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The Environmental Impacts of Increased International Road and Rail Freight Transport

Past trends and future perspectives

Huib van Essen, CE Delft, Delft, the Netherlands

FOREWORD

This paper was prepared by Huib van Essen, CE Delft, Delft, the Netherlands, as a contribution to the OECD/ITF *Global Forum on Transport and Environment in a Globalising World* that will be held 10-12 November 2008 in Guadalajara, Mexico. It discusses the environmental impacts of increased international road and rail freight transport – past trends and future perspectives.

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THE ENVIRONMENTAL IMPACTS OF INCREASED INTERNATIONAL ROAD AND RAIL FREIGHT TRANSPORT – PAST TRENDS AND FUTURE PERSPECTIVES

1. Introduction

1.1 Background

1. Transport has several impacts on the environment. Emissions contribute to air pollution and climate change, noise causes nuisance and health risks and infrastructure has serious impacts on landscape and ecosystems. In addition to these impacts on the environment, transport has also other severe impacts on society. Every year hundred-thousands of people are killed and injured in accidents and in various densely populated areas, high congestion levels result in time losses.

2. The impacts of the transport sector as a whole are the sum of the impacts of the various transport modes, both freight and passenger transport. The freight transport market consists of various submarkets that interact, but do not really compete with each other. At a regional level, distribution of goods takes place, mainly by small and medium sized lorries. At the other side of the spectrum, there are the long-distance global flows between the various continents, in which maritime shipping is the main mode of transport. Somewhere in between is the international haulage market, which can be characterized as the transport chain between shipping of goods between the continents and the regional distribution networks. On this intra-continental international freight transport market, road and rail transport are the most important modes, but also inland shipping and short-sea shipping play an important role in some parts of the world.

3. This paper for the OECD Forum on Sustainable Development assesses the environmental impacts of increased international road and rail freight transport. It gives an overview of major trends and of the main drivers behind them. In addition to that, this paper briefly discusses the main options for tackling the increasing environmental impacts of this important part of the transport sector. The paper discusses various technical and non-technical measures; policy options are not discussed because they are treated in a separate paper. The focus in this paper will be on emissions and noise.

1.2 Environmental impacts from transport

4. Before assessing the trends and perspectives of environmental impacts of international freight transport, it is important to know what these impacts are. We can distinguish the following:

- Impacts from greenhouse gas emissions on climate change.
- Impacts from pollutant emissions on various problems related to air quality.
- Health and nuisance impacts from noise.
- Impacts on landscape from infrastructure.
- Impacts on biodiversity and ecosystems because of infrastructure fragmenting natural habitats.
- Soil wastes in areas close to transport infrastructure.

5. In this paper we focus on the first three impacts of transport. The reasons for this demarcation are that these impacts are the most severe ones and also have the highest data availability. These three most important impacts are briefly further explained in the next subsections.

6. From a broader perspective, also traffic accidents have a very large social and economic impact (see text box). However, these are not discussed further here because this paper is limited to environmental impacts.

Box 1. Trends in transport accidents

The WHO estimated the number of road fatalities at 1.2 million in 1999. Further research showed that this is probably an overestimation (Jacobs & Aeron-Thomas, 2000). They estimated the number of fatalities worldwide at 750,000 to 880,000 in 1999 and the number of people injured by road accidents at 23 to 34 million per year.

It is very difficult to make forecasts for these global figures. In Europe the number of fatalities is rapidly decreasing (from about 71 thousand in 1990 to 41 thousand in 2005). However, in other parts of the world, the transport growth may well exceed the effect of vehicle and traffic safety improvements.

The number of victims from rail transport accidents is much smaller than for road. In the European Union, 105 people were killed in rail accidents in 2004, which was about 0.2% from the number of fatalities in road accidents.

1.2.1 Climate change

7. Climate change is one of the great challenges of current society. In the last decades there has come more and more evidence that the emission of greenhouse gas contributes to the effect of global warming. Particularly the emission of carbon-dioxide (CO_2) from the burning of fossil fuels is a major contributor. For the transport sector, the greenhouse gas emissions are dominated by the CO_2 emissions from burning fossil fuels. These are strongly related to transport energy use.

8. The Intergovernmental Panel on Climate Change (IPCC) has examined a range of future climate change scenarios and found that the globally averaged surface air temperature is projected by models to warm 1.1 to 6.4°C by 2100 relative to 2000, and globally averaged sea level is projected by models to rise 18 to 59 cm by 2100. The warming is expected to vary by region, and to be accompanied by changes in precipitation, changes in the variability of climate, and changes in the frequency and intensity of some extreme climate phenomena (drought, flooding) as well as impacts on ecosystems, and diseases. (IPCC, 2007a)

1.2.2 Air pollution

9. Transport-related air pollution causes damages to humans, biosphere, soil, water, buildings and materials. The most important pollutants are the following:

- Particulate matter (PM_{10}, $PM_{2.5}$).
- Nitrogen oxides (NO_X).
- Sulphur oxide (SO_2).
- Ozone (O_3).
- Volatile organic compounds (VOC).

10. The emissions of pollutants give rise to health costs, building/material damages, crop losses and costs for further damages for the ecosystem (biosphere, soil, water). Each impact is related to one or more type of pollutants (Maibach, *et al.* 2008):

- *Health impacts*: Impacts on human health due to the aspiration of fine particles ($PM_{2.5}$/PM_{10}, other air pollutants). Exhaust emission particles are hereby considered as the most important pollutant. In addition, Ozone (O_3) has impacts on human health. The main health impacts are increased health problems for people who suffer aspiration diseases and a higher risk for anyone to get such a disease.

- *Building and material damages*: Impacts on buildings and materials from air pollutants. Mainly two effects are of importance: soiling of building surfaces/facades primarily through particles and dust. The second, more important impact on facades and materials is the degradation through corrosive processes, due to acid air pollutants like NO_X and SO_2.

- *Crop losses in agriculture and impacts on the biosphere*: crops as well as forests and other ecosystems are damaged by acid deposition, ozone exposition and SO_2.

- *Impacts on biodiversity and ecosystems (soil and water/groundwater)*: the impacts on soil and groundwater are mainly caused by eutrophication and acidification due to the deposition of nitrogen oxides, as well as contamination with heavy metals (from tire wear and tear).

11. The main impacts are the health impacts mainly caused by particulate matter (PM) from exhaust emissions or transformation of other pollutants. There is increasing evidence that in particular ultrafine particles have severe health risks.

12. The World Health Organization estimates the number of people worldwide that die from outdoor air pollution at 865 thousand per year (WHO, 2007), less than 10% of these in European Union. Other estimates are even much higher. The European Commission estimates the number of premature deaths in Europe alone at 370 thousand per year (EC, 2005). This is rather well in line with an estimate from Pimental, who estimated the number of deaths globally from outdoor air pollution at about 3 million per year (Cornell Chronicle, 2007).

13. Unlike the climate impacts of CO_2, the impacts from air pollutant emissions depend on the location. Air pollutants that are emitted in densely populated areas cause considerably more harm than pollutants emitted in remote areas.

1.2.3 Noise impacts

14. Traffic noise has a variety of adverse impacts on human health. The World Health Organization (WHO) has recognized community noise, including traffic noise, as a serious public health problem.

15. Traffic noise has various adverse effects. The most widespread effect is simply annoyance. In addition, there is substantial evidence for serious health problems caused by traffic noise. The main problem is disturbation of sleep patterns, which affects cognitive functioning (especially in children) and contributes to certain cardiovascular diseases. There is also increasing evidence for an impact of noise raising blood pressure (Den Boer & Schroten, 2007).

16. The number of people in the European Union that are affected by cardiovascular diseases that can be traced to traffic noise have been estimated at over 245,000 people per year (Den Boer & Schroten, 2007). About 20% of these people (almost 50,000) suffer a lethal heart attack, thereby dying prematurely. There are no such estimates known for other parts of the world, but there is no reason *not* to assume that also elsewhere a considerable share of the population is seriously affected by traffic noise.

1.3 Reader

17. The contribution of the transport sector as a whole and international road and rail freight transport in particular are discussed chapter 2. These trends in environmental impacts of transport are strongly affected by the trends in transport volume. These trends are discussed in chapter 3. Chapter 4 focuses on the developments in emission factors of road and rail vehicles, particularly the emission standards for reducing pollutant emissions and the differences between the emissions of the various modes. Chapter 5 discusses various technical and non-technical measures for reducing the environmental impacts of international road and rail freight transport. The focus is on measures for reducing CO_2 emissions, a major challenge in environmental policy for transport. Finally, chapter 6 gives an overview of the main conclusions of this paper.

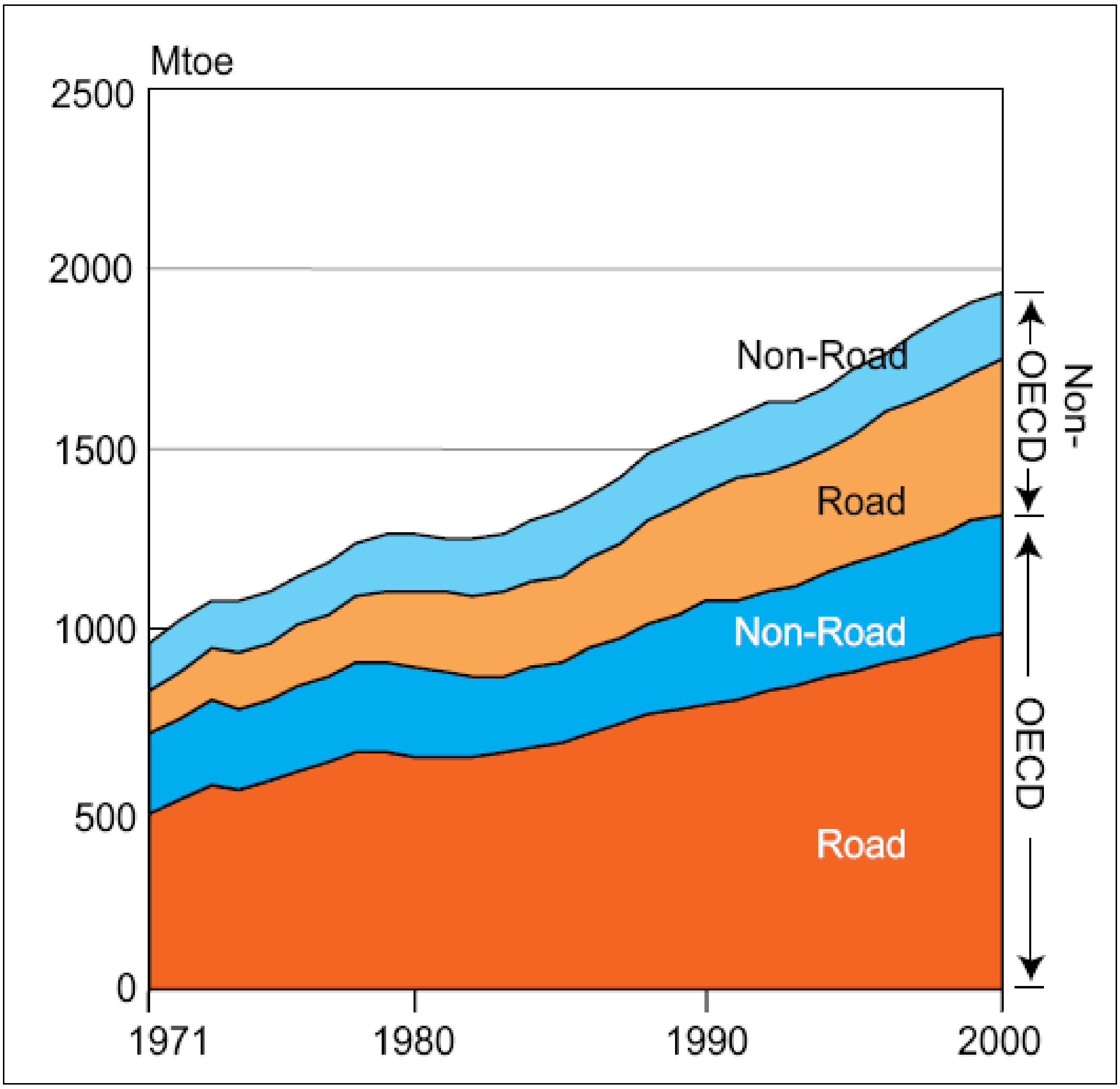
2. Trends in the environmental impacts from the transport sector

18. In this chapter we give an overview of the main trends in the environmental impacts of the transport sector as a whole and the (international) road and rail freight transport in particular. First the trends in energy use are discussed (section 2.1) and then the trends in CO_2 emissions (section 2.2), pollutant emissions (section 2.3) and noise (section 2.4).

2.1 Energy use of the transport sector

19. The trends in the energy use from transport over the last three decades of the previous century are depicted in Figure 1. The energy consumption of transport has almost doubled over this period. The growth in the non-OECD countries has been even higher: the energy use almost tripled in these 30 years time. Both for OECD and non-OECD countries, road transport had by far the largest share: about three quarters, and this share is steadily increasing.

Figure 1. Energy use of the transport sector (worldwide)



Source: (IPCC, 2007b).

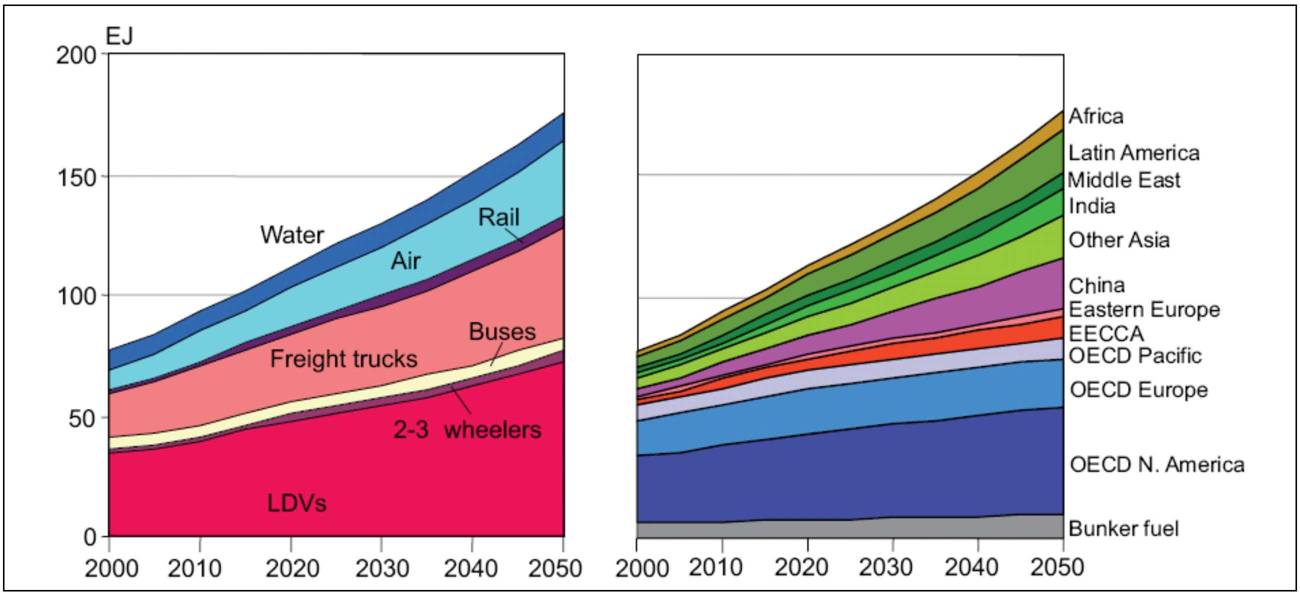
20. Projections for the first five decades of this century are shown in Figure 2. This graph makes clear that the energy use of transport is expected to keep on growing at a similar rate as in the last decades. It is expected to double between 2000 and 2040. The growth rates in road freight transport and rail transport are roughly the same as these general growth rates.

21. Just as happened in the past decades, the energy use of the transport sector is expected to grow much faster in the non-OECD countries than in the OECD countries. Where the non-OECD countries currently take about 36% of the worldwide transport related CO_2 emissions, their share is expected to equal that of the OECD countries somewhere around 2040. Particularly in Asia and Latin America, the energy use of transport is expected to grow strongly.

22. In China this growth is the highest: road energy consumption is expected to grow by a factor of five between 2000 and 2030 (He, *et al.*, 2005). In China, freight transport has grown much faster than passenger transport (almost twice as fast) and is expected to do so in the future. The energy use of Heavy Duty Trucks in China tripled between 1997 and 2002 (He, *et al.*, 2005).

23. This trend makes clear that reducing energy consumption of transport and the related greenhouse gas emissions is becoming more and more a global challenge.

Figure 2. Projection of transport energy consumption by mode and region

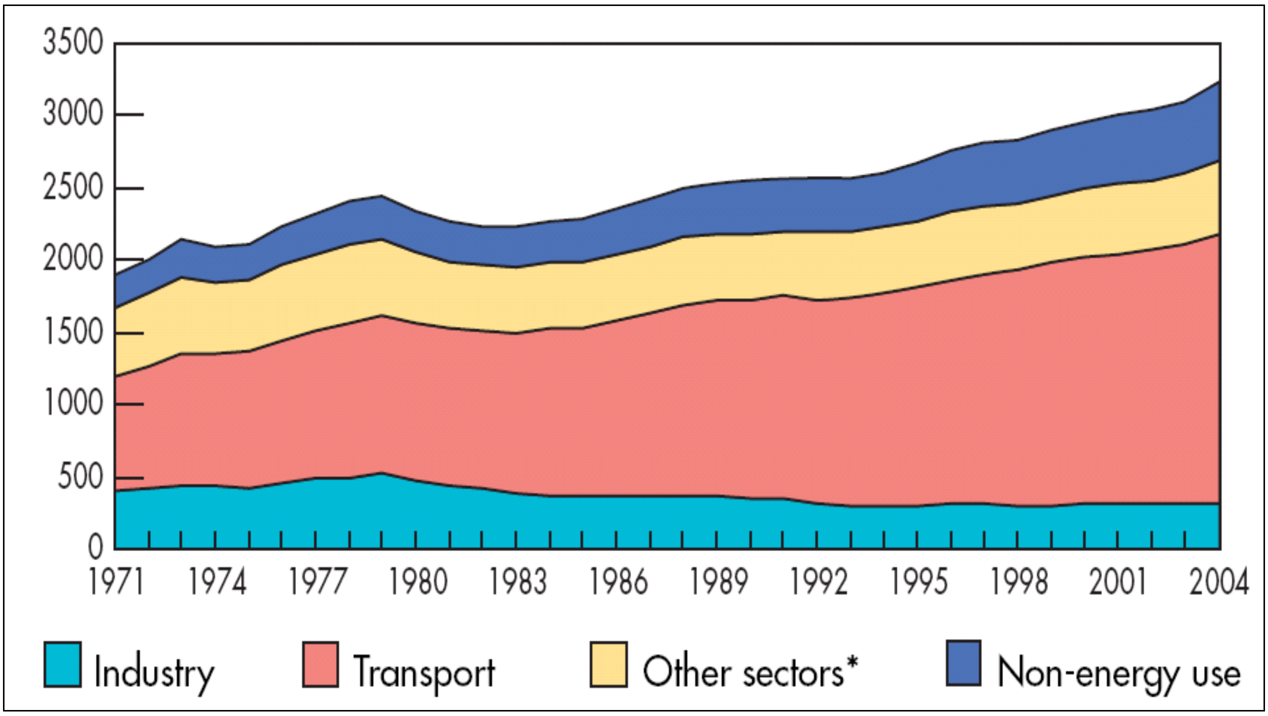


Source: (IPCC, 2007b).

24. The main energy source for transport is fossil fuels. Road transport, shipping and aviation almost entirely rely on oil. The only exception on this is electric rail transport which uses for a considerable share other energy sources, like hydro or nuclear power, depending on the energy mix in electricity generation.

25. The share of the transport sector in the world oil consumption is much higher than the share in the world energy consumption. As we can see in figure 3, also this share is steadily increasing. Currently more than half of the world oil production is consumed by the transport sector.

Figure 3. Evolution of worldwide final oil consumption per sector in Mtoe



Source: Smokers & Kampman (2006).

26. So far, we discussed the general trends in energy use of the transport sector. In this paper, we focus on international road and rail freight transport. Data from (IPCC, 2007b) show that currently, road freight transport takes about 25% of the total energy use of transport, 16 % by heavy lorries and 9% by medium lorries. From the perspective of international road transport, particularly the heavy lorries (including truck-trailer combinations) are important, since these are the vehicles that are used within the international haulage market.

27. Rail transport is responsible for only 1.5% of the global transport energy use. Light duty vehicles (including passenger cars) have the highest share with 44%. The other main energy users within the transport sector are aviation (12%), maritime shipping (10%) and buses (6%).

28. There are no worldwide statistics on the share of international road and rail freight transport in the energy use of total freight transport. However, data on the share of international freight transport in the transport volume can give a good indication. As elaborated in section 3.1, international transport has generally a minor share in road transport (8% in North America, 30% in Europe). In rail transport, the share of international transport varies a lot (5% in North America, 51% in Europe).

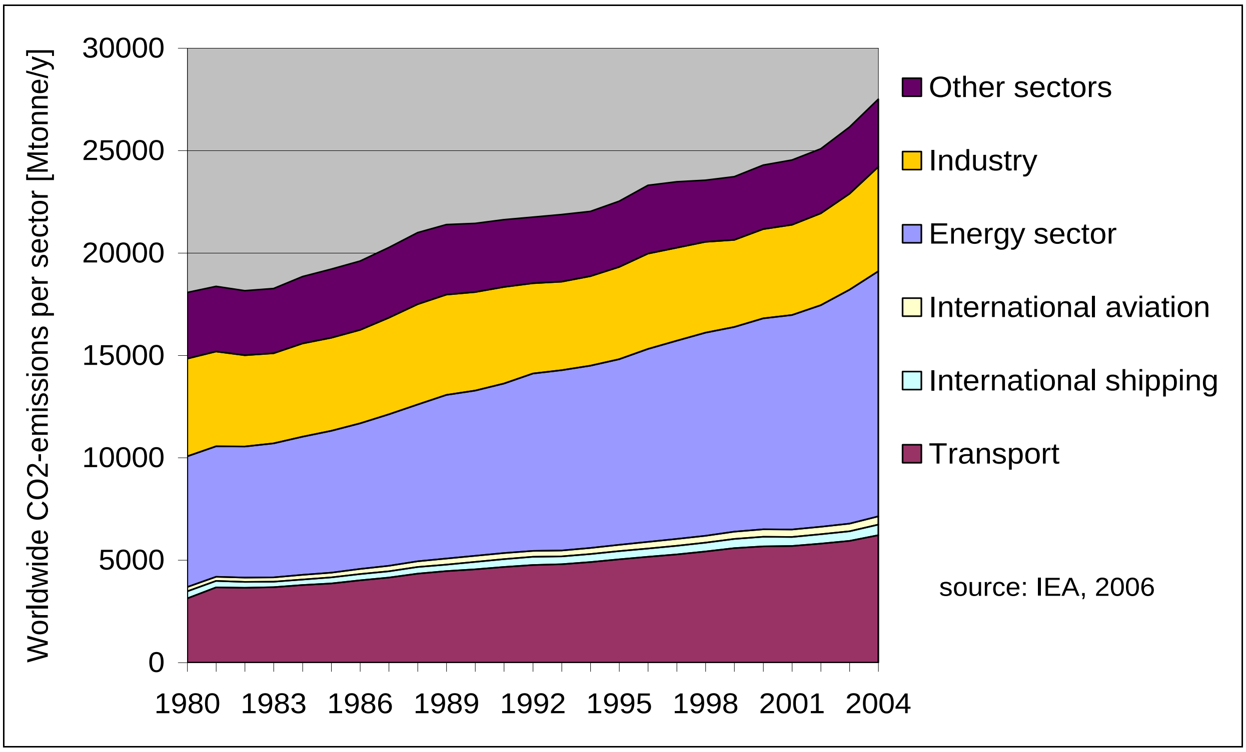
2.2 Greenhouse-gas emissions of the transport sector

29. The worldwide greenhouse emissions of all sectors together show a steady growth. Despite policy interventions like the Kyoto protocol, this growth tends to continue. However, there are big differences between sectors.

30. While greenhouse gas emissions of many other sectors stabilized or even decreased over the last decades, the CO_2 emissions of the transport sector keep on growing. Together with the energy sector, transport is the only sector with still strongly increasing CO_2 emissions. Figure 4 shows the trend in

worldwide CO_2 emissions and the share of the various sectors. The share of transport increases from about one sixth in the early 1980s to now almost one fourth (23%). In the OECD countries this share is even higher (about 29%, ECMT, 2007).

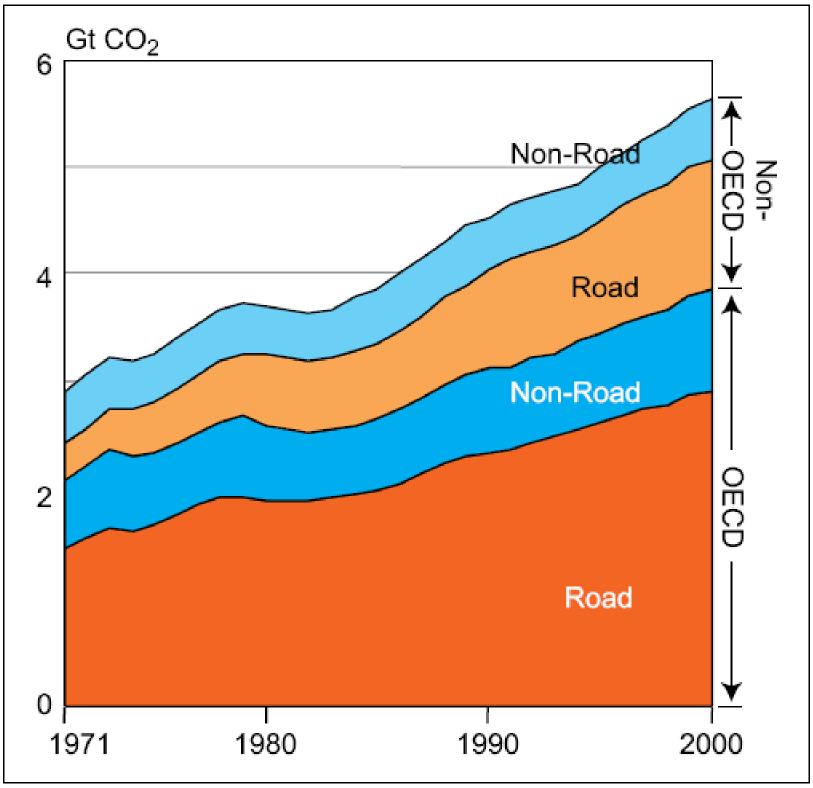
Figure 4. Energy-related CO_2 emissions of various sectors (worldwide)



Source: Smokers & Kampman (2006), based on (IEA, 2006).

31. Within the transport sector, the shares and trends in CO_2 emissions of the various transport modes are comparable to the shares and trends in the energy use (see Figure 1). As depicted in Figure 5, road transport has the highest share in the transport CO_2 emissions. Just like for the energy use, the growth in non-OECD countries is higher than in OECD-countries, particularly for road.

Figure 5. CO_2 emissions of the transport sector (worldwide)

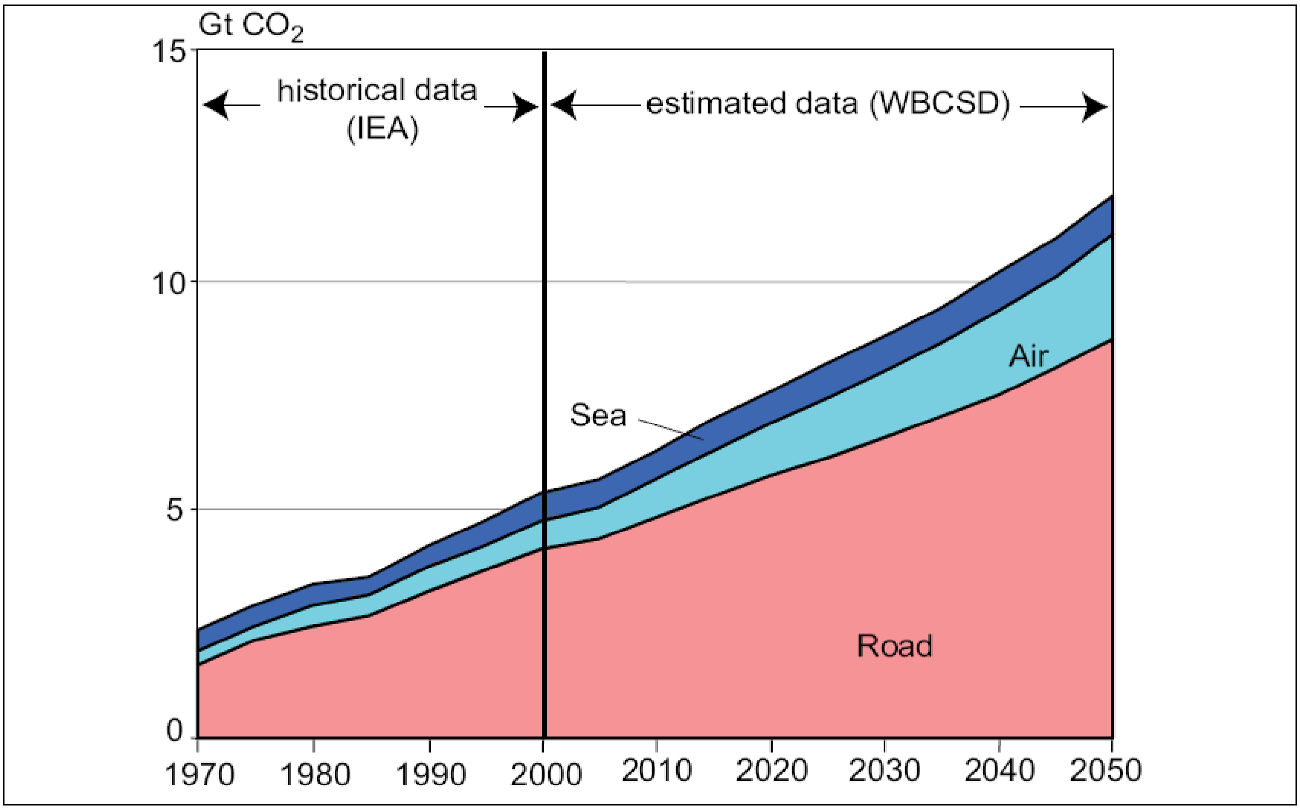


Source: (IPCC, 2007b).

32. In Europe, aviation shows the highest increase in CO_2 emissions. In the European Union, the CO_2 emissions of land transport increased by 26% between 1990 and 2005 and the CO_2 emissions of international aviation and maritime shipping by as much as 66% (EEA, 2008b).

33. Without policy intervention, the current growth in transport CO_2 emissions is expected to continue. Figure 6 shows projections for the global transport emissions per sector from 1970 to 2050. Between 2000 and 2050, the transport CO_2 emissions are expected to double. It becomes clear that the main growth is to be expected from road transport and aviation. Freight transport has been growing even more rapidly than passenger transport and is expected to continue to do so in the future (IPCC, 2007b).

Figure 6. Historical and projected CO_2 emissions from transport by mode (worldwide)



Source: (IPCC, 2007b).

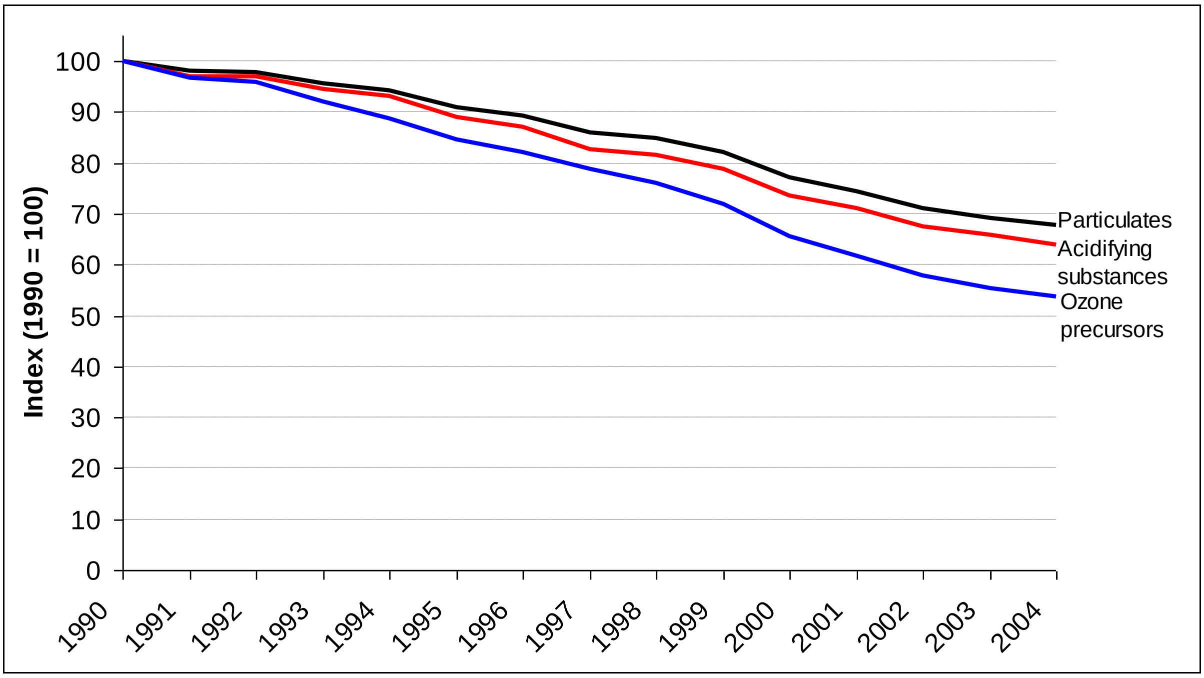
2.3 Trends in pollutant emissions

34. Pollutant emissions from transport have considerable impact on human health. Where energy use and climate change emissions show steady a growth, the emission of pollutants have been curbed to a decreasing trend. This is the result of emissions regulation which is yet present in most countries (see also section 4.1).

35. Figure 7 shows the trends in air pollutant emissions from transport in Europe. We see that despite growing energy use of transport, pollutant emissions decrease steadily. This is the case for both particulates, acidifying substances (NO_x and SO_x) and ozone precursors (NO_x and VOC). Despite the decrease in air pollutant emissions, many European cities still have problems meeting the current air quality standards, which are expected to be further tightened from 2010. At the other hand, given the further tightening of emissions standards and natural renewal of the fleet, emission levels are expected to keep on decreasing.

36. Also in most other parts of the world, stricter vehicle emission standards result in an overall reduction of pollutant emissions. Only in regions with an extremely strong growth of transport volumes, particularly road (*e.g.* China), the emission reduction per vehicle-kilometre may not be strong enough to result in an overall decrease in pollutant transport emissions.

Figure 7. Transport emissions of air pollutants for EEA[1] countries in 1990-2005

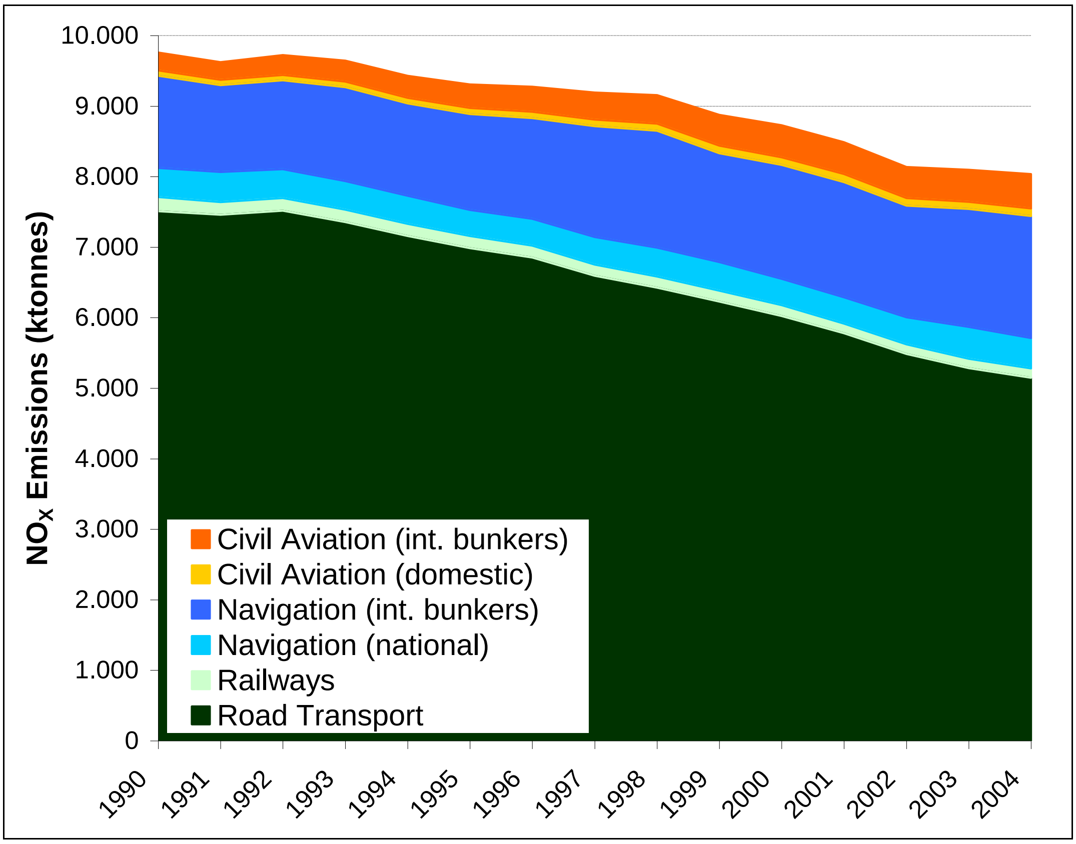


Source: EEA (2006a).

37. A further breakdown of the NO_x emissions to the various transport modes makes clear that the decrease in pollutant emissions can for a large part be explained by a reduction in road transport pollutants, see Figure 8. The decrease in pollutant emissions from road vehicles, results in an increase of the relative share of the non-road modes. However, since also for these modes emission standards have been or will soon be applied (see section 4.2), also these emissions will start to decrease.

1. EEA countries include EU-27, Croatia, Turkey, Switzerland, Norway, Iceland and Liechtenstein.

Figure 8.Transport emissions of air pollutants for EEA countries in 1990-2003



Source: EEA (2006a).

2.4 Trends in noise emissions

38. Unlike greenhouse gas and pollutant emissions, there is little data on the trends in traffic noise levels and the number of people exposed.

39. The European Environment Agency (EEA) made an overview of the number of people in Europe exposed to traffic noise levels above 55 dB, which are regarded as harmful. They concluded the following:

> "About 120 million people in the EU (more than 30 % of the total population) are exposed to road traffic noise levels above 55 Ldn dB. More than 50 million people are exposed to noise levels above 65 Ldn dB. It is estimated that 10% of the EU population are exposed to rail noise above 55 LAeq dB. The data on noise nuisance by aircraft are the most uncertain, but studies indicate that 10 % of the total EU population may be highly annoyed by air transport noise." (EEA, 2001)

40. We did not find any data for other parts of the world, but it can be expected that also elsewhere, a considerable share of the population is exposed to traffic noise.

3. Trends in transport volume – a main driver behind the environmental impacts

41. The trends in environmental impacts of transport are strongly affected by the trends in transport volume. This chapter discusses the global developments in transport volume in general and where possible for international road and rail freight traffic in particular.

3.1 Global trends in freight transport volumes

42. Freight transport volumes are growing strongly. This growth is fuelled by economic growth. In some parts of the world (notably the European Union) also the removal of internal borders and other market barriers contribute to the growth. Scaling-up and efficiency improvements have resulted in a reduction of real transport costs. This allows companies to benefit from differences in labour costs and skills in different regions. Transport over long distances is becoming more and more profitable compared to alternatives like local production.

43. Azar made an assessment of the growth in freight transport worldwide between 1990 and 2100. The same study gives also estimates for the energy use in 2100. The results of this assessment are depicted in Table 1.

44. Worldwide the share of road and rail transport are currently roughly the same (Azar, 2003; IRF, 2007). Also within the OECD, the share of road and rail is comparable (OECD, 2007).

Table 1. Growth in global freight transport volumes

	Transport volume in Ttkm/year		Energy demand (EJ/year)	
	1990	**2100**	**1990**	**2100**
Road	6.4	40	23	72
Rail	6.1	13	3.1	4.3
Domestic water	2.6	5.0	1.2	1.6
Ocean	29	126	5.8	16
Air	0.07	0.28	0.32	0.62
Total	*44*	*184*	*33*	*95*

Source: (Azar, 2003).

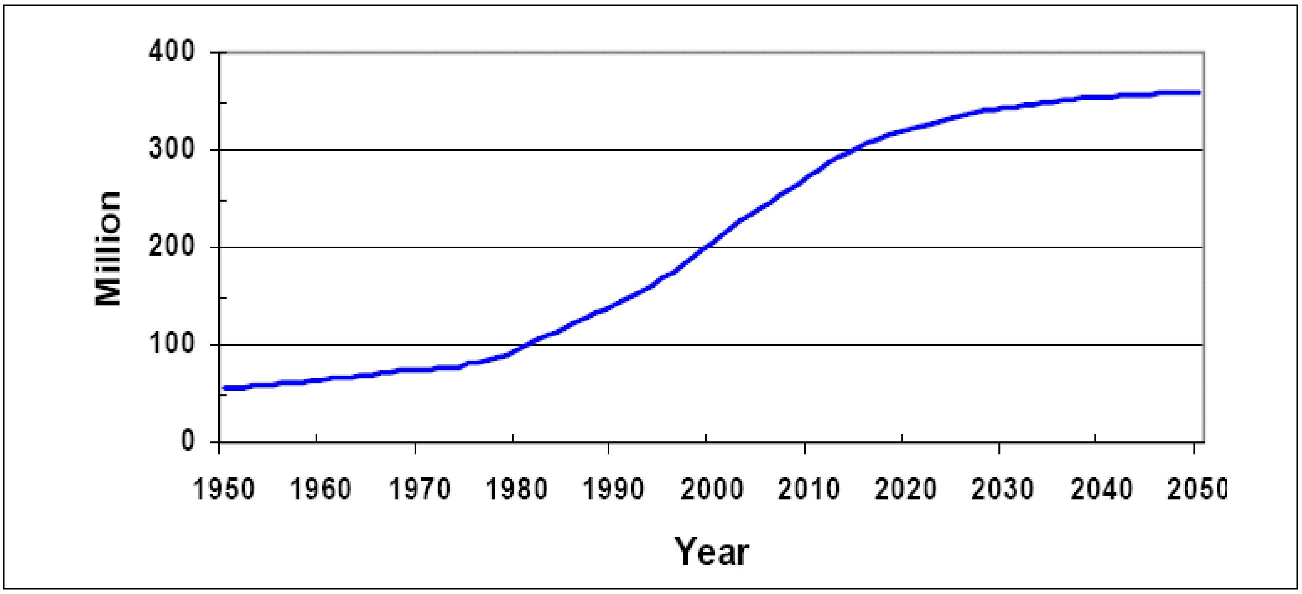
45. Table 1 shows that the expected growth in freight transport volume is strongest in road transport. The expected growth in rail transport is much lower than the average. Despite an expected improvement in fuel efficiency, the global energy use of freight transport is expected to triple. This makes clear that the main driver behind the growing energy demand of freight transport is the transport growth.

46. Assessments of the EEA show a similar picture. Freight transport volumes in Europe grow strongly, outpacing economic growth (EEA, 2008a). This growth in transport volume mainly in road freight, is the main driver behind the increasing energy demand of freight transport. Road freight transport volume in the European Union is expected to grow 78% between 2000 and 2030. This means an even stronger growth than in the past twenty years (Smokers *et al.*, 2007).

47. The modal split differs a lot between countries. In Russia, the rail freight transport volume is several times larger than the road freight transport volume and also in China, the share of rail is much higher than that of road. In the USA, road and rail have rather comparable shares, while in Europe, rail transport has only a minor share in the inland freight market which is dominated by road transport. As can be seen in Table 1 and also known from other forecasts, particularly the share of road transport is expected to increase strongly worldwide.

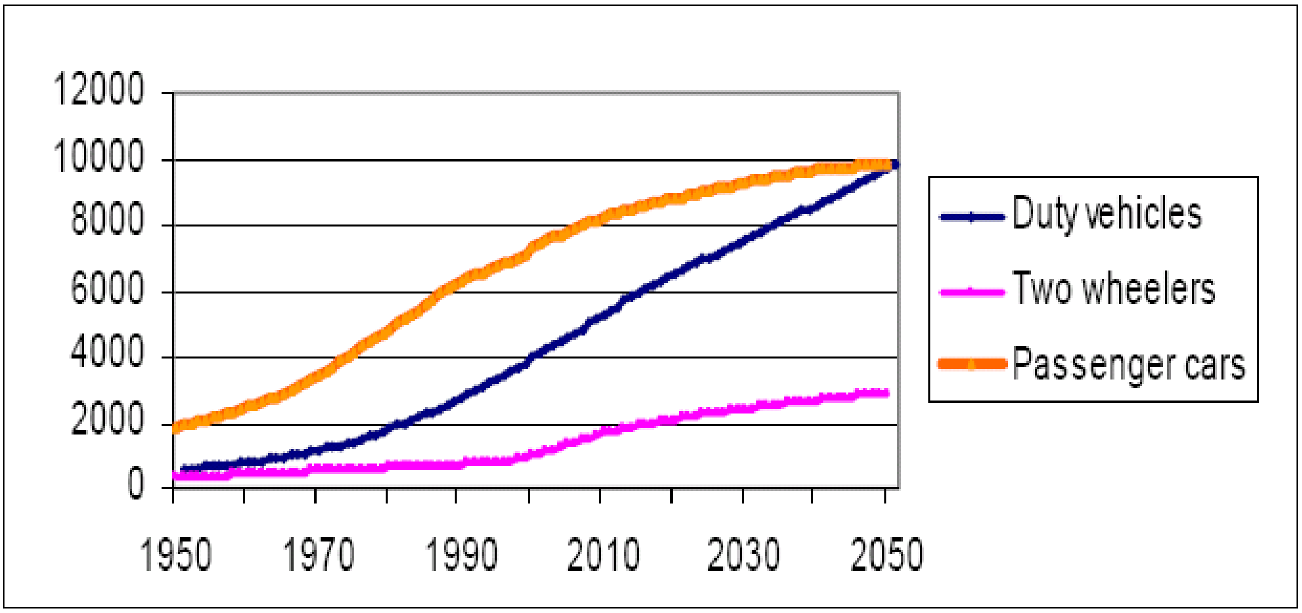
48. The growth in road freight transport volumes is accompanied by a growth in both the number of vehicles and vehicle-kilometres. Figure 9 shows an estimate for the number of road freight vehicles worldwide. The number of lorries is expected to keep on growing over the next decades. The growth in kilometres driven is expected to be even stronger, as can be seen in Figure 10.

Figure 9. Estimated trend of worldwide number of freight vehicles



Source: (Metz, 2005).

Figure 10. Estimates of the total mileage trends road transport worldwide in 1000 Mio kilometres



Source: (Metz, 2005).

3.2 The share of international freight transport

49. Only a part of all freight transport is international. The share of total freight transport volume that is crossing borders differs per continent.

50. Within the European Union, the share of international road freight in the number of tonne-kilometres of road transport is about 30% (EC, 2007). These 30% of international freight transport volume is for 94% between countries within the European Union (Eurostat, 2006). The international road transport with non-EU countries is for three quarter with Switzerland, Norway and the Russian Federation.

International road freight transport in the European Union grows twice as fast as national transport volumes; 25% against 12% growth between 2000 and 2005 (EC, 2007).

51. For European rail freight transport, the share of international transport is considerably larger, about 51% (Eurostat, 2007).

52. In North-America, the share of international transport in total road freight transport is much smaller: about 8% (US Department of Transportation, 2006; IRF, 2007). The share of international rail transport in total freight rail transport in North America is only 5%. These small shares can be explained by the small number of (very large) countries involved: international surface transport in North-America is limited to transport between Canada, USA and Mexico.

4. Developments in emission factors of road and rail vehicles

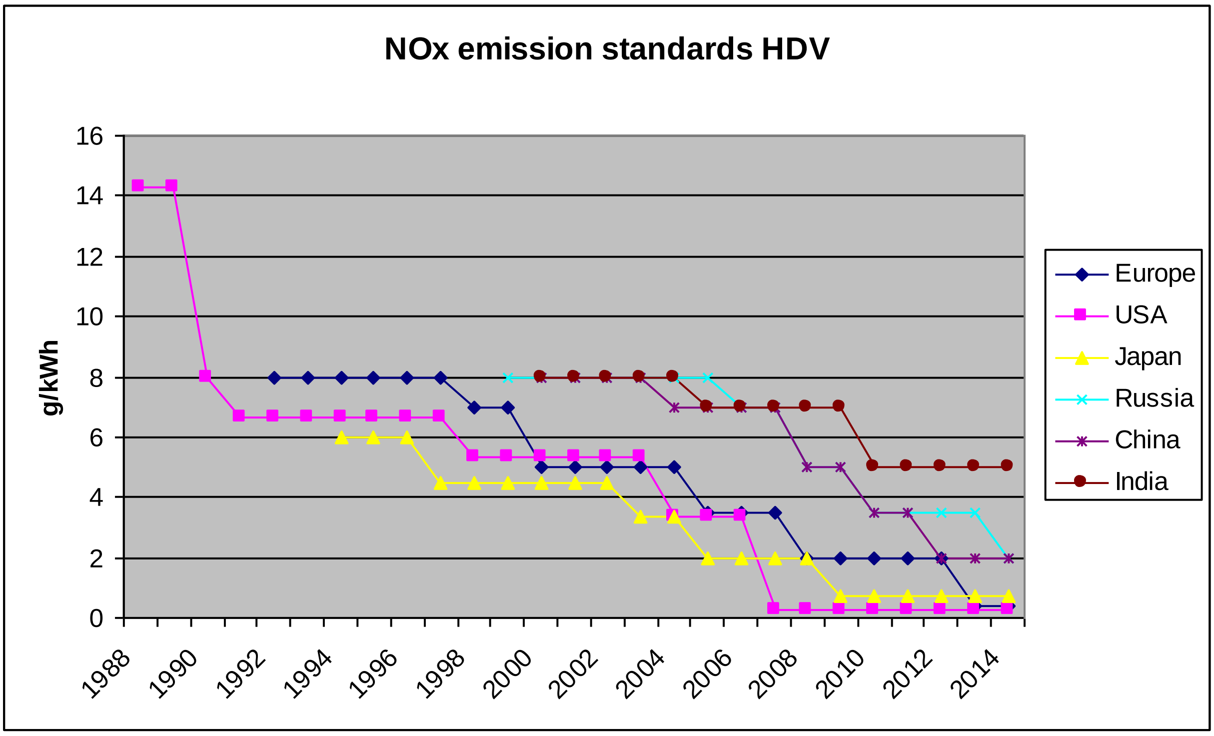
53. Transport emissions are driven by transport volumes, which were discussed in the previous chapter, but also by the emissions per vehicle kilometre and the shares of various modes. In this chapter we discuss the emission factors of road and rail transport. First, we discuss the emission standards for pollutants. Second we discuss the emissions levels per kilometre for both long distance road and rail transport.

4.1 Emission standards for diesel engines of heavy duty vehicles

54. All over the world, countries have regulated the pollutant emission level of new vehicles, both passenger cars and heavy duty vehicles. At type-approval, every vehicle needs to meet certain emission standards at a prescribed test-cycle. Both the emissions levels that new vehicles should meet and the test cycles that are applied vary between countries. The three main streams are the European, Japanese and American standards. Countries like Russia, China and India tend to apply the European standards, but at a later year.

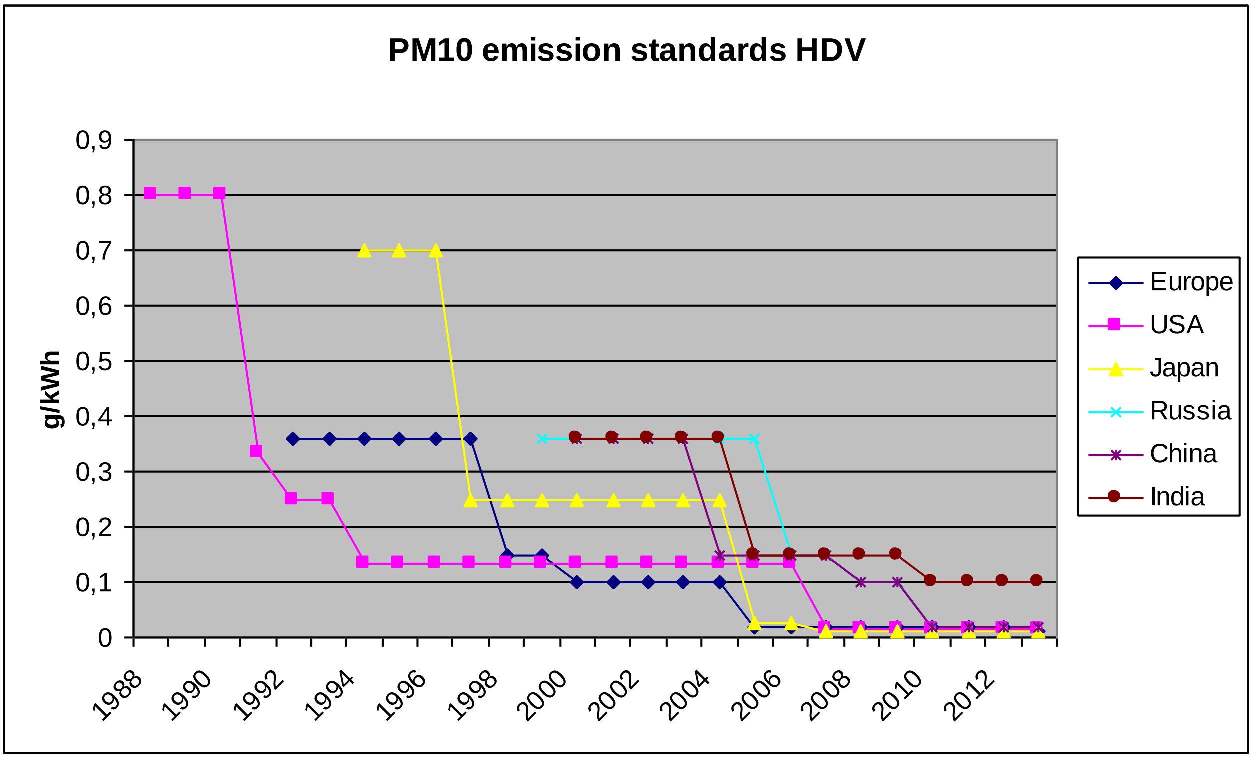
55. Figure 11 and 12 give an overview of the NO_x and PM10 emission standards for heavy duty vehicles in various parts of the world. In some cases multiple standards apply, depending on for example engine power. In those cases, a typical engine for a large lorry has been selected. Because of other differences in definition and the test cycle that is used, standards may not be completely comparable. However, these graphs give a rough overall picture of the worldwide developments in emission standards.

Figure 11. NO_x emission standards for Heavy Duty Vehicles in selected countries



Source: compiled with data from the following website: www.dieselnet.com/standards.

Figure 12. PM10 emission standards for Heavy Duty Vehicles in selected countries



Source: compiled with data from the following website: www.dieselnet.com/standards.

56. Various technologies have been developed and implemented in order to meet the various standards, *e.g.* various types of catalysts and, more recently diesel particulate filters. Together with technological improvements, also the knowledge on the impacts of air pollution has developed. Recently there is increasing attention to the health impacts of ultrafine particles.

57. It should be noted that the emissions of vehicles on the road differ from the emission levels in test-cycles. Real life emissions are generally considerably higher, because manufacturers tune engines to the test cycle conditions. Despite this so-called test-cycle by-passing, real life emissions are still decreased by the various emissions standards, but at a lower speed than one might conclude from the emissions standards themselves.

58. Overall, we conclude that the pollutant emissions from heavy goods vehicles are reduced effectively, but that the total emissions are not yet at a desired level. Further tightening of emission levels that takes place in the coming decade is expected to contribute to a further reduction of pollutant emissions.

4.2 Emission standards for non-road mode diesel engines

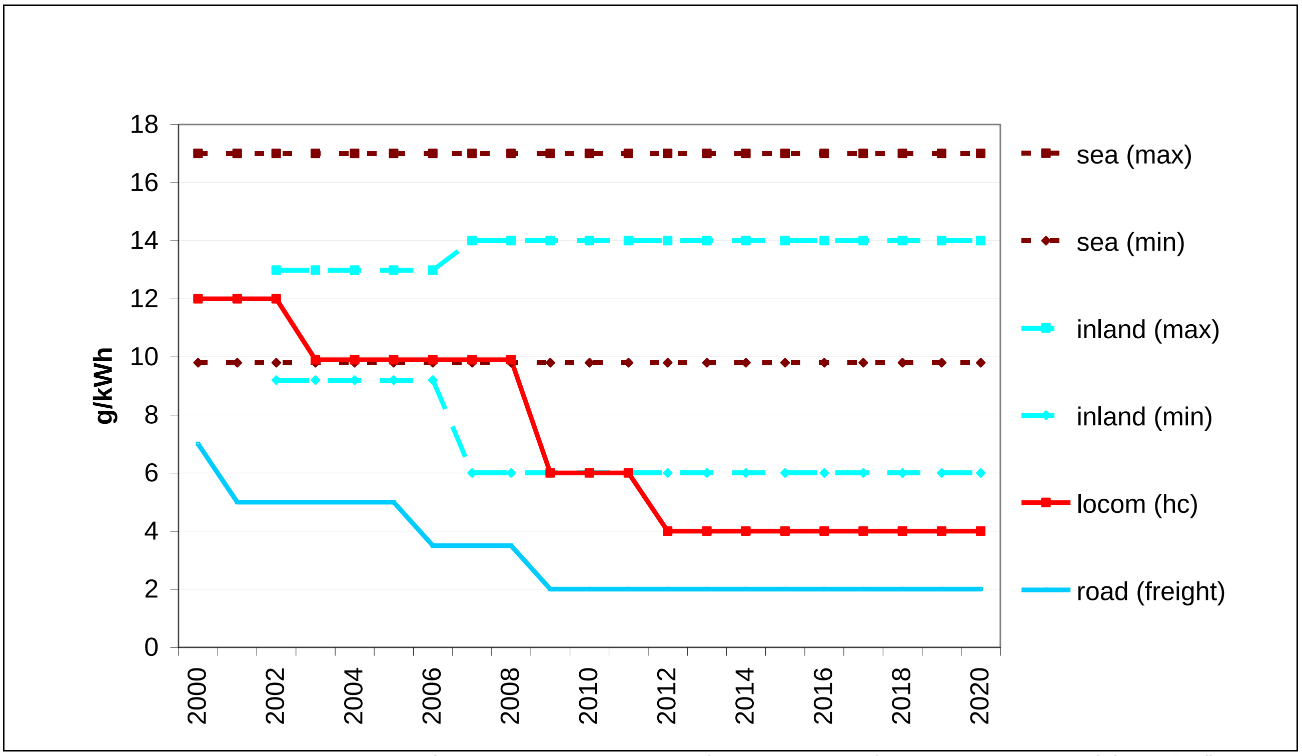
59. Emission regulation first tended to be focused on road transport. The reason for this is the large share of road transport in pollutant emissions. However, with the significant improvements made in road transport, the attention shifted to reduction of pollutant emissions from non-road modes, particularly diesel engines of trains and ships.

60. In the European Union, since about 2000, emission standards for non-road modes are being introduced. In the non-road mobile machinery directive (2004/26/EC), emission standards (HC, CO, NO_x and PM_{10}) and deadlines are set for rail and inland navigation, distinguishing between *e.g.* types and engine sizes. The directive introduces progressively lower emission standards until 2015. For rail and inland navigation, the first standards were introduced in 2006. Earlier standards for rail (diesel engines) were set by the UIC. For inland navigation, the Central Commission for Navigation on the Rhine (CCNR) earlier set standards, starting from 2002.

61. For maritime transport, an emission standard for NO_x is set (varying with engine speed in rpm) in the MARPOL convention (IMO). Although the emission standard was ratified only in 2005, it applies to all engines constructed after 2000. Currently a tightening of this standard is subject of discussion.

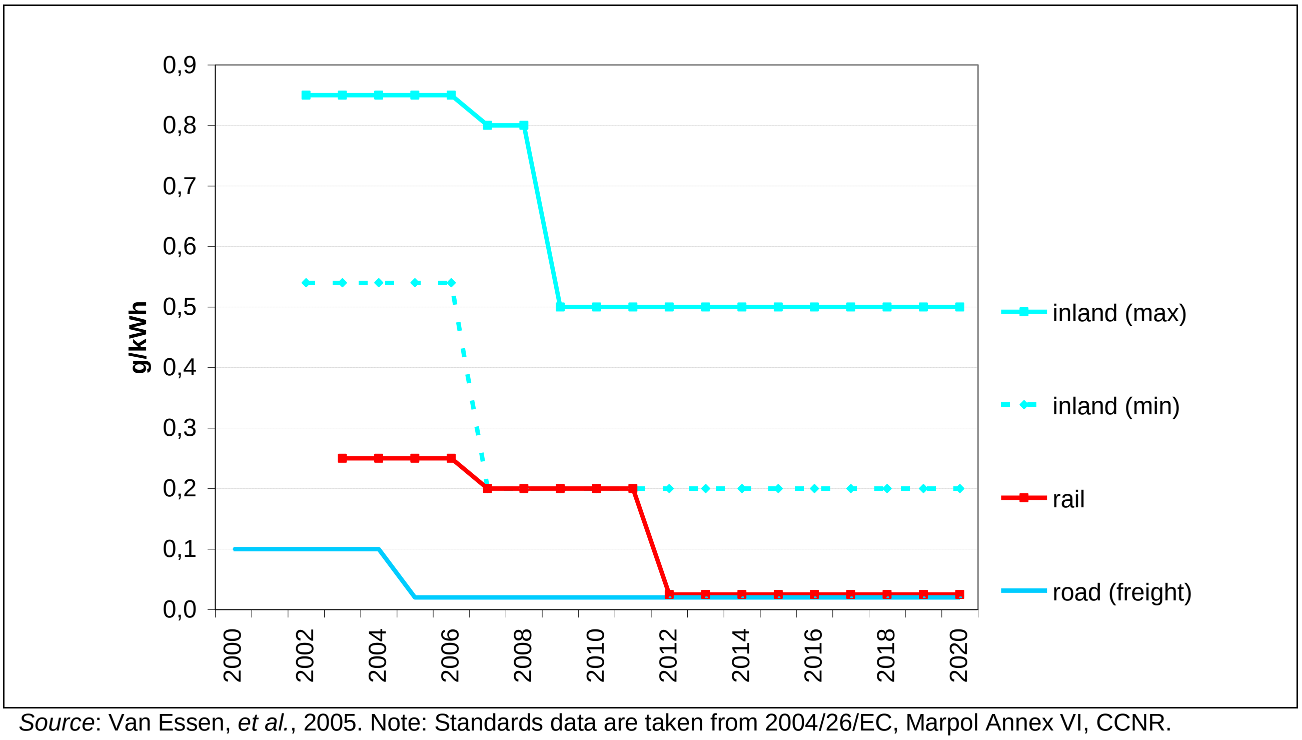
62. In Figure 13 (NO_x) and 14 (PM), an overview is presented of the European emissions standards coming into force until 2015. For each mode, both the highest and lowest standards are shown. In practice, those different standards apply to *e.g.* different power classes for the same mode. For comparison, the standards for road freight transport (since 2000) are shown as well. The standards are given in gram per kWh (mechanical energy delivered by the engine).

Figure 13. Emissions standards for NO_x emissions for diesel vehicles in the European Union



Source: Van Essen *et al.*, 2005. Note: Standards data are taken from 2004/26/EC, Marpol Annex VI, CCNR. “hc” indicates combined standard for hc+NO_x emissions).

Figure 14. Emissions standards for PM_{10} emissions for diesel vehicles in the European Union



Source: Van Essen, *et al.*, 2005. Note: Standards data are taken from 2004/26/EC, Marpol Annex VI, CCNR.

63. For NO_x, the standards for maritime transport are clearly higher than for other modes of transport. Standards for road transport will remain stricter than the other modes for quite some time. For particulate emissions, no standards exist for sea-going engines. For rail, the standard for PM coincides with that for road freight from 2012. Standards for inland navigation vessels are considerably higher.

64. It should be noted that emission standards do not offer a direct comparison of modes in terms of environmental effect. The specific test cycles vary a lot and the same standard may be very strict for one mode but easy to achieve for another mode, due to technological differences. Moreover, these emission standards are set per kWh. This cannot be directly translated to the actual effects of the sector and its efficiency, in terms of, for instance, tonne-km. It is fair to say, however, that for non-road modes standards have been set much later than for road transport. Also, standards generally take longer to show actual effects on fleet emissions: non-road modes typically deal with smaller markets and fewer vehicles with a much slower turn-over over the fleet than road does.

65. Recently (March 2008), also the USA has introduced emission standards for diesel locomotive engines and ship engines. When fully implemented, these new standards will cut PM10 emission factors by 90% and NO_x emission factors by 80% (Sustainable Business, 2008).

Box 2. Sulphur content of fuels

In addition to engine emission standards, also the sulphur content of fuels is increasingly subject to standards. Reducing the sulphur content of fuels has a large impact on exhaust emissions as it enables the introduction of more sophisticated after-treatment systems. There is a huge range in sulphur content in fuels. For 2009, for road transport the European standard will be 10 ppm, yet a factor 100 lower than for diesel trains. For comparison, the sulphur content in marine fuel is on average 7 times higher than for diesel trains.

4.3 Emissions levels per kilometre for both long distance road and rail transport.

66. So far we discussed the emission standards of the various modes. In this section we turn to the actual emission levels of transport modes. Transport causes emissions in various ways:

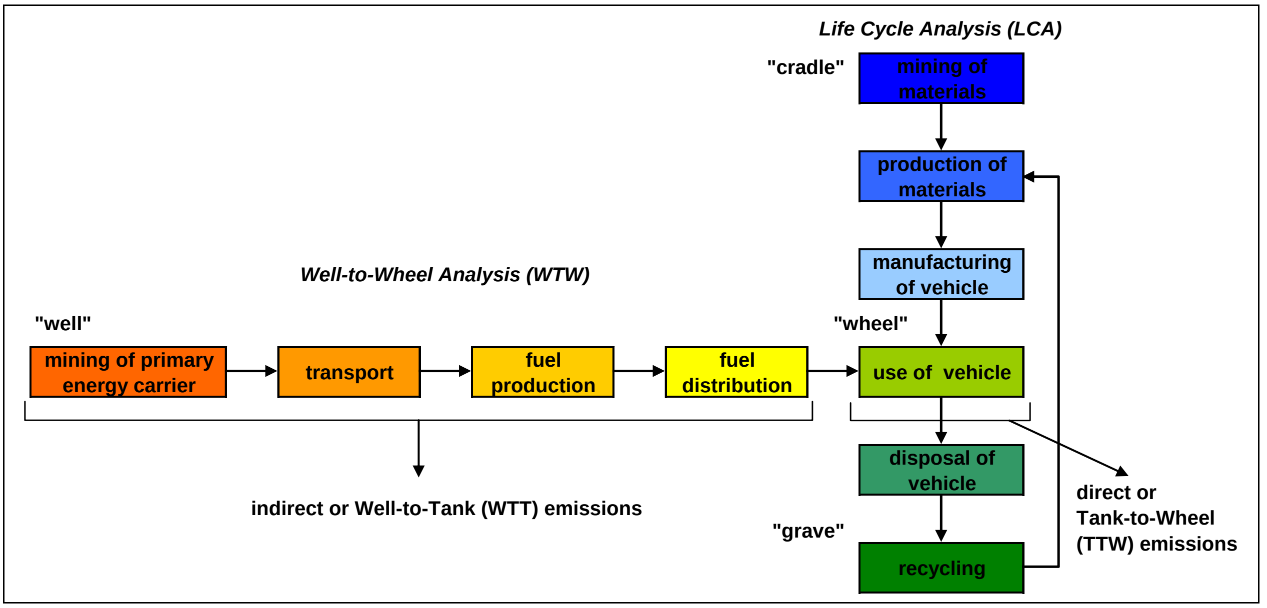
- Vehicle usage: burning of fuels.
- Fuel production.
- Vehicle production, maintenance and disposal.
- Infrastructure building, maintenance and adjustments.

67. The first type of emission is generally regarded the most important source of transport-related emissions. In order to be able to compare various modes, emissions along the whole energy chain (both the production and burning of the fuel) are usually taken into account. In the case of electric trains this includes the electricity production. This approach is called ‘well-to-wheel’. The well-to-wheel emissions of various freight transport modes can be compared by expressing them in gram per tonne-kilometre.

68. The emissions from the production, maintenance and disposal of vehicles can be analysed by the Life-cycle-analysis (LCA) approach. Both the well-to-wheel and LCA approach are depicted in Figure 15.

69. For passenger cars, the emissions of vehicle use are about 80% of the total emissions; the other 20% are emissions related to infrastructure provisioning and the production, maintenance and disposal of vehicles (CE Delft, 2008). For passenger transport by rail, the estimates of these shares vary a lot, probably because of differences in the energy mix. There are no estimates available for road or rail freight transport.

Figure 15. Illustration of 'well-to-wheel' (WTW) analysis of energy chains and 'life-cycle analysis' (LCA) of products



70. For a sound comparison of the well-to-wheel emissions, competing modes should be compared within market segments. Differences in logistical parameters like load factors, empty rides and detours should be taken into account. In addition it is important to compare whole transport chains. Transport by non-road modes usually needs some road transport to and from loading points.

71. Rail transport relies both on diesel and on electricity. The environmental performance of electric trains is generally better than that of diesel trains. The actual difference depends on electricity mix and the applied diesel technology. An important difference is that electric transport offers the possibility to use sustainably generated electricity. In that case the environmental performance of electric trains is much better than that of diesel trains. However, in an integrated electricity market, the marginal environmental impact from electric energy will be determined by the "marginal" supplier of electricity. It is difficult to determine from which source any particular use of electricity stems.

72. Emissions per tonne-kilometre depend on the emission factors (in g per kWh), the energy use and the vehicle utilisation. These factors vary a lot between countries and specific situations for the following reasons:

- There is a wide bandwidth in emission factors, particularly for pollutant emissions.
- There is huge variation in logistical parameters, particularly load factors.
- Differences exist in the energy mix of electricity used for electric trains.

73. In specific markets, the differences between transport modes are generally small. Differences depend more on logistical characteristics and technology (*e.g.* emission standards) than on mode per se (Van Essen, *et al.*, 2003).

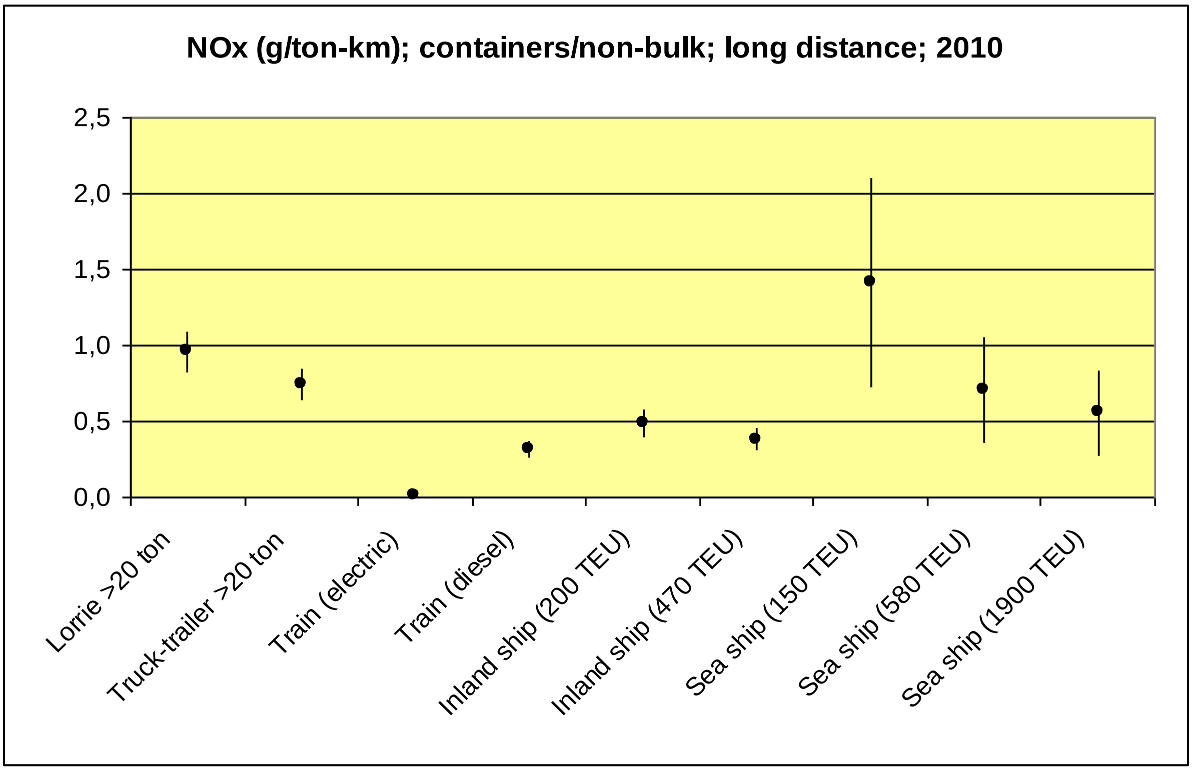
74. In a recent study, emissions factors for the Netherlands were compared. The results for pollutant emissions of long-distance container transport are shown in Figure 16. The NO_x and PM_{10} emissions per tonne-kilometre are highest for sea shipping. In this case, emissions of rail transport are lower than those of road transport. The differences between the modes depend on the emission factors and the energy-

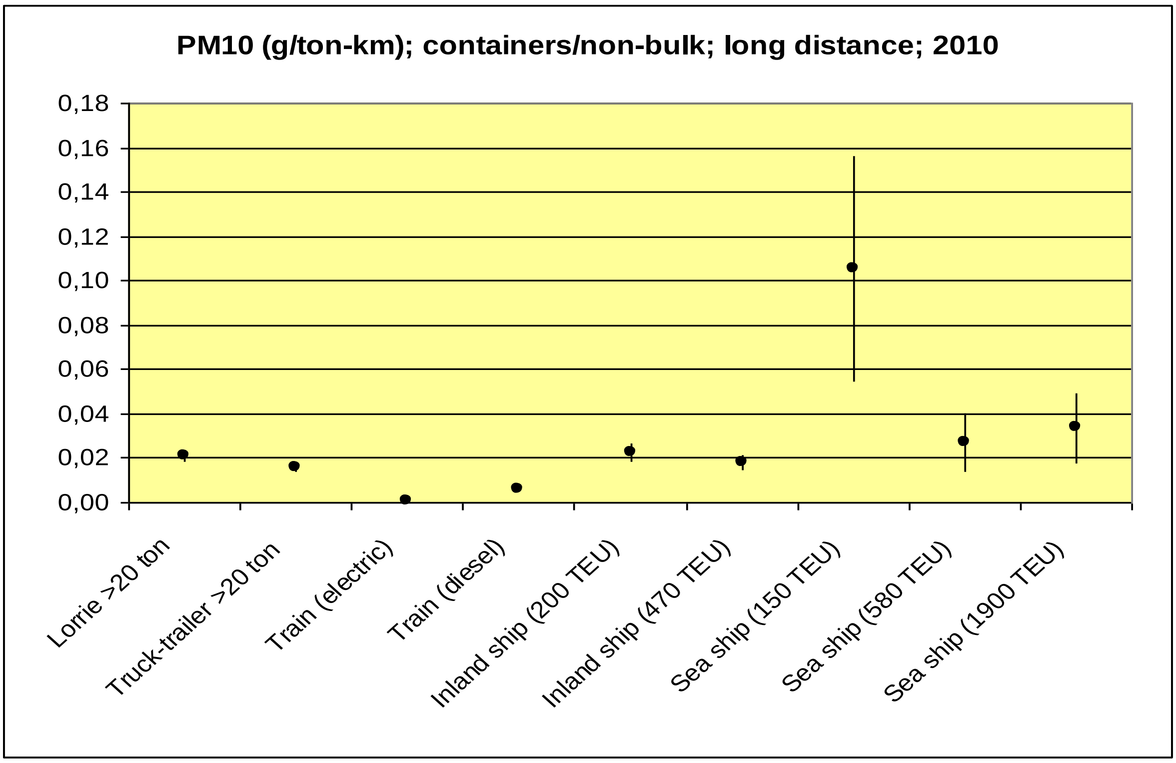
efficiency of each mode. The average emission factor for heavy duty vehicles in this case is about the level of Euro-3.

75. At least as important are the differences in the average vehicle utilisation. In the specific case of the non-bulk market in The Netherlands, the average utilisation of freight trains (86%) is considerably higher than the average utilisation of lorries (26%), articulated truck-trailer combinations (33%) or inland vessels (64%), which is directly reflected in the emission levels per tonne-kilometre.

76. For comparison we also present the CO_2 emissions per tonne-kilometre for the same case: long-distance non-bulk container transport. In both cases, the CO_2 emissions of road transport are again higher than those of rail transport. Just like for the pollutant emissions, the differences in CO_2 emissions per tonne-kilometre are strongly depending on the vehicle utilisation. The emissions of a fully loaded truck are comparable to those of competing modes when the whole transport chain is considered.

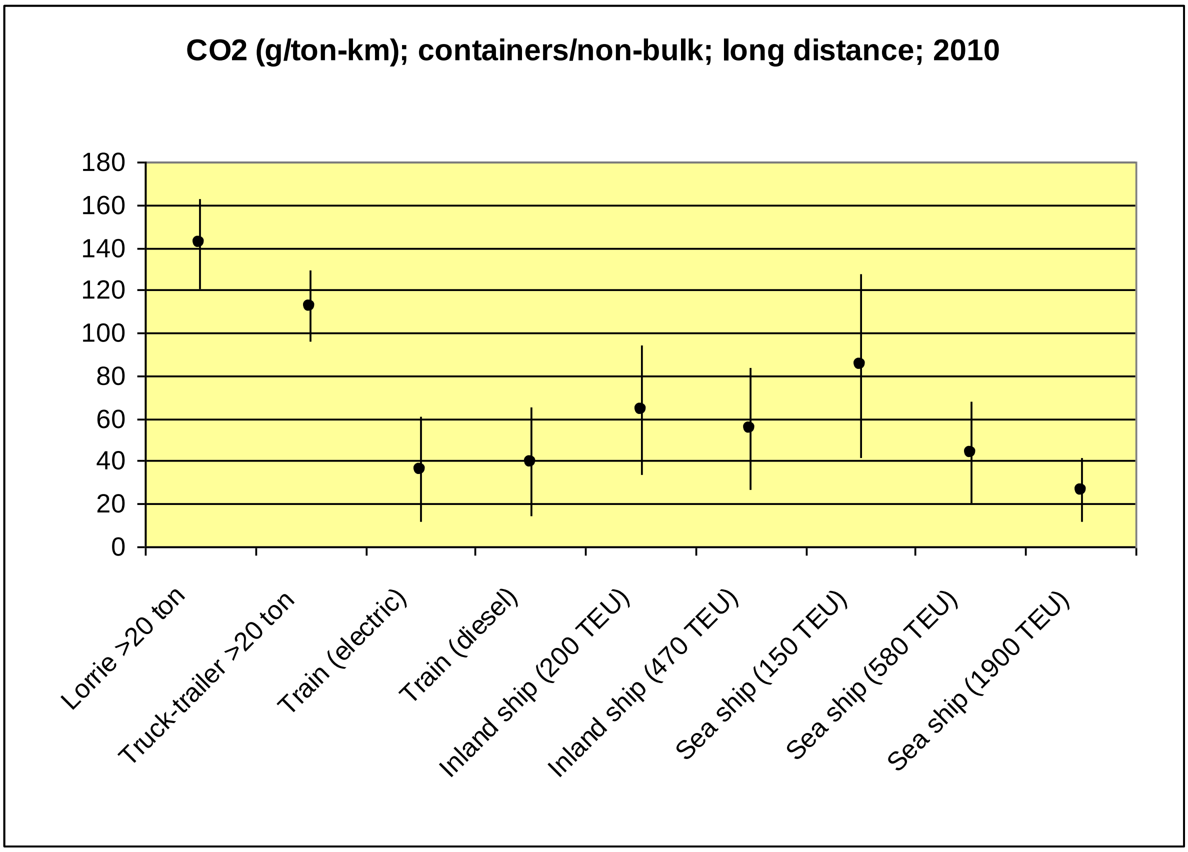
Figure 16. NO$_x$ and PM10 emissions per tkm for long distance container and other non-bulk freight transport in the Netherlands





Source: Den Boer *et al.*, 2008. Note: based on data for the Netherlands (logistical characteristics, energy mix, emission factors). Bandwidth are based on variation a 15% variation of load factor and for the non-road modes also a variation in detour factor and with or without transport to/from loading points.

Figure 17. CO_2 emissions per tkm for long distance container and other non-bulk freight transport in the Netherlands



5. Perspectives for improving the environmental performance of freight transport

77. As presented in Section 2, the CO_2 emissions of transport show an increasing trend. This is contrasting with the ambitious CO_2 reduction targets discussed within the post-Kyoto climate policy and which have already been adopted by some countries (*e.g.* the European Union). In the short term, many developed countries will be able to meet their CO_2 reduction goals under the Kyoto protocol without drastic measures in the transport sector. For the long term, however, CO_2 emission reductions of 40 to 60% compared to 1990 are expected to be necessary in order to limit the effects of global warming to acceptable levels. Given the expected growth of the transport sector in the next decades and its strong reliance of fossil fuels, such long-term reduction goals cannot be met without significant contributions from the transport sector.

78. In this section, the main options for CO_2 reduction in international road and rail freight transport will be discussed[2]:

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2. Sections 5.1 to 5.4 have been based on the assessment made by Smokers & Kampman (2006).

- International road freight transport:
  1. Technical measures (Section 5.1)
  2. Non-technical measures (Section 5.2)
- Measures for CO_2 reduction in international rail freight transport (Section 5.3)
- General measures for CO_2 reduction in international surface freight transport:
  3. Biofuels and other alternative fuels (Section 5.4)
  4. Measures aimed at volume reduction and modal shift (Section 5.5)

79. Pollutant emissions of long-distance freight transport can most effectively be reduced by further tightening of vehicle emission standards (see Section 4.1 and 4.2). Also the measures discussed in Section 5.5 may contribute to a reduction of pollutant emissions, *e.g.* a shift towards electric rail transport in combination with a shift to greening electricity production.

80. The options for reducing noise emission from international transport are briefly discussed in section 5.6.

5.1 Technical measures to improve the energy efficiency in road freight transport

81. Fuel costs are a significant part of the operating costs of heavy duty vehicles. For this reason, efficiency improvement has traditionally been an important driver in vehicle and engine developments for freight transport. Furthermore, the engine in a heavy duty application is generally used in a more energy efficient way, because of a smaller power-to-weight ratio than passenger cars and the use of an optimised gearbox (Smokers & Kampman, 2006).

82. As a consequence, the potential for further efficiency improvement in road vehicles for freight transport is rather limited, especially in the sector of long-distance transport. For urban distribution trucks and city buses, the driving-pattern is generally more dynamic, so that engine improvements and application of a hybrid power-train may offer significant fuel economy benefits.

83. The main technical options for improving energy-efficiency in heavy duty vehicles are (Smokers & Kampman, 2006):

- Low rolling resistance tyres (≈6%).
- Engine improvements (≈5%).
- Reduction of air resistance (≈6%).
- Increased weight limit to 44 or 60 tonne (≈9 - 20%).
- Lightweight construction (≈7%).
- Hybrid propulsion for city buses and distribution trucks (≈15%).

84. The percentages between brackets are fuel consumption reduction values for new vehicles. For the current heavy duty vehicles that are used for international road freight transport, the overall reduction potential is about 20% per vehicle-kilometre. The potential reduction of an increased weight limit has not been counted yet. This could result in an additional reduction of up to 20%.

85. While pollutant emissions from heavy duty vehicles are regulated, CO_2 emissions are not. For passenger cars, fuel efficiency standards have been developed in various parts of the world. The tightest ones are currently developed in Europe. For heavy duty vehicles, only Japan has introduced CO_2 emission standards, aiming at a reduction of 12% of the average CO_2 emissions per vehicle-kilometres of heavy duty vehicles, between 2002 and 2015 (ECMT, 2007). The European Commission is investigating the costs of various technical options for improving the fuel-efficiency of heavy duty vehicles, which might be

followed by the development of some kind of fuel-efficiency standards for these vehicles as well. An important precondition for such a standard would be the development of a test-cycle for heavy duty vehicles or engines. This is probably more complicated than for passenger cars because of the larger variety in applications of heavy duty vehicles and a related larger bandwidth of vehicle weight, which is a key driver for fuel consumption.

5.2 Non-technical measures to improve the energy efficiency in road freight transport

86. Besides technical measures, also a number of non-technical measures can be implemented to reduce fuel consumption in passenger cars, vans and heavy duty vehicles. In the following subsection we list the main options, according to Smokers & Kampman (2006).

5.2.1 Eco-driving

87. The main elements of a fuel-efficient driving style (eco-driving) are:

- Maintaining a low engine rpm by early shifting to higher gear during acceleration and driving in the highest possible gear at more constant speeds. At a given power-demand, the engine load (torque) is higher when the engine is operated at low rpm. At higher loads, the engine's efficiency is better than under part-load conditions.

- Anticipative and smooth driving in order to avoid unnecessary (strong) accelerations and to reduce the unnecessary waste of kinetic energy by strong braking.

88. Depending on their initial driving style, drivers of passenger cars may save between 5 and 25% fuel directly after an eco-driving course. Smokers, *et al*. (2006) estimates, however, that the long-term average improvement for passenger cars is of the order of 3%. The potential may be improved by the use of a gear shift indicator or a fuel-economy meter.

89. Although the maximum reduction potential for lorries is smaller than for passenger cars, for this application the fuel consumption reduction potential of eco-driving is estimated to be 5%. The reason for this higher potential lies in the fact that professional drivers may be expected to better maintain an efficient driving style and that they may be expected to receive more intensive or more frequent training. The CO_2-abatement costs associated with eco-driving depend on the costs of lessons, the assumed effectiveness and the fuel price. Both for passenger cars and for lorries, the abatement costs are expected to be negative for most combinations of fuel price and costs of lessons (Smokers, *et al.*, 2006).

90. In the long term, the effectiveness of eco-driving is expected to decrease as many technical measures implemented to improve energy-efficiency of vehicles do this by improving the part-load efficiency of the engine.

5.2.2 Traffic measures

91. Various traffic measures can be implemented to smoothen traffic flow and reduce driving dynamics. Examples are synchronisation of traffic lights and lower speed limits on congested highways. These undoubtedly reduce fuel consumption and CO_2-emissions per vehicle kilometre. On the other hand, such measures also tend to improve the flow of traffic and to reduce congestion, which may result in increased traffic. This may counteract possible benefits per vehicle. Moreover, for international road transport, this type of measures is not expected to have large reduction potential, since international road transport mainly uses motorways.

5.2.3 *Improved logistics*

92. According to Pischinger *et al.* (1998), Pischinger & Hausbergerm (1998) and Bates *et al.* (2001), improved logistics could lead to a reduction in road freight kilometres resulting in 10 to 20% fuel consumption reduction based on the following measures:

- Improved logistic organisation.
- Better co-ordination between all transport operators (also intermodal).
- Improved route planning.

93. CO_2-avoidance costs are estimated to be negative, meaning that the cost of implementation of these measures is lower than the total cost savings. To get these type of measures implemented it is important to learn about the reasons why these measures are currently not applied. This generally has to do with various types of organisational reasons. It should also be noted that the resulting reduction of the overall cost of transport may in turn increase transport demand, which may (partly) counteract the absolute reduction in fuel consumption and CO_2-emissions.

94. The current vehicle utilisation on long-distance road freight transport (like in The Netherlands, see Section 4.3) leaves quite some room for improvement. The current vehicle utilisation is a trade-off between the direct costs vehicle kilometres and the various cost of optimizing logistical chains. The second include costs related to time-losses, lower flexibility, storage, which might increase when vehicles are used in a more efficient way. Therefore, optimizing logistics is not just a task for the transport sector, but it is also strongly related to governmental measures, in particular transport pricing.

5.3 Measures to improve the energy efficiency in rail freight transport

95. Diesel trains are responsible for only 0.5% of the EU-25 CO_2-emissions. Efficiency improvement for these vehicles therefore does not have a high policy priority. The efficiency of modern electric trains has improved greatly due to the use of power electronics and regenerative braking. The effects of this, however, are partly compensated by the increase in energy consumption because of increased speed. For electric trains further well-to-wheel efficiency improvements or CO_2-emission reductions are stimulated by the fact that electricity generation is part of the EU ETS emission trading system (Klooster & Kampman, 2006).

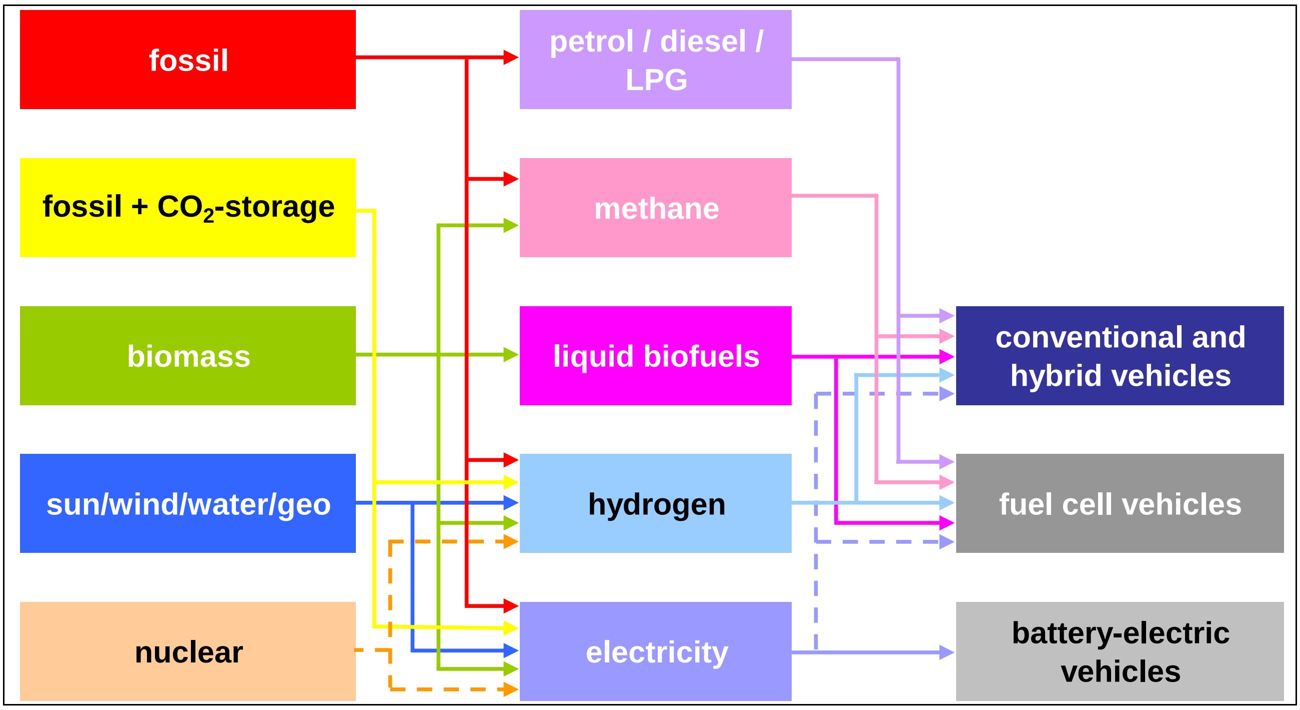
96. For further improving the energy-efficiency and reducing engine emissions of trains, there exists a range of technical measures (limited to measures that are relevant for freight trains):

- Non-engine based measures to increase energy efficiency (Nielsen *et al.*, 2005):
  5. Optimizing physical parameters: mass reduction, improved aerodynamics and decreasing friction.
  6. Regenerative braking with energy recovery.
  7. Energy-efficient driving, to optimize speed at all times during the journey, for instance reducing braking.
  8. Increasing the load factor.
- In-engine measures for diesel trains.

5.4 Biofuels and other alternative fuels

97. As mentioned in Section 2.1, oil is presently the dominant energy source for the transport sector, but in the long term, a multitude of energy chains could become available on the basis of fossil energy, various sustainable sources and nuclear power. This is illustrated in Figure 18.

Figure 18. Various routes from primary energy sources, via secondary energy carriers to final use of energy in vehicles with different propulsion systems



98. In the left hand column of Figure 18, the range of available primary energy sources is presented. The centre column shows the various categories of secondary energy carriers, into which the primary energy sources can be converted, for distribution to final energy-use applications. Energy carriers include traditional fuels (petrol, diesel and LPG, from refining of oil or synthetically produced from gas or coal), various fossil and renewable alternative fuels (*e.g.* natural gas, biogas, bioethanol, biodiesel, biomass-to-liquids (BTL) and hydrogen), as well as electricity. On-board of vehicles, these energy carriers are converted into propulsion-energy, using various power train technologies. These are displayed in the right-hand column of Figure 18.

99. It is clear from this graph that an advantage of hydrogen and electricity is that both can be produced from all possible primary sources. Similarly internal combustion engine based power trains (conventional as well as hybrid) and fuel cell power trains can be fed with all possible fuels, whereby hybrid configurations are also able to (partly) use electricity.

5.4.1 Alternative fossil fuels

100. Liquefied Petroleum Gas (LPG) and, especially, Compressed Natural Gas (CNG) are presented as clean fossil alternatives for petrol and diesel. By the application of 3-way catalysts and tightening of emission limits, the air-quality-related advantages of LPG and CNG vehicles compared to petrol have been greatly reduced (Hendriksen, *et al.* 2003). CO_2 emissions of LPG vehicles are in between those of petrol and diesel vehicles. The well-to-wheel greenhouse gas emissions of CNG vehicles are some 20% lower than those of petrol vehicles and as such comparable to those of diesel vehicles. The CO_2 benefit of CNG, however, is strongly affected by the origin of the natural gas and the associated transport distances.

101. For example, as Europe by now is a net importer of natural gas, it may be assumed that the additional demand for natural gas from future vehicles on CNG is met by imports from Russia, the Middle East and south-west Asian countries. Data from Concawe (2006) and Smokers, *et al.* (2006) show that

while Natural-Gas Vehicles on average EU-mix natural gas have 23% lower well-to-wheel greenhouse gas emissions, this benefit reduces to 17% resp. 8% when imported gas is used that is transported over a distance of 4,000 resp. 7,000 km. The role of LPG and CNG in the context of a CO_2 policy for the transport sector will therefore be limited in Europe.

102. CNG could play a role in various transition paths towards the use of biogas and hydrogen, but in this context an investment in a CNG distribution infrastructure for transport probably only makes sense if it is part of a more integral, regional approach to promote the use of natural gas, biogas or hydrogen.

103. The same can be said for LNG and for new alternatives such as DME (dimethyl ether) and synthetic diesel derived from natural gas (GTL: Gas-To-Liquid) or coal (CTL: Coal-To-Liquid). GTL and CTL allow the production of high value (premium) transport fuels from other fossil sources. This is economically attractive on the one hand because remote sources of especially natural gas can be exploited and on the other hand because blending of synthetic components into diesel enables further improvements in fuel quality which are necessary to improve the efficiency and emissions of modern combustion engines.

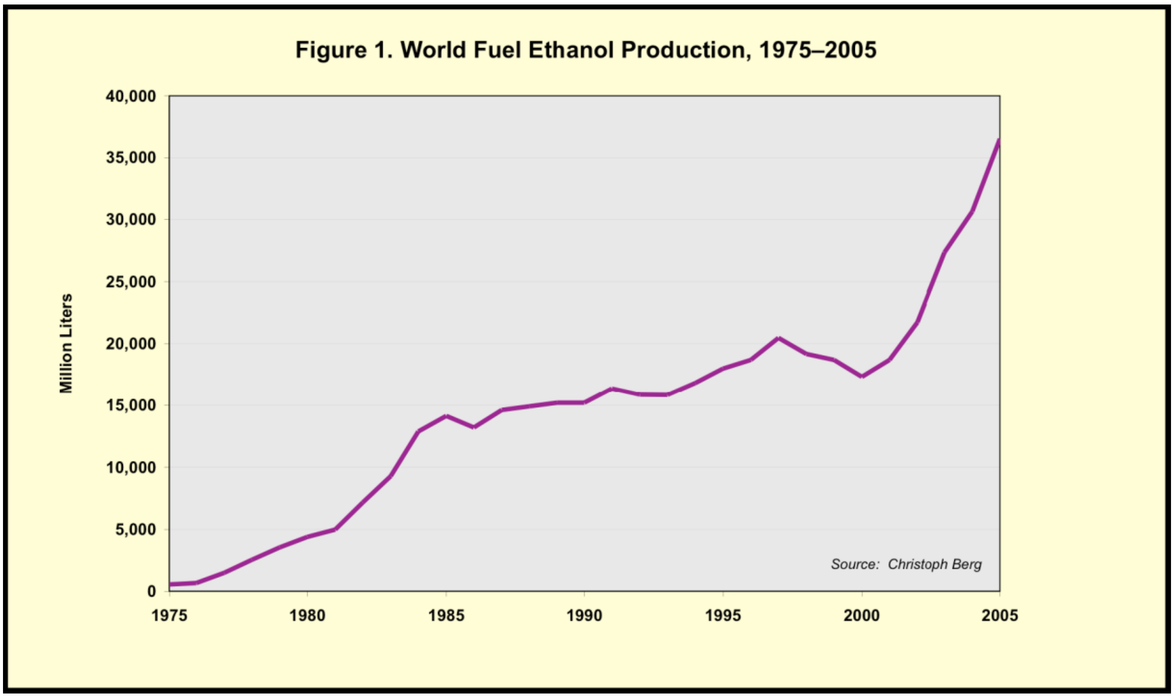
5.4.2 Biofuels

104. Production and use of biofuels are increasing strongly in recent years, both in the EU and globally. The current biofuels industry is composed of two main sectors: biodiesel and bioethanol. Globally, bioethanol production exceeds biodiesel production by a factor 10, as can be seen in Figure 19 and Figure 20. In the EU, this ratio is reverse, with biodiesel production being 10 times higher than bioethanol production. This has to do with government policies of various member states, the rapeseed production potential of the EU (rapeseed oil is one of the main raw materials that can be converted to biodiesel) and the relatively high share of diesel in EU fuel sales. In 2005, 3.9 million tones of biofuel were produced in the European Union, marking a 65.8% growth compared to 2004. Production of bioethanol is much lower in the EU, but also increased significantly, by 70.5% between 2004 and 2005.

105. Biofuels have the advantage that the CO_2 that is emitted during combustion is equal to the CO_2 that is taken up by the biomass during cultivation. However, they still contribute to climate change because of greenhouse gas emissions during cultivation of the biomass (N_2O emissions mainly, due to fertilizer use), transport and production of the biofuel.

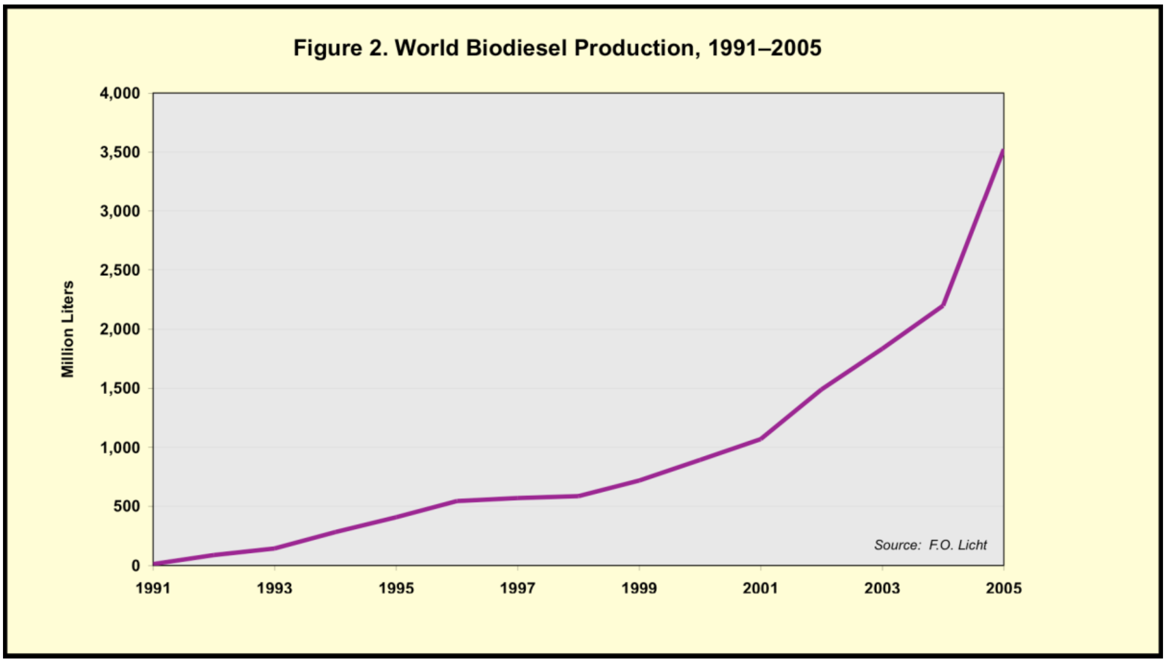
106. Compared to fossil diesel and petrol, Figures for the European Union show that current biofuels (biodiesel and bioethanol) achieve, on average, well-to-wheel greenhouse gas reduction percentages between 30 and 60% (Concawe, 2006). However, new biofuels processes are currently under development, that are expected to achieve a greenhouse gas reduction of 80-90%. In the coming years, these new biofuels, often called second-generation biofuels, will have to be developed further.

Figure 19. Development of global fuel ethanol production, 1975-2005



Source: WWI, 2006.

Figure 20. Development of global biodiesel production, 1991-2005



Source: WWI, 2006.

107. Even though biofuels have a greenhouse gas emission advantage, they also have some negative effects. First of all, the cost of most biofuels is higher than that of fossil fuels. The only exception is bioethanol from Brazil, that started stimulating the use of this fuel in the 1970s. Likewise, costs from

European biofuels may come down in the future due to learning effects. However, costs will also depend on demand and supply.

108. Secondly, concerns about the potential negative effect of biofuels on biodiversity are growing. The substantial rise of the demand for biomass from both the biofuel and bioenergy sector puts additional pressure on farmland and forest biodiversity, as well as on soil and water resources. It may also counteract other current and potential environmental policies and objectives, such as waste minimisation or environmentally oriented farming (EEA, 2006b). EEA (2006b) also concludes that significant amounts of biomass can technically be available to support ambitious renewable energy targets, even if strict environmental constraints are applied. However, it also concludes that environmental guidelines need to become an integral part of planning processes at the local, national and EU level. Other studies confirm that the biofuel potential is certainly not unlimited, due to constraints regarding biodiversity, food production, water availability, etc. (see *e.g.* WWI (2006)).

5.4.3 Long-term options: hydrogen and electricity

109. In the long term, also hydrogen and electricity can be envisaged to play a role in the energy supply of the transport sector. It should be noted here that both are *energy carriers* and not *energy sources*. As such, the well-to-wheel efficiency and CO_2-emissions depend on the primary source and conversion processes that are used to produce hydrogen and electricity. With the present EU-mix for electricity generation, application of electricity in transport may already now have well-to-wheel efficiency benefits. For hydrogen this is only the case if it is produced from renewable sources (see *e.g.* (Concawe, 2006)).

110. By many authors, visions are presented of a 'hydrogen economy' that will solve all our future energy problems. It is, however, highly questionable whether distribution of energy in the form of hydrogen is the most optimal solution from a system point-of-view. Possibly a more limited role for the production of hydrogen as a buffer to match demand patterns with the supply patterns of renewable energy in the context of an 'all electric society' is more appropriate.

Box 3. A system-efficiency perspective

The example of hydrogen shows that in some cases measures to improve the energy-efficiency of the transport sector should not just be reviewed at the level of a vehicle-to-vehicle comparison, or a Well-to-Wheel comparison, but that a system approach is necessary, in which the relation of a given energy source with other applications outside the transport sector is taken into account, and in which the overall target is optimisation of system efficiency rather than optimisation of the efficiency of transport. Already now, the efficiency of *e.g.* refineries is closely linked to processes in other sectors through the use of process-energies and the generation of by-products. This will probably be even more the case for future fuel production systems. An interesting example already is the Fischer-Tropsch process for production of synthetic fuels, of which the overall system efficiency and well-to-wheel CO_2-emissions are strongly dependent on the weather and where the electricity, that can be generated as a by-product, is used.

5.5 Volume reduction and modal shift

111. The trends in the environmental performance of transport, including those for international road and rail freight transport, are strongly driven by the growth of transport volume. Limiting the expected growth of transport volume can be an important way in reducing the environmental impacts of transport. For limiting the growth of CO_2 emissions from freight transport, the available technical options seem not able to compensate for the expected growth in transport volume. Therefore, an effective mix of measures for limiting transports' contribution to climate change includes measures that curb transport demand growth.

112. In specific cases, measures aiming at a shift of transport volumes to the most efficient modes of transport can be an effective approach. However, the net impacts of modal shift measures depend a lot on the type of measure and on the logistical and environmental performances of the various transport modes involved in that particular situation.

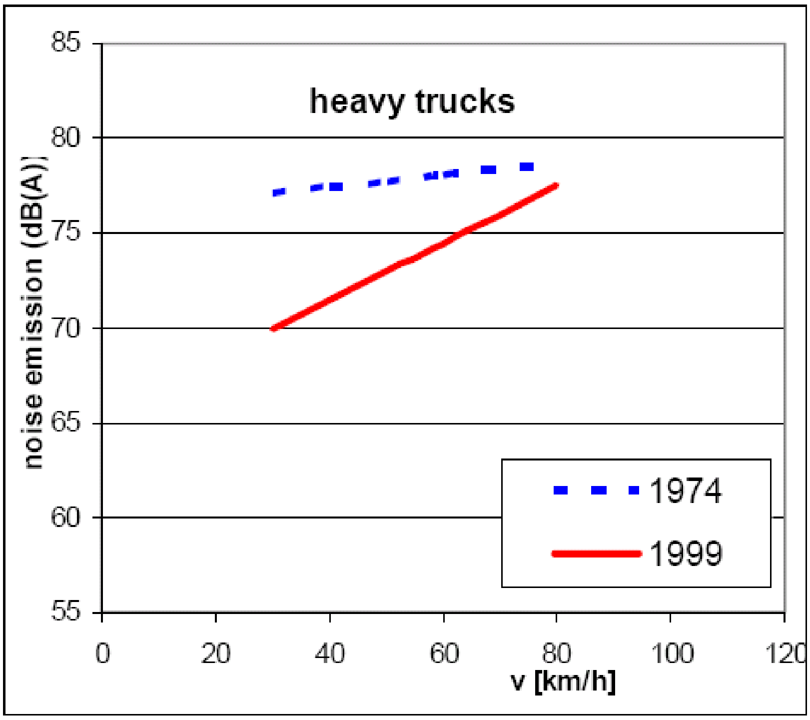
113. In addition, specific measures aimed at modal shift, like building new rail infrastructure, may boost the transport volume of rail without decreasing road transport volumes. In those cases, the net effect is higher transport volume and higher total emissions (Van Essen *et al.*, 2003). Therefore, measures that try to reduce the environmental impacts of transport by forcing modal shift should always be assessed on their environmental impacts, rather than on their impacts on the modal split as such.

5.6 Options for reducing noise emissions

114. There are essentially two routes to noise abatement (Den Boer & Schroten, 2007). Firstly, noise emissions can be reduced at their source, through measures relating to vehicles/drivelines, tyres, road surfaces and traffic management. Secondly, noise can be abated by reducing the exposure of people by means of anti-propagation or insulation measures (by increasing the distance between source and recipient, for example, or hampering noise propagation by insulating buildings or constructing noise barriers).

115. In Europe, the USA, Japan and Australia noise limits apply to road vehicles. Of these various limits the European limits are relatively the most stringent ones (Close, 2001). Within the European Union, noise type approval limits are in force since 1970. However, despite these limits, since then there has been no tangible reduction of noise emissions under real driving conditions for passenger cars and only a 2-4 dB(A) reduction for heavy duty vehicles (Den Boer & Schroten, 2007). Figure 21 shows the difference between the noise level of heavy duty vehicle in 1974 and 1999 for various speeds.

Figure 21 Noise level of Heavy Duty Vehicles in 1974 and 1999 for various speeds



Source: (Blokland, 2004).

116. There is plenty of scope for reducing ambient noise levels by at least 3-4 dB(A) in the short term using currently available technology. The most cost-effective measures are those addressing the noise at-source (Den Boer & Schroten, 2007). This includes noise from the engine, exhaust, mechanical systems and contact between tyres and road, or wheels and track. The associated costs are generally limited, for vehicles and tyres at least. There are signs that use of composite brake blocks on rail wagons also comes at a modest cost.

7. Conclusions

117. The most important environmental impacts from the transport sector are caused by emissions of air pollutants, CO_2 and noise. International road and rail freight transport are responsible for a minor, but increasing, share of these transport emissions.

118. The contribution to air pollution is decreasing in most parts of the world, mainly due to various vehicle emission standards that have been implemented all over the world and are periodically tightened. Only in those parts of the world that have an extremely high growth in transport volumes, the overall emissions of air pollutants may not yet decrease.

119. Noise is an important environmental problem which, just like air pollution, has severe health impacts causing high numbers of deaths each year. There are various measures that could be taken to reduce the contribution of freight traffic to ambient noise levels. The most cost-effective measures are those addressing the noise at-source.

120. The CO_2 emissions of international road freight transport are increasing all over the world, and there is not yet a sign that this trend is to be curbed soon. For this challenging problem, there is no single cure available. A mix of measures, like improving fuel efficiency of vehicles, alternative fuels and logistical improvements, is needed.

121. An effective policy for reducing the environmental impact of international road and rail transport should aim at improving the environmental performance of all modes of transport as well as ensuring a level playing field for the various modes. Regulation, infrastructure measures and pricing measures that take into account the environmental costs can contribute to this.

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