles, power plants, residential wood burning, forest fires, agricultural burning and some industrial processes. Considering the potential to harm human health, PM is one of the most important pollutants as it penetrates into sensitive regions of the respiratory system. In addition, Black Carbon (BC) is the strongest light-absorbing component of PM (US EPA, 2012b). Emitted directly into the atmosphere in the form of fine particles ($PM_{2.5}$) and notwithstanding its short lifetime, BC is estimated to have a 20-year Global Warming Potential (GWP) more than 4000 times higher than the GWP of CO_2 and a 100-year GWP 1,500 to 2,240 times higher than CO_2 (Jacobson, 2007). This, combined with the amounts emitted in the atmosphere, is such that BC is likely to be one of the leading causes of global warming after carbon dioxide (Jacobson, 2007).

Sulphur oxides (SO_X): SO_X are emitted when fuels containing sulphur are burned. They contribute to acid deposition, the impacts of which can be significant: adverse effects on aquatic ecosystems in rivers and lakes, and damage to forests.

Nitrogen oxides (NO_X): NO_X are emitted during fuel combustion by industrial facilities and the road transport sector. As with SO_X, NO_X contribute to acid deposition but also to eutrophication of soil and water.

Ammonia (NH3): NH3, like NO_X, contributes to both eutrophication and acidification.

Carbon monoxide (CO): CO is produced as a result of fuel combustion. The road transport, commercial, household and industry sectors are important sources. Long-term exposure even to low concentrations of CO can result in neurological problems and potential harm to unborn babies.

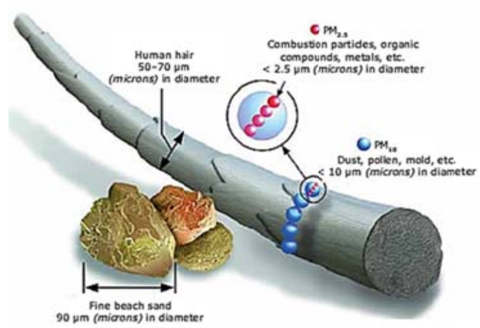
Non-methane volatile organic compounds (NMVOC): NMVOC, important O3 precursors, are emitted from a large number of sources including paint application, road transport, dry-cleaning and other solvent uses.

Heavy metals (HMs): the HMs arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg), chromium (Cr), copper (Cu), nickel (Ni), selenium (Se) and zinc (Zn) are emitted mainly as a result of various combustion processes and industrial activities, like metals works and smelters.

Sources: EEA, 2012a; US EPA, 2012a

15. Many air pollutants, including NO_X and sulphur dioxide (SO_2), are directly emitted into the air from anthropogenic activities such as fuel combustion or releases from industrial processes. Other air pollutants, such as O3 and the major part of PM, form emissions in the atmosphere irrespective of an anthropogenic or a natural origin. Natural sources of aerosol particle emissions that are included in PM may occur from volcanic eruptions, soil-dust and sea-spray uplifts, natural biomass burning fires, and biological material release. Major anthropogenic sources include fugitive dust emissions, fossil-fuel combustion, biomass burning and industrial emissions (Jacobson, 2012). Particulate Matter (PM) can also be distinguished as primary PM, directly emitted from its sources, secondary PM, subsequently formed in the atmosphere by chemical processes from a range of previously emitted precursor gases. Secondary PM is generated mainly through a series of chemical reactions involving nitrogen oxides (NO_X), sulphur dioxide (SO2), ammonia (NH3) and a large number of volatile organic compounds (VOCs), which may react with other reactive molecules in the atmosphere forming the secondary inorganic aerosol (SIA) and secondary organic aerosol (SOA).

Figure 1. Illustration of $PM_{2.5}$ and PM_{10} particle size



Source: EPA, 2010.

16. These considerations are important bearing in mind that complex links exist between the emissions of air pollutants and the air quality (the latter being measured via the ambient/atmospheric concentration of pollutants). As a result, changes in the emissions of selected pollutants do not always lead to a corresponding change in their atmospheric concentrations, even if they are a necessary step towards the improvement of air quality.

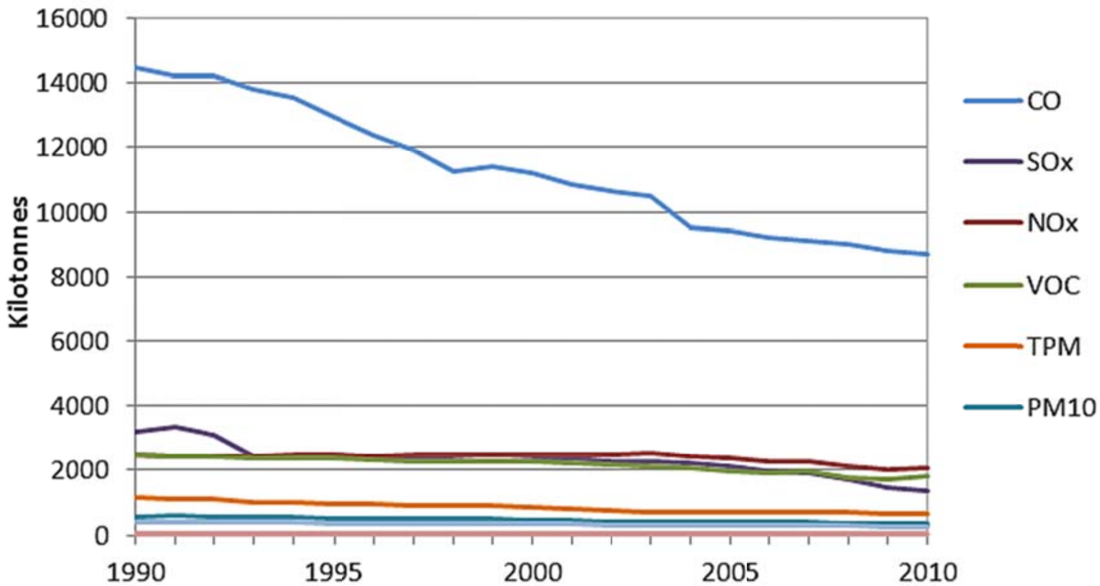
II.2. Historical Trends.

17. A number of models have been developed, largely in developed countries, for estimating the emissions of diesel engines over time and their attribution to different main sources. According to the model results, the emissions of diesel engines in the atmosphere are in a downward trend in developed countries. A similar evolution is also expected to continue in the forthcoming years. According to the experimental measurements of the concentration of air pollutants in the atmosphere, the concentration of air pollutants also tended to improve, but the results are not as encouraging as in the case of emissions.

18. In rapidly developing countries, the economic development is expected to be coupled with a strong growth in the activity of economic sub-sectors that are responsible for the emissions of a wide range of air pollutants. As a result, emission trends may or may not follow downward paths. In the case of transport, the policy framework can play a very relevant role, since the evolution of the emission trend is strongly dependent on the enforcement of emission regulations (WBCSD, 2004).

II.2.1. Canada

Figure 2. Canadian PM emission trends (open and natural sources excluded)



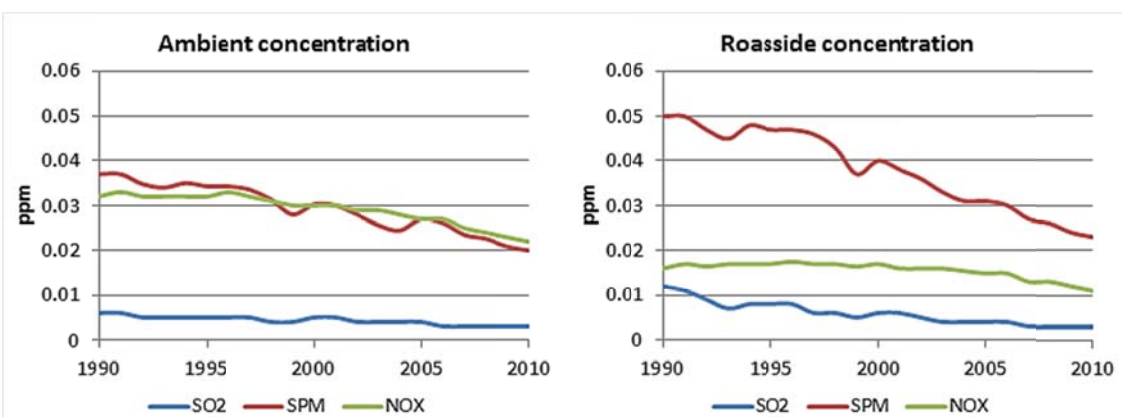
Source: Canada, 2013a

19. In Canada, the emissions of diesel engines experienced a significant reduction in recent years. Between 1990 and 2010, Canada's total SO_X emissions decreased by 57 per cent, PM_{10} by 35 per cent and NO_X emissions by 18 per cent (Figure 2).

II.2.2. Japan

20. In Japan, results from the environmental monitoring of the atmosphere are conducted by the prefectures in compliance with the Air Pollution Control Law and reported to the Ministry of the Environment. The evolution of the atmospheric concentration of SO_2, suspended particulate matter (SPM) and NO_X, shown in Figure 3, illustrates that the atmospheric concentration of all these pollutants has been decreasing over the past few decades.

Figure 3. Atmospheric concentration of suspended particulate matter in Japan



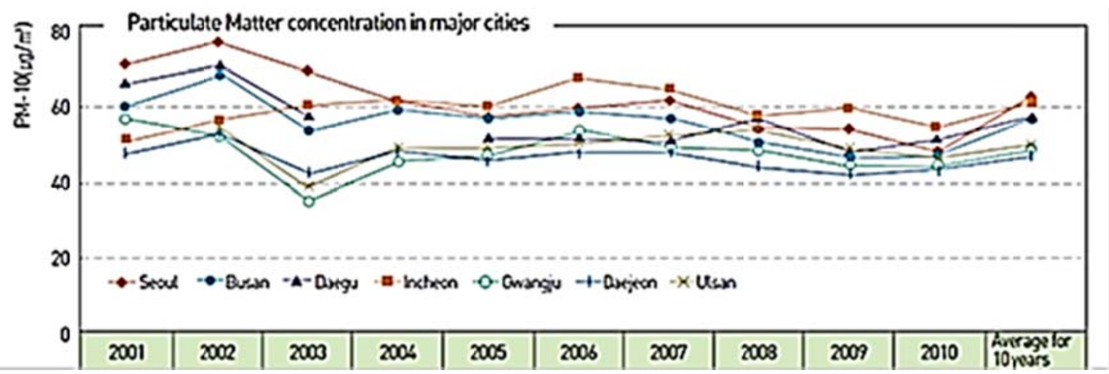
Source: JASIC, 2013

II.2.3. Republic of Korea

21. In the Republic of Korea (Korea), air pollutants are continuously and automatically monitored. Real time data are collected by the National Ambient air Monitoring Information System (NMAIS) and published by Air Korea.

22. In 2001, the Ministry of Environment (MOE) published information on concentration levels of air pollutants such as particulate matter (Figure 4) in an environmental review. The MOE underlined a downward trend of sulphur dioxide emissions. This was achieved thanks to the strengthening of the fuel regulation system. A higher concentration of nitrogen dioxide in Seoul, was observed where economic activities are concentrated and traffic is the heaviest. At the same time, a decrease of the concentration of particulate matter since 2008 was achieved (MOE Korea, 2011).

Figure 4. Atmospheric concentration of PM in the Republic of Korea

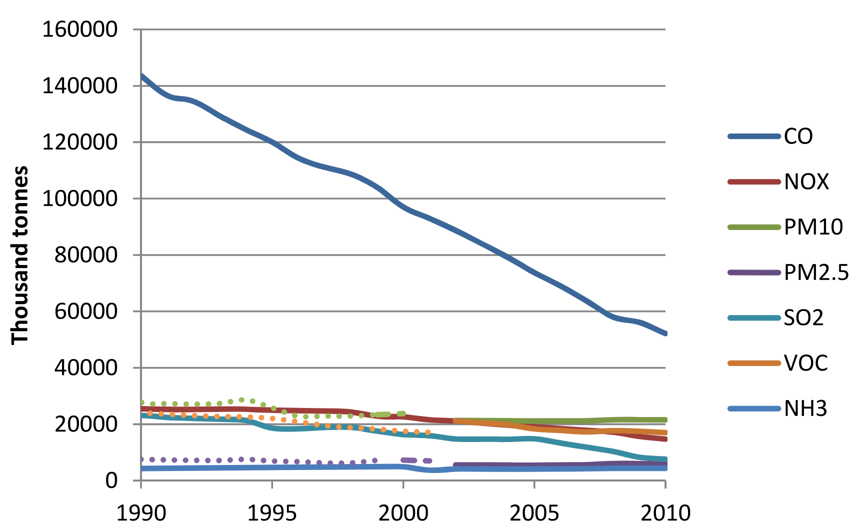


Source: MOE Korea, 2011

II.2.4. United States of America

23. Downward trends are observable in the United States of America (Figure 5), where, between 1990 and 2012, both PM_{10} and $PM_{2.5}$ emissions declined by roughly 20 per cent.

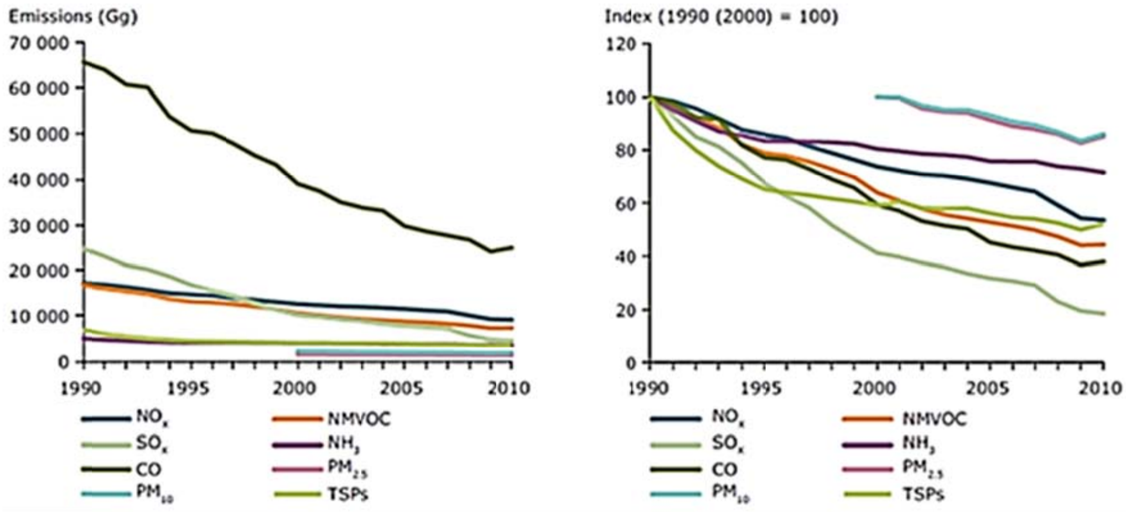
Figure 5. PM pollutant emissions trends in the United States of America



Source: US EPA, 2012

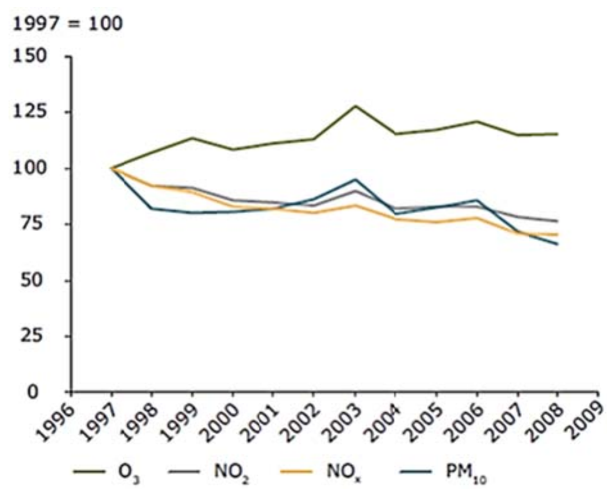
II.2.5. European Union

Figure 6. EU-27 emission trends for the particulate matter and other air pollutants



Source: EEA, 2012a

Figure 7. Indexed trends in air quality



Source: EEA, 2010

24. According to the EEA (which builds on the results from these models), air pollutant emissions in Europe (including EEA member States and countries of the Western Balkans) have decreased since 1990. In 2010 (EEA, 2012a):

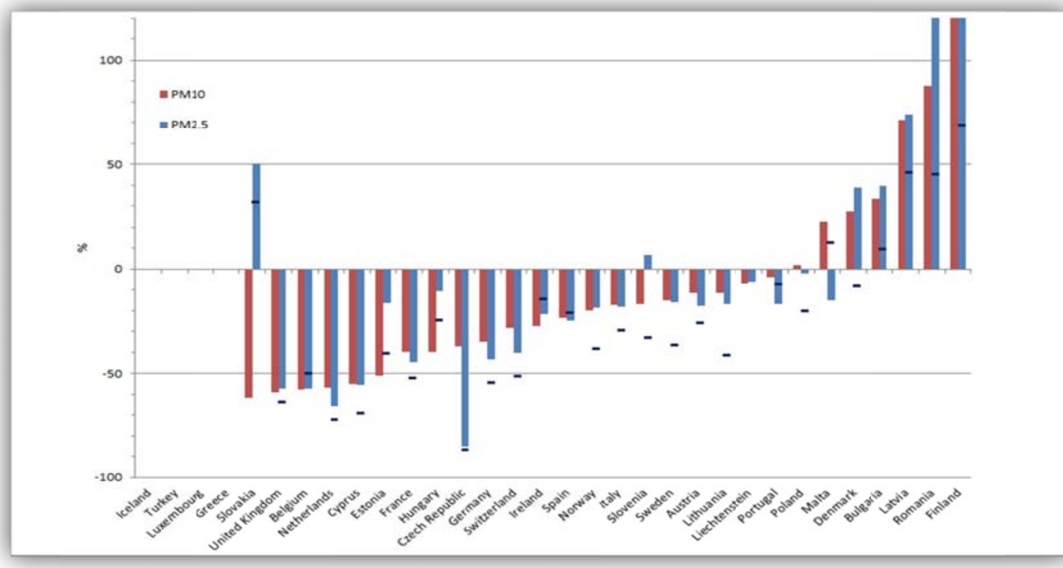
EEA Reports that since 2000, PM10 and PM2.5, emissions have been reduced by 14 per cent and 15 per cent, respectively.

a) SO_X emissions were 82 per cent lower than in 1990;

b) Total Suspended Particles (TSP) have been reduced by 48 per cent since 1990. For PM_{10} and $PM_{2.5}$, the aggregated EU-27 emission reduction achieved since 2000 is 14 per cent and 15 per cent, respectively.

25. Despite these reductions, measured concentrations of health-relevant pollutants such as PM and O_3 have not shown a corresponding improvement (Figure 7) (EEA, 2010).

Figure 8 . Percentage of change in $PM_{2.5}$ and PM_{10} emissions 1990-2010 (EEA member countries)

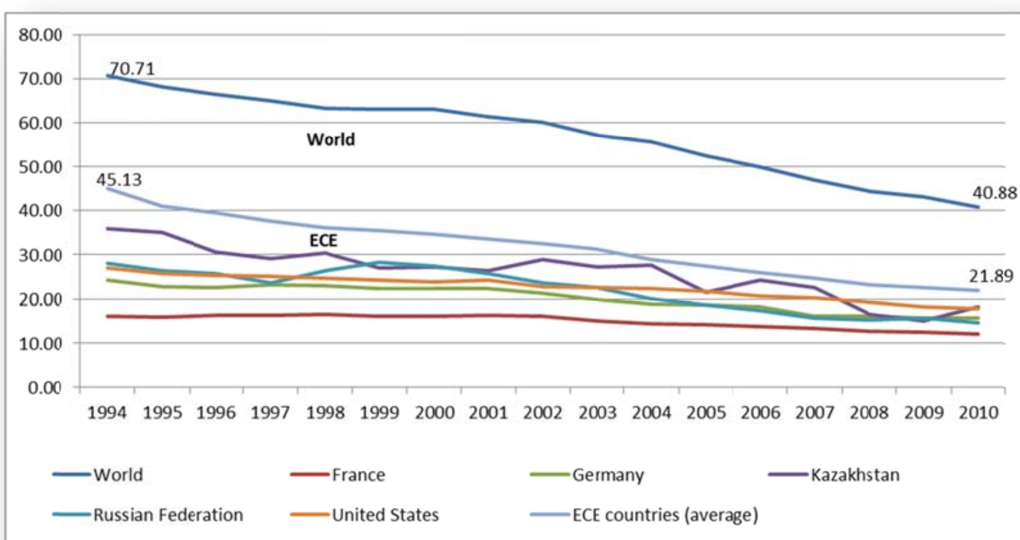


Source: EEA, 2012a

26. Annual emissions of primary PM_{10} have decreased by 26 per cent across the EEA-32 region between 1990 and 2010, with significant reductions within most countries (Figure 8). The largest reductions have been reported by Slovakia (62 per cent), the United Kingdom of Great Britain and Northern Ireland (59 per cent) and Belgium (58 per cent). In contrast, emissions have increased in seven countries in the same time period. The greatest increases have been reported in Finland (175 per cent), Romania (88 per cent) and Latvia (71 per cent).

II.2.6 The Trend Worldwide and in the UNECE region

Figure 9. PM_{10}, country level (micrograms per cubic meter)UNECE member States and the World



Source: World Bank, UNECE

27. Worldwide, annual emissions of primary PM_{10} have decreased from 70.71 micrograms per cubic meter in 1994 to 40.88 in 2010. In the UNECE region, the data for 52 out of 56 UNECE member States, present a significant reduction. In terms of micrograms per cubic meter PM_{10} emissions have reduced on average from 45.13 in 1994 to 21.89 in 2010. The emission reduction achieved in the UNECE region in PM_{10} micrograms per cubic meter is 51 per cent since 1994.

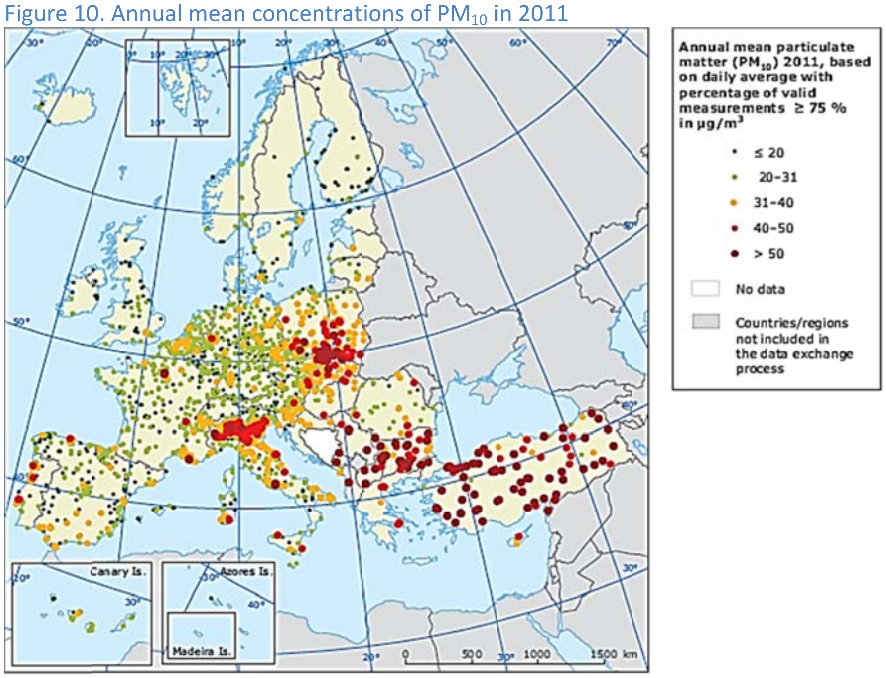
III. Diesel engine exhaust emissions and harmful effect on human health and the environment

28. Notwithstanding the progress in reducing anthropogenic emissions of the main air pollutants over recent decades, poor air quality remains an important public health issue (EEA, 2010). This is particularly relevant for airborne particulate matter (PM), tropospheric (ground-level) ozone (O3) and nitrogen dioxide (NO_2).

29. The air quality in cities is of the biggest concern since:

a) A significant proportion of the global population lives in urban areas;
b) Cities are the areas with the highest exposure to air pollution because this is where most exceedances of the air quality reference levels occur (e.g. EU (EC, 2008) and WHO (WHO, 2011));

Figure 10. Annual mean concentrations of PM_{10} in 2011



Note: The red and dark red dots indicate stations reporting exceedances of the 2005 annual limit value (40 µg/m³), as set out in the Air Quality Directive (EU, 2008c).

The orange dots indicate stations reporting exceedances of a statistically derived level (31 µg/m³) corresponding to the 24-hour limit value.

The pale green dots indicate stations reporting exceedances of the WHO air quality guideline for PM_{10} of less than 20 µg/m³.

The dark green dots indicate stations reporting concentrations below the WHO air quality guideline of 20 µg/m³ for PM_{10}.

Source: EEA 2013

c) In the EU member States, 16 to 30 per cent of the urban population was exposed (in the period 2008-2010) to PM2.5 concentrations above the EU reference levels (the percentages increase to 90-95 per cent for WHO reference levels)(EEA, 2012) (figure 11);

d) In Japan, the rates of achievement of environmental quality standards fall close to 90 per cent for roadside monitoring stations, and 100 per cent for ambient monitoring stations for PM, but much lower for $PM_{2.5}$ and ozone. Levels of concentration of $PM_{2.5}$ were about 30 per cent in 2010, when the first valid monitoring of $PM_{2.5}$ was conducted (JASIC, 2013).

30. As pointed out in Section IV, emissions from buildings used for households and commercial/institutional activities are among the most important contributors to PM ambient concentrations levels. Other important anthropogenic sources include industrial processes and road transport.

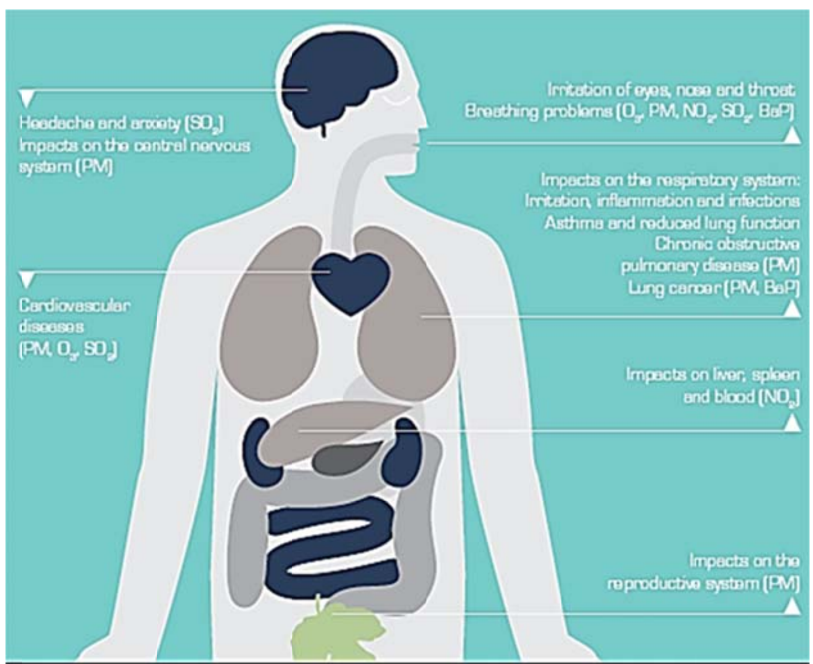
Figure 11. Percentage of the urban population in the EU exposed to PM pollutant concentrations above the EU and WHO reference levels (2009–2011)

Pollutant	EU reference value	Exposure estimate (%)	WHO AQG	Exposure estimate (%)
$PM_{2.5}$	Year (20)	20-31	Year (10)	91-96
PM_{10}	Day (50)	22-33	Year (20)	85-88
O_3	8-hour (120)	14-18	8-hour (100)	97-98
NO_2	Year (40)	5-13	Year (40)	5-13
BaP	Year (1)	22-31	Year (0.12)	76-94
SO_2	Day (125)	< 1	Day (20)	46-54
CO	8-hour (10)	< 2	8-hour (10)	< 2
Pb	Year (0.5)	< 1	Year (0.5)	< 1
Benzene	Year (5)	< 1	Year (1.7)	12-13

Colour coding:	< 5 %	5-50 %	50-75 %	> 75 %

Source: EEA, 2013e (CSI 004); AirBase v. 7; ETC/ACM.

Figure 12. Key health effects for PM and other air pollutants



Source: EEA 2013

31. Figure 12 summarises the key health effects from major air pollutants. Of particular concern in Europe is PM (EEA, 2013).

32. Air pollution also damages the environment and it is estimated that two-thirds of the protected sites in the EU Natura 2000 network are severing threated by air pollution (EC, 2013).

33. Internal Combustion Engines (ICEs) powered by diesel fuel oil tend to offer better performances in terms of fuel consumption as comparable gasoline engines. Even if diesel ICEs costs more than their gasoline equivalents, the fuel savings generated tend to exceed the incremental investment cost gap required for their purchase. Since savings are larger in applications that require an intensive use of the ICE,

diesel ICEs are the main technological choice in heavy-duty stationary and mobile applications. This is also the case for a wide range of economic and industrial sectors, including for instance construction and agriculture.

34. In June 2012, the World Health Organization's International Agency on Research on Cancer (IARC) concluded that diesel engine exhaust is carcinogenic to humans (IARC, 2012). IARC thereby changed its finding from 1988, when diesel exhaust was classified as probably being carcinogenic to humans. The finding from a previous evaluation in 1989, that gasoline exhaust is possibly carcinogenic to humans, remained unchanged.

35. It is noteworthy that the IARC decision was unanimous and claimed that its decision was based on "compelling" scientific evidence. It urged a worldwide reduction of exposure to diesel fumes as much as possible. Large populations are exposed to diesel exhaust in everyday life, whether through their occupation or through the ambient air. People are exposed not only to motor vehicle exhausts but also to exhausts from other diesel engines, including those from other modes of transport (e.g. diesel trains and ships) and stationary sources (e.g. power and motion generators used in the energy and in the industrial sectors).

IARC reports that "Diesel Engine exhaust is carcinogenic to humans"

36. However, the mounting concern of the cancer-causing potential of diesel exhaust was based on findings in epidemiological studies that were re-emphasized by the publication in March 2012 of the results of a US National Cancer Institute/National Institute for Occupational Safety and Health study of occupational exposure to such emissions by underground miners showing an increased risk of death from lung cancer when working in closed areas. (IARC, 2012).

37. Dr. Kurt Straif, the Head of the IARC Monographs Programme, indicated that "the main studies that led to the above-mentioned conclusion were from highly exposed workers (mines) and that they came to this conclusion based on other carcinogens, such as radon, that initial studies showing a risk in heavily occupational groups were followed by positive findings for the general population" (IARC, 2012).

38. Dr. Christopher Wild, the IARC Director, answering the question if the new diesel engines are so clean that the findings from this monograph meeting are no longer relevant to today´s situation, replied: "the new diesel engines contain far fewer particles and chemicals compared to the older technology engines. In addition to that, there are also qualitative changes, so the composition of the mixture in the exhaust is different". He also added that "what we do not know at this stage is if this composition and the decreased levels of these components translated to a different healthy fact in exposed people and here we should encourage further research in the future" (Wild, 2012). He also underlined that in many developing countries the transition from the old technology to the new one will take time and, therefore, for many people in the world, the exposures are still from the exhaust of old diesel engines (Wild, 2012).

39. The United States of America Environmental Protection Agency (EPA) considers that the health effects of diesel emissions are well studied, but complex (US EPA, 2002). Even if the level and duration of exposure that causes harm varies from one substance to the next, the EPA has designated diesel exhaust as a likely carcinogen to humans by inhalation at environmentally adequate exposures (US EPA, 2002). A number of other agencies (US National Institute for Occupational Safety and Health, the International Agency for Research on Cancer, the World Health Organization, California EPA, and US Department of Health and Human Services) have made similar classifications.

40. In October 2013, IARC (IARC, 2013) announced it had classified outdoor air pollution as carcinogenic to humans. After thoroughly reviewing the latest available scientific literature, the world's leading experts convened by the IARC, concluded that there was sufficient evidence that exposure to outdoor air pollution causes lung cancer. They also noted a positive association with an increased risk of bladder cancer. Particulate matter, a major component of outdoor air pollution, was evaluated separately and was classified as carcinogenic to humans. By this announcement, IARC extended its earlier ruling, on carcinogenic effects to humans of diesel exhausts, to particulate matter and to the entire outdoor air pollution.

41. The UNECE convention on Long-range Transboundary Air Pollution (LRTAP, 2013) addressed the major part of carcinogenic air pollution through the amendments to the Protocol to Abate Acidification, Eutrophication and Ground level ozone (Gothenburg Protocol, LRTAP, 2012). The amended Protocol now includes national emission reduction commitments for the year 2020 and beyond for fine particulate matter ($PM_{2.5}$). The amended Protocol also calls for emission reduction measures with respect to black carbon, an important component of $PM_{2.5}$, thus covering potentially the most harmful components of air pollution.

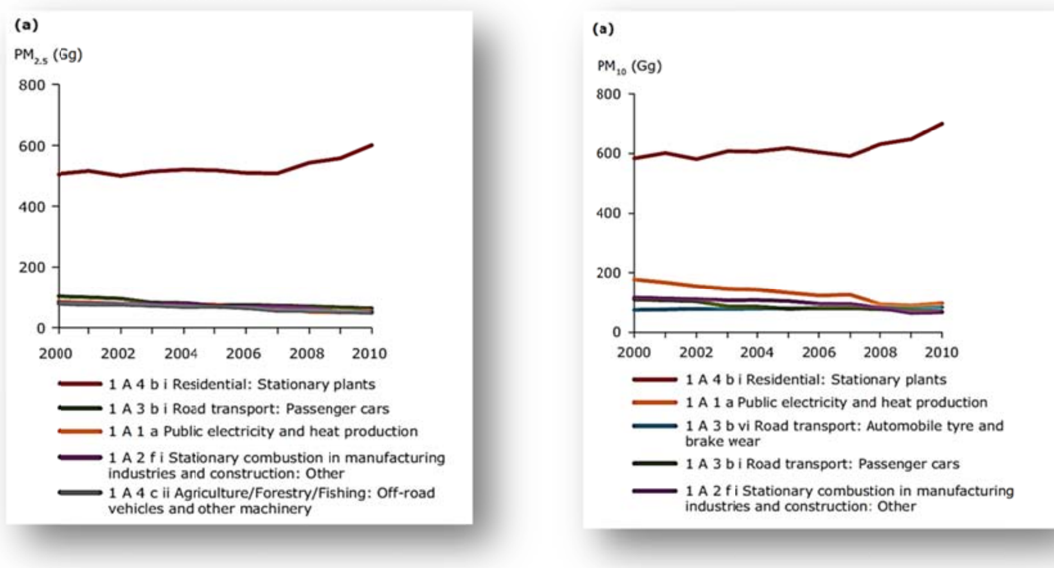
42. Overall, the importance of the health risks pointed out by the IARC and other authoritative sources calls for continued action aiming at limiting emission of air pollutants characterizing diesel exhaust and, more broadly, to reduce human exposure to them.

IV. Sources of air pollution that use diesel engines

IV.1. The role of different economic sectors

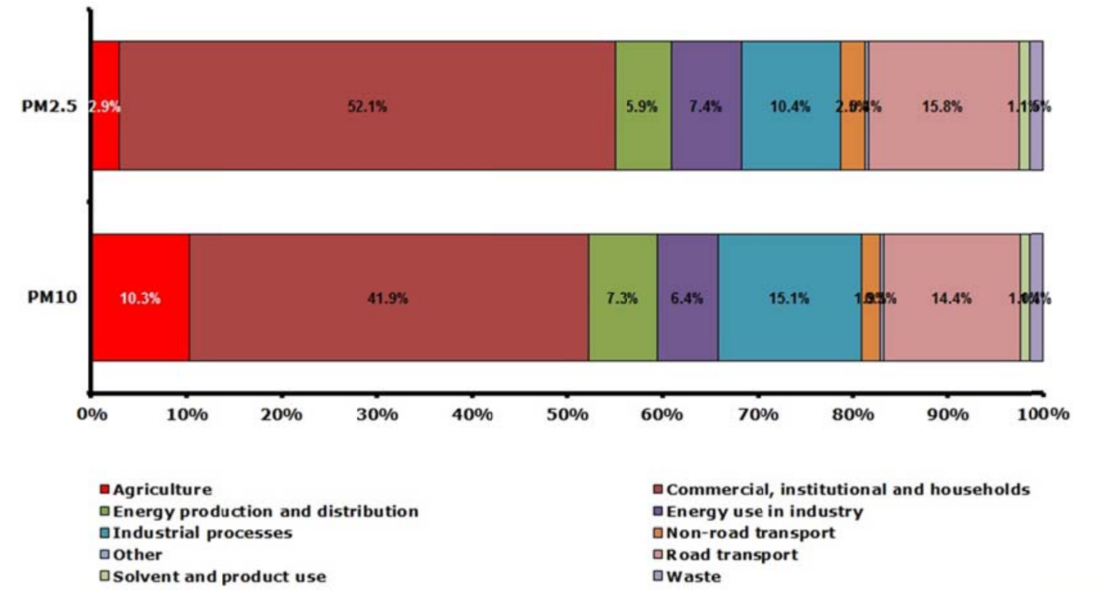
43. In addition to total emissions, the EEA estimated the role of different European economic sectors with respect to the emissions of $PM_{2.5}$ and PM_{10} pollutants. The figures 13 and 14 and Table 1 show the trends and the share of $PM_{2.5}$ and PM_{10} emissions by sector groups (EEA, 2012a).

Figure 13. Trend in $PM_{2.5}$ and PM_{10} emissions from the five most important key categories, 1990–2010



Source: EEA, 2012a

Figure 14. Sectoral contributions of emissions of primary particulate matter in 2010 (EEA member countries)



Source: EEA, 2012a

Table 1. Share of EU-27 emissions of the PM and other pollutants by sector group

Pollutants	Sector with highest share per pollutant		Road Transport	Non Road Transport
	Sector	Share		
NO_X	Road Transport	42 per cent	42 per cent	7 per cent
NMVOC	Solvent and product use	43 per cent	16 per cent	2 per cent
SO_X	Energy production and distribution	58 per cent	0 per cent	4 per cent
NH_3	Agriculture	94 per cent	2 per cent	0 per cent
$PM_{2.5}$	**Commercial, institutional and households**	**52 per cent**	**16 per cent**	**2 per cent**
PM_{10}	**Commercial, institutional and households**	**41 per cent**	**15 per cent**	**2 per cent**
CO	Commercial, institutional and households	41 per cent	29 per cent	2 per cent
Pb	Energy use in industry	36 per cent	10 per cent	1 per cent
Cd	Commercial, institutional and households	39 per cent	3 per cent	1 per cent
Hg	Energy production and distribution	41 per cent	0 per cent	4 per cent
PCDD/Fs	Commercial, institutional and households	37 per cent	1 per cent	1 per cent
Total PAHs	Commercial, institutional and households	59 per cent	2 per cent	0 per cent
HCB	Industrial processes	70 per cent	2 per cent	0 per cent
HCH	Industrial processes	66 per cent	0 per cent	0 per cent
PCBs	Waste	35 per cent	4 per cent	0 per cent

Source: EEA, 2012a

44. The commercial, institutional and household sector emerged as the most important source for $PM_{2.5}$ and PM_{10} with 52 per cent and 41 per cent respectively (figure 14). Domestic fuel use in the residential category '1 A 4 b i — Residential: Stationary plants' is the most important key category for $PM_{2.5}$ emissions, making up 45 per cent of total $PM_{2.5}$ emissions. Among the top five key categories, the highest relative reductions in emissions between 2000 and 2010 were achieved in the third most important key category, '1 A 1 a — Public Electricity and Heat Production' (– 41.5 per cent), and the fourth most important key category,

EEA reports that the commercial, institutional and household sector emerged as the most important source for $PM_{2.5}$ and PM_{10} with 52 per cent and 41 per cent respectively

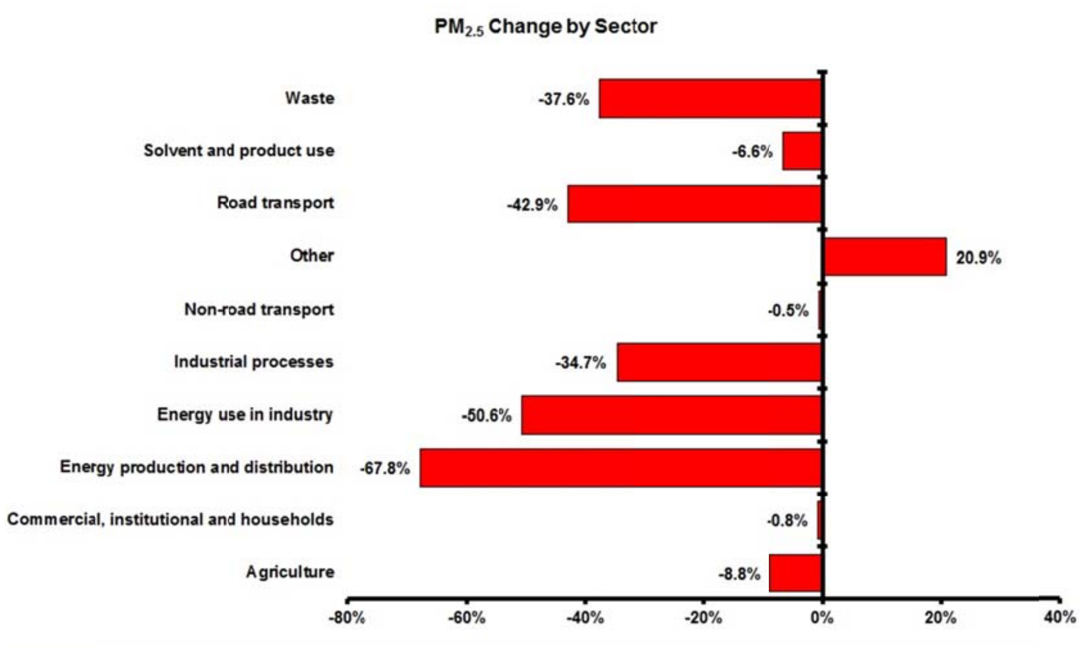
'1 A 2 f i — Stationary combustion in manufacturing industries and construction: Other' (– 37.8 per cent).

45. Among the top five key categories, the highest relative reductions in emissions between 1990 and 2010 were achieved in the second most important key category, '1 A 1 a — Public electricity and heat production' (– 49.2 per cent) (Figure 13) and the fifth most important key category '1 A 2 f i — Stationary combustion in manufacturing industries and construction: Other' (– 44.4 per cent).

46. Emissions of primary PM_{10} from most sectors have decreased from 1990 to 2010 (Figure 16), with the exception of the 'Agriculture', 'Other', 'Non-road transport' and 'Commercial, institutional and households' sectors, in which emissions have risen by 9.2 per cent, 8.5 per cent, 3.0 per cent and 0.6 per cent respectively.

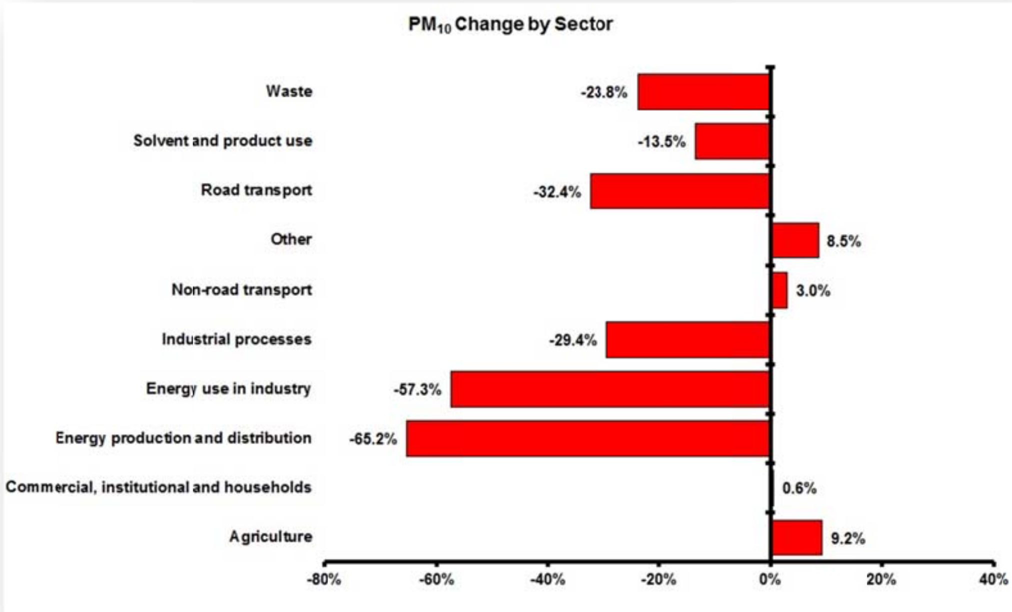
47. Since 1990, emissions from the combustion-related sectors 'Energy production and distribution', 'Energy use in industry' and 'Road Transport' have reduced significantly, contributing 39 per cent, 25 per cent and 20 per cent respectively of the total reduction in sub-10µm particulate matter emissions.

Figure 15. Percentage of change in primary $PM_{2.5}$ particulate matter emissions for each sector and pollutant between 1990 and 2010



Source: EEA, 2012a

Figure 16. Percentage of change in primary PM_{10} particulate matter emissions for each sector and pollutant, 1990-2010



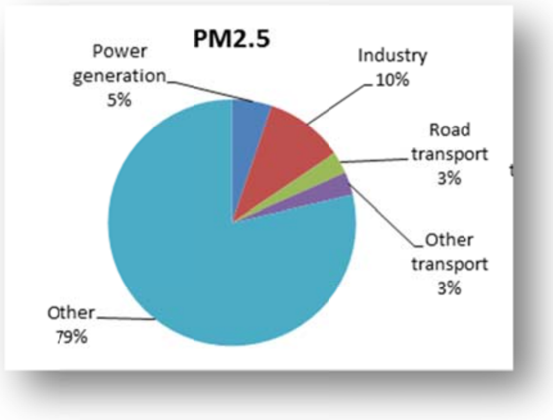
Source: EEA, 2012a

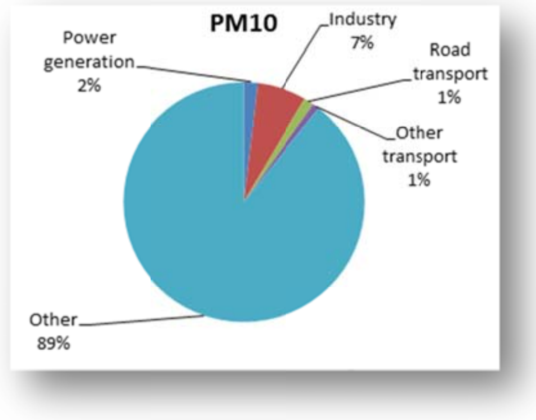
48. In the United States of America, the EPA published similar data, illustrating the evolution of emissions in different economic sectors. Figure 17 summarizes the information available from the National Emissions Inventory (NEI) Air Pollutant Emissions Trends Data (US EPA, 2013a). Transport (and especially road transport) plays a relevant role for what concerns CO and NOX, and it is an important source of emission for VOC emissions. Notwithstanding different classifications of the economic sectors, the main difference with the European shares can be identified in the PM emissions, where road transport has a lower relevance in the United States of America. This difference can be explained with the actions taken in North America, where diesel technology, for light vehicles, is by far less widespread than in other regions of the world, and where stricter PM emission limits than in Europe have been enforced. As in the case of Europe, low-sulphur fuels allowed achieving very low SO_2 emissions in the transport sector.

In the United States of America road transport has lower relevance regarding PM emissions (3 per cent share among the economic sectors)

49. In Canada, emission trends due to transportation follow comparable patterns to those of the United States of America, with $PM_{2.5}$ emissions from the diesel powered on-road fleet counting less than in Europe and experiencing a 75 per cent decrease between 1985 and 2010. As in the case of Europe and the United States of America, these changes occurred despite an increase in the total annual vehicle kilometres travelled by diesel vehicles.

Figure 17. Share of emissions of the particulate matter by economic sector in the United States of America





Source: US EPA, 2013

IV.1.1. Energy Sector

50. The 'energy production and distribution' sector grouping comprises emissions from a number of activities involving fuel combustion in order, for example, to produce energy products and electricity. It is an important source of many pollutants, especially SOX. Despite significant past reductions, this sector group still contributes 58 per cent of the total EU-27[1] emissions of this pollutant.

51. For PM_{10}, a reduction of more than 43 per cent has occurred within this sector group since 2000 (figure 18). The 'energy use in industry' sector is an important source for lead and cadmium (figure 19).

Figure 18. EU-27 emission trends in the sector 'energy production and distribution'

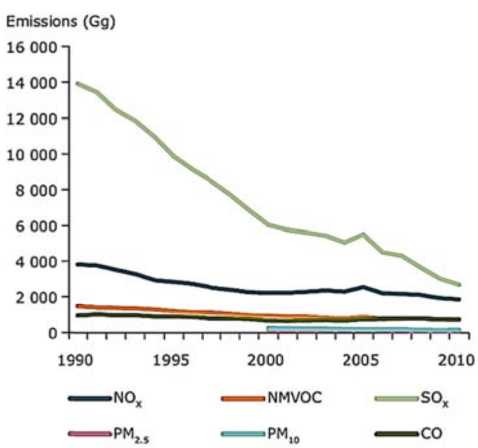
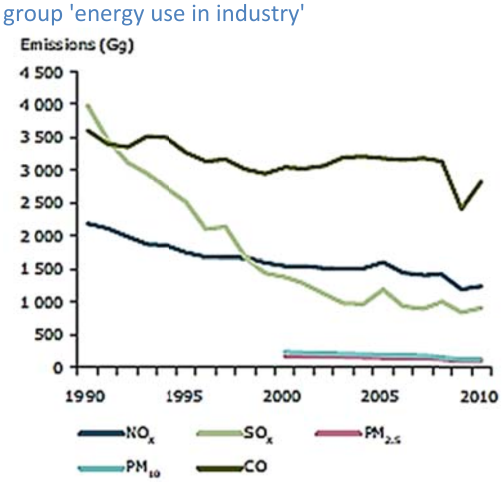


Figure 19. EU-27 emission trends in the sector group 'energy use in industry'



Source: EEA, 2012a

[1] Data is based on the EEA report "EEA (2013), Air quality in Europe report" with 27 EU member States

IV.1.2. Transport Sector

52. The 'road transport' sector group contributes significantly to the emissions of a number of pollutants, including NOX, NMVOC, CO, $PM_{2.5}$, PM_{10} and certain POPs (figure 20) : 15.8 per cent of $PM_{2.5}$ emissions and 14.4 per cent of PM10 emissions (figure 14).

53. The non-road transport sector includes railways, inland waterways, national navigation (shipping), civil aviation (Domestic, LTO), international aviation (LTO) and national fishing. NOX is an important pollutant in the 'non-road transport' sector group (Figure 21): contributing 2 per cent of $PM_{2.5}$ emissions and ofPM_{10} emissions (figure 14).

Figure 20 EU-27 emission trends in the sector group 'road transport'

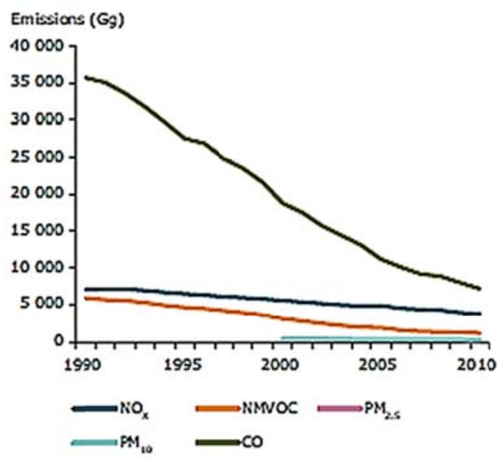
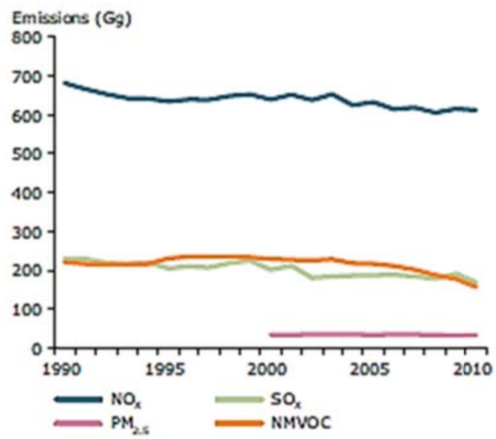


Figure 21. EU-27 emission trends in the sector group 'non-road transport'

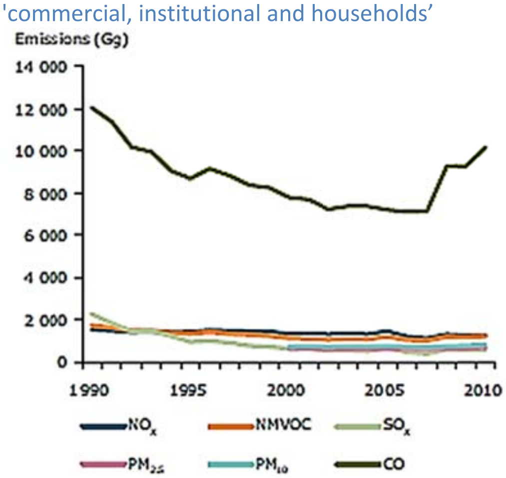


Source: EEA, 2012a

IV.1.3. Households and commercial / institutional buildings

54. Emissions of fuel combustion from the 'commercial, institutional and households' sector significantly contribute to the total emissions of many pollutants. This sector is an important source for PAHs, $PM_{2.5}$, PM_{10} and CO. For the main pollutants, the highest relative reduction between 1990 and 2010 for the sector grouping again occurred for SOX (– 74 per cent) (Figure 22). In contrast, PM emissions have changed little since 2000. The sector contributes 52 per cent of PM2.5 emissions and 41 per cent of PM_{10} emissions (figure 14).

Figure 22. EU-27 emission trends in the sector group 'commercial, institutional and households'



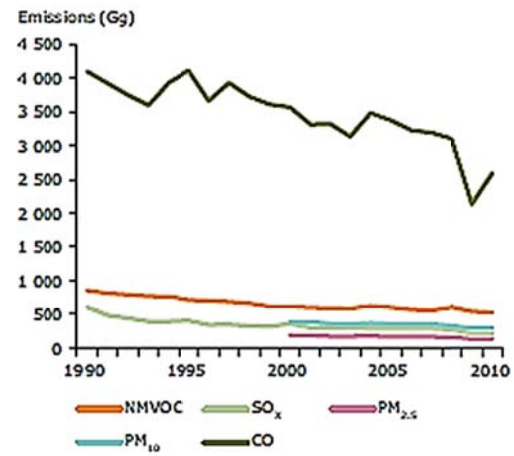
Source: EEA, 2012a

IV.1.4. Industry

55. The 'industrial processes' sector refers to emissions from industrial sources other than from fuel combustion. This sector is the most important sector for HCB and HCH emissions, as well as CO, PM, HMs and POPs (figure 23).

56. The sector contributes 11 per cent of $PM_{2.5}$ emissions and 15 per cent of PM_{10} emissions (figure 14).

Figure 23. EU-27 emission trends in the sector group 'industrial processes'



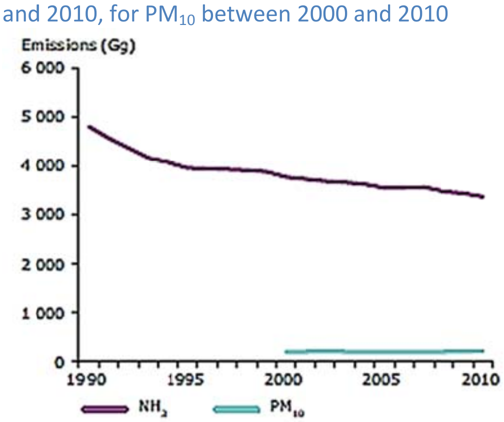
Source: EEA, 2012a

IV.1.5. Agricultural Sector

57. The agriculture sector is particularly important for its large part of NH3 emissions in the EU-27. Agriculture accounts for about 95 per cent of Europe's NH_3 emissions (figure 24).

58. The sector also contributes around 11 per cent of PM_{10} emissions. Emissions of PM_{10} increased between 2000 and 2010 by 8 per cent.

Figure 24. EU-27 emission trends in the sector group 'agriculture' for NH_3 in Gg between 1990 and 2010, for PM_{10} between 2000 and 2010



Source: EEA, 2012a

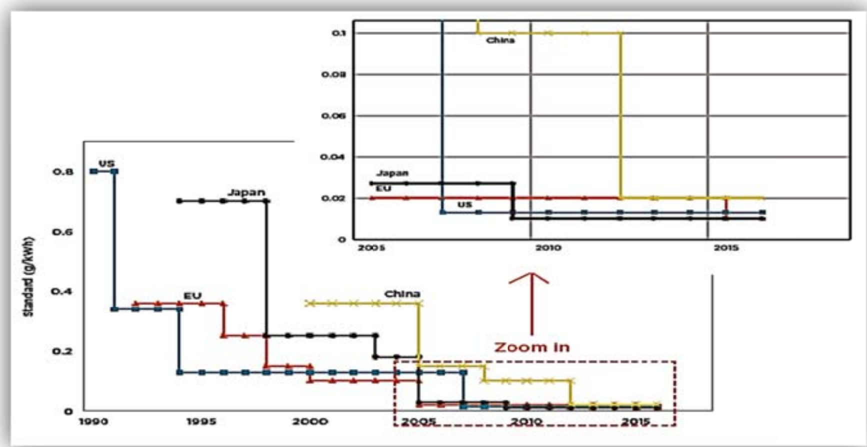
IV.2. The role of Inland Transport

IV.2.1. Road Transport

59. Diesel engines provide important advantages in fuel economy and durability for large heavy-duty trucks, buses and non-road equipment. On the other hand they also emit significant amounts of particulate matter (PM), oxides nitrogen (NOx) and and to some extent hydrocarbon (HC), carbon monoxide (CO), etc...

60. Significant developments in engine technology and after treatment devices have allowed a steady strengthening of emission standards over time, as shown in Figure 25, which illustrate PM limits for heavy-duty vehicles. The Euro VI (heavy-duty) limits for PM are 95 per cent more stringent than those of Euro I (ICCT 2011).

Figure 25. PM standards for heavy-duty vehicles in China, Japan and the United States of America, European Union

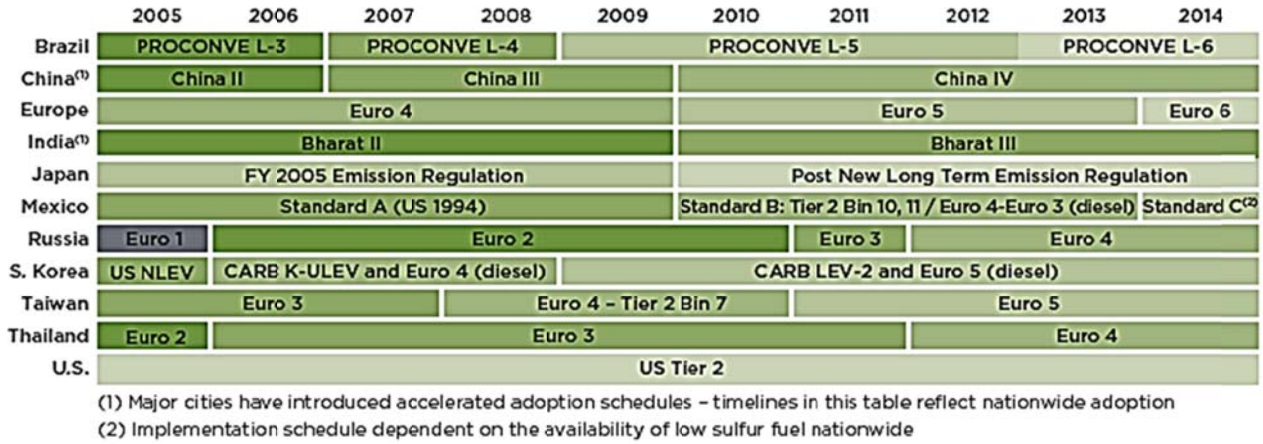


Source: ICCT 2011

61. In 2012, the European Environment Agency (EEA) noted [2] that eleven member States had not reduced their air pollutant emissions as set in the National Emission Ceilings Directive (2001/81/EC). The Directive contains national emission limits that are either equal to or slightly more ambitious than those in the Gothenburg Protocol. The EU ceiling for nitrogen oxides (NOx) in the Directive is also exceeded. This is partly because the transport sector has grown more than expected, and because the real-world emissions from vehicles turned out to be higher than the estimates set at the adoption of the standards for vehicle emission limits. In addition, the replacement of old vehicles with new and cleaner ones was slower than projected. However, worldwide, the move to cleaner vehicles has started. The EU and the United States of America are already using vehicles with Euro VI / EPA 10 technology (figure 26).

[2] www.eea.europa.eu/highlights/eleven-member-states-exceed-air

Figure 26.Vehicles are "cleaner" worldwide



Source: The International Council on Clean Transportation, 2012

62. In the late 1990s, China began setting limits for its major vehicle categories following the Euro standards pathway, with Beijing and Shanghai leading the way with accelerated adoption of standards. The European Union introduced Euro I in 1992. Figure 27 shows that over the past 10 years, the time lag between adoptions in China (not including major cities) and in the European Union has decreased from eight years to just over four years for heavy-duty vehicles.

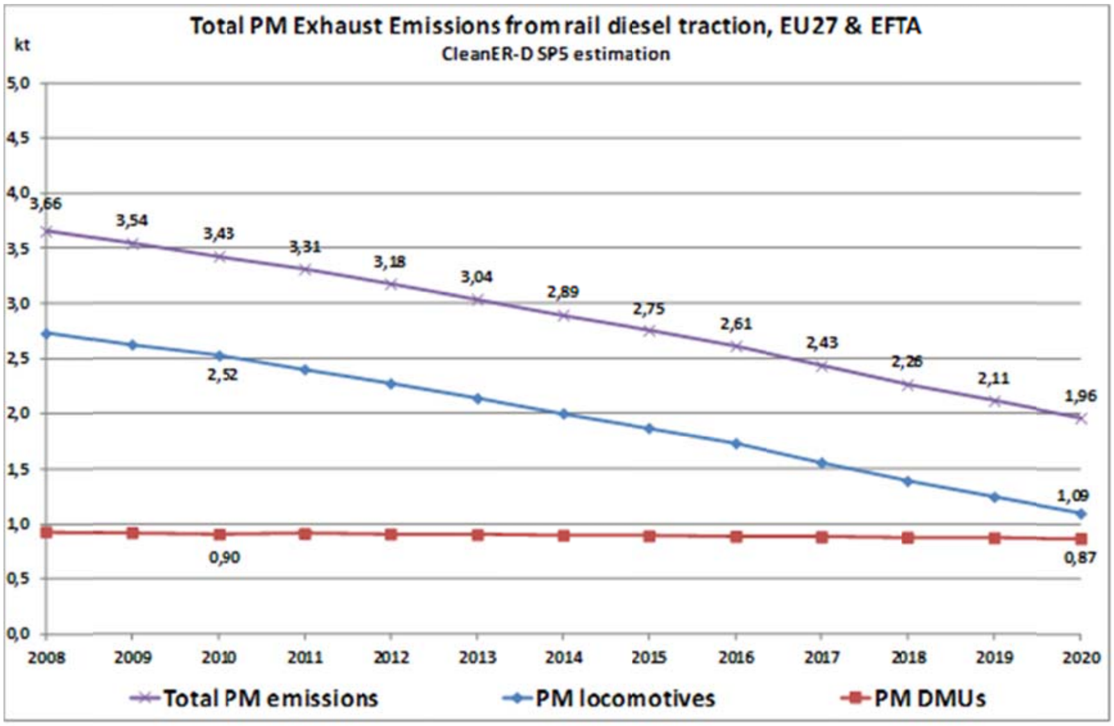
Figure 27. Heavy-duty vehicle standard adoption timeline in China and the European Union

Source: ICCT 2011

IV.2.2. Rail Transport

63. Rail exhaust emissions from rail diesel traction in Europe (EU-27 & EFTA) are very low. Rail diesel traction accounts for less than 4.5 per cent particulate matters (EEA 2008) out of the total transport emissions. The European railways committed to reduce their total exhaust emissions of PM by 40 per cent by 2030. From 1990 to 2008, PM emissions from rail diesel traction already decreased by approximately 35 per cent. Calculations by the CleanER-D consortium suggest a further substantial decrease of PM by approximately more than 25 per cent from 2008 to 2020 (International Union of Railways (UIC), 2013).

Figure 28. Total PM Exhaust Emissions from Rail Diesel Traction in EU27 & EFTA, CleanER-D estimation until 2020



Source: UIC, CleanER-D project

64. The significantly improved emission performances are the result of:

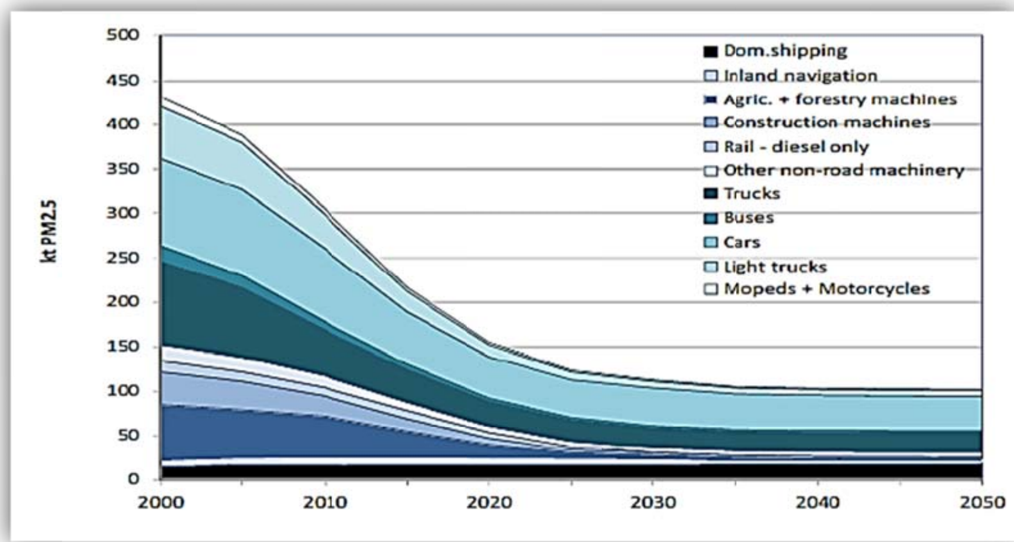
(a) The introduction of cleaner engine technologies and limit values (Non-Road Mobile Machinery (NRMM), stage IIIB) into the European vehicle fleet;
(b) A smaller diesel locomotive fleet (UIC statistics indicate that a high share of diesel locomotives are no longer in service in Europe) and lower mileages of old vehicles with old engines;
(c) More efficient operation of diesel locomotives and Diesel Multiple Units (DMU);
(d) Further electrification of railway lines (e.g. EU TEN-T corridors).

65. The key factor for further emission reduction is to accelerate the market uptake of IIIB compliant rail diesel engines into the vehicle fleet, as the fleet scenario highlights a substantial percentage of pre-NRMM engines in the future. In 2020, the share of stage IIIA and IIIB engines is estimated to be 30 per cent for locomotives and 41 per cent for DMUs. This share can only be increased if adequate market conditions are provided, i.e. legislation framework, incentives as well as technologies with Low Cost Carbon (LCC).

IV.2.3. Inland Waterways

66. The PANTEIA project, which was financed by the European Commission, reported that Inland Waterway Transport (IWT) in Europe is an efficient, safe and environmentally-friendly mode of transport. However, the previously undisputed competitive position of IWT in low emissions is increasingly contested. The gap between road transport and IWT is rapidly becoming smaller. A major concern has become the poor progress made on the emission of air pollutants with in particular, the emission of nitrogen oxides (NOx) and particulate matter (PM). In contrast to the road haulage sector, the emission standards for new engines are much less stringent and the average lifetime of engines in inland vessels is very long. Consequently, IWT already has higher air pollutant emission levels than road transport per tonne kilometre for certain vessel types (Panteia, 2013).

Figure 29. Development of $PM_{2.5}$ emissions from mobile sources in EU27

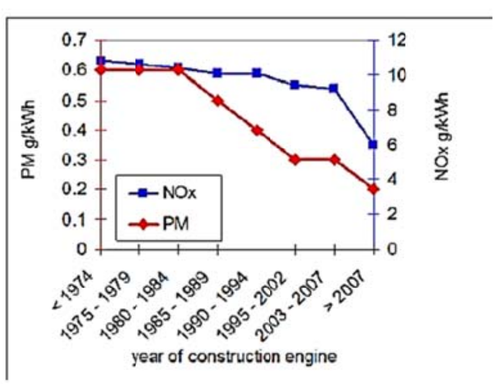


Source: EU and the Review of Air Quality the Thematic Strategy on Air Pollution, AECC Seminar 27 November 2012 on Emissions from Non-Road Mobile Machinery, presentation by Mr Thomas VERHEYE, DG ENVIRONMENT

67. Engines used in IWT have been subject to Stage IIIA emission requirements (Directive 97/68/EC on emissions from non-road mobile machinery engines) since 2007. Despite this measure, the atmospheric pollution from inland shipping remains significant with 17 per cent of the overall non-road emissions and high concentration levels in certain harbours and cities. It should also be noted that around 9 out of 10 inland waterway vessels in the EU are registered in Belgium, the Netherlands, Germany and France, where the environmental impacts are more intense, due to a higher concentration of the population along waterways.

Figure 30. Relation between engine year of construction and PM emission profile in Inland Waterways

Year of construction of main engine	*NOx [g/kWh]*	*PM [g/kWh]*
<1974	10.8	0.6
1975-1979	10.6	0.6
1980-1984	10.4	0.6
1985-1989	10.1	0.5
1990-1994	10.1	0.4
1995-2002	9.4	0.3
2003-2007*	9.2	0.3
>2007*	6	0.2



** CCNR I from 2002, NRMM Stage IIIA / CCNR II from 2007*

Source: PANTEIA project

Table 2. Number of IWT Vessels and average age of diesel engines

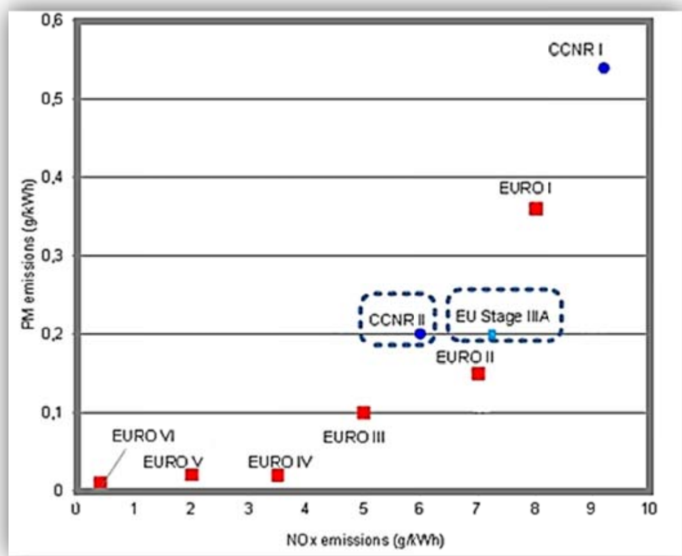
Country	Total number of inland navigation vessels	age of diesel engines	
		Num	Age (years)
Austria	42	No information	
Bulgaria	363	Up to 5 years	3
		Up to 10 years	10
		Up to 15 years	9
		Up to 20 years	7
		Up to 25 years	14
		Up to 30 years	10
		Up to 35 years	24
		Up to 40 years	12
		Up to 45 years	16
		Up to 50 years	6
		Over 50 years	26
Czech Republic	14,000		≤ 25
France	1,395		No information
Lithuania	401		Avg 23 (1957 to 2012)
Luxembourg	39		Avg 37
Russian Federation	30,964	20,964	Avg 30
		10,000	Avg 5
Serbia	939	270	Avg43
		669	No information
Slovakia	207	27	1945 - 1960
		58	1961 - 1970
		75	1971 - 1980
		32	1981 - 1990
		15	1991 – up to now
Ukraine	1,325		No information

Source: UNECE, Working Party on Inland Waterways (SC.3)

68. The reduction of emission levels of IWT is stagnating in comparison to other modes, because the innovation rate of engines for other modes is faster. The long lifetime of inland barge engines (30,000 to over 200,000 hours, depending on the engine type) results in a slow uptake of the new engines in the fleet. Breakthrough and large-scale innovations are introduced at a relatively slow pace. The transport vehicles used in inland waterways are self-propelled dry cargo and tank vessels, push boats, tugs and non-motorized barges. Inland vessels thereby, have a longer life span than maritime vessels. Bulk vessels on the Rhine are on average about 50 years old; the average age of liquid cargo ships is about 35 years. A pushed convoy on the Danube has an average age of 20 years, with the exception of Serbia and Croatia, where the average age of vessel units is more than 25 years. The pushed convoys of Romania and, particularly in the Ukraine, are by far the largest and youngest on the Danube. In addition, engines of inland vessels have a longer lifespan than other modes. According to the International Association the Rhine Ships Register (IVR), 83 per cent of the vessels are equipped with an engine built before 2003 and therefore, have no limits with respect to emission characteristics. The Central Commission for Navigation on the Rhine (CCNR) norms on emissions apply since

2003 (CCNR-I) for new engines, while in road freight transport emission restrictions have been in force since 1992 (Euro I) and Euro VI will be in force from 2014.

Figure 31. Current emission standards for road transport and Inland Water Transport : NOx/PM



Source: PLATINA, 2012

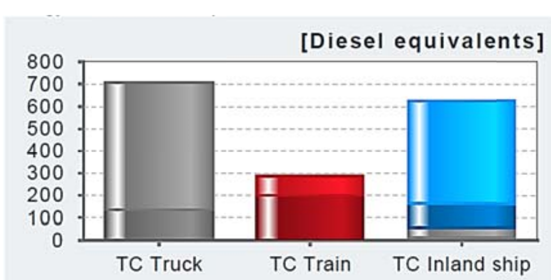
IV.2.4. A diesel engine emission scenario among the three inland transport modes

69. The following scenario provides information on the environmental impact of goods transported by truck, rail and inland waterways – all using diesel engines - from Vienna to Budapest. The calculations use the Ecological Transport Information Tool (EcoTransIT) that compares the energy consumption, greenhouse gas and exhaust emissions of freight transported by rail, road, ship and aircraft. [3]

Figure 32. Comparative analysis of road, rail and Inland Water Transport PM emissions

Train well to tank
Train tank to wheel
Truck well to tank
Truck tank to wheel
Inland ship well to tank
Inland ship tank to wheel

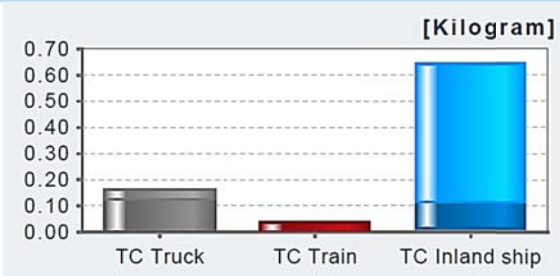
Primary energy consumption



	TC Truck	TC Train	TC Inland ship
Truck (WTT)	134	0	11
Truck (TTW)	571	0	46
Train (WTT)	0	200	0
Train (TTW)	0	87	0
Inland ship (WTT)	0	0	109
Inland ship (TTW)	0	0	461
Sum	706	287	626

[3] www.ecotransit.org

Particulate matter



	TC Truck	TC Train	TC Inland ship
Truck (WTT)	0,125	0	0,010
Truck (TTW)	0,037	0	0,004
Train (WTT)	0	0,036	0
Train (TTW)	0	0	0
Inland ship (WTT)	0	0	0,101
Inland ship (TTW)	0	0	0,528
Sum	0,162	0,036	0,643

70. Figure 32 illustrates the results of the scenario analysis. Road transport consumes more diesel fuel to travel from Vienna to Budapest. However, inland waterways are, by far, the biggest polluter of PM with 0.64 kilograms compared to 0.16 in road transport and 0.03 in rail transport.

V. International Agreements and regulations

V.1. Policy approach to emissions at national and regional level

V.1.1. Governments focus

71. Several governments have developed national legislation to provide an umbrella or framework of regulations to monitor and improve air quality.

V.1.1.1 Canada

72. In Canada, the *Canadian Environmental Protection Act, 1999* (Canada, 2013b) aimed at preventing pollution, protecting the environment and human health, and contributing to sustainable development. The Canadian Ambient Air Quality Standards (CAAQS) for fine particulate matter ($PM_{2.5}$) and ozone has recently been established under the authority of the *Canadian Environmental Protection Act, 1999* by Environment Canada and Health Canada. These health-based standards are more stringent and more comprehensive than the previous Canada-wide Standards for $PM_{2.5}$ and ozone; providing lower short-term limits for both $PM_{2.5}$ and ozone and introducing a long-term (annual) exposure limit for $PM_{2.5}$.

73. The standards (summarized in Table 3) are a key component of the Air Quality Management System being implemented by federal, provincial, and territorial governments, and will improve air quality across the country. The air quality standards for $PM_{2.5}$ and ozone were developed first because of their significant impact on human health. The work to support the development of additional standards for sulphur dioxide and nitrogen dioxide has been initiated by federal, provincial, and territorial governments and is expected to be completed during the coming years.

Table 3. Canadian Ambient Air Quality Standards (CAAQS)

Pollutant	Averaging Time	Canadian Ambient Air Quality Standards		Form or Metric
		Effective in 2015	Effective in 2020	
$PM_{2.5}$	Annual	10 µg/m³	8.8 µg/m³	The 3-year average of the annual average concentrations
$PM_{2.5}$	24-Hour	28 µg/m³	**27 µg/m³**	**The 3-year average of the annual 98th percentile of the daily 24-hour average concentrations**

V.1.1.2. Japan

74. In Japan, the Environmental Quality Standards for Air (EQSs), summarized in Table 4 and established by the Basic Environment Law are designated to protect human health from environmental pollution. The substances targeted by the EQSs include Suspended Particulate Matter (SPM), NOx and $PM_{2.5}$. In transport, vehicle emissions regulations were first established in Japan under the Air Pollution Control Law in 1973 for gasoline vehicles and in 1974 for diesel vehicles. A reinforcement of these regulations resulted in adding PM as the targeted substance for regulations in 1994.

75. In Japan, the Central Environment Council is in charge of issuing recommendations to review and reinforce measures for vehicle emission, including establishing the maximum permissible limits, in response to inquiry by Minister of the Environment. The Council, responsible for consideration of issues related to environmental protection, discusses measures for vehicle emissions taking into account technological development and changes in regulations taking place in other global areas.

Table 4. Japanese environmental air quality standards

Substance	Environmental conditions	Measuring method
Suspended particulate matter	The daily average for hourly values shall not exceed 0.10 mg/m^3, and hourly values shall not exceed 0.20 mg/m3. (notification on 8 May 1973)	Weight concentration measuring methods based on filtration collection, or light scattering method; or piezoelectric microbalance method; or b-ray attenuation method that yields values having a linear relation with the values of the above methods
Fine Particulate Matter ($PM_{2.5}$)	The annual standard for $PM_{2.5}$ is less than or equal to 15.0 mg/m^3. The 24 hour standard which means the annual 98th percentile values at designated monitoring sites in an area, is less than or equal to 35 mg/m^3. (notification on 9 September 2009)	Mass measurement with filter sample collection, which is designated as a reference method or alternative automated methods, designated as equivalent methods, which are proved to have measurement performance comparable to the corresponding reference method.

Source: JASIC, 2013

V.1.1.3. Republic of Korea

76. The first comprehensive national policy addressing air quality came into effect in the Republic of Korea in August 1990. All national ambient air quality regulations are based on the Clean Air Conservation Act of the Ministry of Environment (MOE), a part of the Environmental Conservation Act (1977) within the Environmental Pollution Prevention Act (1963) (TransportPolicy.net, 2013 and Lim, 2013).

77. Sulfur dioxide (SO_2) was first regulated in the Republic of Korea in 1978. CO, NO_2, TSP, O_3 and total hydrocarbons (HC) were added to the list of the regulated pollutants in 1983. Lead (Pb) was added in 1991. In 1993 and 1995 the regulatory limits for SO_2 and CO were made more stringent. PM_{10} regulations were established in 1995. In 2001, TSP became exempt from any environmental regulations, while stringencies were increased for SO_2, PM_{10} and lead. Finally, regulatory limits for NO_2 emissions were strengthened in 2007. In the same year, benzene emissions were regulated. This last measure was implemented in 2010. The $PM_{2.5}$ regulation will be implement in 2015 (TransportPolicy.net, 2013 and Lim, 2013).

78. Local legislation focusing on the protection of air quality of certain metropolitan regions was also enforced in the Republic of Korea. A key example is the Special Act on Metropolitan Air Quality Improvement

ratified by the Seoul Metropolitan Air Quality Improvement Promotion Program Organization in 2003 (TransportPolicy.net, 2013 and Lim, 2013).

Table 5. Korean air quality limits

Air pollutants	National ambient air quality standard	
PM_{10}	Yearly	50㎍/㎥ or less
	24-hour	100㎍/㎥ or less

Source: Air Korea, 2013

V.1.1.4. United States of America

79. In the United States of America, the Clean Air Act provides the main framework for undertaking measures aimed to protect air quality. It identifies two types of national ambient air quality standards. Primary standards provide public health protection, including protection of the health of sensitive populations such as asthmatics, children and the elderly. Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings (US EPA, 2011a).

80. Under the Clean Air Act, the EPA's Office of Air Quality Planning and Standards (OAQPS) is responsible for setting the national ambient air quality standards (NAAQS) for pollutants which are considered harmful to people and the environment (US EPA, 2011b).

81. The NAAQS set by the United States of America EPA for PM pollutants are summarized in Table 6.

Table 6. National Ambient Air Quality Standards in the United States of America

Pollutant		Primary/ Seconary	Averaging Time	Level	**Form**
Particulate matter (PM)	$PM_{2.5}$	primary	Annual	12 $\mu g/m^3$	annual mean, averaged over 3 years
		secondary	Annual	15 $\mu g/m^3$	annual mean, averaged over 3 years
		primary & secondary	24-hour	35 $\mu g/m^3$	98th percentile, averaged over 3 years
	PM_{10}	primary & secondary	24-hour	150 $\mu g/m^3$	Not to be exceeded more than once per year on average over 3 years

Source: US EPA, 2011a

V.1.1.5. European Union

82. The European Union (EU) set up a number of instruments aiming to avoid, prevent or reduce harmful effects on human health and the environment as a whole. The policies in place limit the emissions of air pollutants, and/or establish objectives for ambient air quality. Key legislative EU instruments include the following:

83. In 2008, the Air Quality Directive (EC, 2008) merged most of the existing legislation [4] on air quality (i.e. legislation targeting the ambient concentration of pollutants, with the exception of target values for the concentration of arsenic, cadmium, nickel and benzo(a)pyrene in ambient air) into a single directive, with no change to pre-existing air quality objectives. The Air Quality Directive also introduced new air quality objectives for PM2.5 (fine particles), the possibility to discount natural sources of pollution when assessing compliance against limit values, and the possibility for time extensions of three years (PM_{10}) or up to five years (NO_2, benzene) for complying with limit values, based on conditions and the assessment by the

[4] EU Directive on National Emission Ceilings, 2001; Sixth Environment Action Programme (6EAP) 2002; Thematic Strategy on Air Pollution (EC, 2005)

European Commission. The limit values for the protection of human health in the Air Quality Directive for PM_{10} and $PM_{2.5}$ are shown in Table 7.

Table 7. Air quality limit and target values for PM_{10} and $PM_{2.5}$ as given in the Air Quality Directive

Size fraction	Averaging period	Value	Comments
PM_{10} Limit value	One day	50 µg/m^3	Not to be exceeded on more than 35 days per year. To be met by 1 January 2005
PM_{10} Limit value	Calendar year	40 µg/m^3	To be met by 1 January 2005
$PM_{2.5}$ Target value	Calendar year	25 µg/m^3	To be met by 1 January 2010
$PM_{2.5}$ Limit value	Calendar year	25 µg/m^3	To be met by 1 January 2015
$PM_{2.5}$ Limit value (*)	Calendar year	20 µg/m^3	To be met by 1 January 2020
$PM_{2.5}$ Exposure concentration obligation (*)		20 µg/m^3	2015
$PM_{2.5}$ Exposure reduction target (**)	0-20 per cent reduction in exposure (depending on the average exposure indicator in the reference year) to be met by 2020		

Note: *(*)indicative limit value (stage 2) reviewed by the Commission in 2013 in the light of further information on health and environmental effects, technical feasibility and experience of the target value in member States.*
(**) based on a three-year average

Source: EEA, 2013

84. In the case of PM_{10}, by 2005 the majority of EU member States had not attained the limit values required by the Air Quality Directive (EEA, 2010). In particular, the exceeding of the daily mean PM_{10} limit is considered by the EEA as the biggest PM compliance problem in most urban environments (EEA, 2010). Critical issues also emerge when looking at the emission of air pollutants with respect to the limits included in the relevant European and international legislation.

85. In early May 2012, Parties of CLRTAP reached a consensus to revise the Gothenburg Protocol serviced by UNECE. The revision (not yet in force, 2014) sets new emission ceilings for NO_X, SO_2, NH_3 and NMVOCs for the year 2020 and beyond but it also introduces emission ceilings for fine particular matter ($PM_{2.5}$).

V.1.2. Transport focus measures

86. In transport, ambient air quality improvements have mainly been dealt with by measures to reduce road transport emissions that introduce more stringent emission standards for a wide range of vehicle categories.

87. In the United States of America, the first federal automobile emission standards were set in 1965, with the Motor Vehicle Air Pollution Control Act. In the 1970s, catalytic converters were developed in response to the automobile emission regulations related to the amendments of the Clean Air Act of 1963 that specified controls for automobiles. Federal regulation of heavy-duty engine emissions in the United States of America began in 1974. Emissions of air pollutants from motorcycles were first regulated in 1978. Non-road machinery emissions were first regulated in 1994. Amendments and revisions tightened earlier standards with the aim to ameliorate problems due to air pollution (Jacobson, 2013).

88. Similarly, in Canada, progressively more stringent emission standards have been in place for on-road and off-road vehicles since 1971.

89. In the EU, the first measures on air pollution by emissions from motor vehicles (Euro 0) for light vehicles (Directive 70/220/EEC) were introduced in the 1970s, the late 1980s (Directive 88/77/EEC) for heavy-duty engines, and the late 1990s for two wheelers and non-road mobile machinery. In the early 1990s, the

"Euro" regulations were first enforced for light vehicles and heavy-duty engines. Updates were introduced in the years following the first introduction of regulatory measures for all vehicles and engine categories (TransportPolicy.net, 2013).

90. In Japan, emission limits for light vehicles were first established in 1973. Diesel emission regulations for heavy commercial vehicles were first enforced in 1974 (JASIC, 2013). Emissions from non-road machinery were first applied in 2003. As in the case of other developed countries, the regulatory limits have been tightened over the years. The maximum permissible limit values of emissions from road transport are now prescribed by the Road Vehicles Act. The Ministry of Land, Infrastructure, Transport and Tourism enforces the Road Vehicles Act, which prescribes the limit value in consideration of Air Pollution Control Law.

91. Similar regulations on the emissions of air pollutants have also been enforced in transition economies, to varying degrees.

(a) The limits used in China's regulatory measures are similar to those of the European regulations, with a delay in their implementation and enforcement. In China, nationwide emission controls for light vehicles began in the late 1990s. China regulates heavy-duty emission since 2001, non-road machinery since 2002, and two wheelers since 2003 (TransportPolicy.net, 2013).
(b) India began to lower the pollution emission limits for road vehicles in 2001, also using European regulations as a reference. Non-road vehicle emissions in India were first addressed in 1999 (agricultural tractors) and 2007 (construction equipment). Two and three-wheeler emissions regulations were first enforced in 1991. In the case of two- and three-wheelers, Indian regulations are not aligned with the European ones (TransportPolicy.net, 2013).
(c) Since 1988, Brazil used to adopt emission regulations for light vehicles that were equivalent to those applied in the EU. The regulations have been revised and tightened in following years. Emissions from non-road mobile machinery in Brazil were first regulated in 2011, using the US regulation as a basis. These limits will be effective between 2015 and 2019. Brazilian standards are used as a base by neighbouring South American countries (TransportPolicy.net, 2013).
(d) Mexican emission requirements for light and heavy-duty vehicles became effective in 1993. Emission regulations were tightened in following years, using European and US limit values as a reference (TransportPolicy.net, 2013).

92. In recent years, the introduction of vehicle emission standards was accompanied by parallel legislations that established limits for fuel parameters. This is especially relevant for the sulphur content of fuels, since sulphur in fuels can impair the effectiveness of vehicle technologies for air pollution mitigation such as three-way catalytic converters, oxidation catalysts, NOX traps and particulate filters.

93. Looking specifically at cleaner fuels, the Partnership for Cleaner Fuels and Vehicles of the United Nations Environment Programme (UNEP-PCFV) was launched in 2002.. The UNEP-PCFV has focused its activities on the elimination of lead in gasoline, the phase down of sulphur in diesel and gasoline fuels, concurrent with the adoption of cleaner vehicle technologies.

V.1.3. Diesel engine exhausts focus measures

94. A selection of measures addressing diesel exhaust emissions recently taken by Canada, Japan, Switzerland, the United States of America and the European Union is included in Box 2. Table 8 contains a summary of the limit values of exhaust gas emissions from diesel heavy duty vehicles in Japan, including those that concern the near future.

95. These considerations highlight that, to date, road transport played a very prominent role in the limitation of health and environmental effects due to ICEs, including in those powered by diesel fuel oil. The

efficacy of the regulations limiting the emissions of air pollutants from diesel ICEs used in road transport application is confirmed by the recognition that new diesel engines used on road vehicles contain far fewer particles and chemicals compared to older diesel ICEs, notwithstanding qualitative changes that require further research.

Box 2. Selected regulatory actions on diesel-related emissions in Canada, Japan, Switzerland, the United States of America and the European Union

Canada regulates new on-road light passenger cars and trucks, as well as on-road heavy-duty trucks and off-road machinery. Most recently, Canada aligned its standards with the Tier 4 air pollutant standards of the United States of America for off-road diesel engines used in mining, agricultural and construction sectors. Canada has also implemented regulations to reduce the maximum allowable content of sulphur diesel fuel to 15 part per million (ppm) in order to ensure the effective operation of exhaust after-treatment systems used on diesel engines to meet increasingly stringent emission standards.

The high share of light vehicles with diesel motors lead the European Union to adopt technologies like the diesel particulate filter (DPF) on light vehicles (because of the entry into force of Euro 5 emission regulation). DPFs are also necessary to comply with heavy-duty emission regulation.

The current Japanese "Post New Long Term Regulation" for diesel vehicles came into force in October 2009, in accordance with the Future Policy for Motor Vehicle Emission Reduction (Eighth Report) published by the Central Environment Council in April 2005. The Tenth Report, published in July 2010, recommends the adoption of Worldwide harmonized Heavy Duty Certification (WHDC) and reinforcement of NO_X permissible limit for heavy-duty diesel vehicles effective from 2016 on (CEC, 2005 and 2010).

The solutions limiting particle emissions with filters are enforced for several diesel categories (passenger cars, public transport buses, construction machinery, ships, locomotives, heavy duty vehicles); the Swiss Federal Council modified the emission control provisions for construction site equipment, specifying more stringent maximum emission levels which, given current developments in technology, can only be met by employing efficient particle filter systems (Switzerland, 2009 and 2012).

The United States of America has a full series of regulatory actions that address emissions from diesel engines and diesel fuel. Since 2007, diesel engines introduced into the US market must meet the most stringent standards. Diesel sulphur levels were also dramatically reduced at the same time. Diesel engines used in non-road sources like agricultural or construction uses must meet strict Tier 4 emissions requirements from the beginning of 2014. Additionally, the United States of America has adopted regulations for emissions controls from locomotives and marine vessels in the last five years.

Table 8. Limit values for exhaust gas emissions from diesel heavy-duty vehicles in Japan

	1974	1977	1979	1983	1988	1994	1997	2003	2004	2005	2009	2016**
Test	6M					13M			JE05			WHTC
Unit	ppm					g/kWh						
CO	790	790	790	790	790	7.4	7.4	2.22	2.22	2.22	2.22	2.22
HC*	510	510	510	510	510	2.9	2.9	0.87	0.87	0.87	0.87	0.87
NOX	770	650	540	470	400	6	4.5	3.38	3.38	2	0.7	0.4
PM	-	-	-	-	-	0.7	0.25	0.18	0.18	0.03	0.01	0.01

Notes:

* From 2005 HC is changed to NMHC (Non Methane Hydro-Carbon).

** From 2016 Cold Start will be introduced and the weighting factor of Hot start is 86% while the weighting factor of Cold start is 14%.

96. Further opportunities to reduce emissions are available for stationary engines and for the in-use mobile fleet, since older in-use diesel engines and vehicles can remain in operation for over 20 years. Such measures include retrofitting or removing the older models to ensure that the newer engines and vehicles, which are compliant with recent air pollutant regulations, have a chance to improved health and environmental outcomes. A number of governments have already undertaken initiatives. In particular, the Government of Canada is the co-chair of a pan-Canadian working group on reducing emissions from the in-

use fleet. The working group has identified off- and on-road diesel emissions as a concern and is now looking at discrete initiatives to achieve reductions in this area over the next 3 years.

97. In some high exposure areas, there might be the need to set up policy measures aimed at replacing vehicles with older engine technologies by new vehicles complying with the new regulations or to retrofit the engines with appropriate emission control devices. Canada and the United States of America are looking at initiatives aimed at exploring the financial options that can support heavy-duty fleets in further reducing air pollutant emissions by making the purchase of emission reduction technologies more feasible and affordable.

98. In road transport, accelerating the worldwide introduction of cleaner and more efficient vehicle technology remains important. Equally important is the parallel introduction of low sulphur diesel fuels.

99. Regulatory measures aimed at limiting pollution from road transport applications were seldom mirrored by comparable measures in other transport modes and in other economic domains, such as in the residential and commercial/institutional sector. This concerns pollutants associated with modern diesel exhausts (namely PM and NO_X), since substantial amounts of diesel and residual fuel oil are combusted in applications widely employed in the energy, industry and residential/commercial sector, and since a significant fraction of these emissions (namely those originating in the residential and commercial sector, which is responsible for the largest fraction of PM emissions) is likely to insist on urban agglomerations, i.e. the areas subject to the largest exposure to air pollution.

VI. Inland Transport Committee activities

VI.1. Introduction

100. The UNECE World Forum for Harmonization of Vehicle Regulations (WP.29) has already done extensive work in the field of air pollution containment; major achievements include reducing the emissions of air pollutants from all motor vehicle engines. This work benefitted from the regulatory initiatives undertaken by the European Union. The work of the UNECE was particularly relevant to make significant progress on technical matters, including the test procedures that are required for the enforcement of emission control legislation.

VI.1.1. Common test procedures

101. In 1997, a harmonized worldwide test cycle for heavy-duty engines was initiated. This began with the creation, under the Working Party on Pollution and Energy of the informal working group on the Worldwide Heavy-Duty Certification procedure (WHDC). The result was the establishment, in 2006, of a harmonized UN Global Technical Regulation (UN GTR No. 4) (UNECE, 2013a). This text provides a common global basis for measuring the performance of existing and future heavy-duty engines in terms of emissions of gaseous pollutants and particulate matter. The UN GTR contains two representative test cycles (a transient test cycle (WHTC) with both cold and hot start requirements and a hot start steady state test cycle (WHSC)), closely reflecting worldwide on-road heavy-duty engine operation. This was a significant improvement over earlier approaches.

102. In 2001, the informal working group on worldwide-harmonized Heavy duty On-Board Diagnostics (WWH-OBD) was established to develop harmonized prescriptions for technical requirements for on-board diagnostic systems for road vehicles. This activity led to the adoption, in 2006, of the UN GTR No. 5 (UNECE, 2013b), a regulatory text that is directed at OBD requirements for heavy-duty engines/vehicles that is necessary to maintain emissions-related performance (i.e. emissions-OBD). The text facilitates a wider application of OBD in other vehicle systems in the future.

103. In 2001, WP.29 created the informal working group on Off-Cycle Emissions (OCE) to ensure that off-cycle emissions from heavy-duty engines and vehicles are appropriately regulated over a broad range of engine and ambient operating conditions, which are potentially encountered during in-use vehicle operation, but outside of the scenarios foreseen by WHDC. This work resulted in the adoption, in 2009, of the UN GTR No. 10 (UNECE, 2013c), a text that was designed to be applicable to engines certified or type approved under the test procedures of UN GTR No. 4 on the Worldwide harmonized Heavy Duty Certification (WHDC).

104. The work initiated with the UN GTR No. 4 and continued in UN GTRs Nos. 5 and 10 is currently with the informal working group on Heavy Duty Hybrids. The HDH informal working group was established in 2010 to develop new provisions for a hybrid specific engine cycle for the measurement of pollutants and CO_2 emission from heavy-duty hybrids. The focus of this group is to refine the test procedure, in order to keep providing a common technical basis for the Contracting Parties to regulate the emissions of pollutants and CO_2 from heavy-duty vehicles. The HDH informal working group expected to finalize its work by the end of 2013.

105. In 2003, for an informal working group was created on Non-Road Mobile Machinery (NRMM) aiming to develop new worldwide-harmonized provisions for these engines. Similarly to the case of heavy duty vehicles and UN GTR No. 4, the work of the NRMM informal group led to the establishment, in 2009, of the UN GTR No. 11 (UNECE; 2013e), on a common test procedure for measuring emissions of gaseous pollutants (NOX, CO, HC, particles) from NRMM compression-ignition engines.

106. The development of a regulatory text with a Worldwide harmonized Light vehicles Test Procedure (WLTP), covering the measurement procedure for the emissions of gaseous pollutants (NOX, CO, HC) and particles, as well as fuel consumption and the emissions of CO_2, started in 2007, with the creation of a working group under GRPE. In 2009, a proposal for the development of a UN GTR was adopted. By 2010, the work of the WLTP groups was organized in subgroups. Some of the activities originally planned, such as those concerning Mobile Air Conditioning systems, were considered as a parallel work stream to the main development of the regulatory text and the related test procedures. The WLTP drafted a preliminary text for the UN GTR on the light vehicle test (UNECE; 2013f) and is expected to deliver, by 2014, the final regulatory framework on harmonized test procedures to enable the certification of existing and future light vehicles technologies.

VI.2. Regulations and setting limit values for pollutant emissions

107. UN Regulations Nos. 49 (heavy duty vehicles) (UNECE, 2013g) and 83 (light vehicles) (UNECE, 2013h) specify limit values for emissions of particulate matter (both in terms of particulate mass and particle number), carbon monoxide, hydrocarbons (also specifying the part of non-methane hydrocarbons, in the last updates) and oxides of nitrogen. They build on the emission regulations enforced in the European Union (Euro pollutant emission standards, enacted through directives and, in recent years, regulations). Tables 9a and 9b summarize the evolution of emission limits of CO, HC, NO_X, and PM for light vehicles (both for the transport of passengers and goods), since the Euro 1 norms, also specifying the EU regulatory text and the corresponding version of the UN Regulation No. 83 that contain provisions on the different sets of limit values. Tables 10a and 10b provide a similar summary for heavy-duty vehicles regulated by UN Regulation No. 49.

108. Similar limit values, for carbon monoxide (CO), hydrocarbons, NO_X and PM, have been enforced for engines of non-road mobile machinery (UN Regulation No. 96) (UNECE, 2013i), i.e. engine fitted to self-propelled machinery including agricultural/forestry tractors, construction equipment and industrial equipment. The current limit values for the pollutant emissions of non-road mobile machinery depend on the net power of the engine. For PM, they range between 0.025 g/kWh (large engines) and 0.8 g/kWh (small engines). NO_X limits range between 2 g/kWh (lowered to 0.4 g/kWh for a large part of the power range, commencing from 2014) and 8 g/kWh. For CO, the limits are set between 3.5 g/kWh and 5.5 g/kWh. Hydrocarbon emission limits range between 0.19 g/kWh and 1.5 g/kWh.

Table 9a. Emission limits for light vehicles

		Pollutant emission limits													
		CO [g/km]		HC+NOX [g/km]								PM [g/km]		Particle number	
						NOX [g/km]		HC [g/km]							
								Total HC [g/km]		NMHC [g/km]					
Vehicle class	Pollutant emission regulation	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel
M1	Euro 1	2.72	2.72	0.97	0.97								0.14		
	Euro 2	2.2	1	0.5	0.7								0.08		
	Euro 3	2.3	0.64		0.56	0.15	0.5	0.2					0.05		
	Euro 4	1	0.5		0.3	0.08	0.25	0.1					0.025		
	Euro 5	1	0.5		0.23	0.05	0.18	0.1		0.058			0.0015		6.0×10^{11}
	Euro 6	1	0.5		0.17	0.05	0.08	0.1		0.058		0.0045	0.0015		6.0×10^{11}
N1 - I	Euro 1	2.72	2.72	0.97	0.97								0.14		
	Euro 2	2.2	1	0.5	0.7								0.08		
	Euro 3	2.3	0.64		0.56	0.15	0.5	0.2					0.05		
	Euro 4	1	0.5		0.3	0.08	0.25	0.1					0.025		
	Euro 5	1	0.5		0.23	0.05	0.18	0.1				0.0045	0.0015		6.0×10^{11}
	Euro 6	1	0.5		0.17	0.05	0.08	0.1				0.0045	0.0015		6.0×10^{11}
N1 - II	Euro 1	5.17	5.17	1.4	1.4								0.19		
	Euro 2	4	1.25	0.6	1								0.12		
	Euro 3	4.17	0.8		0.72	0.18	0.65	0.25					0.07		
	Euro 4	1.81	0.63		0.39	0.1	0.33	0.13					0.04		
	Euro 5	1.81	0.63		0.295	0.075	0.235	0.13		0.09		0.0045	0.0015		6.0×10^{11}
	Euro 6	1.81	0.63		0.195	0.75	0.105	0.13		0.09		0.0045	0.0015		6.0×10^{11}
N1 - III	Euro 1	6.9	6.9	1.7	1.7								0.25		
	Euro 2	5	1.5	0.7	1.2								0.17		
	Euro 3	5.22	0.95		0.86	0.21	0.78	0.29					0.1		
	Euro 4	2.27	0.74		0.46	0.11	0.39	0.16					0.06		
	Euro 5	2.27	0.74		0.35	0.082	0.28	0.16		0.108		0.0045	0.0015		6.0×10^{11}
	Euro 6	2.27	0.74		0.215	0.082	0.125	0.16		0.108		0.0045	0.0015		6.0×10^{11}

Table 9b. Regulatory texts for light vehicles

Vehicle class	Pollutant emission regulation	EU regulatory text	Entry into force	UN Regulation No.	Entry into force	Test
M1	Euro 1	Directive 91/441/EEC	Jul-92	83.01 (Rev.1)	Dec-92	EDC
	Euro 2	Directive 94/12/EC	Jan-96	83.03 (Rev. 1 amend. 2)	Dec-96	EDC
	Euro 3	Directive 98/69/EC; A-2000	Jan-00	83.05 (Rev. 2); A-2000	Mar-01	NEDC
	Euro 4	Directive 98/69/EC; B-2005	Jan-05	83.05 (Rev. 2); B-2005	Mar-01	NEDC
	Euro 5	Regulation 715/2007/EC	Sep-09	83.06 (Rev. 4)	Dec-10	NEDC
	Euro 6	Regulation 715/2007/EC	Sep-14	83.07 (Rev. 5)		NEDC
N1	Euro 1	Directive 93/59/EEC	Oct-94	83.02 (Rev. 1 amend. 1)	Mar-01	EDC
	Euro 2	Directive 96/69/EC	Jan-98	83.04 (Rev. 1 amend. 4)	Nov-99	EDC
	Euro 3	Directive 98/69/EC; A-2000	Jan-00	83.05 (Rev. 2); A-2000	Mar-01	NEDC
	Euro 4	Directive 98/69/EC; B-2005	Jan-05	83.05 (Rev. 2); B-2005	Mar-01	NEDC
	Euro 5	Regulation 715/2007/EC	Sep-09	83.06 (Rev. 4)	Dec-10	NEDC
	Euro 6	Regulation 715/2007/EC	Sep-14	83.07 (Rev. 5)		NEDC

109. In 2010, WP.29/GRPE established an informal working group on Retrofit Emission Control devices (REC) to evaluate harmonized requirements for the treatment of diesel exhaust emissions with the aim to develop a new UN Regulation for REC to be installed on heavy-duty vehicles, non-road mobile machinery and tractors already in use. The activities of the group follow a number of initiatives aiming to contain pollutant emissions, including in particular the adoption of low emission zones. The technical work of the REC group will address the need for defined performance requirements for retrofit emission control devices, delivering uniform provisions applicable to vehicles engaged in cross-border transport and fostering the market entry of these new technologies. The text of the new UN Regulation on REC was finalized and the performance-oriented requirements were established in November 2013 (UNECE, 2013j).

Table 10. Emission limits for heavy duty vehicles

	Pollutant emission limits													
	CO [g/kWh]		HC+NOX [g/kWh]						CH4 [g/kWh]		PM [g/kWh]		Smoke [1/m]	Particle number
			NOX [g/kWh]		HC [g/kWh]									
					Total HC [g/kWh]		NMHC [g/kWh]							
Pollutant emission regulation	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Diesel	Diesel
Euro 0		11.2		14.4		2.4								
Euro I		4.5		8		1.1						0.36 / 0.612		
Euro II		4		7		1.1						0.15		
Euro III		2.1		5		0.66						0.1 / 0.13	0.8	
Euro III		5.45		5				0.78		1.6		0.16 / 0.21		
Euro IV		1.5		3.5		0.46						0.02	0.5	
Euro IV		4		3.5				0.55		1.1		0.03		
Euro V		1.5		2		0.46						0.02	0.5	
Euro V		4		2				0.55		1.1		0.03		
EEV		1.5		2		0.25						0.02	0.15	
EEV		3		2				0.4		0.65		0.03		
Euro VI		1.5		0.4		0.13						0.01		8.0x10[illegible]
Euro VI	4	4	0.46	0.46	0.16		0.16		0.5		0.01	0.01		6.0x10[illegible]

VI.3. Other relevant activities

110. A number of other activities were started in order to support the work undertaken by the groups working on UN GTRs and UN regulations.

(a) In 2001, WP.29 established an informal working group on the Particle Measurement Programme (PMP). The focus of this group is the development of standardized methodologies to measure emissions of solid tailpipe particles from vehicles and engines. This has been the basis for the development of regulatory instruments targeting the emission reduction of pollutants, notably particulate matter (PM) and particle number (PN). The PMP informal working group focused its activities on the development of an alternative metric with increased sensitivity compared to the existing PM mass measurement system for heavy-duty and light-duty engines/vehicles (M and N category vehicles). This concluded with the development and adoption into UN Regulations Nos. 83 (for light-duty emissions) and 49 (for heavy-duty emissions) of a PN counting method for ultrafine solid particles. The PMP activities also led to enhancements of the PM mass measurement procedure in UN Regulation No. 83. Initially, this updated PN protocol was applied in diesel engines/vehicles only in the 06 series of amendments to UN Regulation No. 83 and the 06 series of amendments to UN Regulation No. 49. A subsequent extension covers spark-ignition direct injection engines (07 series of amendments to UN Regulation No. 83). As a result of the introduction of emission requirements based on the particle number measured according to the methodology developed by the PMP group, diesel road vehicles complying with the latest series of amendments of UN Regulations Nos. 83 and 49 need to be fitted with the best available technology, i.e. the wall-flow diesel particulate filters which are capable of reducing particle emissions with an efficiency of at least 95 per cent.

PMP remains an active informal working group with activities on calibration issues and is considering the possible extension (e.g. to non-road mobile machinery) and improvement (namely for PN) of the tailpipe measurement method.

(b) The informal working group on Electric Vehicles and the Environment (EVE), established under GRPE by WP.29 in 2012, was created to examine a range of issues related to electric vehicles, including sharing information on developing technologies, current regulatory activities, policy approaches, research priorities, and the deployment of EVs. The EVE informal working group is currently developing a global EV Regulatory Reference Guide on requirements (voluntary, regulatory, etc.) for hybrid, plug-in and electric vehicles for Contracting Parties and WP.29 informal working groups.

VI.4. Emission regulations and fuel quality parameters

111. Since 2012, the Special Resolution No. 1 (UNECE, 2013k) and the Consolidated Resolution on the Construction of Vehicles (R.E.3) (UNECE, 2013l), developed in the framework of the 1998 Agreement on UN Global Technical Regulations and the 1958 Agreement concerning the Adoption of Uniform Technical Prescriptions, administered by WP.29, contain recommendations developed to guide Governments on appropriate market fuel quality that is protective of vehicle emission control technologies.

VII. Conclusions and recommendations

VII.1. Conclusions

112. Diesel fuels are used in many areas of the economy, i.e. farming, mining, forestry and timber industry, construction, as well as the transport sector. Within transport, freight delivery in most inland modes today cannot be imagined without the use of diesel. Maritime transport is also a heavy user of diesel. In addition, bus transit systems both in urban and inter-urban areas are mostly run by diesel driven vehicles. Consequently, as the economy grows,

- ✓ more farm and timber machinery is required to produce ever larger amounts of food and wood, and to increase the productivity and competitiveness of agriculture and forestry economies;
- ✓ more construction equipment is required to make buildings and to build infrastructure;
- ✓ more heating boilers will be used to heat houses and buildings;
- ✓ more trucks, locomotives, and ships are required to move the increasing volume of goods;
- ✓ more vehicles for public transport/mass transit are to be put in operation to satisfy the increasing need for mobility in a sustainable manner.

113. While diesel engines have an obvious productive role in national economies, they have negative externalities, i.e. harmful effect on human health. Emissions, especially PM from diesel engines in trucks, boats, locomotives, buses, agricultural and forestry tractors, construction and household equipment can cause serious health problems for adults and have extremely harmful effects on children and the elderly.

114. In 2012, the World Health Organization’s International Agency on Research on Cancer (IARC) concluded that diesel engine exhaust is carcinogenic to humans. Research experiments carried out in closed areas, i.e. indoor sent warning signals and urged people worldwide to reduce their exposure to diesel fumes as much as possible. In 2013, IARC evaluated separately the particulate matter, a major component of outdoor air pollution, and classified it as carcinogenic to humans.

115. Exposure to diesel exhaust gases is complex and from many sources: stationary sources (e.g. power and motion generators used in the energy industry), mobile sources (e-g- different modes of transport, road vehicles, diesel trains and ships). Still diesel driven road vehicles came to the centre of attention to the extent that they have become “demonised”.

116. Trends and statistical analysis made by the United States of America, other countries and the European Commission show that road transport and other modes of transport are not the biggest emitters of particulate matter among the economic sectors. In fact, road transport counts for only three per cent of diesel emissions in the United States of America and 15 per cent in the European Union.

117. Based on EEA data analysis, the commercial, institutional and household sector emerged as the most important source of $PM_{2.5}$ and $PM_{10,}$ with 52 per cent and 41 per cent, respectively. Domestic fuel use in the residential category '1 A 4 b i — Residential: Stationary plants' is the most important key category for $PM_{2.5}$ emissions, making up 45 per cent of total $PM_{2.5}$ emissions.

118. Despite its relative low share in particulate matter emissions, the transport sector has taken consistent measures to significantly limit its negative effects. Between 1990 and 2010, emissions from the road transport and non-road transport sectors have been significantly reduced, contributing to a 43 per cent reduction in $P.M_{2.5}$ and 29 per cent reduction in $P.M_{10}$ emissions. The reduction in overall emissions of particulate matter between 1990 and 2010 was mainly due to the introduction or improvement of abatement measures across the transport sector, including the strict restrictions. As vehicle technologies are constantly improved and stationary fuel combustion emissions are controlled through abatement or use of low-sulphur fuels, such as natural gas, emissions of primary PM_{10} are expected to further decrease in the future. The introduction of particle filters on new vehicles; the introduction of three way catalytic converters for petrol-fuelled cars; and the introduction of exhaust particle traps for diesel HGVs to meet emission standards EURO V are some of the factors that have contributed to the reduction of both primary PM_{10} and secondary particulate matter emissions.

119. The share of other inland transport modes, such as railways and inland waterways (non-road transport), is less than 1.5 per cent compared to the other economic sectors. Exhaust emissions from rail diesel traction in Europe (EU27 & EFTA) are generally very low. European railways are committed to reducing their total exhaust emissions of nitrogen oxides (NOx) and PM by 40 per cent by 2030. Introduction of cleaner engine technologies, smaller diesel locomotive fleet and lower mileages of old vehicles with old engines, more efficient operation of diesel locomotives and wider application of diesel multiple units (DMU), as well as continued electrification of railway lines (e.g. EU TEN-T corridors), are some of the main factors that will contribute to the further decrease of railway PM emissions.

120. Contrary to road and rail transport, inland waterways have not significantly on reduced emissions. A major concern is the poor progress made on the emission of air pollutants particularly the emissions of NOx and PM. In contrast to the road haulage sector, the emission standards for new engines in IWT are much less stringent and the average lifetime of engines in inland vessels is very long. The share of IWT in the PM emissions compared to other sectors is very low (1 per cent), however further actions should be taken to speed up the introduction of new engines and stricter emissions limitations and targets.

121. From the data and facts mentioned above, we conclude with a high degree of reliability that it is misleading to claim that people’s exposure to diesel engines of road motor vehicles is the cause of increased risk of lung cancer. ***Eighty three per cent of particulate matters emissions in European Union countries (EEA, 2012a) and 97 per cent in the United States of America (EPA 2013) and Canada, is generated by other economic sectors, mainly the commercial, institutional and household sector. Therefore, the claim that emissions from diesel engine exhausts from road transport are the main cause of lung cancer in humans needs to be seriously challenged. It does not mean however, that measures to improve the environmental performance of the transport sector can stop. On the contrary, they must continue and in an aggressively well targeted way.***

122. It also need to be mentioned that in other sectors, such as the household and commercial/institutional sector, legislative initiatives have been undertaken with less frequency and with lower ambitions than in road transport. One of the few examples of legislative action in the residential and commercial area is from Germany, where new, small firing installations, such as stoves, are subject to regulatory requirements, and where the same legislative framework requires the modernization of existing installations of the same kind (BMU, 2010).

123. Thus **to improve the quality of air around us more attention must be given to the primary PM emitters.**

124. Despite the measures taken, it is expected that within many of the urban areas across the EU, PM_{10} concentrations will still be well above the EU air quality limit value. Further substantial reductions in emissions will therefore be needed if the limit value set in the Air Quality Directive of the European Union is to be reached. The 2012 revision of the Gothenburg Protocol to the UNECE LRTAP Convention set emission reduction targets for $PM_{2.5}$ based on 2005 emission totals, to be met by countries by or before 2020. By 2010, average annual reductions of $PM_{2.5}$ emissions in thirteen EEA-32 countries were greater than that required to achieve their targets by 2020, and five countries had already achieved the reductions specified in the protocol. Therefore, more strategically targeted actions should be taken.

125. In summary, the following conclusions are drawn:

(a) Diesel engines emissions in the air are carcinogenic to humans based on scientific research evidence; the emission of particulate matters is the most dangerous for humans health; the danger is the highest in closed areas, such as in-door and in areas with inadequate ventilation;
(b) Diesel engines are currently at the heart of economic growth and of all economic activity and, therefore, it is not feasible to replace and eliminate them at this stage;
(c) Transport is only one of the sectors using diesel engines. Industrial, agricultural, timber, commercial, institutional and household sector are some of the other economic sectors that use diesel engines;
(d) The commercial, institutional and household sectors are the most important source of $PM_{2.5}$ and PM_{10} ;
(e) The transport sector is by far not the most significant source of PM emissions, nonetheless up till now it has been the most rigorous in introducing measures to address this issue;
(f) The transport sector is the most regulated sector where the most intensive initiatives and actions have been taken. Decisions and performance oriented emission regulations have been adopted that set limits and targets resulting in the dramatic decrease in PM and other emissions;
(g) Other economic sectors are lagging behind in their initiatives, strategies and actions to address their share of PM and pollutants emissions.

VII.2 Recommendations

126. Although transport is not the main source of air pollution, the measures to improve the environmental performance of the transport sector should be continued and further fine-tuning should be warranted.

127. Three tracks of actions are recommended:

(a). improved modal split, particularly from individual to public transport in personal mobility and from roads to rail in long term freight transport while improving environmental performance at micro level
(b). development of new technologies (vehicle, fuel, traffic management) and global norms and standards and acceleration of the fleet as well as engine renewal;
(c). Review and evaluation of health risks for people working in transport related occupational groups such as toll booths operators and professional truck drivers;

128. <u>A. Improved modal split, particularly from individual to public transport in personal mobility and from roads to rail in long term freight transport while improving environmental performance at micro level;</u>

129. More than half of the world's air pollution comes from urban areas. Cities do have their own microclimates. A number of cities around the world have shown visionary leadership in setting targets and

devising and implementing plans to reduce air pollution. Cities in developed countries as well as in developing countries offer a wealth of experience regarding good practices and innovative approaches in this area that other cities can learn from and follow.

130. Improvement of public transport, promotion of walking and biking are desired measures to reduce the use of personal cars. Walking and biking requires appropriate infrastructure to be put in place, which can be at relatively low cost, but the benefits in terms of impact on health and quality of life are huge. Public transport, on the other hand, offers a massive solution both for individual mobility, its environmental performance and also in reducing congestion. It is also attractive from an economic sustainable perspective since public transport provides more capacity at less marginal cost Well designed and well-linked modal structure for urban, sub-urban, regional and national public transport using buses, light rail transit, metro, suburban rail can be a feasible mitigation option for the transport sector.

131. Individual travel behavior and our decisions on when and how much to drive are subject to the built environment and the transportation options available to us. Land use and transportation funding policies heavily influence our travel behavior and travel choices. Studies show that mixed-use neighborhood with adequate pedestrian and bicycle facilities linked to public transport services is more likely to be a city with fewer car trips and a greater amount of trips by walking, cycling, and transit.

132. Long distance freight movement definitely favours railways provided the railways services are competitive for which both investments and reforms may be warranted.

133. B. Development of new technologies (vehicle, fuel, traffic management) and global norms and standards and acceleration of the fleet as well as engine renewal;

134. Development of new technologies is often seen as the ultimate solution. They are important indeed, but they are not the only solution. New technologies under development have different goals, such as:

(a). development of energy efficient engines and vehicles, such as electric or hybrid propulsions systems

(b). more fuel efficient and less polluting existing engines;

(c). innovative technologies to control and filter the exhausts emissions;

(d). strengthened requirements for market fuel quality (unleaded fuels, low sulphur content, etc.).

135. The after-treatment technologies could lead to further reduction of emissions. However, there are implications and trade-offs that can prove to be complex and potentially critical for their implementation, particularly those related to system integration. In railways, for instance, simulation work in SP6 (Emerging Technologies) for engines up to 560 kW has shown that such combined designed propulsion unit (BSNOx 1 g/kWh) is about 18 per cent heavier than a conventional Stage IIIB propulsion unit. Similarly, technologies currently in the research domain for automotive Euro VI heavy-duty application could eventually achieve a status that would allow them to be the state-of-the-art application for railways in the future. However, it is estimated that this will not be feasible to achieve before at the very least 2020.

136. Stricter timeframe for the replacement of old technology by new one and adoption of measures that promote such replacement could be recommendation way to follow. For instance, the replacement of old engines in inland waterway vessels with new ones could be a challenge. The new technologies have positive impacts on air quality and it could only be realized if vessel fleets are renewed. Therefore, measures should be introduced to speed-up the introduction of cleaner and more efficient technologies, in both developed countries and emerging economies. Policies requiring the introduction of advanced vehicle technologies should also be coupled with measures introducing the necessary fuel quality improvements.

137. In some high exposure areas, there might be the need to set up policy measures aimed at replacing vehicles equipped with older engine technologies with new vehicles which comply with the new regulations or at retrofitting the existing engines with appropriate emission control devices and after-treatment systems.

138. Retrofitting of existing and new engines in inland waterway transport should be optimised further in order to reduce compliance costs and associated administrative and enforcement burdens. Governments should follow the requirements of the new UN Regulation on the recyclability of new vehicles (established by

WP.29 in November 2013) and also establish a national recycling system for vehicles and their parts after their final use, especially also the energy storage systems such as batteries (due to the usual content of heavy metals and their negative impact on the environment).

140. *C. Review and evaluation of health risks for people working in transport related occupational groups such as toll booths operators and professional truck drivers*;

141. Most people are exposed to diesel exhaust mainly by breathing in the soot and gases, which then enter the lungs. The amount of diesel exhaust people are exposed to varies greatly. Measuring the level of these exposures is not easy because diesel exhaust is chemically complex and many parts of it are found in many other sources. Truck drivers, tollbooth workers, miners, forklift drivers and other heavy machinery operators, railroad and dock workers, and garage workers and mechanics are among occupational groups with some of the highest exposures to diesel exhaust at work. Some farm workers may also spend a lot of time around diesel exhaust machines. Exposure to diesel exhaust may be higher when in a vehicle, especially when traveling on roads with heavier truck or bus traffic. Commuting to and from work is a potential source of diesel exhaust exposure for many people. One particular area of concern is exposure of children to diesel exhaust and other pollutants while riding in school buses, as these buses themselves typically run on diesel fuel.

142. The particulate matters emitted in diesel engine exhaust are not the only potential carcinogenic threat to human health. It is not easy to establish the possible health effects of diesel exhaust on people since it might be difficult to precisely define and measure the level of exposure due exclusively to diesel exhaust. The main difficulty is that it might be necessary to factor in the other cancer risk factors that people who are exposed to diesel exhaust might have, such as smoking, nutrition, lifestyles, physical inactivity, etc. Therefore, more sophisticated screening methods would be needed for more evidence-based results.

143. At the same time, it is a serious concern that particulate matters emitted in diesel engine exhaust are carcinogenic to humans. Therefore, irrespective of the level of potential harm to health, and irrespective of the good progress in reducing these harmful effects, proactive measures have to be in place to further minimise the vulnerability of the transport workers who are most exposed to such pollutants in the transport sector. Among them truck or locomotive drivers or people in toll booths or collecting tolls on the curbs even without being in a booth could be considered at the highest potential risk. A review of their situation and of best practices in their protection would be a useful exercise to raise awareness and to facilitate exchange of information, particularly if such a review could result in a status report.

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