Air Quality Plan for Berlin 2011-2017
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Preface

Clean air is quality of life! Yet, in all metropolitan areas, keeping the air clean is a major challenge – also in our city. Various measures of the Air Quality Plan 2005-2010 have already been successful in significantly improving Berlin’s air in recent years. Foremost the environmental zone and the promotion of environmentally friendly means of transportation have led to a considerable reduction of the air pollution in Berlin. However, despite of these successful steps, the regulatory limit values for nitrogen dioxide and particulate matter continue to be exceeded along Berlin’s main traffic routes.

That’s why we have developed this new Air Quality Plan. It covers the period from 2011 to 2017. It is our aim that in the long term the regulatory limit values will be met in whole Berlin. In the next few years we will not succeed everywhere in the city, but we can minimise the number, duration and intensity of the exceedances to the extent possible. After all, air pollution reduced by just one microgram is a contribution to protecting the health of all Berliners.

The measures focus on reducing pollutant emissions, i.e. we specifically target the sources of pollution. More than ever, measures are required in all areas today: Even if the focus continues to be on road traffic as the biggest source, increasing measures are planned at construction sites, in the supply of heat, in the industry and business sector. For this purpose, Berlin intends to use new technical possibilities, such as retrofitting of construction machines with particle filters. This is currently being tested in a pilot project. As an example for controlling emissions of nitrogen oxides, public busses have been retrofitted with a new exhaust gas cleaning system starting already end of 2013. However, a sustainable clean air policy comprises of more than just technical measures. Especially in road traffic, the Air Quality Plan also focuses on an optimised routing of traffic, promotion of alternative environmentally friendly means of transportation such as public transport, pedestrian and bicycle traffic, while it also aims at avoiding traffic by preserving and creating compact, traffic-reducing city structures, in order to keep travel distances short. Maintaining the air clean will furthermore be rooted more firmly as an interdisciplinary task of city development and urban planning. The clean air policy will from now on be supported more strongly through subsidies provided by the European Regional Fund, which are to be utilised for clean air measures in combination with climate protection.

Even if all effective measures that are compatible with the city are implemented in Berlin: on our own, we will not be able to solve the problem of increased air contamination. This is so because air pollution does not stop at the city boundaries. Especially particulate matter is transported over large distances, so that meeting the limit values can only succeed with a large-scale reduction of air pollutants at the European and national levels. For this purpose, the European Union and the Federal Government need to create suitable framework conditions – reaching from stricter emissions standards to funding programmes for a swift introduction of new technologies.

I will support this in the Council of Federal States and by making use of direct contacts with the Federal Government and the European Commission. We can only get better air if all of us contribute to it. This can be done for example, in that we use the bike or go on foot more often instead of using our car. Quite often, this saves time and money. Moreover, the physical exercise also promotes our health. It is also helpful when we sometimes do not light the fireplace even if it comforts us. When we need a new vehicle or if a new heater has to be purchased, we should choose the model with the lowest emissions. Perhaps also an older system, vehicle or construction machine can be retrofitted to avoid pollutants. So, please everyone participate! Contribute to the further improvement of the air in our city. All of us profit from it – our health, quality of life and the attractiveness of our city.

Andreas Geisel
Senator for Urban Development and the Environment
Executive summary

The Air Quality Plan 2011-2017 revises and updates the previous 2005-2010 Clean Air and Action Plan for Berlin. It includes a package of measures developed based on a reassessment of the air quality and trend forecasts for the years 2015 and 2020 and a causal analysis of high air pollution levels. The package not only encompasses various existing measures, but also new concepts for reducing exhaust emissions and improving the air quality.

The air quality in Berlin has improved significantly due to numerous measures taken in recent years. Many of the ambitious EU air quality limit values are already being met reliably. This includes the air pollutants sulphur dioxide, benzol, carbon monoxide, and the very small particles (PM$_{2.5}$) and heavy metals in particulate matter whose concentrations are well below the limit values.

In order to be able to achieve the limit values for particulate matter (PM$_{10}$) and nitrogen dioxide over busy roads, however, further measures are necessary. Due to the Low Emission Zone, the concentration of these pollutants over inner city roads has decreased much faster than elsewhere in the city. Nonetheless, a number of residents near main roads are still exposed to higher air pollution levels from particulate matter and nitrogen dioxide than inhabitants of remote residential areas where the limit values are generally met. Especially when climatic conditions are unfavourable with poor dilution of the locally emitted pollutants and high inputs of pollutants from outside the city, the limit values for particulate matter (PM$_{10}$) and nitrogen dioxide (NO$_2$) are exceeded on main roads, resulting in a health risk for the people living there.

Road transport is still the most important local source of pollution in in Berlin, particularly with regard to nitrogen dioxide pollution. The Senate of Berlin will thus continue its successful policy of reducing the levels of pollutants from transport by increasing the use of clean vehicle technology, types of motor and fuels. These measures are complemented by a sustainable transport policy that is based on the Urban Development Plan on Transport and envisages transport avoidance, a re-balancing of transport modes in favour of the most environmentally friendly modes, and optimized traffic management. The aim is to integrate the mobility requirements of a growing metropolis with a healthy and sustainably managed environment. Thus, in order to further reduce transport-induced emissions, most of the measures in this plan address the transport sector.

In this context, emphasis is placed on measures for reducing nitrogen dioxide pollution. While the release of nitrogen oxides has been reduced in recent years through the modernization of the vehicle fleet, it has not been achieved to the extent anticipated. One main reason for this is shortcomings in the definition of EU standards for car exhaust emissions. As a result, the actual reduction of exhaust emissions under normal inner city driving conditions was largely non-existent. In addition, the relative share of nitrogen dioxide in waste gas generally increased, particularly for modern diesel cars.

Therefore, the aim of meeting the EU annual limit value for nitrogen dioxide by 2010 was not achieved despite the introduction of the Low Emission Zone and successful traffic planning. Nearly every larger city in Europe faced the same problem. Along with 56 other areas and agglomeration zones in Germany, Berlin found itself forced to notify the European Commission in October 2011, that it had to make use of the option to extend the compliance deadline until 2015, as provided for in the air quality directive. The postponement of the compliance deadline is subject to the provision of evidence that all available and pro-
portionate measures have already been taken and that they will be complemented by additional measures to meet the limit value by the extended deadline. Berlin meets these conditions, for instance by successfully implementing the Low Emission Zone and the package of additional measures aimed at significantly reducing the nitrogen dioxide pollution as presented in this Clean Air Plan.

The same applies to the concentration of particulate matter (PM$_{10}$), although it is not yet clear that the aim of a permanent and comprehensive compliance with the daily limit value will be met. This is due to the widespread pollution of particulate matter, which, in contrast to Berlin’s contributions, has only declined slightly. This will be shown in further detail below. The massive trans-boundary transport of fine dust particles alone, which are emitted by industrial plants and domestic heating in neighbouring Eastern European Countries, has resulted in numerous exceedances of the daily limit value for particulate matter. In the last few years the number of exceedance days permitted was thus exceeded again, after successfully remaining below the threshold in 2007 and 2008. This countervailing effect, which is enhanced by frequent easterly wind weather conditions, could not be fully compensated for by the Low Emission Zone.

The reduction of traffic-induced particulate matter that has already been achieved emphasises the importance of addressing other sources to tackle the pollution of particulate matter in Berlin. This includes wood and coal combustion in fireplaces and stoves as well as emissions resulting from the use of construction machines. In addition, future trends need to be taken into account with a view to potential impacts on air quality. It is not foreseeable yet whether the trend in de-centralized electricity production through mini co-generation units will result in higher emissions, as the exhaust gas standards applied to these facilities are still less stringent than those applied to larger power plants. These aspects were taken into consideration when developing the present package of measures.

The primary objective of the air quality directive and this medium-term clean air planning is to permanently fall below the air quality limit values of particulate matter (PM$_{10}$) and nitrogen dioxide by 2011 and 2015 at the latest. However, an assessment of the impact of the planned measures has shown that the sole implementation of the proportionate and source-related measures available at the local level in Berlin alone is not sufficient to ensure compliance with limit values at all locations within the deadline. As ruled by the European Court of Justice, it is necessary in these cases to reduce at least the extent and duration of the limit value exceedances as much as possible. In choosing measures for reducing the pollution of particulate matter, the additional effect of dust components particularly damaging to health, such as ultrafine particles from combustion engines, has to be taken into account. The present package of measures takes account of this requirement and includes a mixture of measures targeting the enhanced use of exhaust gas reduction technologies and environmentally oriented city and transport planning.

In addition to the measures taken at the local level in Berlin, initiatives for improving exhaust gas standards and for quickly introducing modern and emission-reducing technologies are necessary at the federal and European level.

To reduce trans-boundary air pollution, the EU Directive on National Emissions Ceilings has to be updated and supplemented by a cap for the total emissions of fine particles in every EU member state. Moreover, Berlin, Brandenburg, and other states concerned will urge the Federal Government to follow up and intensify the dialogue with the eastern European neighbouring countries on the implementation of additional measures for reducing the pollution of particulate matter. The Federal State of Berlin will support the regions and municipalities concerned in the process of implementing effective reduction measures.

The most important results of the Air Quality Plan are summarised in the following.
1. Air quality in Berlin between 2005 and 2010

This assessment of air quality is based on the evaluation of data from the air quality measurement network of Berlin [Berliner Luftgütemessnetz] from 2005 to 2010, and on simulations of the air pollution in urban residential areas on main roads by statistical models. The methods for evaluating the air quality and their results are outlined in the main part of Chapter 3.

Nitrogen dioxide

The limit value for the annual mean of nitrogen dioxide was exceeded every year and at every traffic station with values of 42 to 69 micrograms per cubic (µg/m³). The highest pollution levels occurred at the station Hardenbergplatz due to the high contribution from bus traffic. In 2009, approximately 48,000 residents were affected by limit value exceedances along 58 km of main roads. Despite unfavourable conditions for dispersion and a general increase in the background pollution in residential areas at the city periphery, a slight decline of 1 to 2 µg/m³ was achieved on roads. This is partly a result of the introduction of Stage 2 of the Low Emission Zone (LEZ) in 2010.

The short-term limit value (not more than 18 hourly measured values above 200 µg/m³ per year) was met continuously at all stations.

Particulate matter

Between 2005 and 2010, the average annual pollution was below the relevant limit value of 40 µg/m³ at all measuring points. However, the daily limit value – with 35 days permitted per year with mean values above 50 µg/m³ – was not achieved in all years. Pollution levels were particularly high at traffic-side measuring points with 42 to 74 exceedance days in 2005, with 48 to 71 exceedance days in 2006 and with 36 to 56 exceedance days in 2010. In 2009, exceedances occurred on 39 days at Frankfurter Allee station and on 73 days at Mariendorfer Damm station. At Mariendorfer Damm, exceedances were caused by construction work close to the station on 44 days. Among the stations in the inner city background, the station Nansenstraße in Neukölln exceeded the daily limit value with 37 exceedance days in 2006 and 39 exceedance days in 2010. Due to construction works, 59 exceedance days were observed at the station in Mitte close to Jannowitzbrücke in 2006. In 2006 and 2010, up to 27 and 28 exceedance days were recorded at the city periphery, respectively, meaning that on those days air pollution exceeded the threshold of 50 µg/m³ even outside of Berlin.

The daily limit value for particulate matter was not met each year despite several measures taken in Berlin, such as the introduction of the Low Emission Zone (LEZ) in 2008, filter retrofitting of public transport vehicles, or reducing traffic volumes. However, the number of additional exceedance days occurring on roads additional to the urban background decreased from 43 and 33 additional days in 2005 and 2006, respectively, to 19 additional days in 2009 and 15 additional days in 2010. This shows that the additional air pollution on roads, mainly caused by traffic, and consequently the extent of limit value exceedances, was reduced. Meteorologically, 2010 was the most unfavourable year for air quality, with very bad conditions for dispersal, high background pollution, and increased demand for heating as a result of an extremely cold winter. Yet, without the locally achieved reductions of air pollutants, air pollution levels would have been higher in 2010.

Model calculations of the air pollution for the entire network of main roads totalling around 1,600 km show that in 2009 approximately 64,300 residents on 79 km of main roads were exposed to deleterious pollution of particulate matter above the limit value.

2. Most important sources of air pollution in Berlin in 2009

On the basis of statistics regarding the activities causing pollutants, the total emission of the released pollutants in Berlin was calculated for each source group (such as traffic, domestic heating, industry and commerce). The calculations were made for 2009, as the re-
required input data such as quantity of fuel, number of installations, furnaces, motor vehicles and driven vehicle kilometres were entirely available for this period from the latest official road traffic census. The determination of the emission of pollutants and all other findings are to be found in Chapter 4.

Nitrogen oxides
The emission of nitrogen oxides in the urban area declined by around 15 % from 2002 to 2009. The main source is emissions from road traffic, contributing 39 %. Further significant sources of pollution are power plants and industrial combustion systems with a 34 % share and domestic heating with a 14 % share.

Particulate matter (PM$_{10}$)
Particulate matter originates from multiple sources, such as large and small combustion plants, industrial processes, construction sites, internal combustion engines, abrasion of tires, brakes or tracks, and the re-suspension of road dust by vehicles. Apart from anthropogenic sources, natural sources such as wind re-suspension or pollen also contribute to particulate matter emission. In addition, particles are released into the atmosphere due to the conversion of gases, such as sulphates from sulphur dioxide and nitrates from nitrogen oxides. The emission of the gaseous precursors will be considered within the scope of the source analysis.

With a share of 21 %, the largest contribution of emissions in Berlin arises from abrasion and re-suspension processes of the road traffic. Contrary to diesel soot, these are primarily coarse particles with diameters of more than 2.5 µm, which are breathed less deeply into the lungs. Much smaller and thus more harmful are the particles originating from motor vehicle exhaust gases, although their 7 % share regarding the total output of particulate matter is relatively low. In total, road traffic attains a 28 % share of the total particulate matter emission. Further important sources are the combustion of wood with a 12 % share of total emission, mobile machinery, such as construction machines, with a share of about 4 %, and also diffuse dust emissions from construction sites with a share of around 10 %. However, these data are partly subject to considerable uncertainties, as the emissions emerging from these sources have so far only been gathered and calculated in an incomplete manner.

The emission of particulate matter from all sources in Berlin decreased by around 25 % between 2002 and 2009. In the same period, the emissions from motor vehicle exhausts decreased by 43 % from 394 t/a to 225 t/a by 2009, due to, amongst other things, the introduction of stage 1 of the low emission zone. The reduction in emissions from stage 2 of the low emission zone by a further 40 % took effect only in 2010 and was thus not taken into account.

3. Apportionment of source groups in 2009
The proportion of an individual source group of the total air pollutant emissions in Berlin cannot be equated to the percentage contribution to the air pollution that is measured at one of the air quality monitoring stations. In order to determine the contributions from individual sources or source groups to air pollution, it is necessary to take into account the conditions for dispersion, i.e. the dilution of the emitted air pollutants between the source and the monitoring site, as well as atmospheric transformation and removal processes.

Emissions from high stacks contribute much less to local pollution than ground-based emitting sources such as motor vehicle traffic. As a rough estimate, emissions from high stacks of power plants are diluted by a factor of 1,000 before reaching the considered street canyon; emissions from smaller operations and domestic heating systems with lower chimneys are diluted 50 times more than pollutants from road traffic on these sites.
In addition, the figures mentioned above only take into account the sources in Berlin. Since particulate matter, in particular, is transported over long distances by air-flow, sources outside Berlin also contribute to air pollution in the city area.

The share of source groups was calculated by means of mathematical models for 2009. These included the large-scale air pollution. On the other hand, air quality monitoring data were evaluated together with meteorological data. The processes and their results are outlined in Chapter 5.

**Nitrogen dioxide (NO₂)**

With regard to the exceedance of the NO₂ annual limit value, road traffic is by far the most important source of pollution with a share of 78%. Other sources are secondary.

**Particulate matter PM₁₀**

Around 36% of the particulate matter pollution on main roads is caused by sources located in Berlin. Of these sources, motor vehicle traffic still accounts for the largest share of pollution by far. In total, 27% of the total particulate matter pollution is derived from motor vehicle traffic (sum of additional local contribution from traffic on the considered roads and the contribution of the remaining urban road traffic). Compared with 2002, when road traffic in Berlin accounted for 42%, traffic-induced air pollution was reduced significantly. By now, the proportion of pollution caused by abrasion and re-suspension is dominant, for which hardly any effective abatement techniques are known. Of the 36% contribution of Berlin sources, 74% are caused by road traffic. The greatest potential for reducing emissions thus lies in the reduction of road traffic, the consolidation of traffic flows and the lowering of speeds.

Emissions from heating systems only account for approximately 1% of particulate matter pollution. Industrial plants cause less than 0.5% of the pollution from particulate matter on typical main roads, but locally, they may cause considerable increases in the pollution levels near industrial parks. Around 7% of particulate matter pollution derives from so-called “other sources”. This includes construction work, construction machines, abrasion from mobile machines, and other transport and re-suspension from wind and other activities, as well as the combustion of wood in chimneys, which has shown a growing trend in recent years.

The import of particulate matter from regional, national and Europe-wide sources caused around 64% of the particulate matter pollution in 2009. The relative influence of Berlin sources has thus decreased in recent years, especially due to the achieved reduction of emissions in the transport sector. In 2002, the contribution of Berlin sources specified by model calculations was about 50%.

To determine the reasons for the PM₁₀ short-term limit value exceedances, the measured air quality values in Berlin were analysed in relation to the prevailing weather conditions and the wide-scale air pollution, or in the context of temporary local sources such as construction works.

Increased concentrations of particulate matter from construction works were identified by means of examining the typical time periods with temporarily very high concentration peaks. In 2009, 44 exceedance days at the Mariendorfer Damm station were attributed to the influence of construction works. During this time, a large construction side (demolition and new construction of a multi-storey building) was located adjacent to the monitoring station. Despite introducing measures to minimise the emissions, the influence of the construction site was substantial.

Increased daily mean values due to the influence of long-distance transport mainly occur in situations with low winds, south-east winds and low temperatures. Air masses for the
most part originate in the eastern neighbouring countries and carry along an increased load of pollutants. Added to this are local emissions, e.g. from domestic fuel.

The proportion of exceedance days deriving from the considerable influence of long-distance transport of particulate matter over the German-Polish border reached up to 33 % or 18 days at traffic sites in 2006, and up to 54 % or 26 days in 2010. In the absence of increased pollution levels from long-distance transport, the PM$_{10}$ short-term limit value would also have been achieved in Berlin in 2009 and 2010. This may be claimed when establishing the reasons for the exceedance before the European Commission. It does not however exempt Member States from the obligation to take local measures to limit pollution from particulate matter.


Based on the Clean Air and Action Plan for Berlin 2005-2010, multiple measures were implemented. The objective of all measures was to reduce the emission of pollutants. Between 2002 and 2009, the measures adopted, combined with the nationwide implementation of different legal exhaust emission regulations (for instance the emission standard EURO 5 for motor vehicles) and nationwide policies (such as the promotion of particulate filters for motor vehicles), resulted in a decrease in particulate matter emission by 25 % and by 15 % in nitrogen oxide emission.

Whether this results in a decrease of the concentration of the atmospheric pollution strongly depends on the specific weather-related dilution conditions, and, for particulate matter (PM$_{10}$) especially, on the pre-pollution of the air outside of Berlin each year. It is certain, however, that lower emissions of pollutants are an indispensable contribution to reducing air pollution. Fewer pollutants under otherwise identical conditions can also lead to lower concentrations in the air. Conversely, the pollutant concentration can also increase with the exhaust being consistent when worse meteorological conditions impede the dilution of the pollutants. An increase in air pollution from year to year thus does not imply that a measure that verifiably led to a reduction in the emission of pollutants was ineffective. Instead, without this reduction, the pollutant concentration in the atmosphere would have been accordingly higher under unfavourable conditions. When evaluating the measures with regard to their effect on the air quality, this definitely has to be considered. A short description of the measures will be found in Chapter 6 of the principal report.

The central measure of the Clean Air and Action Plan was the introduction of the LEZ, which took place in two stages. On the basis of detailed technical data of the vehicle fleet running inside the low emission zone, it was possible to calculate that due to stage 2 of the low emission zone (green sticker), the emission of diesel soot was reduced by 173 t per year compared with the anticipated trend development without the low emission zone, and the emission of nitrogen oxides decreased by 1,517 t per year. This is a decrease of 58 % in diesel soot emission and 20 % in nitrogen oxide emission from motor vehicle traffic. Without this reduction in the emission of pollutants, the mean particulate matter pollution in 2010 would have been higher by 7 %, and around 10 additional exceedances would have occurred. The nitrogen oxide concentration would have been higher by about 5 % on average, which corresponds to 2 µg/m$^3$.

Moreover, it was possible to attain considerable reductions in the emission of pollutants by retrofitting BVG’s public service buses with particulate filters and by the increased procurement of modern buses. Compared to the 2004 bus fleet, the present fleet emits around 22 t per year or 90 % less diesel soot and 441 t per year or 50 % less nitrogen oxides. The high degree of filter equipment of almost 95 % meant that measurements at the Hardenbergplatz monitoring station had the lowest particulate matter concentrations out of all traffic stations despite the location’s high share of buses in traffic. However, the reductions in nitrogen oxides is not yet sufficient, since the nitrogen oxide concentrations at Harden-
bergplatz still show higher values than other stations. In this respect, further measures such as the retrofitting of buses with systems intended to reduce nitrogen oxides are necessary.

A goal equally important to the implementation of modern low-emission vehicle technologies, as with the low emission zone, is to seek those reductions in emissions that are attained by shifting from motorised traffic to ecological means of transport (the "ecomodes", i.e. local public transport, cycling and walking) and by measures with regard to traffic control and management. From 2002 to 2010, motor vehicle traffic in Berlin decreased by 10 to 14 % on most main roads. Thus, it not only reduced the exhaust of diesel soot and nitrogen oxides from motor vehicle exhausts, but also the release of particles due to tyre debris and dust re-suspension.

On highly polluted road sections, locally effective measures were implemented and tested. The traffic ban for trucks on Silbersteinstraße led to a reduction in air pollution of about 10 %. Due to the order and control of a 30 km/h speed limit on Schildhornstraße, the incremental local pollution caused by motor vehicle traffic declined by about 30 % for particulate matter and 15 % for nitrogen oxides. This is a reduction of the total pollution on Schildhornstraße by approximately 5 to 10 %. On Leipziger Straße, which is one of the most polluted roads in Berlin, several concepts intended to stabilise the traffic flow and the speed limit of 30 km/h and its effect by means of complex measurements and model calculations within the project IQMobility were tested for several months. The evaluated reduction in the emission of pollutants on this road section, being partly overburdened due to a high traffic volume and further constrained due to a construction site on another road, was around 3 to 10 %.

Passenger ships are not subject to the low emission zone regulation, but they can cause considerable pollution due to diesel exhaust locally on waterways. As a successfully implemented pilot project has shown, retrofitting with particulate filters can reduce the diesel soot exhaust of the engines by more than 90 %.

Within two projects, intensified street cleaning as a potential measure for the reduction of the particulate matter pollution due to the re-suspension of particles in road traffic was tested. This was intended to reduce the amount of dust on the road surface. However, no significant reduction of the particulate matter concentration was measured. Thus the measure has not been pursued any longer.

5. Forecast of future air quality in 2020 without additional measures

In order to develop an Air Quality Plan, it is first necessary to know about the future trends in air quality if no additional measures are taken. Based thereon, the necessary extent of further measures that are proportionate, effective and take into account the source of pollution can be determined. The years under consideration are 2015 and 2020 as a longer-term perspective. 2015 is the year by which the limit value for nitrogen dioxide has to be met even in the case of postponing the compliance deadline. The bases and results of these forecasts are outlined in detail in Chapter 7.

Nitrogen dioxide

Nitrogen oxide emissions will be approximately 11 % lower in 2015 and approximately 30 % lower in 2020 than in 2009. The largest source group related decrease is expected in motor vehicle traffic at 22 % and 45 %. It was assumed thereby that all planned measures will be implemented or that no additional measures will be taken (trend scenario).

The limit value for the annual mean of 40 µg/m³ will not be met in 2015 on almost 13 km of main roads – despite the reduction of air pollutant emissions achieved in Berlin and Europe-wide. This would affect 11,400 residents. Only by 2020 will the reduction of the air pollutant emissions from the forecasted high share of vehicles with Euro VI emission
standard be sufficient to meet the limit value for nitrogen dioxide on all roads and thus in all parts of Berlin.

An extension of the compliance deadline for nitrogen dioxide value is only possible to 31/12/2014, however. For this reason, additional measures need to be specified in this Air Quality Plan to reduce the pollution from nitrogen dioxide. In the case of annual mean value exceedances by up to 3 µg/m³, a reduction of exhaust emissions by 15 % is sufficient, which can be achieved by local measures. In order to also comply with the limit values at the road sections with the highest pollution levels, e.g. Potsdamer Straße, the emissions generated from motor vehicle traffic would need to be reduced by 40 to 54 %. Bearing in mind the principle of proportionality, this cannot be achieved by local measures. Support at national or European level is thus additionally required, i.e. by an earlier introduction to the market of low-emission vehicles with Euro VI emission standard and an enhanced promotion of environmentally friendly modes of driving and fuels.

**Particulate matter**

In the trend scenario without additional measures, the total particulate matter emissions in Berlin decrease by 4 % in 2015 compared to 2009, and by 11 % in 2020. The declines differ for individual sources. The highest reductions are expected for diesel soot particles, with 45 % by 2015 and 73 % by 2020, due to the introduction of Stage 2 of the low emission zone in 2010, a further modernization of the vehicle fleet, and the introduction of the Euro VI emission standard.

The declines in the particulate matter emission anticipated in Berlin and Europe-wide, however, will not be sufficient to meet the daily limit value for particulate matter by 2020. According to the model calculations, the trans-regional pollution of particulate matter will only decrease by a maximum of 5 % by 2015 or 2020 in the trend scenario without additional measures. The traffic-induced incremental pollution on Berlin’s main roads however, will drop by around 23 % and the additionally generated pollution in inner city residential areas with low traffic volumes by 14 %.

Irrespective of the assumed trends, more than 35 exceedance days of the daily limit value of 50 µg/m³ are still forecast under this scenario for numerous main roads for 2020. At least the length of the road sections with limit value exceedances on main roads and the number of affected residents falls by 32 % in 2015, and by 79 % by 2020 compared to 2009. In 2015, exceedances are predicted for 52 km of main roads with 43,500 persons affected. In 2020, in contrast, exceedances will likely occur on only 15 km of the network of main roads, where around 13,300 persons reside.

Further measures to reduce the particulate matter pollution are therefore necessary, even if the potential for reduction through measures at the level of Berlin is very limited due to the high share of the large-scale background pollution outside of Berlin. In order to achieve compliance with the particulate matter limit value in the year 2015 solely through local measures in Berlin, the contribution of sources in Berlin would have to be lowered by a disproportionate scale. This way, a reduction of about 40% to 70% of the additional local pollution from road traffic would be required depending on the pollution load in the particular roads. Measures such as a rather drastic reduction of road traffic would be necessary for this purpose, which would neither be appropriate in light of the cause nor remain on a proportionate scale. A considerable reduction of the particulate matter pollution in Berlin can therefore only be obtained, if the import of air pollutants is also reduced by a significant quantity through national and Europe-wide measures. Berlin will leverage its membership in European City Networks to support this cause in the Federal Council and directly in Brussels.

In order to attain a reduction in emissions towards the intended improvement of the air quality going beyond the trend development, measures from the five areas of spatial, urban and landscape planning, traffic, heat supply, construction and installations in industry and commerce were integrated into the Air Quality Plan. Also measures from other plans, such as the Urban Development Plans for traffic, centres and also industry and commerce were included. The measures of the Air Quality Plan are presented in Chapter 9 of the detailed version.

Measures for reducing nitrogen dioxide pollution focus entirely on the traffic sector. In order to reduce the particulate matter pollution, however, due to the high number of sources, measures from different fields have to be taken, though measures in traffic continue to be highly important. This is particularly valid with regard to the further reduction of diesel soot particles, which are a very harmful factor to health.

A further reduction in traffic-related emissions can be attained by improving vehicle technologies (retrofitting with particulate filters and nitrogen oxide reduction systems; the promotion of clean vehicles) and by reducing exemptions for the LEZ. The further optimisation of traffic flow, customised urban-friendly speeds, logistical concepts, and the shift of transport mode to the ecomodes, consisting of walking, cycling and the local public transport, also lead to a reduction in the emission of pollutants. The Air Quality Plan does not include an expansion of the LEZ or the introduction of a third stage with advanced traffic bans, as the required legal basis is lacking. Furthermore, this would be disproportionate compared to retrofitting options for exhaust reduction systems to decrease nitrogen oxide emissions.

In order to reduce particulate matter, it is also pursued in addition, to retrofit construction machines and stationary industrial engines with particle filters and to reduce the emissions from fossil fuel combustion (e.g. from wood burning). Likewise, the measures of the climate protection strategy to reduce the heat requirement of buildings and the use of strict environmental standards for mini-block heating plants contribute to mitigating the air pollution.

It has not been possible to quantify the future mitigation effects for all measures, since reliable data on the specific effects on polluting activities is often missing. Therefore, for some measures for which assumptions of plausible data have been employed or in cases where information on the potential for reduction is available, model calculations on the effect in percentages could be furnished for the time horizon until 2015. The results are described in Section 8 of the long version.

Very broad assumptions are underlying in the model calculations for local measures so to explore the maximum potential for reduction. This includes for example, the complete avoidance of all traffic jams along the main routes, a comparably higher share of electrical vehicles or a complete avoidance of particle emissions from the combustion of coal and wood in small combustion plants. In practice, this can mostly be achieved only to partial extent. Using even these broad assumptions, the limit value for particulate matter can be met neither in the year 2015 nor in the year 2020, since the background pollution is so high, that the additionally achievable reductions in Berlin are not sufficient. The calculation of the future development of the background pollution outside of Berlin is based on the conservative assumption that in the neighbouring foreign countries and in Germany, no further reduction of emissions will materialise by 2020, in excess of implementing the already planned measures or measures made compulsory by existing regulations.

What can be achieved with a maximum implementation of the aforementioned measures is a reduction by about 60% in the number of residents who are affected by particulate matter limit value transgressions, whereby roughly another 5,000 will remain affected then. Among the measures in traffic, speed reductions (30 km/h) on the roads with limit
value exceedances at a simultaneous steadying of the traffic flow show the strongest ef-
fect, as this also reduces the resuspension of particles. A noteworthy aspect is the mitiga-
tion potential emerging from a reduction of the particle emissions from all solid fuel com-
bustions, e.g. from wood heating systems, and the particle reduction achieved with soot 
filters on construction machines. The sum of this potential leads to a forecast reduction in 
the number of residents living in non-compliance areas by about 40 %. However, the cal-
culation of the emissions caused by these sources is associated with much greater uncer-
tainties than the calculation of road traffic emissions. To improve the data stock, further 
studies are still necessary, some of which have already been started, such as a pilot project 
for the testing of the particle filter retrofitting for construction machines accompanied by 
monitoring of the emissions.

While the limit value for nitrogen dioxide can be met in 2020 without additional measures, 
this is not yet safely feasible everywhere in Berlin by means of the measures that can be 
implemented by 2015. It can be expected at least, that the number of residents affected by 
the limit value transgressions will drop by 40 %. Full compliance with the limit values will 
only be possible, if the percentage of vehicles assumed to have the emission standard of 
Euro 6 in the year 2020 was already reached in the year 2015.

Berlin has already approached the European Commission in September 2005 with the re-
quest to introduce stricter emissions standards for diesel vehicles five years earlier than 
scheduled. In effect, during the then revision of the emissions standards, the Euro 5 emis-
sions standard for diesel vehicles, which became binding in 2009, should have been set 
already at a more ambitious level corresponding approximately to the limit value of the 
present, much stricter Euro 6 emission standard. Unfortunately, this standard has become 
mandatory only in 2014. This is much too late so as to achieve a mentionable reduction of 
the nitrogen dioxide emissions of diesel vehicles by 2015. Furthermore, an additional limi-
tation of the NO₂ concentration to 10 % of the nitrogen dioxide emissions was proposed so 
that the above-mentioned counterproductive effect of rising nitrogen dioxide shares in 
emissions would have been largely avoided. Unfortunately, the EU Commission did not 
grant this proposal to the consequence that the existing technical potential for a reduction 
of the nitrogen dioxide emissions of diesel vehicles remained largely unexploited.

**Conclusion**

The present Air Quality Plan demonstrates that the clean air measures taken in the last 
few years have resulted in a considerable improvement of air quality. This improvement is 
largely due to the modernization of the vehicle fleet, the introduction of a LEZ, the retrofit-
ting of filters in buses of Berlin’s public transportation services, and a decrease in motor-
ized traffic. In addition, the almost complete switch from domestic heating to more envi-
ronmentally friendly sources of energy and the reduction of energy demand through better 
insulation equally contributed to the improvement of Berlin’s air quality. Nevertheless, 
complying with air quality limit values for particulate matter (PM₁₀) and nitrogen dioxide 
remains a major challenge for Berlin and other European cities. To achieve this objective or 
to get as close as possible, further measures are required in Berlin but also at the nation-
wide and Europe-wide level. For Berlin, this Air Quality Plan provides a broad package of 
measures to reduce air pollution. In order to reduce the traffic-induced air pollutants, em-
phasis is placed on further modernization of the vehicle fleet, e.g. retrofitting of up to 
200 service buses of Berlin’s public transportation services with de-nitrification systems, 
and measures to optimize the traffic flow or promote the ecological modes of transport. 
At the same time, potential emission reductions in small combustion plants and construc-
tion machines should be examined and implemented to reduce pollution from particulate 
matter.
1 Background, Rationale and Framework of the Air Quality Plan

1.1 Reasons for this Air Quality Plan: the associated risks to human health and the environment of exceeding air quality limit values

In order to protect human health and the environment the European Community has set limit values for air pollutants to be met by a certain date. Particular protection should be given to vulnerable population groups and be based on the guidelines of the World Health Organization (WHO). “Pollutant” refers to any substance present in ambient air that is “likely to have harmful effects on human health and/or the environment as a whole” (2008/50/EC). Of particular interest is particulate matter with an aerodynamic diameter of less than 10 μm (PM$_{10}$) and less than 2.5 μm (PM$_{2.5}$), ozone (O$_3$), and nitrogen dioxide (NO$_2$).

In Berlin, nitrogen dioxide and particulate matter (PM$_{10}$) have exceeded the limit values in some areas, thus potentially entailing an increased risk for human health.

Depending on its size, particulate matter can be carried deep into the lungs via the respiratory passages. It may be deposited in the alveolus from where it may enter the blood circulation. Epidemiological and toxicological studies have examined a possible link between the exposure to particulate matter and its impacts on mortality and morbidity rates$^1$. According to current scientific knowledge, short-term and long-term exposure to increased concentrations of particulate matter can be linked to a higher risk of cardiovascular and respiratory tract diseases. In addition, lung growth may be adversely affected in children. Studies have shown that diesel soot in particular is carcinogenic to humans. Soot particles act as sublimation surface for metals and for diverse volatile and non-volatile hydrocarbons. This combination of soot particles and other gaseous and solid air pollutants leads to statistically significant injuries to human health. As of yet, however, it is not clear which combination of air pollutants is the most dangerous one. Diesel soot has been reclassified by the WHO as carcinogenic to humans. It is not possible to define a threshold value for PM$_{10}$ below which no adverse effects on human health can be expected. However, it has been shown that the probability of early deaths due to cardiovascular and respiratory diseases is significantly higher for persons living within 50 m of a main road. The smaller the particles, the more dangerous they are for human health. NO$_2$ enters the human body via the respiratory passages and may have lasting and harmful effects on human health. Vulnerable people, such as children and the elderly, are particularly affected by impairments of the respiratory passages and cardiovascular diseases. A study in North Rhine Westphalia$^2$ has shown that the relative risk of dying from cardiovascular diseases increases by 50 % if concentrations of NO$_2$ increase by 15 μg/m³. It further revealed that long-term exposures to increased NO$_2$ concentrations are linked to increasing occurrences of bronchitis and asthma symptoms.

Gaseous NO$_2$ converts into nitrates in the atmosphere, which may bond with alkaline cations such as ammonium and form solid particulate matter. Nitrates may also be deposited on soot particles and significantly contribute to human health problems. Additionally, nitrates lead to soil acidification and threaten environmentally sensitive ecosystems when entering the soil by dry or wet deposition processes.

Increased NO$_2$ concentrations together with volatile hydrocarbon are also responsible for increased concentrations of ozone at ground level. It is proven that ozone affects the human lung function and causes harm to plant leaves.

Based on broad consensus in the scientific community, the WHO has adopted guidelines to improve ambient air sustainably. In this context, indicative values were proposed which

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2. Study commissioned by the State Environment Office of North Rhine Westphalia and carried out by the Department of epidemiology of the Ludwig-Maximilian-University Munich and the GSF-Institute for Epidemiology.
also form the basis for defining air pollution limit values in Europe. The guidelines further provide indication of possible ways to improve or maintain air quality. Depending on the region, emphasis is placed on different sources of pollution: While in the poorer African and Asian countries open wood-fired ovens and outdated industrial plants are responsible for increased air pollution, the main cause of excessive concentrations of pollutants in Europe is traffic, especially in cities.

1.2 Legal framework
By adopting Directive 2008/50/EC on ambient air quality and cleaner air for Europe in May 2008 the EU has adapted its environmental legislation, namely the (previously) existing Framework Directive 96/62/EC and the Daughter Directives 1993/30/EC, 2000/69/EC and 2002/3/EC to the latest scientific findings, and merged these into a single Directive. This has created a new basis for the standardized assessment and control of the air quality in cities and regions.

The principles and objectives of the Directive can be summarized as follows:

- A legally agreed and quantitative definition of air quality targets “designed to avoid, prevent or reduce harmful effects on human health and the environment as a whole”.
- The introduction of common methods and criteria for assessing air quality.
- The obligation to take measures to ensure compliance with the limit values within a specified deadline or to maintain compliance once the limit values have been met. To this end, Air Quality Plans may be required in polluted zones and agglomerations.
- The obligation to inform the public about the current air quality and to warn them once a certain alert threshold has been exceeded, and, if necessary, to draw up short-term action plans.
- To communicate to the Commission whether or not limit values were met, what plans with measures are in place for ensuring compliance, and, if necessary, any potential need to extend the compliance deadline.

The directives were transposed into German Law through the 8th amendment to the Federal Pollution Control Act [Bundes-Immissionsschutzgesetz – BImSchV] and the 39th Implementing Regulation to the Act 39. BImSchG in August 2010.

At the heart of the new air quality Directive and the 39. BImSchV, respectively, are the legally binding limit values for the air pollutants sulphur dioxide (SO₂), lead, carbon monoxide (CO), benzene, nitrogen dioxide (NO₂), particulate matter (PM₁₀ and PM₂.₅) and the non-binding target values for ozone, arsenic, cadmium, nickel and benzo(a)pyrene, that are set in Directive 2004/107/EC.

Compliance with these limit values has to be primarily ensured at presumed pollution hotspots “where the highest concentrations occur to which the population is likely to be directly or indirectly exposed for a period which is significant in relation to the averaging period of the limit value(s)”⁴, according to the Directive. This refers to locations with an estimated maximum pollution, where humans are not temporarily, but often and repeatedly exposed. Residential areas with homes, schools, hospitals or similar establishments located in the vicinity of an industrial plant with high emissions could potentially be affected, as could those near a major urban road with high levels of traffic. Measurement and sampling points should be sited between 1.5 m and 4 m above the ground and no more than 10 m from the kerbside. Compliance assessments are thus normally conducted on the pavements typically used by pedestrians or at locations where there are windows of flats close to the road. Additionally, the concentration of air pollutants should be assessed in residential areas that are “representative of the exposure of the general population”.

Most of the limit and target values and their deadlines for compliance have been taken over from former Directives without any change. The limit values for PM₁₀ have not been

⁴ Directive 2008/50/EC, Annex III, Section B.
tightly but are subject to possible revision under the daughter Directive 1999/30/EG.; instead the existing limit values have been maintained. What is new is that the Directive sets new standards for particulate matter with an aerodynamic diameter of up to 2.5 μm (PM$_{2.5}$). It introduces a legally binding limit value which must be achieved by 2015 (see table 1.1) and an identical, but non-binding target value, which should be achieved, “where possible”, by 2010.

In addition, the Directive sets a “national target” aimed at reducing, on a percentage basis, the average exposure to PM$_{2.5}$ in urban areas. Given that the measurement is just an average value (Average Exposure Indicator, or AEI) calculated on the basis of 36 sampling points in urban areas for Germany as a whole and has to be reduced by 15 % in total in a decade, relevant programmes will be developed and implemented by the Federal Government and not at local level. Likewise, due to the wide-ranging distribution of ozone and its precursors measures against ozone pollution can only be implemented in a meaningful manner at the national and European level. For this reason, the present Air Quality Plan for Berlin does not include any specific measures aimed at ensuring compliance with the target values for ozone and the national target to reduce exposure to PM$_{2.5}$.

The plan rather focuses on ensuring compliance with those limit values that have been exceeded in Berlin in the last few years (see table 1.1). § 47 BlmSchV and § 27 of 39. BImSchV requires the preparation of an Air Quality Plan once excessive levels of air pollution have been detected. This obligation already existed under the previous EU framework Directive and its Daughter Directives. Since Berlin first exceeded the limit values and the margin of tolerance set in these Directives in 2002, it had to prepare a Clean Air Plan for the term 2005-2010. The present 2011-2017 Air Quality Plan revises and updates the previous Clean Air and Action Plan.

The planning instrument of Action Plans, provided for in the Framework Directive 96/62/EC, which required short-term measures once deadlines for addressing values beyond the limit were exceeded, is no longer applicable under the new Air Quality Directive 2008/50/EC and the corresponding consolidated version of the Federal Pollution Control Act. It aimed at triggering a smog alert in cases where alert thresholds for ozone, sulfur dioxide and nitrogen dioxide were exceeded. It further sought to limit exceedances after expiry of the compliance deadline as quickly as possible by taking long-term measures. As it became evident while preparing the former Clean Air Plan 2005-2012 that it was not possible to avoid limit value exceedances of particulate matter (PM$_{10}$) upon expiry of the 2005 deadline, an Action Plan was integrated into the Clean Air Plan. This Action Plan included not only permanent measures but also measures that can be implemented comparatively quickly.

Replacing those Action Plans, the new Air Quality Directive in Article 24 introduces so called “short-term action plans” to prevent that levels of pollutants exceed the alert thresholds specified for ozone, sulfur dioxide and nitrogen dioxide. The alert thresholds correspond to the trigger values of the earlier smog directives. Short-term action plans are thus smog alert plans that provide for short term and temporary interferences, e.g. in traffic or in the operation of industries, if peak values of air pollution are reached. In Berlin, pollution levels have been far below the alert thresholds for the last 12 years, when the latter were introduced. Therefore, short-term action plans are currently not relevant for Berlin.

However, Article 24 of the Air Quality Directive provides for the possibility of drawing up short-term action plans to prevent limit value exceedances. This would only meaningfully apply to tackling exceedances of the short-term exposure limit for nitrogen dioxide, which is defined as an hourly value (see table 1.1). However, exceedances of those limit values have not occurred since 2003 and are not expected in the future. While drafting the 2005-2010 Plan the analysis of particulate data already indicated that short-term measures related to smog alert interferences are also not effective for ensuring compliance with the limit values for particulate matter. This view has been confirmed by recent data, as the
observations in Section 5.3.2. show. Apparently, the same also applies to the limit value of nitrogen dioxide defined as an annual mean. In that case, only longer-term measures are adequate to ensure compliance.

Therefore, Berlin would not benefit from drawing up a short-term action plan to prevent exceedances of air pollution limit values.

Where there is a risk of continuous or repeated limit value exceedances upon expiry of the compliance deadline, additional measures should be taken. This is currently the case for the annual limit value for nitrogen dioxide and the daily limit value for particulate matter (PM$_{10}$). Clean Air Plans, as provided for in the new Air Quality Directive, thus take on the same role as the former action plan. They should include appropriate measures to ensure that the period of noncompliance is as short as possible. The catalogue of measures presented in Chapter 9 takes account of this requirement in that it includes several permanent measures which can be implemented in the short term.

The measures in the Clean Air Plans or/and Action Plans must further fulfil the following legal requirements:

- The measures must be directed at all air pollution emission sources or source sectors that contribute to limit value exceedances. Burdens must be shared "on the basis of a pro-rata allocation of costs and in accordance with the principle of proportionality".
- The measures – for example, potential traffic restrictions in certain streets – should not result in any limit value exceedances elsewhere.
- The aim of complying with the limit values also extends to local hot spots like street canyons. Local conditions must be carefully analysed when developing local traffic measures to avoid displacement effects.

Table 1.1. shows the limit values and corresponding deadlines for compliance set for the pollutants in excess of these limit values, which are relevant when planning measures in Berlin.

### Table 1.1: Limit values for the air quality of selected air pollutants

<table>
<thead>
<tr>
<th>Components</th>
<th>Mean over</th>
<th>Limit value</th>
<th>Exceedance days permitted</th>
<th>Limit value to be achieved by</th>
<th>Potential extension of compliance deadline until</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate matter (PM$_{10}$)</td>
<td>24 h</td>
<td>50 µg/m$^3$</td>
<td>35 x / year</td>
<td>01.01.2005</td>
<td>11.06.2011</td>
</tr>
<tr>
<td></td>
<td>1 year</td>
<td>40 µg/m$^3$</td>
<td>--</td>
<td>01.01.2005</td>
<td>11.06.2011</td>
</tr>
<tr>
<td>Nitrogen dioxide (NO$_2$)</td>
<td>1 h</td>
<td>200 µg/m$^3$</td>
<td>18 x / year</td>
<td>01.01.2010</td>
<td>01.01.2015</td>
</tr>
<tr>
<td></td>
<td>1 year</td>
<td>40 µg/m$^3$</td>
<td>--</td>
<td>01.01.2010</td>
<td>01.01.2015</td>
</tr>
<tr>
<td>Benzo[a]pyrene* (BaP)</td>
<td>1 year</td>
<td>1 ng/m$^3$</td>
<td>--</td>
<td>01.10.2013</td>
<td></td>
</tr>
<tr>
<td>Particulate matter (PM$_{2.5}$)</td>
<td>1 year</td>
<td>25 µg/m$^3$</td>
<td>--</td>
<td>01.01.2015</td>
<td></td>
</tr>
</tbody>
</table>

* non-binding target value

1.3 Option of extending the compliance deadlines for limit values

It is also established under the new Directive that compliance deadlines can be extended until mid 2011 for particulate matter (PM$_{10}$) and until 2015 for nitrogen dioxide (NO$_2$), as indicated in table 1.1. This option was granted because the large-scale background pollution of particulate matter (PM$_{10}$) and the NO$_2$ values at traffic-exposed monitoring stations only dropped relatively slowly, or not at all, despite ambitious measures in many European regions. In many regions throughout Europe the relevant limit values were not met within the stipulated time period in all cases (see Figure 1.1). Reasons for non-compliance with the limit values in Berlin will be discussed in more detail in Chapter 5.
The postponement of compliance deadlines is, however, subject to certain conditions. The Member States must communicate all relevant information to the Commission required to assess whether or not the relevant conditions are satisfied. The following needs to be demonstrated:

- an Air Quality Plan is established,
- all appropriate (abatement) measures have been taken to reduce the air pollution, for example the installation of the best available exhaust gas treatment/purification technologies in installations, the use of clean fuels, measures to limit transport emissions through planning and management, the establishment of LEZ, retrofitting programmes for catalytic particulate filters, etc,
- conformity with the limit values must be achieved before the new deadline.

With respect to particulate matter \( (PM_{10}) \) it further needs to be shown that it was not possible to achieve conformity with the limit values due to site-specific dispersion characteristics, adverse climatic conditions or transboundary contributions.

On the basis of this notification, the Commission assesses whether or not a postponement of the compliance deadlines is justified, or whether or not a non-compliance procedure will be initiated.

Such a notification was not necessary in Berlin since the limit values were met in 2007 and 2008 (see Section 3.2.2). The limit value exceedances observed in subsequent years were primarily due to the transboundary transport of particulate matter from mainly Polish sources (see Section 5.3.2). The contribution of pollutant sources in Berlin to exceedances of daily limit values for particulate matter has significantly declined because of the establishment of the LEZ and various other measures. Berlin was, for formal reasons, brought into the infringement proceeding against the Federal Republic of Germany for exceeding \( PM_{10} \) limit values ongoing since 2009 through a letter of formal notice of 25/04/2013 from the Commission, as the daily limit value of \( PM_{10} \) was exceeded by Berlin for five between 2005 and 2011. In its statement Berlin will refer to the significant contribution from transboundary transport of particulate matter.

However, with regard to compliance with the annual limit value for \( NO_2 \), Berlin together with 56 areas and agglomeration zones in Germany found it necessary to request an extension of the compliance deadline until 2015 in October 2011 compliance. The Commission has objected to extending the compliance deadline in Berlin and 34 other areas in Germany (Resolution 20/02/2013), as Berlin could not demonstrate that the formal criteria for achieving the limit value in 2015 were met. The extent to which locally available measures were and are already exhausted taking into account the principle of proportionality has not been conclusively notified by the Commission.

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7 Directive 2008/50/EC, Annex XV, Section B.
8 Senate Department for Health, the Environment and Consumer Protection: One Year Low Emission Zone, Stage 2 in Berlin – Analysis of the effect on emissions from road traffic and on the air quality in Berlin. 2011 Berlin.
9 The notifications submitted to the Commission are published under the following link:
1.4 Planning area
The planning area encompasses the entire area within the state boundaries of Berlin. Detailed information on the planning area is provided in Chapter 2.

1.5 Competent authority
Berlin’s Federal State law assigns the responsibility for the planning process to the Senate Department in charge of environment protection. That is the Senate Department of Urban Development and the Environment Unit IX C Noise and Air Pollution Control (Immissionsschutz) Brückenstraße 6 10179 Berlin

1.6 Environmental Impact Assessment
Pursuant to § 14b Abs. 1 Nr. 2 of the Law on Environment Impact Assessment (UVPG) in conjunction with Annex 3 Nr. 2 UVPG, Air Quality Plans are among the plans and programmes that require a Strategic Environmental Assessment provided that the Air Quality Plan sets a framework for taking decisions on the admissibility of projects that require an Environmental Impact Assessment or a preliminary examination in the individual case. According to § 14 Abs. 3 UVPG such frameworks concern predefinitions that are relevant for later authorisation decisions on projects, in particular their need, size, location, nature, their operating conditions or allocated resources. Such a framework is not set with the present Air Quality Plan for Berlin. In addition, the Air Quality Plan for Berlin does not include any requirements for projects pursuant to Annex 1 UVPG. Therefore, a strategic Environmental Assessment is not necessary.

1.7 Public Participation
§ 47 Abs. 5 BImSchV provides for the possibility of involving the public in the process of drawing up Air Quality Plans in an appropriate manner. The plans must be made available for the public in an appropriate manner. In this context, respect must be given to the requirements of the Gesetz über die Öffentlichkeitsbeteiligung in Umweltangelegenheiten (Act on Further Development of Public Participation in Environmental Matters) according to the EU Directive 2003/35/EC.

The draft (of the) Air Quality Plan was made publicly available for inspection from the 27th April 2012 to the 27th May 2012 in the official building of the Senate Department of Urban Development and Environment, Brückenstraße 6, 10179 Berlin, from Monday to Thursday 8am-3pm, Friday 8am-1pm (except holidays) or by appointment. In addition, the draft was available for inspection at the European Environmental Agency, Copenhagen.
made available for download under www.berlin.de/luftreinhalteplan. Furthermore, the public was able to submit written comments to the Senate Department of Urban Development and Environment until the 15th June 2012. The possibility of public participation was announced in the Official Journal No. 17 dated 27/04/2012, through a press release dated 27/04/2012 and by displaying on 27/04/2012 on three of Berlin’s daily newspapers (Tagesspiegel, Berliner Zeitung, Berliner Morgenpost).

In total, 34 comments were received from individuals, citizens’ initiatives, business associations, chambers and guilds, as well as local authorities. The comments were presented and discussed at a public hearing on 26/06/2012. All objections were examined by the competent authority, and, to the extent possible and necessary, adequately taken into account. Written responses were provided to all those who objected.

The adopted version will be published in Berlin’s Official Journal and on the Internet at www.berlin.de/luftreinhalteplan. The maps of air pollution on main roads created for the Air Quality Plan are made available in Berlin’s Environmental Atlas under http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/dinh_03.htm. They illustrate the congestion, emissions and air pollution for each section in the main road network.

Additional information on air pollution is available on the website of the Senate Department for Urban Development and Environment: http://www.stadtentwicklung.berlin.de/umwelt/luftqualitaet/.

1.8 Entry into force
2 General information

2.1 Basic data
The city state of Berlin is the largest connectedly constructed agglomeration in the Federal Republic of Germany. Berlin’s urban area comprises a surface area of 892 km². Its biggest extension is 45 km in east-west direction and 38 km in north-south direction. The surrounding Brandenburg area (greater Berlin) comprises a surface area of 2,581 km².

Politically, Berlin is split into 12 boroughs, which have their own competences for numerous concerns with regard to air quality management such as the monitoring of installations not requiring a permit.

Relevant structural data for Berlin for selected years from 1990 to 2009 is provided in Table 2.1.

Following a slight decrease in the years 1994 to 2000, Berlin’s population has steadily increased since 2004 up to currently 3,460,725 residents (status 31/12/2010). In the greater Berlin area live approximately another one million people. A further modest growth of 1 to 3 % up to 3,478 to 3,549 million residents is expected for 2020\(^\text{11}\). The mean population density in Berlin is 3,880 persons/km\(^2\) ranging from 1,440 persons/km\(^2\) in the borough Treptow-Köpenick up to 13,500 persons/km\(^2\) in the borough Friedrichshain-Kreuzberg. The areas with the highest population density are located in the inner city as shown in Figure 2.1.

With a growth of 5 % between 2005 and 2009, the number of households has increased considerably more than the population. In this respect Berlin is following the trend of households decreasing in size.

After the most recent low point in 2005, the number of persons in employment has increased by 8 %, driven by growth in the service sector, whereas the number of employed persons in the manufacturing industry continues to decrease.

Table 2.1: Development of relevant structural data from 1999 to 2009

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population (persons)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berlin</td>
<td>3,433,695</td>
<td>3,382,169</td>
<td>3,395,189</td>
<td>3,442,675</td>
</tr>
<tr>
<td>Brandenburg</td>
<td>2,641,152</td>
<td>2,601,962</td>
<td>2,559,483</td>
<td>2,511,525</td>
</tr>
<tr>
<td><strong>Total Berlin and Brandenburg</strong></td>
<td><strong>6,074,847</strong></td>
<td><strong>5,984,131</strong></td>
<td><strong>5,954,672</strong></td>
<td><strong>5,954,200</strong></td>
</tr>
<tr>
<td><strong>Number of households</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berlin</td>
<td>1,754,600 (1991)</td>
<td>1,822,800</td>
<td>1,897,900</td>
<td>1,988,000</td>
</tr>
<tr>
<td>Brandenburg</td>
<td>1,038,900 (1991)</td>
<td>1,160,500</td>
<td>1,218,300</td>
<td>1,245,300</td>
</tr>
<tr>
<td><strong>Total Berlin and Brandenburg</strong></td>
<td><strong>2,793,500</strong></td>
<td><strong>2,983,300</strong></td>
<td><strong>3,116,200</strong></td>
<td><strong>3,233,300</strong></td>
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<tr>
<td><strong>Employees in Berlin</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing industry</td>
<td>470,000</td>
<td>285,700</td>
<td>219,700</td>
<td>215,600</td>
</tr>
<tr>
<td>Service sectors</td>
<td>1,180,000</td>
<td>1,282,500</td>
<td>1,317,700</td>
<td>1,447,400</td>
</tr>
<tr>
<td><strong>Total Berlin</strong></td>
<td><strong>1,660,000</strong></td>
<td><strong>1,575,400</strong></td>
<td><strong>1,543,000</strong></td>
<td><strong>1,667,900</strong></td>
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<tr>
<td><strong>Buildings in Berlin</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flats in Berlin</td>
<td>1,713,000</td>
<td>1,862,766</td>
<td>1,881,837</td>
<td>1,894,564</td>
</tr>
<tr>
<td>Total office space (in qm)&lt;sup&gt;2&lt;/sup&gt;</td>
<td>11,000,000</td>
<td>18,600,000</td>
<td>18,600,000</td>
<td></td>
</tr>
<tr>
<td>Sales areas (in qm)&lt;sup&gt;3&lt;/sup&gt;</td>
<td>1,173,000</td>
<td>1,862,766</td>
<td>1,881,837</td>
<td>1,894,564</td>
</tr>
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</table>

Unless stated otherwise, the source of data is: State Statistical Institute Berlin-Brandenburg

<sup>1</sup> Berlin Land Use Plan (FNP) 2009<sup>12</sup>
<sup>2</sup> Economic and Labour Market Report Berlin 2009/2010<sup>13</sup>

Figure 2.1: Berlin and its boroughs and density in inhabitants by statistical areas (2009)<sup>14</sup>

Population density in inhabitants per 1,000 m<sup>2</sup>

- < 5
- 5 to < 10
- 10 to < 15
- 15 to < 20
- ≥ 20

- Berlin
- Borough
- Urban area

2.2 Topography
Berlin is situated on 52° 30’ Northern latitude and 13° 30’ Eastern longitude amidst the North German Plain, about 160 to 220 km south of the Baltic coast and in equal distance north of the edge of the Saxon-Thuringian Uplands. The Polish border is at an approximate distance of 80 km.

Situated in the Berlin-Warsaw ice age glacial valley [Urstromtal], the Spree Valley pervades the urban area from southeast to northwest. The relatively level valley in the of the city’s surroundings has a width of 10 km, up to the city centre it narrows to approximately 4 km. Its average level is 35 m above sea level. Starting from the Spree Valley, the area of the Barnim Plateau quickly mounts to 50 m to the northeast and then smoothly mounts to a height of 60 to 70 m to the periphery. To the southwest it rises at a similar pace up to 50 m.

Behind this extends the Teltow Plateau with an average height of 45 m to the southern periphery. In the west of the city rise the Havel Hills up to a height of 97 m. The highest natural elevations are the Müggel Hills [Müggelberge] with a maximum height of 115 m. They are situated as inselbergs amidst the glacial valley. There are a number of artificial elevations beyond. The elevations in the Volkspark Friedrichshain and the Volkspark Prenzlauer Berg, the Hellersdorf Hills and the Teufelsberg (Devil’s mountain, 115 m), for instance, arose through construction waste and debris deposits.

2.3 Climate and meteorological conditions
Climate and meteorological conditions highly influence the concentration of air pollutants encountered in Berlin. This applies both to the level of pollution as well as to dilution, transport, chemical or physical transformation and removal processes of pollutants from the atmosphere. The seasonal temperature determines the length of the heating period and thereby the emission quantities from combustion installations. The degree of dilution and the transmission of air pollutants are primarily based on factors such as wind speed, wind direction, the stability of the atmospheric stratification and occurring temperature inversions. Furthermore, precipitations affect the composition of the atmosphere, especially the particulate matter concentration.

Berlin is situated in the transition area between continental and oceanic climate. In the winter dominates the continental impact that is caused by eastern European high-pressure areas and often provokes temperature inversions. The summer months are usually characterised by oceanic climate.

Selected parameters are shown in Table 2.2. Some meteorologically influencing factors will be described in further detail in the following sub-sections.

Temperature
Berlin shows annual variations in temperature with relatively low temperatures in winter and relatively high ones in summer, which are typical of such European latitudes. The annual mean temperature was 9.2°C from 1971 to 2000, wherein the coldest month was January, with an average temperature of 0.5°C, and the warmest month was July with an average temperature of 18.4°C.

The benchmark for the installation of heating systems and the thermal insulation of buildings for Berlin is a minimum daily mean temperature of 15°C. Lower values rarely occur. Data by Berlin’s gas works corporation show that people start heating from temperatures of 14°C. Thereby, the heating period approximately starts in the middle of September and ends early in May, lasting about 230 days. A benchmark for the heating requirements for one year is the heating degree that is defined as the sum of all differences to daily average temperatures below 15°C to a heating temperature of 20°C. The higher the heating degree within a year, the more pollutants from heating systems are to be expected. The average heating degree amounted to 3,677 Kd/a with the highest monthly value in January.
Further data on temperatures is provided in Table 2.2.

**Wind speed**
The wind speed describes the atmospheric velocity and the capacity of the atmosphere to dilute the emitted quantity of pollutants horizontally. For the model calculations, simulating the spatial distribution of the air pollution, the Grunewald monitoring station of the Berlin air quality monitoring network (BLUME) serves as a reference point in order to describe the climatic conditions in Berlin. The monitoring station is installed at a height of 27 m above the ground and at a height of 10 m above the treetops.

This station was chosen because of the consistent tree population structure around the monitoring station, which prevents the wind measurement from being distorted by obstructions. Furthermore it represents Berlin’s rough conditions, with numerous trees and buildings, much better than the two monitoring stations of the German Weather Service at the airports Tempelhof and Tegel, where the measured wind speeds are approximately 1.5 metres per second higher.

The average wind speeds at Grunewald monitoring station are at their lowest level during the summer months at 2.3 metres per second. From September, the values increase and reach a peak of 3.1 metres per second in February. With a share of 40%, wind speeds of 2 to 4 metres per second are most common. Wind speeds less than 1.5 metres per second, which are unfavourable for the dispersion of pollutants, represent a 15% share. Especially low wind speeds that are recorded by the monitoring instruments as wind calms only occur in 1 to 2% of all cases. The frequency distribution tends to increase during the winter period.

**Wind direction**
The wind direction effects the local air pollution through individual sources of pollution. Moreover it determines to what extent the air that flows into the agglomeration of Berlin is contaminated with pollutants.

The averaged frequency distributions for the wind directions between 1988 and 2003 are provided for the whole year, the summer period from June to August and the three winter months December to February in Figure 2.2. According to this, northwest to southwest winds are most frequent in Berlin. Winds from north to northeast are most seldom. A second frequency maximum occurs with wind directions between southeast and east.

The frequently occurring northwest and southwest winds are especially common in winter combined with higher wind speeds. They mostly transport well-mixed and relatively clean maritime air masses into the Berlin area. Lower wind speeds with wind directions between south and east-southeast in winter are dominant. They are furthermore characterised by frequent high-pressure weather conditions with temperature inversions and an influx of continental air masses. Due to worse vertical exchange conditions and the accumulation of pollutants in continental air masses, wind directions from south to east increase the likeli-
hood for a higher air pre-pollution, especially in terms of particulate matter ($\text{PM}_{10}$). This will be discussed in greater detail in Chapter 5.

Despite the consistent distribution of wind velocity and the frequency of inversions, the correlation between south-eastern wind flow and an increased pre-pollution of the air also exists in summer in a diluted form. Wind directions from the south-eastern sector often correspond with dry weather periods in which atmospheric dust dispersal and lifetime of particulate matter are increased.

**Stability of the atmospheric stratification and inversions**

The wind speed and thermal stratification in the lower atmosphere affect the removal and dilution of the pollutants. When a warm air mass moves over a cooler one - which is called temperature inversion – the vertical air exchange and thus the removal of pollutants issued predominantly close to ground-level is severely constrained.

Temperature inversions are caused by nocturnal radiation, especially above vast surfaces of snow (radiation inversion), by warm air moving over cold air (frontal inversion) and by a dynamic subsidence of air in high-pressure areas (subsidence inversion). Under unfavourable conditions, inversions can occur with a thickness of up to 1,000 m and a temperature increase of up to $20^\circ$C. In areas without fog formation and with a clear sky, the height of the inversion lower limit shows a strong diurnal cycle which is also perceivable in the diurnal cycles of the air pollution. The inversion often disintegrates in the course of the day due to sunlight exposure, but may regenerate during the night.

Inversions with lower limits under 700 m height at midday have a particularly bad effect on the spread of pollutants. More than 50 % of the relevant inversions persisting during the day that are responsible for the occurrence of increased pollution occur in Berlin in the wind direction sector 135 to 225 degrees (southeast to southwest) and about 85 % in the sector 90 degrees (east) to 225 degrees (west-southwest) (Figure 2.3). During the course of the year, these inversions are typically detectable only during the winter season, since during the day, solar radiation during the summer period rapidly warms up the ground and the adjacent air layer near it, and thus ensures a good vertical exchange of air pollutants. As a consequence, increased concentrations are often measured in winter, as the vertical exchange of air pollutants is hampered. Additionally, there is often air coming from south and southeast that had already been pre-polluted.

**Figure 2.3: Frequency of temperature inversions depending on the wind direction**

Total frequency: $102 \pm 12$ days per year
Precipitation effectively removes particulate matter and several further atmospheric air pollutants. Furthermore, the resuspension of particles from moist or wet surfaces is considerably lower than from dry surfaces. Due to climate change\textsuperscript{15}, dry periods during the summer are tending to increase. If the current trend persists, the occurrence of periods with high particulate matter concentrations may intensify.

The yearly mean precipitation in Berlin between 1971 and 2000 was 578 mm, with a maximum monthly mean amount of 67 mm in June and a monthly minimum mean of 36 mm in February. The annual mean for this period is 12 mm lower than that one from 1961 to 1990, a period which is often used as a reference for climate issues (see Table 2.2).

Some data describing the climate in Berlin is summarised in Table 2.2.

Table 2.2: Climate data in Berlin (Source: Institute of Meteorology of Freie Universität Berlin, 2004. Unless otherwise noted, the mean values refer to the reference period 1961-1990)

<table>
<thead>
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</thead>
<tbody>
<tr>
<td><strong>Air temperature (°C in 2 m height ü.Gr.)</strong></td>
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<tr>
<td>Mean monthly average (1971-1990)</td>
<td>0.5</td>
<td>1.2</td>
<td>4.6</td>
<td>8.7</td>
<td>13.9</td>
<td>16.5</td>
<td>18.4</td>
<td>17.8</td>
<td>13.6</td>
<td>9.1</td>
<td>4.4</td>
<td>1.8</td>
<td>9.2</td>
</tr>
<tr>
<td>Highest monthly average</td>
<td>5.0</td>
<td>6.2</td>
<td>8.0</td>
<td>11.9</td>
<td>16.8</td>
<td>21.0</td>
<td>22.8</td>
<td>21.6</td>
<td>18.0</td>
<td>12.4</td>
<td>8.0</td>
<td>5.2</td>
<td>10.5</td>
</tr>
<tr>
<td>Mean daily maximum</td>
<td>1.8</td>
<td>3.5</td>
<td>7.9</td>
<td>13.1</td>
<td>18.6</td>
<td>21.8</td>
<td>23.1</td>
<td>22.8</td>
<td>18.7</td>
<td>13.3</td>
<td>7.0</td>
<td>3.2</td>
<td>12.9</td>
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<tr>
<td>Lowest monthly average</td>
<td>-9.6</td>
<td>-10.5</td>
<td>-0.3</td>
<td>4.8</td>
<td>10.5</td>
<td>11.9</td>
<td>15.1</td>
<td>14.9</td>
<td>10.0</td>
<td>5.1</td>
<td>-0.6</td>
<td>-5.4</td>
<td>7.0</td>
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<td>-2.2</td>
<td>0.5</td>
<td>3.9</td>
<td>8.2</td>
<td>11.4</td>
<td>12.9</td>
<td>12.4</td>
<td>9.4</td>
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<td>2.1</td>
<td>-1.1</td>
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<td>0</td>
<td>0</td>
<td>0.1</td>
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<td>2.5</td>
<td>1.6</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
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<td><strong>Summer days (max. ≥ 25°C)</strong></td>
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<td>0</td>
<td>0</td>
<td>0.4</td>
<td>3.3</td>
<td>7.8</td>
<td>10</td>
<td>9.1</td>
<td>2.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>33.1</td>
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<td><strong>Frost days (min. &lt; 0.0°C)</strong></td>
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<td>17.6</td>
<td>12.6</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1.3</td>
<td>8.4</td>
<td>17.0</td>
<td>80.3</td>
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<td><strong>Ice days (max. &lt; 0.0°C)</strong></td>
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<td>5.9</td>
<td>1.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.3</td>
<td>7.2</td>
<td>24.8</td>
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<tr>
<td><strong>Mean amount of coldness</strong></td>
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<td>38.7</td>
<td>10.3</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6.5</td>
<td>40.4</td>
<td>162.6</td>
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<tr>
<td><strong>Mean heating degree total</strong></td>
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<td>552.6</td>
<td>504.3</td>
<td>351.5</td>
<td>129.3</td>
<td>28.8</td>
<td>5.3</td>
<td>75.0</td>
<td>329.3</td>
<td>470.3</td>
<td>590.0</td>
<td>3,677.4</td>
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</tr>
<tr>
<td><strong>Cloudiness/sky cover</strong></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>Mean cloudiness (in eights)</td>
<td>6.0</td>
<td>5.6</td>
<td>5.3</td>
<td>5.0</td>
<td>4.7</td>
<td>4.8</td>
<td>4.8</td>
<td>4.5</td>
<td>4.7</td>
<td>5.2</td>
<td>6.0</td>
<td>6.2</td>
<td>5.3</td>
</tr>
<tr>
<td>Mean cloudiness (in %)</td>
<td>75</td>
<td>70</td>
<td>67</td>
<td>63</td>
<td>59</td>
<td>60</td>
<td>60</td>
<td>56</td>
<td>59</td>
<td>65</td>
<td>76</td>
<td>78</td>
<td>66</td>
</tr>
<tr>
<td><strong>Sunshine</strong></td>
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<td></td>
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</tr>
<tr>
<td>Mean sum (hours)</td>
<td>45.4</td>
<td>72.3</td>
<td>122.1</td>
<td>157.7</td>
<td>221.6</td>
<td>220.9</td>
<td>218.0</td>
<td>210.2</td>
<td>156.3</td>
<td>110.8</td>
<td>52.4</td>
<td>37.4</td>
<td>1,624.8</td>
</tr>
<tr>
<td>in % from the capacity in an astronomic regard</td>
<td>17.7</td>
<td>26.2</td>
<td>33.3</td>
<td>37.9</td>
<td>45.5</td>
<td>44.0</td>
<td>43.2</td>
<td>46.2</td>
<td>41.0</td>
<td>33.5</td>
<td>19.8</td>
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<td><strong>Air humidity</strong></td>
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<tr>
<td>Mean relative humidity (%)</td>
<td>85</td>
<td>82</td>
<td>75</td>
<td>69</td>
<td>67</td>
<td>69</td>
<td>70</td>
<td>73</td>
<td>80</td>
<td>83</td>
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<td>86</td>
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<tr>
<td><strong>Precipitation</strong></td>
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</tr>
<tr>
<td>Mean amount (l/m²)</td>
<td>43.2</td>
<td>36.6</td>
<td>37.5</td>
<td>42.2</td>
<td>55.3</td>
<td>70.7</td>
<td>53.1</td>
<td>65.3</td>
<td>45.5</td>
<td>35.8</td>
<td>49.5</td>
<td>54.5</td>
<td>589.2</td>
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<td>Number of days with ≥ 0.1 l/m² precipitation</td>
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<td>14.3</td>
<td>15.5</td>
<td>14.2</td>
<td>14.0</td>
<td>14.9</td>
<td>13.9</td>
<td>13.4</td>
<td>14.4</td>
<td>14.3</td>
<td>17.0</td>
<td>18.2</td>
<td>181.9</td>
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<td>Days with snow cover ≥ 1 cm</td>
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<td>0.3</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>2.2</td>
<td>8.2</td>
<td>41.8</td>
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<tr>
<td>Days with fog</td>
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<td>4.2</td>
<td>1.6</td>
<td>1.0</td>
<td>0.6</td>
<td>0.3</td>
<td>0.3</td>
<td>1.0</td>
<td>1.8</td>
<td>5.9</td>
<td>5.4</td>
<td>4.9</td>
<td>32.3</td>
</tr>
</tbody>
</table>
2.4 Land use

A further concern for the Air Quality Plan is land use. It influences the urban climate and is thus a relevant factor for the spread of air pollutants. Air pollution tends to be higher in areas that are characterised by buildings and traffic zones. Water areas and green spaces tend to show lower concentrations of pollutants.

The land use proportions of Berlin’s total area of 892 km² for 2009 are provided in Figure 2.4. In total, about 60 % of the area is building space and traffic zones. About 40 % is water, wooded, recreation and agricultural areas. The share of traffic zones (roads, pathways and railway areas) amounts to 137 km², more than 15 % of the total. Though there is a good range of public transport, the traffic volume of motorised private transport is quite high, leading to a significant level of air and noise pollution especially on the urban motorways and in the radial streets in the inner city area. This also affects residential locations and recreation areas.

Figure 2.4: share of the area of different land use categories in Berlin\(^\text{16}\) (total 892 km\(^2\)) in 2009

More important than the summary proportions of land use from the total area is the spatial distribution of living space, industrial sites, traffic zones and green space. The spatial distribution depends on the position of the pollutant emission sources and sensitive areas and also on the supply of fresh air. Figure 2.5 illustrates the spatial distribution of land use in Berlin.

Two structural characteristics are especially relevant to air quality planning. On the one hand, there is Berlin’s developed urban structure, which is marked by spatial proximity and the mixing of residential and commercial segments. On the other hand, there is the size and density of Berlin’s inner city.

The green spaces of the Tiergarten, which are surrounded by a belt of closed development, are located in the inner city. More than 1.1 million residents live there in an area of 120 km². Further central areas are the borough centres such as Spandau, Tegel, Pankow, Köpenick and Zehlendorf. 358 km² of the urban area is building space including the related open area, of which 11 % is used as commercial or industrial building space (4.8 % of the urban area). These areas are focused in a few locations and a number of small areas. The biggest continuous industrial and small business areas are located in the areas of Spandau, Siemensstadt and Tiergarten along the rivers Havel and Spree and the Westhafen. Others are in the eastern part of the city, west of the Berlin outer ring between the urban railway station Hohenschönhausen and Biesdorfer Kreuz and also in Lichtenberg south of Landsberger Avenue in the Herzberg Street region. Further large industrial areas are situated in the regions Tegel, Borsigwalde and Reinickendorf and along the urban railway line towards Lichtenrade. Smaller commercially used space and areas for municipal utility services are scattered over the whole urban area.

2.5 Spatial structure development
The spatial and settlement structure in Berlin and Brandenburg continues to be organised in a transport-efficient manner, especially compared to other German and European cities. One of the most outstanding features of Berlin’s urban structure is the urban polycentricity, its small-scale settlement development in a number of quarters and also the linkages between the different urban spaces (inner city – outer city – urban hinterland).

The push of suburbanisation, which began after the fall of the Berlin Wall in 1990, has noticeably declined. Furthermore, the increases in the Berlin hinterland are concentrated on certain subdivisions. One reason for the decrease in the current trend towards uncontrolled development of housing and commercial buildings is demographic development. Another reason is the instruments of the Joint Regional Planning Berlin-Brandenburg and the Urban Development Planning Berlin initiatives, which have provided effective support since the late 1990s and early 2000s.

Beyond this, Berlin’s spatial-structural development has been marked by a dynamic internal development. Less than 10% of land use is accounted for by urban expansion. Further commercial and retail areas continue to arise, especially in the inner city, related to the existing centre structure. The stock of office space, which is primarily concentrated in the city centre, is estimated at more than 18 million m², of which about 8.6 million m² emerged after 1990. However, over the last few years, office area construction has seen a downward trend.

In order to coordinate the centres in Berlin on a citywide level, the Berlin Senate adopted the urban development plan “Centres 3” (StEP). Its objectives are among others to ensure polycentricity, to strengthen the mixed-use areas in the centres, to maintain the proximity of services and to integrate large retail facilities in a “city-friendly” manner compatible with urban living. Thus the StEP “Centres 3” also affects aspects of air quality management, as the retail industry has a considerable impact on traffic development and thereby on traffic-related air pollutants. That is why the StEP “Centres 3” also contains advice and stages for the development of retail locations that support the objectives of preventing traffic and improving local mobility. This includes the integration of transport by means of excellent connections to the public transit network, limitations on the number of parking spaces (however, without determining specific numbers), good accessibility by foot or by

Figure 2.5: Distribution of land use in Berlin 2009

Simplified outline based on Figure 6.01 (actual usage of built-up areas) of the Berlin Environmental Atlas http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/dd601_06.htm#Abb3

bike and, with regard to specialised retail stores, the installation of access roads and development roads that comply with urban planning and traffic. Specialised retail stores are supposed to be integrated where appropriate (specialised retail store agglomeration).

In order to ensure and stimulate future development of the commercial and industrial sector, the Berlin Senate adopted the urban development plan (StEP) “Commerce and Industry – Concept to ensure industry areas” in January 2011\(^\text{19}\). This is supposed to protect areas used by production-sector companies against competitive types of use such as retail and entertainment facilities, and to ensure a differentiated way of reserving areas and developing land for different kinds of commercial usage. Particular importance is attached to the development of the BBI Business Park Berlin in the city’s southeast near the future Schönefeld airport, the Clean Tech Business Park in the northeast of Berlin and the special location Tegel airport whose area is intended for commercial and industrial purposes after its closure. The air quality planning objectives are particularly supported with regard to the intended avoidance of conflicts related to the Pollution Control Law by means of ensuring sufficient distance between sensitive usages (e.g. residential areas, hospitals, schools) and industrial locations and also through the consideration of traffic concerns. In this respect, there are plans to expand and further develop existing connections to rail and waterways. Also the intended preservation of local commercial locations near residential areas could aid to avoid more traffic.

Housing construction in Berlin has been confined to a moderate level for a number of years. New housing is mainly built in the suburbs, predominantly in Pankow, Steglitz-Zehlendorf, Treetow-Köpenick and Marzahn-Hellersdorf. New housing in the form of additions to existing buildings is gaining in importance. Its share has steadily increased in recent years and achieved a 22% share in all completions in 2008. Residential construction on existing buildings primarily occurs in the inner city and comprises mainly apartments, but also includes a few inner city detached and semi-detached houses.

2.6 Development of the traffic in Berlin

Though an emissions reduction has been achieved, road traffic continues to be the most significant individual source of current and future air pollution in Berlin (see Chapter 5) and thus the decisive field requiring action in terms of air quality planning. Against this background, the present section will look at traffic infrastructure development and transport demand during the past decade.

2.6.1 Transport infrastructure

In national and international comparison, Berlin possesses high-quality and efficient infrastructure for road and rail, which is by and large equipped with adequate spare capacity. The road network has a distinct radial structure with a strong beaming effect of traffic, which on the one hand leads to hot spots by means of traffic-related air pollutants, yet on the other hand keeps the traffic out of other areas, which is particularly relevant to noise abatement in residential areas.

Since 1990, the focus of the infrastructure development has been the interconnection of the networks of East and West Berlin, which showed substantial structural disparities due to their separate development for more than 50 years. This included the re-opening of out-of-commission or interrupted network areas, interconnection of networks, modernisations and extensions of roads, and the establishment of new underground and light trains and tramways. The light train (S-Bahn), for example, has been in full operation again along the whole inner light train ring (S-Bahnring) with the lines S41 and S42 since May 2006.

Important road building measures of recent years that are relevant to the whole network:

- Completion of the tunnel in the urban district Britz in 2000 and extension of the urban motorway A100 up to the Grenzallee junction in 2004
- Completions of the Tiergarten tunnel in 2006 for the federal road B96 running in a north-south direction, the traffic facilities of the long distance and regional railway and completion of two sections of the planned underground railway lines U3 and U5
- Completion of the motorway A113 in May 2008 and thus the junction of the urban motorway A100 to the supra-regional motorway system (motorway A10) south-east of the city
- Construction of sections of the East Tangential Link (TVO) as part of a supra-regional road planned between Adlergestell (federal road B96a) and Alt Biesdorf (federal road B1/5)

Relevant structural data on traffic for the years 2001, 2005 and 2009 is summarised in Table 2.3.

It is notable that the public road network grew by approximately 70 km (+1.3 % of the total length) between 2005 and 2009 and the local public transport (ÖPNV) network grew by 19 km (+0.8 %). The most dynamic expansion has been seen in cycle paths, whose length grew by 256 km, about 27 %, from 2005 to 2009 and, for comparison, from 2002 has grown by 641 km or 62 %. Also the number of bike stands was further increased. However, there are still significant bottlenecks for cycle traffic, as the cycling network continues to be fragmentary and only covers a small fraction of the length of the road traffic network.

### Table 2.3: Characteristics for the development of traffic infrastructure in Berlin

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>2001</th>
<th>2005/6</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public roads</td>
<td>km</td>
<td>5,377.2</td>
<td>5,341.7</td>
<td>5,413.1</td>
</tr>
<tr>
<td>of which federal motorways</td>
<td>km</td>
<td>62.3</td>
<td>68.1</td>
<td>76.7</td>
</tr>
<tr>
<td>Total motor vehicles*</td>
<td>Thousand</td>
<td>1,294.5</td>
<td>1,262.2</td>
<td>1,266.9</td>
</tr>
<tr>
<td>Parking management zones*</td>
<td>Spaces</td>
<td>47,726</td>
<td>59,674</td>
<td>80,980</td>
</tr>
<tr>
<td>Total ÖPNV-network</td>
<td>km</td>
<td>2,462.2</td>
<td>2,481.2</td>
<td>2,481.2</td>
</tr>
<tr>
<td>Underground railway</td>
<td>km</td>
<td>144.2</td>
<td>144.2</td>
<td>146.3</td>
</tr>
<tr>
<td>Tramway</td>
<td>km</td>
<td>187.7</td>
<td>187.7</td>
<td>189.7</td>
</tr>
<tr>
<td>Length of bus lines*</td>
<td>km</td>
<td>n.a.</td>
<td>1,662.0</td>
<td>1,675.0</td>
</tr>
<tr>
<td>Urban railway*</td>
<td>km</td>
<td>251.8</td>
<td>257.0</td>
<td>257.0</td>
</tr>
<tr>
<td>Regional railway*</td>
<td>km</td>
<td>156.0</td>
<td>211.3</td>
<td>213.2</td>
</tr>
<tr>
<td>Bus lanes*</td>
<td>km</td>
<td>101.5</td>
<td>101.7</td>
<td>101.5</td>
</tr>
<tr>
<td>Length cycle paths*</td>
<td>km</td>
<td>1,030.0</td>
<td>1,315.0</td>
<td>1,671.0</td>
</tr>
<tr>
<td>Bike stands*</td>
<td>Spaces</td>
<td>16,500</td>
<td>24,500</td>
<td>26,600</td>
</tr>
</tbody>
</table>

Unless stated otherwise, the source of data is: State Statistical Institute Berlin-Brandenburg: Die kleine Berlin-Statistik 2010 (statistics for the City of Berlin, key facts and figures). Potsdam 2010


a Indication does not apply before 2006, as the method of calculating was modified in 2004 and hence, the values cannot be compared.

### 2.6.2 Development of transport demand

The development of the motorised road traffic is of high importance to air quality planning, as high air pollution primarily occurs on main roads and, to a significant extent, is caused by traffic-related emissions. Thus a decrease in vehicle density and improvement in travel speed and thereby fuel efficiency in road traffic also means a decline of the corresponding emissions. That is why the objective of Berlin’s traffic policy was and still is to
shift the motorised road traffic to modes of transport that are lower in emissions (railway, busses, bicycles, walking). This is not only important in terms of air pollution control, but also reduces the noise pollution and the emission of gases that are harmful to the climate, and furthermore contributes to road safety. In addition, walking and cycling are beneficial to health, and could counteract an increasing lack of physical exercise.

Long-term evaluations at 36 selected automatic counting stations since 2002 show that the total car and heavy vehicle traffic declined by 10 to 14% on average compared to 2002 (see Figure 2.6). Similar results follow from official network statistics showing a decline of 8 to 10% within the main road network. However, the consideration of individual streets reveals differences. In this regard, the traffic mainly decreased in the inner city, whereas several radial main roads and motorway sections increased in traffic volume. The introduction of a low emission zone (LEZ), however, has not caused a displacement of traffic into areas outside the LEZ, as the decreases shown in Figure 2.6 are detectable inside and outside the zone to the same extent. This also applies to the heavy goods vehicle (HGV) traffic, although it demonstrates on the whole a greater volatility.

![Figure 2.6: Relative change of traffic volume from 2002 to 2010 at 36 selected counting stations for the whole road traffic (cars and heavy goods vehicles) and for the HGV traffic](image)

**Development of passenger transport**

The decreasing automobile traffic comes along with an increase in the use of local public transport (ÖPNV) as well as cycling and walking. Despite the urban railway crisis, which started in summer 2009 and has consisted of problems ranging from limited transport service up to total failure on individual network sections, the number of passengers in the urban railway has remained constant. Other means of local public transport posted increases. The cycling traffic volume increased by 32% between 2001 and 2009.
Table 2.4: Development of travel demand\(^a\) in passenger transport

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>2003/2004</th>
<th>2005</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ÖPNV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underground railway</td>
<td>Mio. vkt(^a)</td>
<td>20.4</td>
<td>20.2</td>
<td>20.1</td>
</tr>
<tr>
<td>Tramway</td>
<td>Mio. vkt</td>
<td>21.0</td>
<td>20.5</td>
<td>19.0</td>
</tr>
<tr>
<td>Bus</td>
<td>Mio. vkt</td>
<td>91.0</td>
<td>89.1</td>
<td>87.6</td>
</tr>
<tr>
<td>Urban railway</td>
<td>Mio. train km</td>
<td>29.0</td>
<td>29.0</td>
<td>25.0(^c)</td>
</tr>
<tr>
<td>Number of passengers</td>
<td>ÖPNV Mio.</td>
<td>1,203</td>
<td>1,307</td>
<td>1,351</td>
</tr>
</tbody>
</table>

**Cycling traffic**

<table>
<thead>
<tr>
<th></th>
<th>per 1,000 inhab.</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicycle ownership</td>
<td></td>
<td>721</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycling traffic index</td>
<td>(2001 = 100 %)</td>
<td>101</td>
<td>111</td>
<td>132</td>
</tr>
</tbody>
</table>

**Vehicle traffic**

<table>
<thead>
<tr>
<th></th>
<th>per 1,000 inhab.</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle ownership</td>
<td></td>
<td>325</td>
<td>319</td>
<td>324</td>
</tr>
<tr>
<td>Vehicle mileaged(^d)</td>
<td>Mio. km/a</td>
<td>11,021.4</td>
<td>10,405.2</td>
<td></td>
</tr>
</tbody>
</table>

\(^b\) Underground railway mileage, bus mileage
\(^c\) Decline due to the urban railway crisis
\(^d\) Vehicle mileage from the surveys about the emission cadastre Traffic; Basis: official traffic census

The decreasing reliance on motor vehicle traffic and increasing use of transport services that align with environmental objectives (public transport, pedestrian and bicycle traffic) are also clearly reflected in their shares of total journeys (modal split). Berlin is the leader in Germany as to choosing environmentally friendly modes of transport, altogether holding an average share of 68 % in total passenger transport, whereas, on the whole, cars are used for only 32 % of all distances (see Figure 2.7, on the right). Since a survey of 1998 showing a motor vehicle share of 38 %, car use has declined by approximately 16 %. In the national average, motor cars hold a 58 % share in all journeys, the average share in cities with more than 500,000 inhabitants is 43 %\(^{20}\).

The situation is different when choosing means of transport from and to Berlin, wherein 62 % of all distances are travelled by car. The proportions are shown in Figure 2.7.
Since 2002, the automotive portfolio in the urban area has shown a downward trend. In 2009, however, a slight increase was recorded. The vehicle ownership in Berlin came to 324 motor vehicles per 1,000 inhabitants in 2009 and is thus one of the lowest rates in Europe. Regarding vehicle ownership, the rates in the eastern and western parts of the city have mostly equalised. However, there is a significant gap between the inner city (just under 200 motor cars/1,000 inhabitants) and its surrounding areas (over 500 motor cars/1,000 inhabitants). Still, almost 50% of Berlin’s households possess their own car.

Freight traffic and trade
As shown in Figure 2.6, the HGV traffic is more volatile, which is primarily due to economic reasons. The downward trend during the past years, however, also reflects the changing economic structure, with a growing service sector and a decreasing amount of manufacturing output. With an 85% share, heavy goods vehicles continue to dominate freight traffic, including that in urban areas. Railway services come to an 8% share and inland water vessels amount to 7%. An emerging segment of freight traffic is goods transport with light commercial vehicles in the CEP market (courier, express and parcel services), for instance from increasing purchases of goods via e-commerce and internet orders and the demand for fast and small-sized deliveries.

In trade traffic, commercially approved motor vehicles travel in total more than 500,000 journeys and 11.5 million vehicle kilometres every day, about two thirds of which come from business passenger traffic (business-related travel with briefcase, working equipment etc.). Considering the expansion of the service sector, this area is anticipated to grow in significance.

Urban-rural-traffic
Due to the late urbanisation in terms of housing and business, the demand for a functional integration between Berlin and its surrounding federal state Brandenburg has decreased further since the 1990s.

The strong commercial interactions between the federal states are also shown by the increasing number of commuters. In 2009, approximately 260,000 persons commuted into Berlin, and about 137,000 Berlin citizens have their workplace outside the city. The vast majority of the commuters either come from or go to Brandenburg for work. In addition, there are journeys for leisure trips, shopping and recreational purposes, which also increase the demand for urban-rural-traffic. As Figure 2.7 shows, with a 62% vehicle share of the traffic from and to Berlin made by the residential population of Berlin, twice as many journeys are travelled by car compared to those in urban areas. This partly explains the observed increase in traffic on the radial highways in Berlin.

3 Air quality in Berlin: an assessment of the ambient air quality and its nature

3.1 Assessment criteria
Crucial to any air quality planning is a comprehensive spatial evaluation of the air pollution over time with regard to limit values. For this purpose the European Air Quality Directive 2008/50/EC and the 39. BlmSchV, respectively, provide for the following options:

a) Continuous air quality measurements of high temporal resolution:
   In all areas and agglomeration zones in which the air pollution levels risk exceeding the limit values, a defined minimum number of sampling points per habitant has to be established. This applies in particular to locations where the exposure is presumably the highest. Accordingly, at least seven sampling points for particulate matter PM$_{10}$ and nitrogen dioxide and a minimum of three sampling points for particulate matter PM$_{2.5}$ should be installed in Berlin.

The continuous measurements may be supplemented by

b) Measurements in the form of spatial and periodic sampling or aggregated measurements over time with simplified procedures,
c) Statistical methods for extrapolation and interpolation,
d) the application of dispersion models.

The Senate Department of Urban Development and Environment operates an extensive monitoring network with respect to a) and b) which will be briefly outlined in the following.

Since, for reasons of costs and capacity, only a limited number of monitoring stations can be operated, intensive use is made of simulation models. These have the following advantages:

- Information on the spatial dispersion of ambient air may be gathered between the air quality monitoring stations
- Future trends of ambient air quality may be estimated based on the assumptions of scenario calculations (e.g. increased use of reduction technologies through particle filters for diesel vehicles).

3.1.1 Measurement of ambient air quality – the air quality monitoring network of Berlin [Berliner Luftgüte-Messnetz] BLUME
Since 1975, air quality in Berlin has been monitored continuously by Berlin’s air quality monitoring network (BLUME).

In 2010 the monitoring network covered 16 stationary monitoring points for air pollutants, including six along highly frequented roads, five situated in the inner city background (residential areas and business parks) and five at the city periphery or in forests. Air pollution is measured by using the required standard procedures. Additionally, all automatic dust monitors devices were equipped with a soot measuring head which serves to continually determine the blackening of the filter as measure for the concentration of elementary carbon (soot). Due to changes in the device type in 2011, however, soot-measuring heads can no longer be used at all measuring locations. Among the air pollutants measured at the stations are nitrogen oxides (NO and NO$_2$), ozone (O$_3$), particulate matter (PM$_{10}$, PM$_{2.5}$) and soot, benzene, carbon monoxide (CO) and sulphur dioxide (SO$_2$). However, not all components are measured at each station. At three measuring points the levels of the heavy metals lead (Pb), cadmium (Cd), arsenic (As) and nickel (Ni) are additionally determined as
part of the PM$_{10}$ fraction, and at 5 measuring points the levels of benzopyrene (BaP) are taken. Table A-1 in the Annex provides an overview of the equipment of all measuring points.

In order to determine the „Average Exposure Indicator“ (AEI) pursuant to 39. BlmSchV, gravimetric particulate measurements of the PM$_{2.5}$ fraction, expressed as daily mean values, are carried out at three stations in the inner city background, and at one station at a main road.

In 2011, dust measuring devices were removed at two stations (Marienfelde and Schöneberg). Due to a close correlation with other stations of the same category, the measurement results of these stations did not provide additional information relevant for the air quality assessment, but incurred substantial costs.

In addition, there is a meteorological station and a monitoring bus for easy mobility.

On working days at 12 am, the values measured the day before are supplied to various newspapers, radio stations and TV stations for publication. In parallel, the data is uploaded and can be accessed online at: www.berlin.de/sen/umwelt/luftqualitaet/de/messnetz/index.shtml.

Since 1997, the monitoring network BLUME has been supplemented by the monitoring network RUBIS. RUBIS consists of 30 small and low cost samplers which are primarily installed at lampposts on main roads. The miniaturized devices each contain a sampler for soot and benzene [Ruß-, Benzol-, Immissions-Sammler {RUBIS}] and one NO$_2$-passive collector. The samples are collected continuously over 14 days and are analysed subsequently in the laboratory. This value represents the average pollution during the 14-days sampling time. Since the limit value for benzene has been met on all main roads for the last years, benzene measurements have been confined to a few locations in 2009 for the purpose of internal quality assurance.

Soot and NO$_2$ measurements are essential for examining the effectiveness of traffic-related measures on air quality improvement. In this way, nitrogen dioxide and soot were recorded at 23 traffic sites in 2010 in addition to the air pollutants recorded at monitoring containers. Furthermore, the soot concentration allows for the calculation of PM$_{10}$ concentration, which is published in the annual report as an annual mean.

Figure 3.1 shows the distribution of monitoring sites in Berlin.

### 3.1.2 Air pollution modelling and simulation

Models for calculating the dispersion of air pollutants emphasise the causal link between emissions of air pollutants and the resulting air pollution. They are used for the spatial representation of air pollutant dispersions and the planning of measures at all scales (national, agglomeration zone, roads).

As outlined in detail in Chapter 5, there are links between the source of air pollutants and the receptors over long distances. This is because air pollutants such as particulate matter (PM$_{10}$) or ozone are, in some cases, first formed by chemical processes in the atmosphere where they may remain for several days. Since the density of sources of air pollutants is comparatively high in Central Europe, there is a widely distributed background level which contributes considerably to limit value exceedances, in particular of PM$_{10}$ limit values and thus constrains the local room for manoeuvre to reduce ambient air quality. In order to calculate this background pollution and its future trend, models are necessary that cover both Berlin and its immediate surroundings, but are also capable of calculating the long-distance transmission of air pollutants over hundreds of kilometres and across national borders.
High concentrations of air pollutants also occur near areas with high emissions of air pollutants, as for instance in very busy street canyons. Unlike in most industrial zones, people – whether as inhabitants, clients or employees – are exposed to increased air pollution on very busy roads. To meet the requirements that were set in the European Directive, a fully traceable quantification of the ambient air quality is necessary to comply with limit values at the location with the highest exposure level. To this end, the measurements described above have been supplemented by model calculations in all busy roads in which limit values may potentially be exceeded. However, even in a traffic-exposed street canyon the share of the pre-existing pollution caused by the remaining pollutant sources in the city or the long-distance transmission of air pollutants plays a key role. Therefore, a system of models was applied which is capable of calculating both the wide-ranging influence of far removed sources as well as the contributions of all emitters in the urban area (including street canyons). Figure 3.2. schematically shows the spatial distribution of the models and their resolution.

The following models are used for the individual scales:

**Street canyon scale**
Traffic-induced air pollution in street canyons is calculated for the entire network of main roads by using the program IMMISluft. IMMISluft is a simplified program (screening-model) to determine incremental and the total pollution from motor vehicles in street canyons. The total pollution in street canyons is determined as the sum of the incremental pollution and the urban background pollution. The results of the IMMISluft calculation are annual mean values of the incremental pollution and the total pollution of the air pollutants under consideration.

At road sections with measuring points, air pollution was additionally modelled with the more cumbersome program IMMIScpb. This is an analytical-empirical dispersion model for built-up urban areas. It makes it possible to calculate hourly values of air pollutant concentrations caused by local traffic at any point (receptors) of a street canyon with differing building height and wind-permeable gaps between the buildings on the basis of meteorological factors that are easily accessible. Another essential input parameter is the emission of each road section. These were calculated on the basis of up-to-the-minute traffic data with the program IMMISem.

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**Figure 3.2: Schematic illustration of the spatial distribution and resolution of the dispersion models used for the air quality planning in Berlin**

![Figure 3.2: Schematic illustration of the spatial distribution and resolution of the dispersion models used for the air quality planning in Berlin](image)

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The urban background pollution, which is necessary for determining the total concentration of air pollutants in both programmes, was calculated with the program IMMISnet. Urban background pollution is caused by the remaining emissions in the city.

Urban background pollution

IMMISnet is a climatological dispersion model for calculating the spatial extent of air pollution at the urban level. Treated as a stationary process, the model describes the dilution and the transport of pollutants from point, line or area sources, assuming a Gaussian normal distribution. On the basis of the Gaussian smoke plume equation, IMMISnet calculates concentration contributions from the emissions of all point, line or area sources of the city. The contribution of sources from outside the agglomeration zone, which is particularly relevant for PM10, is not included in the calculations of the programme. Therefore, the regional background pollution has to be modeled separately.

Regional background pollution

The regional background pollution, which is necessary for determining total pollution, was calculated by using the REM-CALGRID-Model (RCG). The RCG-model is a so-called aerosol-chemistry-transport model that has been developed by the Free University of Berlin [Freie Universität Berlin] on behalf of the Federal Environment Agency [Umweltbundesamt]. It simulates the main chemical-physical processes taking place in the atmosphere that result in the formation of oxidants such as ozone, nitrogen dioxide or the formation of secondary particulate matter such as sulphate, nitrate and ammonium. These particles represent a significant share of the particulate matter (PM10) pollution level. The model also takes into account the natural contribution of PM10 such as whirled up dust rising from the ground. The RCG-model is used for calculating the short and long-term air pollution on a European-wide, national or regional/urban scale. All air quality parameters defined in the EU Directives can be determined.

3.2 Assessment of air quality on the basis of measurements

3.2.1 Nitrogen dioxide

The concentration of nitrogen dioxide (NO2) has been recorded at various monitoring points in the city for years. Diagram 3.3 illustrates the multi-year trend in the mean NO2 pollution at three types of monitoring stations at which continuous measurements with high temporal resolution were carried out:

- at five traffic sides on main roads (red curve),
- at three measuring points that are representative for the pollution in inner city residential streets with little traffic (blue curve),
- at five measuring points at the city periphery (green curve).

At all three types of stations the concentration of NO2 has hardly changed during the last ten years. The values measured at roads with high levels of traffic (red curve) still significantly exceed the EU limit value of 40 µg/m³ in the annual mean. The expected reduction of nitric oxide emissions from the improvement of exhaust technologies of vehicles has not happened to the extent anticipated. The share of NO2 pollution generated by local traffic has slightly declined as a result of the LEZ. In urban residential areas and the peripheral zone, on the other hand, the annual limit value of NO2 was met.

In contrast, concentrations of nitrogen monoxide (NO) – marked in pink – have declined continuously at all traffic-exposed monitoring stations until 2007. They declined from 98 µg/m³ in 1999 to 44 µg/m³ in 2007. A further decline to 42 µg/m³ was only reached in 2010.

The obvious discrepancy between the trend in NO2 pollution relevant to air hygiene on the one hand, and the traffic induced NOx emissions on the other hand, is not a phenomenon confined to Berlin. It has been observed in many European agglomeration zones. The dis-
crepancy is a result of the increased number of diesel vehicles and a shift in the ratio of NO/NO$_2$ to NO$_2$ due to the introduction of oxidation catalysers in diesel vehicles.

Figure 3.3: Multi-year trend in nitrogen dioxide and nitrogen monoxide values in Berlin

![Graph showing multi-year trend in nitrogen dioxide and nitrogen monoxide values in Berlin](image)

Limit value for NO$_2$

Table 3.1 shows the development of the annual mean values for the individual monitoring stations from 2005 to 2010. While the limit values were met at all monitoring points in the city periphery and inner city background, the annual mean values for NO$_2$ exceeded the limit value of 40 µg/m$^3$ at all main road stations in each year. The short-term value, however, was not exceeded.
### Table 3.1: Annual mean values for nitrogen dioxide in Berlin 2005-2010

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>NO$_2$ Annual mean value [µg/m$^3$]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2005</td>
</tr>
<tr>
<td>Peripheral zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>027</td>
<td>Marienfelde</td>
<td>14</td>
</tr>
<tr>
<td>032</td>
<td>Grunewald</td>
<td>15</td>
</tr>
<tr>
<td>077</td>
<td>Buch</td>
<td>15</td>
</tr>
<tr>
<td>085</td>
<td>Friedrichshagen</td>
<td>14</td>
</tr>
<tr>
<td>145</td>
<td>Frohnau</td>
<td>13</td>
</tr>
<tr>
<td>Inner city background</td>
<td></td>
<td></td>
</tr>
<tr>
<td>010</td>
<td>Wedding</td>
<td>30</td>
</tr>
<tr>
<td>018</td>
<td>Schöneberg</td>
<td>29</td>
</tr>
<tr>
<td>042</td>
<td>Neukölln</td>
<td>26</td>
</tr>
<tr>
<td>171</td>
<td>Mitte</td>
<td>26</td>
</tr>
<tr>
<td>282</td>
<td>Karlshorst</td>
<td>19</td>
</tr>
<tr>
<td>Main road</td>
<td></td>
<td></td>
</tr>
<tr>
<td>115</td>
<td>Hardenbergplatz</td>
<td>59</td>
</tr>
<tr>
<td>117</td>
<td>Schildhornstr.</td>
<td>59</td>
</tr>
<tr>
<td>124</td>
<td>Mariendorfer Damm</td>
<td>-</td>
</tr>
<tr>
<td>143</td>
<td>Silbersteinstr.</td>
<td>49</td>
</tr>
<tr>
<td>174</td>
<td>Frankfurter Allee</td>
<td>44</td>
</tr>
<tr>
<td>220</td>
<td>Karl-Marx-Str.</td>
<td>47</td>
</tr>
</tbody>
</table>

Highlighted: exceedances of the NO$_2$ annual limit value of 40 µg/m$^3$

### 3.2.2 Particulate matter (PM$_{10}$)

Diagram 3.4 shows the multi-year trend in PM$_{10}$-concentrations – recorded with automatic measurement devices – in Berlin and its surroundings over the last years since the switch in measurements from total dust to the fine dust fraction PM$_{10}$ in 1998.

The red curve shows the pollution as a mean value over four urban traffic sites (main roads). The blue and the dark green lines illustrate the concentration at three monitoring stations in inner city residential areas and at four monitoring points at the periphery. For comparison, data from four rural background stations in Brandenburg was added.
It is discernible that the annual mean values strongly fluctuate. Since 2007, the values for particulate matter PM$_{10}$ were substantially lower than in previous years, especially at the traffic sites. The increases in 2009 and 2010 are attributable to increases in the pre-existing pollution of the air flowing into Berlin, and, in 2010 also to increased emissions from radiators and worsened conditions for dispersal. Unfavourable climatic conditions prevailed in 2010, particularly during winter (see also Chapter 5.1). Due to the high demand for heating, exceedances of PM$_{10}$ limit values were observed even at the inner city background station in Neukölln (Nr. 042).

The annual mean values for each station from 2005-2010 are summarized in Table 3.2. The limit value for the annual mean of particulate matter was not exceeded.

Table 3.2 shows that the concentration of particulate matter increased by approximately 1 µg/m$^3$ from 2009 to 2010 from the annual mean at most measuring points. This is due to the unfavourable climatic conditions in 2010 (Chapter 5). However, as demonstrated by an analysis on the LEZ$^{28}$, a higher annual mean value of 2 µg/m$^3$ would have been expected without the emission reduction in the transport sector due to the LEZ. Accordingly, the annual mean concentration would have increased by 3 µg/m$^3$ from 2009 to 2010 – instead of 1 µg/m$^3$ – due to the unfavourable climatic conditions for dispersal of vehicle exhaust emissions.

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$^{28}$ Senate Department for Health, the Environment and Consumer Protection: One Year Low Emission Zone, Stage 2 in Berlin – Analysis of the effect on emissions from road traffic and on the air quality in Berlin. 2011 Berlin.
### Table 3.2: Annual mean values for particulate matter PM$_{10}$ in Berlin 2005-2010

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Annual mean value in µg/m$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2005</td>
</tr>
<tr>
<td>No.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peripheral zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>027</td>
<td>Marienfelde</td>
<td>24</td>
</tr>
<tr>
<td>032</td>
<td>Grunewald</td>
<td>21</td>
</tr>
<tr>
<td>077</td>
<td>Buch</td>
<td>24</td>
</tr>
<tr>
<td>085</td>
<td>Friedrichshagen</td>
<td>23</td>
</tr>
<tr>
<td>Inner city background</td>
<td></td>
<td></td>
</tr>
<tr>
<td>010</td>
<td>Wedding</td>
<td>25</td>
</tr>
<tr>
<td>018</td>
<td>Schöneberg</td>
<td>25</td>
</tr>
<tr>
<td>042</td>
<td>Neukölln</td>
<td>28</td>
</tr>
<tr>
<td>171</td>
<td>Mitte</td>
<td>29</td>
</tr>
<tr>
<td>Road</td>
<td></td>
<td></td>
</tr>
<tr>
<td>115</td>
<td>Hardenbergplatz</td>
<td>32</td>
</tr>
<tr>
<td>117</td>
<td>Schildhornstr.</td>
<td>36</td>
</tr>
<tr>
<td>124</td>
<td>Mariendorfer Damm</td>
<td>-</td>
</tr>
<tr>
<td>143</td>
<td>Silbersteinstr.</td>
<td>38</td>
</tr>
<tr>
<td>174</td>
<td>Frankfurter Allee</td>
<td>37</td>
</tr>
<tr>
<td>220</td>
<td>Karl-Marx-Str.</td>
<td>37</td>
</tr>
</tbody>
</table>

* = influenced by road works

Table 3.3 illustrates the number of short-term limit value exceedances (24 h limit value of > 50 µg/m$^3$) between 2005 and 2010. Exceedances mainly occurred in 2005, 2006 and 2010 especially due to the entry of pre-polluted air masses. This has become particularly evident in 2010: during weather conditions with long-distance transport, inlet stations are the stations Marienfelde and Friedrichshagen. With 27 and 28 exceedance days, respectively, in 2010, these stations had much higher values than the other two city periphery stations with 22 exceedance days. Compared to 2009, the number of days exceeding the limit value has increased by 21 days at the periphery station Friedrichshagen. The increase was markedly lower at Frankfurter Allee where 15 more exceedances occurred in 2010 than in 2009. Comparing the frequency of limit value exceedances in 2010 with 2006, the year that comes closest to 2010 due to its climatic conditions, it can be seen that the number of exceedances occurring additionally to the city periphery and the urban background was much lower in 2010. Thus, in 2006 the number of exceedances on Frankfurter Allee was 34 days higher than in the urban background. In 2009, there were 19 more exceedance days and in 2010, despite unfavourable dispersal conditions, only 15 additional exceedance days (as a difference from the station Neukölln).
Table 3.3: Number of days on which the 24 hour limit value for PM\textsubscript{10} in Berlin 2005-2010 was exceeded

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Number of days exceeding the daily mean value of 50 µg/m\textsuperscript{3}</th>
<th>Per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2005</td>
<td>2006</td>
</tr>
<tr>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>City periphery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>027</td>
<td>Marienfelde</td>
<td>18</td>
<td>23</td>
</tr>
<tr>
<td>032</td>
<td>Grunewald</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>077</td>
<td>Buch</td>
<td>17</td>
<td>27</td>
</tr>
<tr>
<td>085</td>
<td>Friedrichshagen</td>
<td>15</td>
<td>21</td>
</tr>
<tr>
<td>Inner city background</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>010</td>
<td>Wedding</td>
<td>21</td>
<td>26</td>
</tr>
<tr>
<td>018</td>
<td>Schöneberg</td>
<td>21</td>
<td>26</td>
</tr>
<tr>
<td>042</td>
<td>Neukölln</td>
<td>30</td>
<td>37</td>
</tr>
<tr>
<td>171</td>
<td>Mitte</td>
<td>28</td>
<td>59*</td>
</tr>
<tr>
<td>Road</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>115</td>
<td>Hardenbergplatz</td>
<td>44</td>
<td>48</td>
</tr>
<tr>
<td>117</td>
<td>Schildhornstr.</td>
<td>60</td>
<td>54</td>
</tr>
<tr>
<td>124</td>
<td>Mariendorfer Damm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>143</td>
<td>Silbersteinstr.</td>
<td>74</td>
<td>67</td>
</tr>
<tr>
<td>174</td>
<td>Frankfurter Allee</td>
<td>73</td>
<td>71</td>
</tr>
<tr>
<td>220</td>
<td>Karl-Marx-Str.</td>
<td>59</td>
<td>55</td>
</tr>
</tbody>
</table>

* = influenced by road works
Highlighted: more than 35 exceedances of the daily value of 50 µg/m\textsuperscript{3}

The daily limit value exceedances as well as the individual daily mean values strongly fluctuate from year to year. As illustrated in Diagram 3.5, considerable variations were observed at the individual monitoring stations between 2005 and 2010. The diagram shows the number of exceedances in relation to the extent of the exceedance. The share of exceedance days that may be attributed to high daily mean values with concentrations of more than 20 µg/m\textsuperscript{3} above the threshold value of 50 µg/m\textsuperscript{3}, thus reaching more than 70 µg/m\textsuperscript{3}, is illustrated by the dark-coloured parts of the columns. The light-coloured parts of the columns show the contribution of exceedances that merely exceed the limit value. With daily mean values of up to 55 µg/m\textsuperscript{3}, they exceed the limit value by less than 5 µg/m\textsuperscript{3}.

In 2007 and 2008, years with favourable climatic conditions, the values recorded on most exceedance days were just above the threshold of 50 µg/m\textsuperscript{3}. Even in 2009 the limit value on Frankfurter Allee (No. 174) would have been achieved by reducing the pollution of particulate matter by 5 µg/m\textsuperscript{3}. In that case no more exceedances would have occurred, illustrated by the light-coloured column, and the total number of exceedance days would have remained below the number of days permitted (35 days) per year. This scale can generally be achieved by local measures in Berlin.

Unfavourable years, such as 2005, 2006 and 2010, require significantly higher reductions of more than 10 µg/m\textsuperscript{3}. This is because the number of high daily means with a concentration of 70 µg/m\textsuperscript{3} or higher already fill the permitted quota of 35 exceedance days by 60 %. An improvement by 5 µg/m\textsuperscript{3}, however, would at least ensure compliance with the limit value in the inner city residential areas (monitoring site Nansenstraße, No. 042).
3.2.3 Particulate matter (PM$_{2.5}$)

Since 2004, PM$_{2.5}$-particles, i.e. particles with an aerodynamic diameter of up to 2.5 µm, have been measured and analysed for selected content substances at the traffic station Frankfurter Allee in Berlin-Friedrichshain and at the urban background station on Nansenstraße in Berlin-Neukölln.

Diagram 3.6 shows the trend in the annual mean value of the PM$_{2.5}$-concentrations as mean value of the three urban background stations as well as the trend in Frankfurter Allee as main road.

Figure 3.5: Classification of exceedances of the daily limit value for 2005-2010 according to the excess above 50 µg/m$^3$ (blue line: 35 days > 24 h limit value for PM$_{10}$) for different monitoring stations (MC)
Table 3.4 summarizes the annual mean values for PM\textsubscript{2.5} since 2004. The target/limit value for PM\textsubscript{2.5} of 2 µg/m\textsuperscript{3}, which has to be met by 2015, was only exceeded at the traffic station in 2005 and 2006 and has been met at all stations since 2007.

<table>
<thead>
<tr>
<th>Position</th>
<th>No.</th>
<th>Location</th>
<th>PM\textsubscript{2.5} Annual mean value in µg/m\textsuperscript{3}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban background</td>
<td>010</td>
<td>Wedding</td>
<td>18 18 20</td>
</tr>
<tr>
<td></td>
<td>042</td>
<td>Neuköln</td>
<td>20 22 25 18 19 19 21</td>
</tr>
<tr>
<td></td>
<td>171</td>
<td>Mitte</td>
<td>19 18 21</td>
</tr>
<tr>
<td>Road</td>
<td>174</td>
<td>Frankfurter Allee</td>
<td>24 26 29 23 22 22 24</td>
</tr>
</tbody>
</table>

On average, 76 % of the particulate matter PM\textsubscript{10} in the urban background consist of particles with an aerodynamic diameter of up to 2.5 µm (PM\textsubscript{2.5}). On roads, the share of PM\textsubscript{2.5} accounts for 70 % on average, as larger particles with diameters of more than 2.5 µm are released by road dust abrasion and re-suspension.

### 3.2.4 Polycyclic Aromatic Hydrocarbons (PAH)

Polycyclic aromatic hydrocarbons (PAH) are organic compounds that are deemed carcinogenic. The main component used for these compounds is benzo[a]pyrene. PAHs are mainly formed by the incomplete combustion of carbon intensive fuels such as oil, coal or wood. The most important sources of PAH are coal and wood heating systems and diesel engines. PAHs are further contained in coal and oil. As a natural component of mineral-oil-based extender oils, they occur in tyres and enter the air due to tyre debris.

By adopting the 4\textsuperscript{th} Daughter Directive of the European Framework Directive 96/62/EC, a target value of 1 ng/m\textsuperscript{3} was set for benzo[a]pyrene (BaP) in 2006, which has to be met by 2013. Since 2006 BaP has been measured again at five monitoring stations in Berlin (main roads, urban background and city periphery). The annual mean values are depicted in table 3.5.
### Table 3.5: Annual mean values of benzo[a]pyrene in Berlin 2006-2010

<table>
<thead>
<tr>
<th>Position</th>
<th>No.</th>
<th>Location</th>
<th>benzo[a]pyrene Annual mean values in ng/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>City periphery</td>
<td>077</td>
<td>Buch</td>
<td>0.65 0.57 0.79</td>
</tr>
<tr>
<td>Urban background</td>
<td>042</td>
<td>Neukölln</td>
<td>1.32 0.70 0.76 0.96 1.18</td>
</tr>
<tr>
<td>Road</td>
<td>115</td>
<td>Hardenbergplatz</td>
<td>0.66 0.39 0.36 0.50 0.67</td>
</tr>
<tr>
<td></td>
<td>117</td>
<td>Schildhornstr.</td>
<td>1.24 0.68 0.57 0.97 1.32</td>
</tr>
<tr>
<td></td>
<td>174</td>
<td>Frankfurter Allee</td>
<td>1.22 0.67 0.71 0.85 1.03</td>
</tr>
</tbody>
</table>

Highlighted: exceedance of the 2013 target value of 1 ng/m³

In 2006 and 2010, the target value was still exceeded at the urban background station in Neukölln (No. 042) and several road stations. Further actions are thus necessary to ensure compliance with the target value by 2013. Compared with values from the 1990’s with concentrations of approximately 5 ng/m³, however, the BaP pollution has dropped by a factor of 5. The reason for this is the extensive replacement of coal heating systems with alternative types of heat, especially gas and district-heating.

### 3.3 Assessment on the basis of model calculations

In addition to measurements, model calculations are carried out to assess Berlin’s air quality. Unlike measurements, which only represent a limited area surrounding the measuring station, modelling reflects the concentration of air pollutants in the entire urban area. In contrast to measurements, models also allow for the prediction of future trends in air quality. The models used were already described in section 3.1. The initial situation of the air quality was assessed on the basis of traffic and emission data from 2009. This is currently the most recent and comprehensive data available. The year 2005 was chosen as the meteorological reference year for all calculations as it represents the average meteorological conditions in Berlin quite well. It is thus well suited for any forecast. The meteorological conditions in 2005 were more unfavourable than in 2009, however, so the modelling results tend to be higher than the measured values.

The total pollution of the main road network in Berlin in 2009 was analysed with appropriate concentration groups of the modelled annual mean values for NO₂, PM₁₀, and PM₂.₅ and depicted in cartographic form. On road sections with a speed limit of 30 km/h the reduction effect observed on the Schildhornstraße was taken into account.

The calculated concentrations of air pollutants are not comparable with the model calculations of the previous Clean Air and Action Plan, since the emission factors for road transport were changed with the update of the Handbook Emission Factors for Road Transport (HBEFA 3.1). In many cases, the emission factors are now higher than in the previous version HBEFA 2.1. This is because emission factors could previously only be measured partially and were thus only predicted on the basis of the envisaged reduction of the emission limit values. Therefore, the newly calculated concentrations of air pollutants are in parts higher than predicted by the previous factors in the Clean Air and Action Plan 2005. This does not indicate an actual deterioration in air quality.
3.3.1 Results of nitrogen dioxide for the year 2009

The modelled distribution of NO₂ concentration within the urban background is illustrated in Diagram 3.7. With values of up to 28 µg/m³ (up to 30 µg/m³ at some stations), the highest concentrations occur in inner city areas. Here the high density of main roads throughout the entire area causes higher levels of pollution. Increased concentrations are discernible along large parts of the urban motorway A100. Approaching the city periphery, the concentrations drop to values of approximately 10 up to 15 µg/m³.

Figure 3.8 shows the NO₂ concentrations on main roads, which comprises the sum of the urban background pollution and the incremental pollution caused by local traffic. Road sections exceeding the NO₂ annual mean value of 40 µg/m³ are marked in red, blue and brown. The sections exceeding a value of 60 µg/m³ which are relevant for the extension of the compliance deadline are marked in black.

According to the model calculations, exceedances of the NO₂ annual mean value of 40 µg/m³, as applicable since 2010, have occurred at 411 road sections with a total length of 58 km. Around 48,000 persons (rounded value) are affected by these limit value exceedances. At five road sections with a total length of 600 m and 590 persons concerned, the NO₂ annual mean value was above 60 µg/m³. Here the limit value was exceeded including the margin of tolerance. Since 2010, the latter has to be met even in the case of a postponement of the compliance deadline. NO₂ concentrations of 36–40 µg/m³ were calculated for further 96 km main roads with 58,500 residents.
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Figure 3.7: Modelled urban background concentrations for nitrogen dioxide in 2009

Modelled annual mean concentration of urban background NO$_2$ in $\mu$g/m$^3$
Base year 2009

- 10 up to 14
- 14 up to 18
- 18 up to 22
- 22 up to 25
- above 25

Low emission zone

Figure 3.8: NO$_2$ annual mean values calculated for the network of main roads 2009

Modelled annual mean concentration of NO$_2$ in main roads in $\mu$g/m$^3$
Base year 2009

- 10 up to 38
- 38 up to 40
- 40 up to 42
- 42 up to 44
- 44 up to 60
- above 60

Limit value NO$_2$: 40 $\mu$g/m$^3$
### 3.3.2 Results for particulate matter PM$_{10}$ for the year 2009

The models used for calculating concentrations of particulate matter in the urban background (IMMIS$^\text{net}$) and in the network of main roads (IMMIS$^\text{luft}$) provide the annual mean value as a result. They are not capable of calculating the number of times the 24 h limit value was exceeded. This would require a much more sophisticated modelling of time series. Ordinarily, the models underestimate the episodes with particularly high concentrations. Therefore, use was made of a much simpler, but sufficiently accurate method, namely the statistical link between the annual mean value and the number of times the 24 h limit value was exceeded. This correlation had been observed over several years. From this follows that, in the event of an annual mean value of 30 µg/m$^3$, 35 or more exceedances of the 24 h value can be expected with a 50 % probability. If the annual mean value reaches 32 µg/m$^3$ or more, this is almost certain.

The modelling result of the particulate matter concentrations for the urban background is illustrated in Diagram 3.9. The lowest concentrations of 21-22 µg/m$^3$ occur at the southwest and southeast city borders in the forest areas of Grunewald and in the vicinity of Müggelsee Lake, respectively. Towards the inner city, the concentration increases to values of 24-26, sometimes even 28 µg/m$^3$.

As the modelling result for the network of main roads shows (Figure 3.10), the annual mean value of 30 µg/m$^3$ was exceeded at various road sections in 2009. For a value exceeding 30 µg/m$^3$, 35 or more days with mean values higher than 50 µg/m$^3$ are to be expected. Colour coding matches the sections according to the modelled annual mean values. At sections marked in grey the annual mean is below 28 µg/m$^3$ and the 24 h limit value is therefore met. Similarly, exceedances are unlikely at sections coloured in green (total length of 127 km) with values between 28 and 30 µg/m. However, exceedances may occur especially in years with very high initial levels of pollution. Red coloured are sections with PM$_{10}$ annual means between 30 and 32 µg/m$^3$ at which the 24 h limit value is often exceeded. These sections amount to a length of 49 km and affect approximately 39,000 residents. At sections with mean values above 32 µg/m$^3$, the 24 h limit value is either always met or exceeded. These sections are marked in blue (32-34 µg/m$^3$), brown (34-40 µg/m$^3$) and black (> 40 µg/m$^3$). They have a length totalling 30 km and affecting 25,465 inhabitants. At three sections (black) of the Leipziger Straße with a length of 376 m and 429 affected persons, an exceedance of the limit value is modelled for the annual mean of 40 µg/m$^3$. In sum, 563 road sections with a length of 79 km and 64,276 affected persons are above the critical value of 30 µg/m$^3$ which is crucial for complying with the 24 h limit value.

The roads concerned are mainly located in inner city areas, i.e. primarily within the LEZ. This is due to the high density of buildings, which leads to narrow street canyons with particularly unfavourable conditions for dispersal.

Figure 3.9: Urban background concentrations of particulate matter PM$_{10}$ in 2009

Modelled annual mean concentration of urban background PM$_{10}$ in µg/m$^3$
Base year 2009

- 20 up to 22
- 22 up to 24
- 24 up to 25
- 25 up to 26
- above 26

Low emission zone

Figure 3.10: Calculated PM$_{10}$ annual mean values within the network of main roads in Berlin 2009

Modelled annual mean concentration of PM$_{10}$ in main roads in µg/m$^3$
Base year 2009

- 10 up to 28
- 28 up to 30
- 30 up to 32
- 32 up to 34
- 34 up to 40
- above 40

Limit value PM$_{10}$: 40 µg/m$^3$
(24h limit value likely to be exceeded above annual mean of about 30 µg/m$^3$)
3.3.3 Results for particulate matter PM$_{2.5}$ for the year 2009

The spatial concentration of particles with a size of up to 2.5 µm (PM$_{2.5}$) within the urban background is more evenly distributed than the concentration of PM$_{10}$ or nitrogen dioxide. This is illustrated in Figure 3.11. With values of 15-16 µg/m$^3$, concentrations are approximately 2 µg/m$^3$ lower in the outskirt areas of the city than in the inner city areas where values of 16 to 18 µg/m$^3$ were modelled. In a few grid cells only, the values are above 18 µg/m$^3$. In one single cell the concentration reaches nearly 24 µg/m$^3$. This is also the site with the highest PM$_{10}$ pollution within the urban background.

Figure 3.12 illustrates the PM$_{2.5}$ concentrations on main roads in 2009. The annual mean limit value of 25 µg/m$^3$ to be met by 2015 is already achieved in almost all locations. In 2009, it was only exceeded at four sections (Leipziger Straße) with a total length of 473 m and 429 residents. The daily limit value for PM$_{10}$, using the equivalent annual mean value of 30 µg/m$^3$ as a reference value is thus a more stringent requirement than the PM$_{2.5}$ limit value which has to be met only by 2015.

Figure 3.11: Urban background concentrations for particulate matter PM$_{2.5}$ in 2009

Modelled annual mean concentration of urban background PM$_{2.5}$ in µg/m$^3$
Base year 2009

- 14 up to 15
- 15 up to 16
- 16 up to 17
- 17 up to 18
- above 18

Low emission zone

Figure 3.12: PM$_{2.5}$ annual mean values calculated in the network of main roads in Berlin 2009

Modelled annual mean concentration of PM$_{2.5}$ in main roads in µg/m$^3$
Base year 2009

- 10.0 up to 20.0
- 20.0 up to 22.5
- 22.5 up to 25.0
- 25.0 up to 27.5
- above 27.5

Target value PM$_{2.5}$: 25 µg/m$^3$ (2010)
Limit value PM$_{2.5}$: 25 µg/m$^3$ (2015)
3.4 Socio-spatial distribution of air pollutants in Berlin – Environmental justice as a model scheme

As part of the model scheme Umweltgerechtigkeit im Land Berlin [Environmental justice in Berlin]29, it was examined to what extent areas exposed to varying concentrations of social problems are affected by environmental factors that are harmful to health. The assessment is based on the 2006 classification of Berlin’s land as Lebensweltlich orientierte Räume (LOR) [environmental life-oriented areas], forming a new basis for spatial planning, forecasting, and observing demographic and social developments. Among the delimitation criteria for spaces with a life-oriented homogeneity were the standardization of building structures, or the formation of milieus, main roads, natural barriers, as well as a limitation on the number of inhabitants. As a result, 447 planning areas were defined which now serve as small spatial planning units. Within the framework of monitoring the social Urban Development, the social status and change of LORs are evaluated on an annual basis. The assessment is based on various indicators that are combined in one Development Index30. The results are classified in four groups: high, medium, low and very low Development index. The best and the worst categories correlate with the 10 % best and worst values, respectively.

To determine the air pollution on the spatial scale of LORs, concentrations related to the surface area were calculated using the results of the model calculations for particulate matter (PM$_{2.5}$) and nitrogen dioxide under consideration of the urban background concentrations and transport-related incremental pollution on main roads. The concentrations were summarized in four categories (low, medium, high and very high)31.

The distribution of air pollution on the 447 planning areas (PLR) is shown in Figure 3.13, together with the social development index32. 69 (15 %) of the total 447 planning areas were classified as slightly polluted. With 263 PLR (59 %), more than half of all the PLR fall into the category of "moderately polluted”. High levels of air pollution occur in 54 PLRs (12 %) and very high air pollution in 61 PLRs (14 %).

It is shown that air pollution deriving from a combination of particulate matter and nitrogen dioxide is widespread in Berlin. At the planning area level, however, it differs widely. Most of the PLRs with high or very high concentrations are sited within the LEZ, and the areas north of it, in Wedding and Prenzlauer Berg. Areas with a low or very low development index but increased concentrations are in Kreuzberg, Neukölln and in Wedding. While concentrations decrease towards the city periphery, the development index is rather high or very high in these areas.

31 Senate Department for Health, the Environment and Consumer Protection; Field of Action in Environmental Justice, Environmental Pollution and Resources at the Level of Environmental life-oriented Spaces (LOR) – foundations for the development of environmental policy strategies, measures and instruments for the improvement of the environmental quality in the State of Berlin, Base Report. 2011.
Air Quality Plan for Berlin 2011-2017

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Figure 3.13: Socio-spatial distribution of air pollution in Berlin in 2009

Air pollution of PM$_{2.5}$ and NO$_2$ plus development index

PM$_{2.5}$ and NO$_2$ pollution in developed areas with residential use

Development index based on monitoring social urban development 2009

Social equity

The data was evaluated for each of the 447 planning areas in Berlin (small-scale planning level of environmental life-oriented spaces - LOR).

Editor:
Concept:
Processing:
Data base:
Mapping:

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The distribution of air pollution according to the socio development index is illustrated in Figure 3.14. It is visible that concentration levels are low or moderate in PLRs with high or very high development indexes. High concentrations do not occur. In turn, no PLR with a very low socio development index has a low concentration. In half of the areas, air pollution levels are high to very high. In more than half of the PLRs with a moderate development index, air pollution is modest; a third of these PLRs have high or very high levels of pollution. Generally, these are inner city residential areas with high densities of buildings and high levels of traffic.

13 % of the population of Berlin live in PLRs with very high levels of pollution and 16 % in PLRs with high levels of pollution. With 58 % – more than half of the population is exposed to moderate pollution levels. Only 13 % live in areas with low pollution levels.

If the development index (DI) is included, as in Figure 3.15, around 37 % of the population live in moderately polluted PLRs with a moderate DI, followed by 10 % with very high or high levels of pollution, respectively, and a middle-range DI. 8 % of the inhabitants live in moderately polluted PLRs with a high/very high, or low DI, respectively. In PLRs with low levels of pollution and a high/very high DI live around 7 % of the population. This is followed by PLRs with 6 % of inhabitants, which either have a very low DI and a moderate pollution or a middle DI and low pollution levels, respectively. 3 % of the population live in highly polluted PLRs with very low or low DI, respectively. 2 % of the population live in very highly polluted PLRs with a very low DI and 1 % in PLRs with very high pollution levels and a low DI.
Assessment of the PM$_{2.5}$ und NO$_2$ air pollution

Figure 3.14: Number of planning areas in relation to the air pollution derived from a combination of particulate matter and NO$_2$ and the development index in 2009.

Assessment of the PM$_{2.5}$ und NO$_2$ air pollution

Figure 3.15: Share of the population in percent/percentage in relation to the air pollution deriving from a combination of particulate matter and NO$_2$ and in relation to the Development Index in 2009.
4 Emissions of air pollutants

4.1 Emissions in Berlin
The emission of air pollutants in Berlin has been measured at regular intervals since 1979. Dispersion calculations for the air quality planning are based on those measurements.

The following source sectors are part of the emission determination:

- plants requiring a permit (industry),
- combustion plants not requiring a permit (domestic heating),
- other facilities not requiring a permit (small business),
- motor vehicle transport,
- other transport (rail, water and air transport) and
- other sources (i.e. construction sites, mobile machines).

The current cause analysis for the air quality planning until 2020 is supposed to relate to the analysis of 2009, since it provides sufficiently complete data on the emission of air pollutants. It especially includes the last road traffic census for the entire main road network. Relating to the base year 2009 implies considering the impact of the first stage of the Environmental Zone Regulation [Umweltzonen-Regelung], in effect since 01/01/2008. The impact of the second stage, in effect since 01/01/2010, cannot yet be taken into account.

4.1.1 Industry (plants requiring a permit)
The emission inventory for the industrial sector is based on the Emission Declarations [Emissionserklärungen] according to section 27 of the Federal Pollution Control Act [BlmSchG] and to the 11th Ordinance to the Federal Pollution Control Act [BlmSchV]. Those declarations for 2008 were given by the operators of plants requiring a permit. They comprise information on the type, amount and spatial and temporal distribution of, as well as conditions for, the relevant air pollution caused by industrial plants. The next Emission Declaration for 2012 will not be provided before the end of 2013.

Declarations had to be made for several plant types. Table 4.1 shows the development of the number of those plant types.

The energy industry is responsible for the bulk of the emissions of the source sector “plants requiring permission”. At the beginning of the 1990s, many plants were shut down or changed over to more environmentally friendly fuels due to the new political situation. In contrast to the year 2000, 143 plants of the energy sector were released from authorization in 2002, because a new amendment of the 4th Ordinance to the Federal Pollution Control Act [BlmSchV] raised the combustion plants’ thermal input capacity to more than 20 MW for gaseous and liquid fuels. Consequently, smaller plants no longer require permission according to section 4 of the Ordinance to the Federal Pollution Control Act [BlmSchV].

The change of the 11th Ordinance to the Federal Pollution Control Act [BlmSchV] in 2007 led to a high reduction in the number of plants producing food, stimulants and feeding stuff because smaller smokehouses, breweries and coffee roasteries are no longer obliged to make a declaration. Furthermore, numerous recycling and disposal plants, e.g. sorting and waste treatment plants, no longer have to provide an Emission Declaration.
Table 4.1: Plant types and number of plants requiring a permit in Berlin from 1989-2008

<table>
<thead>
<tr>
<th>plant type</th>
<th>number</th>
</tr>
</thead>
<tbody>
<tr>
<td>heat generation, mining, energy</td>
<td>954</td>
</tr>
<tr>
<td>stone and earth, glass, ceramics, building materials</td>
<td>55</td>
</tr>
<tr>
<td>steel, iron and other metals including metal working</td>
<td>124</td>
</tr>
<tr>
<td>chemical products, pharmaceuticals, mineral oil refinery and further processing</td>
<td>58</td>
</tr>
<tr>
<td>surface treatment with organic substances</td>
<td>70</td>
</tr>
<tr>
<td>wood, pulp</td>
<td>3</td>
</tr>
<tr>
<td>food, stimulants and feeding stuff</td>
<td>98</td>
</tr>
<tr>
<td>Recycling and disposal of residues</td>
<td>17</td>
</tr>
<tr>
<td>storage, loading and unloading of materials</td>
<td>61</td>
</tr>
<tr>
<td>others</td>
<td>73</td>
</tr>
<tr>
<td>total</td>
<td>1,513</td>
</tr>
</tbody>
</table>

The decreasing construction activity in Berlin is responsible for the significant decline in plants producing or processing stone and earth, glass, ceramics and building materials. This has led to a considerable decline in plants producing cement and concrete. Nowadays, many of these businesses in Berlin only maintain storage places not requiring a permit. The particulate matter emissions of these facilities have been part of the source sector “small business” since 2008.

The following Table 4.2 shows that in 2008, the large combustion plants (GFA), which exclusively belong to the plant type “heat generation, mining, energy”, produced 95% of the total sulphur dioxide (SO₂) and nitrogen oxide (NOₓ) emissions of industrial plants that are obliged to make a declaration (EKI). In contrast, this plant type caused only 55% of the industrial particulate matter (PM₁₀) emissions. This data was also used for the modelling in 2009, as there were no significant changes to be expected.

Table 4.2: Emissions of plants requiring a permit in Berlin in 2008

<table>
<thead>
<tr>
<th>plant type</th>
<th>emissions in t/a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO₂</td>
</tr>
<tr>
<td>heat generation, mining, energy</td>
<td>6,233.8</td>
</tr>
<tr>
<td>stone and earth, glass, ceramics, building materials</td>
<td>45.1</td>
</tr>
<tr>
<td>steel, iron and other metals including metal working</td>
<td>93.0</td>
</tr>
<tr>
<td>chemical products, pharmaceuticals, mineral oil refinery and further processing</td>
<td>below the mass flow limit (mainly hydrocarbon emissions)</td>
</tr>
<tr>
<td>surface treatment with organic substances</td>
<td>10.4</td>
</tr>
<tr>
<td>wood, pulp</td>
<td>5.0</td>
</tr>
<tr>
<td>food, stimulants and feeding stuff</td>
<td>22.0</td>
</tr>
<tr>
<td>Recycling and disposal of residues</td>
<td>186.5</td>
</tr>
<tr>
<td>storage, loading and unloading of materials</td>
<td>6.2</td>
</tr>
<tr>
<td>others</td>
<td>2.8</td>
</tr>
<tr>
<td>total</td>
<td>6,594</td>
</tr>
</tbody>
</table>
Figure 4.1 and Figure 4.2 show the spatial distribution of the nitrogen oxide and particulate matter emissions caused by plants requiring a permit in Berlin in 2008/2009. The increased emissions of plant sites are obvious.
4.1.2 Domestic heating

The source sector “domestic heating” comprises the emissions of Berlin’s combustion plants not requiring a permit. Those are all the plants listed in the regulation for small and medium-sized combustion plants (1st Ordinance to the Federal Pollution Control Act). Combustion plants not requiring a permit are mainly private households. Furthermore, combustion plants of public buildings and commercial enterprises belong to this sector.

The calculation of the emissions is based on data on the buildings with heatable surfaces, on information about the amount of various heating types and on fuel consumption. District heating is not yet included in evaluating the emissions of domestic heating, as the emissions caused by district heating belong to the source sector “plants requiring a permit”.

Since 1990, the number of buildings with low-emission heating types significantly increased, whereas heating with solid fuel, especially carbon, decreased. Figure 4.3 shows the heating types in relation to the heated surface for the years 1990 to 2009. With 39 %, district heating has the highest share in 2009, followed by gas heating with a share of 31 %. Since 1994, the share of carbon solid fuel heating decreased by 90 % from 21 % to 2 %. Most of the one heating types were converted to another type between 1994 and 1999. If the use of biomass in the form of wood, which is supported for reasons of climate protection, increases in the future, more solid fuel heating and, consequently, more particulate emissions may be expected.

![Figure 4.3: Change of the entire heated surface and the heating type of residential and commercial spaces from 1990 to 2009](image)

In Table 4.3, the fuel consumption of 2009 is compared to the data of the year 1999.

Table 4.3: Fuel consumption in Berlin for domestic heating

<table>
<thead>
<tr>
<th>fuel</th>
<th>1999 consumption</th>
<th>2009 consumption</th>
<th>relative change</th>
</tr>
</thead>
<tbody>
<tr>
<td>light heating oil</td>
<td>845,000 t/a</td>
<td>570,000 t/a</td>
<td>-32 %</td>
</tr>
<tr>
<td>natural gas</td>
<td>709 m. m³/a</td>
<td>1,350 m. m³/a</td>
<td>+90 %</td>
</tr>
<tr>
<td>solid fuel (coal/wood)</td>
<td>90,500 t/a</td>
<td>57,000 t/a</td>
<td>-37 %</td>
</tr>
</tbody>
</table>
Heating oil consumption decreased by 32 %, although the climatic conditions demanded more heating in 2009 than in 1999 and the oil-heated surface only got a little smaller. This goes back to the success of better thermal insulated buildings, improved energy efficiency caused by modernised combustion plants and more economical heat generation. The natural gas consumption increased by 90 % and the gas heated surface by 300 %.

The solid fuel consumption (coal/wood) significantly decreased by 37 %. However, the rate of decrease in the previous period (1994-1999) was 80 %. Since 2000, the use of wood pellet heating in Germany has grown. This trend also exists in Berlin, but the total of a little more than 400 installed pellet heating systems is (still) an insignificant number among the approximately 325,000 buildings in Berlin. For years, less than 5,000 t/a of firewood have been sold in Berlin. However, there are probably more sales of wood from Berlin’s and Brandenburg’s forests that are not officially registered. According to a national estimation of the UBA33 [Federal Environment Agency], approx. 30,000 tons of firewood were consumed. In total, approximately 57,000 tons of solid fuels (wood and coal) were burnt in Berlin’s households in 2009.

Table 4.4 shows the emissions of the various fuels for all buildings in Berlin.

Table 4.4: Fuel emissions of the source sector domestic heating in 2009

<table>
<thead>
<tr>
<th>fuel</th>
<th>fuel consumption</th>
<th>NOx [t/a]</th>
<th>dust [t/a]</th>
<th>benzene [kg/a]</th>
<th>BaP* [kg/a]</th>
<th>SO2 [t/a]</th>
</tr>
</thead>
<tbody>
<tr>
<td>gas</td>
<td>1,350 [m. m³/a]</td>
<td>1,696</td>
<td>2</td>
<td>845</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>heating oil</td>
<td>570,000 [t/a]</td>
<td>1,026</td>
<td>37</td>
<td>75</td>
<td>0.5</td>
<td>1,112</td>
</tr>
<tr>
<td>solid fuel</td>
<td>57,000 [t/a]</td>
<td>84</td>
<td>57</td>
<td>6,840</td>
<td>81</td>
<td>161</td>
</tr>
<tr>
<td>total**</td>
<td></td>
<td>2,806</td>
<td>95</td>
<td>7,760</td>
<td>81.5</td>
<td>1,294</td>
</tr>
</tbody>
</table>

* = benzopyrene
** = due to rounding of the individual items deviations are possible

The table illustrates that solid fuels cause very high specific emissions of particulate matter and benzopyrene (BaP) per ton. Although only one tenth of the oil mass is burnt, the dust emissions are nearly by 60 % higher. This is because the combustion of solid fuels per ton causes 1 kg dust, whereas burning one ton of oil only causes 0.064 kg of dust. Furthermore, the combustion of solid fuels is the most important source for benzopyrene in Berlin. The emissions of domestic fuel differ from the benzopyrene emissions of motor vehicle transport (see Table 4.6) by more than a factor of 10. This corresponds to the relation at the national level, as according to the emission inventory of the Federal Environment Agency [UBA], 90 % of the benzopyrene comes from the domestic heating sector34.

Figure 4.4 and Figure 4.5 illustrate the spatial distributions of nitrogen oxide emissions respectively particulate matter caused by domestic heating. The figures show the spatial distribution of domestic heating emissions in a 1x1 km grid with maximum values in areas with many old buildings and high population density. The highest dust emissions exist in the central districts of Prenzlauer Berg, Kreuzberg and in the north of Neukölln. In areas with primarily district heating, the emissions are especially low, e.g. in the settlements with prefabricated houses in the eastern districts of the city. The emissions caused by district heating belong to the source sector “plants requiring a permit”.

---

Figure 4.4: Nitrogen oxide emissions caused by domestic heating in Berlin in 2009

Domestic heating emissions in 2009 in a 1 km x 1 km-grid
Nitrogen oxide as NOx in kg per year

- 0 up to 50 kg/a
- 50 up to 100 kg/a
- 100 up to 1,000 kg/a
- 1,000 up to 5,000 kg/a
- 5,000 up to 10,000 kg/a
- 10,000 up to 20,000 kg/a
- 20,000 up to 50,000 kg/a

Low emission zone

Figure 4.5: Particulate matter emissions caused by domestic heating in Berlin in 2009

Domestic heating emissions in 2009 in a 1 km x 1 km-grid
Particulate matter (PM10) in kg per year

- 0 up to 50 kg/a
- 50 up to 100 kg/a
- 100 up to 1,000 kg/a
- 1,000 up to 5,000 kg/a

Low emission zone
4.1.3 Small businesses

The emissions of the plants not requiring a permit (small business) are mainly significant as a source of organic gases, which act as precursors for ozone formation in the summer’s atmosphere and are relevant to the development of particles. The emissions of this source sector mainly appear in the finishing-construction business, wood business, metal industry and in the food and luxury food industry (smokehouses). The change of the definition of plants requiring a permit through the amendment to the 11th BlmSchV in 2007 effected that numerous facilities now belong to the sector “small business”. These facilities, e.g. stone and earth plants and storage locations for building materials, mainly cause high particulate matter emissions. This resulted in increasing dust emissions of the sector “small business” between 2005 and 2009 by more than 70%. The dust emissions of the source sector “plants requiring a permit” correspondingly sank. In summary, the increasing emissions in the sector “small business” do not correspond to an increase of the total dust emissions.

Table 4.5 illustrates information on emissions. A part of the emissions from mobile machines and equipment are part of the category “Other Sources” (see Table 4.8).

Table 4.5: Emissions caused by small businesses in t/a from 2005 and 2009

<table>
<thead>
<tr>
<th>component</th>
<th>2005</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate matter (PM$_{10}$)</td>
<td>149</td>
<td>258</td>
</tr>
<tr>
<td>carbon monoxide</td>
<td>168</td>
<td>150</td>
</tr>
<tr>
<td>nitrogen oxide</td>
<td>160</td>
<td>127</td>
</tr>
<tr>
<td>organic gases</td>
<td>5,511</td>
<td>5,500</td>
</tr>
</tbody>
</table>

4.1.4 Motor vehicle transport

For calculating the emissions of motor vehicle transport, data on traffic volume and mileage, fleet composition (vehicle type and emission standard), traffic situation (speed, traffic jam) and the condition of the motor (number of cold starts) is necessary. The immission control law [IMMISem] was used for the calculations. The emission inventory “motor vehicle transport” was updated in 2009 because the results of the current traffic census for the main road network of the Senate Department for Urban Development and the Environment became available. Furthermore, the data from automatic counters installed at about 300 road sections was evaluated. These counters differentiate between cars and trucks and continuously collect information on the traffic volume and speed.

Concerning the secondary road network, emissions are not calculated for single concrete road sections but for areas of one square kilometre. The traffic congestion in side roads was evaluated with the help of VISUM, a programme for traffic assignment. The determined total mileage and the number of heavy commercial vehicles were assigned to the different traffic zones of the city.

The results of a survey on number plates from September 2009 were used for determining the fleet composition according to the emission standard. The changed fleet composition resulting from the introduction of a second low emission zone on 1/1/2010 could not yet be taken into consideration within the emission calculation for the entire road network, as there is no traffic census for 2010. Chapter 6.1 describes the relative emission reduction resulting from the introduction of a second LEZ.

For the emission calculations the model IMMISLuft was used. It is part of the Pollution Control Law [IMMISem]. The new version of the Handbook Emission Factors for Road Transport Handbuch für Emissionsfaktoren HBEFA 3.1, published in February 2010, was applied for...
the first time. Apart from the motor emissions, the model considers the particle emissions caused by abrasion and resuspension\textsuperscript{39}.

Figure 4.6 illustrates the average daily traffic volume of the main road network. According to expectations, the highest traffic volume, with up to nearly 170,000 vehicles per day, occurs on the city motorway A100.

On main roads, heavy trucks exceeding 3.5 tons which produce high emission account for an average of 2.9\% of traffic. On average, the share of heavy goods vehicles on highway sections amounts to 8\%. The highest share in traffic, 19\%, circulates on the highway sections of the northern Berliner Ring, which is part of the A10 highway.

To be able to take the influence of the traffic flow into consideration, the handbook of emission factors [HBEFA 3.1] differentiates four traffic levels (Level of Service – LOS): free (LOS1), dense (LOS2), saturated (LOS3) and traffic jam (LOS4). A free traffic flow only appears if the traffic volume is relatively low, i.e. mainly at night. The respective emission factors are 10 to 20\% lower than for LOS “dense” and “saturated”. The emissions of the two middle traffic levels mostly differ only a little from each other. In contrast, traffic jams can lead to twice the emissions of saturated traffic. Determining the traffic level of a road section is based on capacity assumptions. This means that temporal interruptions, e.g. caused by construction sites, normally cannot be taken into account. On the average, in 2009 8\% of the mileage on the main roads could be assigned to LOS1, 80\% to LOS2, 9\% to LOS3 and 3\% to LOS4 (traffic jam). The traffic jams affected approximately 13 road sections, where the prevalence of traffic jams was between 20 and 30\%.

Table 4.6 shows the mileage in the urban area of Berlin (million km/year), the fuel consumption (t) and the exhaust and abrasion emissions of the motor vehicle traffic (t/year) in 2009. There are six motor vehicle categories. It is obvious that over 80\% of the mileage and of the emissions are caused by main road traffic.


### Table 4.6: Categories of vehicle types in Berlin in 2009 (compared to 2002): mileage (million km/year), fuel consumption (t/a) and exhaust and abrasion emissions (t/a), except benzopyrene in kg/a

<table>
<thead>
<tr>
<th></th>
<th>total</th>
<th>cars and combis</th>
<th>light commercial vehicles</th>
<th>motorbikes</th>
<th>heavy commercial vehicles</th>
<th>public buses</th>
<th>coaches</th>
<th>for comparison 2002: total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>main road network</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mileage [million km]</td>
<td>10,164.0</td>
<td>8,773.3</td>
<td>792.1</td>
<td>101.0</td>
<td>379.1</td>
<td>82.7</td>
<td>35.8</td>
<td>10,598.8</td>
</tr>
<tr>
<td>fuel consumption</td>
<td>690,182.0</td>
<td>595,972.2</td>
<td>53,144.0</td>
<td>6,922.0</td>
<td>25,976.9</td>
<td>5,702.0</td>
<td>2,465.0</td>
<td>85,5105.5</td>
</tr>
<tr>
<td>nitrogen oxides</td>
<td>6,104.7</td>
<td>3,705.3</td>
<td>253.4</td>
<td>16.4</td>
<td>798.8</td>
<td>953.9</td>
<td>376.0</td>
<td>8,497.4</td>
</tr>
<tr>
<td>particulate matter (\text{PM}_{10}) total</td>
<td>741.9</td>
<td>434.9</td>
<td>86.5</td>
<td>2.0</td>
<td>157.9</td>
<td>40.2</td>
<td>20.7</td>
<td>1,193.1</td>
</tr>
<tr>
<td>exhaust particles</td>
<td>180.5</td>
<td>84.9</td>
<td>55.4</td>
<td>0.0</td>
<td>30.6</td>
<td>4.3</td>
<td>5.3</td>
<td>315.7</td>
</tr>
<tr>
<td>abrasion of wheels etc. and re-suspension</td>
<td>561.8</td>
<td>350.0</td>
<td>31.1</td>
<td>2.0</td>
<td>127.4</td>
<td>35.9</td>
<td>15.4</td>
<td>882.7</td>
</tr>
<tr>
<td>elemental carbon (exhaust and wheel abrasion)</td>
<td>100.0</td>
<td>87.1</td>
<td>7.8</td>
<td>0.3</td>
<td>3.7</td>
<td>0.8</td>
<td>0.3</td>
<td>403.4</td>
</tr>
<tr>
<td>benzopyrene [kg/a]</td>
<td>6.1</td>
<td>5.3</td>
<td>0.5</td>
<td>0.1</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>side road network</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mileage [million km]</td>
<td>1,890.7</td>
<td>1,632.0</td>
<td>147.3</td>
<td>18.8</td>
<td>70.5</td>
<td>15.4</td>
<td>6.7</td>
<td>2,167.8</td>
</tr>
<tr>
<td>fuel consumption</td>
<td>157,743.5</td>
<td>136,112.4</td>
<td>12,315.1</td>
<td>1,571.4</td>
<td>5,896.7</td>
<td>1,290.0</td>
<td>559.6</td>
<td>205,498.9</td>
</tr>
<tr>
<td>nitrogen oxides</td>
<td>1,406.1</td>
<td>1,213.3</td>
<td>109.8</td>
<td>14.0</td>
<td>52.6</td>
<td>11.5</td>
<td>5.0</td>
<td>1,957.6</td>
</tr>
<tr>
<td>particulate matter (\text{PM}_{10}) total</td>
<td>151.9</td>
<td>100.8</td>
<td>11.6</td>
<td>1.1</td>
<td>29.5</td>
<td>5.9</td>
<td>3.0</td>
<td>243.1</td>
</tr>
<tr>
<td>exhaust particles</td>
<td>44.6</td>
<td>32.8</td>
<td>3.4</td>
<td>0.0</td>
<td>6.5</td>
<td>1.3</td>
<td>0.6</td>
<td>78.3</td>
</tr>
<tr>
<td>abrasion of wheels etc. and re-suspension</td>
<td>107.2</td>
<td>68.0</td>
<td>8.2</td>
<td>1.1</td>
<td>23.0</td>
<td>4.6</td>
<td>2.4</td>
<td>167.3</td>
</tr>
<tr>
<td>elemental carbon (exhaust and wheel abrasion)</td>
<td>23.1</td>
<td>19.9</td>
<td>1.8</td>
<td>0.2</td>
<td>0.9</td>
<td>0.2</td>
<td>0.1</td>
<td>91.6</td>
</tr>
<tr>
<td>benzopyrene [kg/a]</td>
<td>1.4</td>
<td>1.2</td>
<td>0.1</td>
<td>0</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>total city</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mileage [million km]</td>
<td>12,054.7</td>
<td>10,405.2</td>
<td>939.5</td>
<td>119.8</td>
<td>449.6</td>
<td>98.1</td>
<td>42.5</td>
<td>12,766.6</td>
</tr>
<tr>
<td>fuel consumption</td>
<td>847,925.5</td>
<td>732,084.5</td>
<td>65,459.1</td>
<td>8,493.4</td>
<td>31,873.6</td>
<td>6,992.0</td>
<td>3,024.6</td>
<td>1,060,604.4</td>
</tr>
<tr>
<td>nitrogen oxides</td>
<td>7,510.8</td>
<td>4,918.6</td>
<td>364.1</td>
<td>30.4</td>
<td>851.3</td>
<td>965.4</td>
<td>381.0</td>
<td>10,455.0</td>
</tr>
<tr>
<td>particulate matter (\text{PM}_{10}) total</td>
<td>893.8</td>
<td>555.7</td>
<td>98.1</td>
<td>3.1</td>
<td>187.4</td>
<td>46.1</td>
<td>23.7</td>
<td>1,436.2</td>
</tr>
<tr>
<td>exhaust particles</td>
<td>225.1</td>
<td>117.7</td>
<td>58.8</td>
<td>0.0</td>
<td>37.1</td>
<td>5.6</td>
<td>5.9</td>
<td>394.0</td>
</tr>
<tr>
<td>abrasion of wheels etc. and re-suspension</td>
<td>669.0</td>
<td>418.0</td>
<td>39.3</td>
<td>3.1</td>
<td>150.4</td>
<td>40.5</td>
<td>17.8</td>
<td>1,050.0</td>
</tr>
<tr>
<td>elemental carbon (exhaust and wheel abrasion)</td>
<td>123.1</td>
<td>107.0</td>
<td>9.6</td>
<td>0.5</td>
<td>4.6</td>
<td>1.0</td>
<td>0.4</td>
<td>495.0</td>
</tr>
<tr>
<td>benzopyrene [kg/a]</td>
<td>7.5</td>
<td>6.5</td>
<td>0.6</td>
<td>0.1</td>
<td>0.3</td>
<td>0.1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Figures 4.7 and 4.8 illustrate the spatial distribution of nitrogen oxide and \(\text{PM}_{10}\)-emissions of the entire road network (main and side roads) in a 1x1 km grid. It is obvious that the most emissions are produced on the city’s motorways. The figures also make clear that there are high emissions in the entire inner city.
Figure 4.7: Nitrogen oxide emissions of the entire road transport in Berlin in 2009

Road transport emissions in 2009 in a 1 km x 1 km-grid
Nitrogen oxide as NOx in kg per year

- 0 up to 50 kg/a
- 50 up to 100 kg/a
- 100 up to 1,000 kg/a
- 1,000 up to 5,000 kg/a
- 5,000 up to 10,000 kg/a
- 10,000 up to 20,000 kg/a
- 20,000 up to 50,000 kg/a

Low emission zone

Figure 4.8: Particulate matter (PM10) emissions of the entire road transport in Berlin in 2009

Road transport emissions in 2009 in a 1 km x 1 km-grid
Particulate matter (PM10) in kg per year

- 0 up to 10 kg/a
- 10 up to 50 kg/a
- 50 up to 100 kg/a
- 100 up to 1,000 kg/a
- 1,000 up to 5,000 kg/a
- 5,000 up to 10,000 kg/a

Low emission zone
4.1.5 Other traffic
The source sector “other traffic“ comprises all emissions caused by motor vehicles using other transport ways than roads, i.e. emissions from rail, sea and air transport.

The calculation of emissions by other traffic is based on a survey on emissions caused by rail, sea and air transport in the region Berlin/Brandenburg in 1994 and on current estimations with the help of the Federal Environment Agency [UBA] calculation model TREMOD. A slight increase of 5 % was assumed for air transport between 1994 and 2009, as the specific energy consumption decreased by 25 % and the traffic volume increased by 30 %. In 2009, approximately 85 tons particulate matter (PM_{10}) and approximately 195 tons nitrogen oxides per year were measured at Berlin’s airports (Tegel and Schönefeld) when the planes role and start or land.

The rail traffic volume has remained on quite a constant level since 1994. Many rails in Berlin, however, have been electrified and thus there are nearly no diesel emissions in these days. That is why a significant decrease of specific exhaust emissions by around 40 % was assumed. However, the particulate matter emissions caused by abrasion and resuspension along the rails above the ground are the same as in 1994.

On the one hand, Berlin’s water freight transport decreased by 50 % since 1994. On the other hand, the passenger ship traffic, especially in Berlin’s centre, increased significantly. The specific emission factors for nitrogen oxides and particles caused by water transport have decreased only by around 5 % since 1994. Thus, an emission decrease by 25 % in comparison to 1994 is to be expected. Furthermore, some information on the fuel consumed by water transport per year (approx. 4,000 t/a) has been taken into account for the emission calculation.

The emissions caused by the other means of transport are summarized in Table 4.7.

<table>
<thead>
<tr>
<th></th>
<th>Particulate matter (PM_{10}) in t/a</th>
<th>NO\textsubscript{X} in t/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail transport: emissions from engines</td>
<td>29</td>
<td>250</td>
</tr>
<tr>
<td>water transport</td>
<td>5</td>
<td>196</td>
</tr>
<tr>
<td>air transport (near the ground)</td>
<td>85</td>
<td>195</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td><strong>119</strong></td>
<td><strong>641</strong></td>
</tr>
</tbody>
</table>

4.1.6 Other sources
In Berlin’s surroundings the emission calculations were based on handled or produced substances (EMEP-database). In contrast, in Berlin city, the emission calculations were only based on estimations of different sources. There are many diffuse sources of particulate matter, which cannot be separated. The influence of these sources can only be estimated by plausibility assessments of substance balances. Since September 2004 the result of a research project about the emissions of mobile equipment and machines by the Federal Environment Agency [UBA] is available. The research is based on substance balances.

As there is no detailed information about number, size and duration of Berlin’s construction sites and machinery, the data on emissions in Germany, which was determined in the Federal Environment Agency [UBA] research project, was transferred to the situation in Berlin. Like in the Clean Air and Action Plan 2005, the relation between Berlin’s population and Germany’s population (4.38 %) was used as scaling factor. Table 4.8 shows the resulting exhaust emissions of mobile construction machines in Berlin.

---

### Table 4.8: Exhaust emissions of mobile construction machines in Berlin in 2009

<table>
<thead>
<tr>
<th></th>
<th>exhaust emissions in t/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>particulate matter (PM$_{10}$)</td>
<td>140</td>
</tr>
<tr>
<td>carbon monoxide</td>
<td>7,100</td>
</tr>
<tr>
<td>nitrogen oxide</td>
<td>1,200</td>
</tr>
<tr>
<td>organic gases</td>
<td>350</td>
</tr>
</tbody>
</table>

This data naturally entails a higher uncertainty.

On the one hand, the initial value used nationwide is subject to fluctuations, as there is a lot of different information on the machinery, the use of different machine types, the nominal capacity and the emission factors that can be taken into consideration. Therefore, the values resulting from a renewed evaluation\(^\text{46}\) of the UBA of 2009 are a little lower, e.g. 120 t/a of particulate matter emissions. Especially nowadays, the database for the construction business has improved. According to this data, higher particulate matter emissions of 170 t/a have to be expected in Berlin in 2009. To determine the emissions, the parameter population was transferred from Germany to the population situation in Berlin.

On the other hand, to transfer the data on Germany to the situation in Berlin, other parameters could be used, e.g. the turnover of the construction sector\(^\text{47}\) or the working hours in the civil engineering business. These are two of the very few statistic parameters used by the Federal Statistical Office (Statistisches Bundesamt)\(^\text{48}\). If the emission calculations of the current UBA research project are taken as a basis for using those conversion factors, there would be around 120 t/a respectively 90 t/a of particulate matter emissions. There is thus a huge range for estimating the exhaust emissions of Berlin’s construction machinery\(^\text{49}\).

Table 4.8 shows average values.

In addition to exhaust emissions, mobile machines and equipment also cause abrasion and resuspension emissions, which have to be taken into account. The abrasion and resuspension emissions of mobile machines in Berlin are estimated at 200 t/a. This estimation is based on the experience with road traffic and the fact that the exhaust emissions of these machines are quite high due to the lack of strict exhaust limit values and because these machines are often used off-road. Table 4.9 summarises the particulate matter emissions.

A study\(^\text{50}\) about particulate matter caused by small combustion plants shows that in Germany in 2000, households and small consumers produced five times more energy with firewood than with coal. The transfer of these results to the conditions in Berlin makes clear that much more firewood is burnt than officially bought. This firewood is for example used for fireplaces and causes additional particulate matter emissions of around 360 t/a.

In addition, there are other emissions caused by charcoal barbecues and fireworks. Those emissions are low in relation to the total emissions. However, they can contribute to temporarily higher air pollution. Charcoal barbecues do not contribute to an exceedance of the PM$_{10}$ short-term limit value as they are only used in the summer months. During these months, the daily average limit values are moderate. Apart from prohibitions, it is very difficult or impossible to prevent those emissions.


\(^{47}\) Helms, H., IFEU Institute (2012), personal communication.

\(^{48}\) Berlin’s share is 2.9 % according to the information of the Sectoral Association Construction and of the Construction Industry Association of Berlin-Brandenburg.

\(^{49}\) Berlin’s share is 2.3 % according to the information of the IFEU Institute.

Table 4.9: Emissions from other sources in Berlin in the year 2009

<table>
<thead>
<tr>
<th>Source</th>
<th>particulate matter (PM$_{10}$) in t/a</th>
<th>NO$_x$ in t/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>exhaust of mobile machines</td>
<td>140</td>
<td>1,200</td>
</tr>
<tr>
<td>abrasion and resuspension: mobile equipment, other transport</td>
<td>280</td>
<td>0</td>
</tr>
<tr>
<td>wood combustion and extra heating in private households</td>
<td>360</td>
<td>430</td>
</tr>
<tr>
<td>other combustion-related emissions</td>
<td>56</td>
<td>70</td>
</tr>
<tr>
<td>construction work with transport</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>resuspension through strong wind</td>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td>plants (pollen, organic particles)</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>unknown sources</td>
<td>170</td>
<td>0</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td><strong>1,606</strong></td>
<td><strong>1,700</strong></td>
</tr>
</tbody>
</table>

The dust production on construction sites (without the exhaust emissions of construction machines) should not have changed since 2002, because the lower house building activity was compensated by a higher renovating activity. Together with the emissions caused by the transport of dusty goods, 300 t/a of particulate matter (PM$_{10}$) emissions caused by construction activities have to be expected.

The natural resuspension through strong wind produces approximately 500 t/a dust in Berlin. 200 tons of this dust are particulate matter (PM$_{10}$). Furthermore, Berlin’s plants produce 100 tons of particulate matter. It partly comes directly from pollen and partly from organic gases that are transformed into organic particles through the effect of ozone.

According to the UBA research, the particulate matter exhaust emissions produced by mobile machines have decreased significantly since 2002. From the model calculations it can be deduced that 170 t/a of particulate matter emissions must result from sources that are still unknown.

**4.1.7 Total amount and distribution of emissions in Berlin**

The development of pollutant emissions for all source sectors since 1989 is summarised in Table 4.10. Since the fall of the Berlin Wall in 1989, many industrial facilities have been renovated or shut down and the lignite as fuel for heaters in Berlin’s flats has been nearly completely substituted by heating oil, natural gas and district heating systems. In 1989, domestic heating and industry were important source sectors for sulphur dioxide and particulate matter emissions. After Germany’s reunification, those emissions significantly decreased.

Between 2002 and 2009, the total emissions of nitrogen oxides declined by more than 15 %. Figure 4.9 illustrates the shares of the various sources of nitrogen oxide emissions. The major source of nitrogen oxides still remains road traffic. It caused 39 % of the emissions in 2009, followed by 34 % caused by plants requiring a permit and 14 % caused by domestic heating. In comparison to 2002 the nitrogen oxide emissions of cars shrank from 45 to 39 %. The emissions caused by plants requiring a permit grew from 28 to 34 %. The shares of the other source sectors did basically not change.
Figure 4.9: Contribution of various sources to the nitrogen oxide emissions in Berlin 2009

Figure 4.11 displays the spatial distribution of nitrogen oxide emissions from all other sources. The figure clearly highlights the plant sites and the areas with much traffic on the main roads or highways.

The total emissions of particulate matter decreased by more than 25 % between 2002 and 2009. Figure 4.10 shows the shares of the various sources.

More than half of the particulate matter emissions (52 %) were caused by other sources in 2009. Those sources were abrasion and resuspension from other traffic and mobile machines, exhaust from mobile machines, additional wood combustion in households, other combustion processes, construction site activity and natural sources. With a share of 4 %, the exhaust emissions of mobile machines are nearly as high as the emissions of the road traffic. This is due to the low emission zone and stronger exhaust limit values for road traffic. The exhaust limit values for mobile machines are much lower and furthermore, the mobile machines are excluded from the regulations of the LEZ.

The most important source remains the abrasion and resuspension of particles by road traffic, at 21 %, although the estimation of these emissions was nearly 40 % lower in the emission inventory of 2009 due to new emission factors. In contrast to diesel exhaust, the new emissions mainly consist of bigger particulates with a diameter of more than 2.5 µm. Therefore, the inhalation is not that deep. 7 % of the particulate matter is caused by motor vehicle exhaust. Thus, the entire road traffic produces 28 % of all particulate matter emissions.

Compared to the years 2002 and 2005, the share of particulate matter emissions from plants requiring a permit decreased significantly. Today, it is only 5 %, whereas in 2002, it held a 15 % share. However, the reason for this decrease is not only the actual reduction of the emissions. The emission values also shrunk numerically as nowadays, those emissions are assigned to the source sector “small business”. The share of this source sector therefore doubled from 4 % in 2002 to 8 % in 2009.
This data on particulate matter emissions entails a higher uncertainty than the data on nitrogen oxides. Many processes of the particulate matter emission development, especially that caused by abrasion and resuspension, cannot yet be completely explained. Construction sites and other temporary pollution sources can just be roughly estimated. The comparison to pollution level modelling with actual measured values shows that the estimated total particulate matter emissions are too low. This is due to the fact that the modelling based on the emission inventories underestimates concentrations in the outside air.

Figure 4.12 displays the spatial distribution of particulate matter emissions in Berlin. It is obvious that there are higher emissions in the city centre than in the surroundings, especially caused by domestic heating and traffic. The emissions are highest in areas having big plants.

Figures 4.11 and 4.12 show the NOx and particulate matter emissions of Schönefeld airport in the south east of Berlin’s city. The emission density there is relatively low.

![Figure 4.10: Shares of different sources in particulate matter emissions (PM10) in Berlin in 2009](image)

### Table 4.10: Emissions in Berlin: source sectors in tons per year (t/a)

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>sulphur dioxide</strong></td>
<td>70,801</td>
<td>17,590</td>
<td>8,868</td>
<td>7,158</td>
<td>4,666</td>
<td>3,838</td>
<td>3,666</td>
<td>3,153</td>
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<td>plants requiring a permit</td>
<td>60,470</td>
<td>10,870</td>
<td>5,683</td>
<td>4,433</td>
<td>2,899</td>
<td>2,319</td>
<td>2,310</td>
<td>2,300</td>
</tr>
<tr>
<td>domestic heating</td>
<td>8,526</td>
<td>4,890</td>
<td>2,500</td>
<td>2,400</td>
<td>1,513</td>
<td>1,294</td>
<td>1,150</td>
<td>663</td>
</tr>
<tr>
<td>small business</td>
<td>75</td>
<td>70</td>
<td>60</td>
<td>60</td>
<td>50</td>
<td>45</td>
<td>43</td>
<td>41</td>
</tr>
<tr>
<td>transport (only motor vehicles)</td>
<td>1,440</td>
<td>1,440</td>
<td>400</td>
<td>55</td>
<td>16</td>
<td>13</td>
<td>10</td>
<td>6</td>
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<tr>
<td>transport (other)</td>
<td>140</td>
<td>140</td>
<td>75</td>
<td>75</td>
<td>68</td>
<td>54</td>
<td>51</td>
<td>45</td>
</tr>
<tr>
<td>other sources</td>
<td>150</td>
<td>220</td>
<td>150</td>
<td>135</td>
<td>120</td>
<td>113</td>
<td>102</td>
<td>98</td>
</tr>
<tr>
<td><strong>nitrogen oxide</strong></td>
<td>71,421</td>
<td>43,317</td>
<td>27,681</td>
<td>23,499</td>
<td>21,229</td>
<td>19,380</td>
<td>17,329</td>
<td>13,636</td>
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<td>plants requiring a permit</td>
<td>41,757</td>
<td>16,172</td>
<td>8,331</td>
<td>6,499</td>
<td>6,034</td>
<td>6,594</td>
<td>6,400</td>
<td>6,300</td>
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<tr>
<td>domestic heating</td>
<td>2,704</td>
<td>3,120</td>
<td>2,860</td>
<td>2,860</td>
<td>2,945</td>
<td>2,807</td>
<td>2,739</td>
<td>1,595</td>
</tr>
<tr>
<td>small business</td>
<td>1,200</td>
<td>700</td>
<td>190</td>
<td>185</td>
<td>160</td>
<td>127</td>
<td>124</td>
<td>120</td>
</tr>
<tr>
<td>transport (only motor vehicles)</td>
<td>21,410</td>
<td>19,025</td>
<td>12,400</td>
<td>10,455</td>
<td>9,538</td>
<td>7,510</td>
<td>5,822</td>
<td>3,491</td>
</tr>
<tr>
<td>transport (other)</td>
<td>1,400</td>
<td>1,300</td>
<td>1,000</td>
<td>900</td>
<td>652</td>
<td>641</td>
<td>635</td>
<td>630</td>
</tr>
<tr>
<td>other sources</td>
<td>2,950</td>
<td>3,000</td>
<td>2,900</td>
<td>2,600</td>
<td>1,900</td>
<td>1,700</td>
<td>1,600</td>
<td>1,500</td>
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</table>
### Emissions of air pollutants

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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>carbon monoxide</td>
<td>301,705</td>
<td>210,948</td>
<td>105,128</td>
<td>78,933</td>
<td>72,701</td>
<td>60,935</td>
<td>51,897</td>
<td>40,481</td>
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<td>plants requiring a permit</td>
<td>32,443</td>
<td>3,888</td>
<td>2,028</td>
<td>1,581</td>
<td>1,521</td>
<td>1,637</td>
<td>1,630</td>
<td>1,620</td>
</tr>
<tr>
<td>domestic heating</td>
<td>68,712</td>
<td>41,560</td>
<td>8,000</td>
<td>8,000</td>
<td>5,900</td>
<td>5,673</td>
<td>5,100</td>
<td>3,100</td>
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<tr>
<td>small business</td>
<td>1,500</td>
<td>800</td>
<td>200</td>
<td>193</td>
<td>168</td>
<td>150</td>
<td>140</td>
<td>135</td>
</tr>
<tr>
<td>transport (only motor vehicles)</td>
<td>182,050</td>
<td>144,200</td>
<td>76,500</td>
<td>51,259</td>
<td>47,767</td>
<td>46,025</td>
<td>28,607</td>
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<td>transport (other)</td>
<td>4,000</td>
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<td>3,100</td>
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<td>2,945</td>
<td>2,950</td>
<td>2,920</td>
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<td>other sources</td>
<td>13,000</td>
<td>17,000</td>
<td>15,300</td>
<td>14,800</td>
<td>14,400</td>
<td>14,500</td>
<td>13,500</td>
<td>13,300</td>
</tr>
<tr>
<td>particulate matter (PM₁₀)</td>
<td>17,580</td>
<td>8,804</td>
<td>4,789</td>
<td>4,209</td>
<td>3,864</td>
<td>3,124</td>
<td>2,993</td>
<td>2,778</td>
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<td>plants requiring a permit</td>
<td>9,563</td>
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<td>960</td>
<td>650</td>
<td>384</td>
<td>153</td>
<td>150</td>
<td>145</td>
</tr>
<tr>
<td>domestic heating</td>
<td>2,693</td>
<td>1,148</td>
<td>131</td>
<td>132</td>
<td>96</td>
<td>95</td>
<td>90</td>
<td>84</td>
</tr>
<tr>
<td>small business</td>
<td>250</td>
<td>220</td>
<td>160</td>
<td>153</td>
<td>149</td>
<td>258</td>
<td>250</td>
<td>240</td>
</tr>
<tr>
<td>transport (only motor vehicles, exhaust)</td>
<td>1,736</td>
<td>1,135</td>
<td>667</td>
<td>394</td>
<td>355</td>
<td>225</td>
<td>124</td>
<td>60</td>
</tr>
<tr>
<td>resuspension and abrasion by motor vehicle transport</td>
<td>1,200</td>
<td>1,150</td>
<td>997</td>
<td>1,050</td>
<td>1,099</td>
<td>669</td>
<td>692</td>
<td>631</td>
</tr>
<tr>
<td>transport (other)</td>
<td>238</td>
<td>190</td>
<td>124</td>
<td>130</td>
<td>133</td>
<td>119</td>
<td>119</td>
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<td>1,800</td>
<td>1,750</td>
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<td>1,606</td>
<td>1,568</td>
<td>1,500</td>
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<tr>
<td>particulate matter (PM₂₅)</td>
<td>2,364</td>
<td>1,828</td>
<td>1,707</td>
<td>1,563</td>
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<td></td>
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<tr>
<td>plants requiring a permit</td>
<td>211</td>
<td>89</td>
<td>87</td>
<td>84</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>domestic heating</td>
<td>87</td>
<td>86</td>
<td>81</td>
<td>76</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>small business</td>
<td>119</td>
<td>197</td>
<td>190</td>
<td>185</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>transport (only motor vehicles, exhaust)</td>
<td>337</td>
<td>225</td>
<td>124</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>resuspension and abrasion by motor vehicle transport</td>
<td>714</td>
<td>360</td>
<td>374</td>
<td>341</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>transport (other)</td>
<td>71</td>
<td>69</td>
<td>68</td>
<td>67</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>other sources</td>
<td>824</td>
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<td>784</td>
<td>750</td>
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<td>organic gases</td>
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<td>32,914</td>
<td>26,410</td>
<td>24,947</td>
<td>22,767</td>
<td>19,516</td>
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</tr>
<tr>
<td>plants requiring a permit</td>
<td>11,801</td>
<td>3,473</td>
<td>2,554</td>
<td>1,966</td>
<td>1,596</td>
<td>824</td>
<td>840</td>
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<tr>
<td>domestic heating</td>
<td>5,250</td>
<td>2,340</td>
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<td>550</td>
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<td>478</td>
<td>450</td>
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<td>small business</td>
<td>15,500</td>
<td>15,000</td>
<td>6,500</td>
<td>6,484</td>
<td>5,511</td>
<td>5,000</td>
<td>5,300</td>
<td>5,200</td>
</tr>
<tr>
<td>transport (only motor vehicles)</td>
<td>49,800</td>
<td>33,890</td>
<td>12,500</td>
<td>8,000</td>
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<td>6,915</td>
<td>5,326</td>
<td>3,491</td>
</tr>
<tr>
<td>transport (other)</td>
<td>3,000</td>
<td>2,000</td>
<td>1,710</td>
<td>1,710</td>
<td>1,590</td>
<td>1,200</td>
<td>1,100</td>
<td>1,000</td>
</tr>
<tr>
<td>other sources and households</td>
<td>17,000</td>
<td>17,000</td>
<td>9,100</td>
<td>7,700</td>
<td>7,400</td>
<td>6,850</td>
<td>6,500</td>
<td>6,300</td>
</tr>
</tbody>
</table>
Figure 4.11: Spatial distribution of nitrogen oxide emissions from all source sectors in Berlin 2009

Total emissions of all sectors in 2009 in a 1 km x 1 km-grid
Nitrogen oxide as NO\textsubscript{x} in kg per year

- 0 up to 10 kg/a
- 10 up to 100 kg/a
- 100 up to 1,000 kg/a
- 1,000 up to 10,000 kg/a
- 10,000 up to 50,000 kg/a
- 50,000 up to 100,000 kg/a
- 100,000 up to 1,000,000 kg/a
- above 1,000,000 kg/a

Low emission zone

Figure 4.12: Spatial distribution of particulate matter (PM\textsubscript{10}) emissions from all source sectors in Berlin in 2009

Total emissions of all sectors in 2009 in a 1 km x 1 km-grid
Particulate matter (PM\textsubscript{10}) in kg per year

- 0 up to 5 kg/a
- 5 up to 10 kg/a
- 10 up to 100 kg/a
- 100 up to 1,000 kg/a
- 1,000 up to 5,000 kg/a
- 5,000 up to 10,000 kg/a
- 10,000 up to 20,000 kg/a
- above 20,000 kg/a

Low emission zone
4.2 Emissions in the surroundings of Berlin

Data on emissions from outside of Berlin are needed in order to determine the condition of the air coming into Berlin, i.e. the pollution level of the air coming from the outside. All emissions used for the RCG calculations come from the PAREST emission database\(^5\).

A reference emission database for Germany and Europe was developed in the course of the PAREST project in 2005. It is based on the so-called Top-down Approach. The Top-down Approach does not take local information into account, as it does not exist for the entire territory\(^6\). Instead, the emissions are derived from the nationwide fuel consumption, production amount, activity rates and emission factors\(^7\). Those national emissions are spatially resolved in relation to numerous distribution parameters\(^8\). The developed emission databases have a resolution of 0.125° length and 0.0625° width for Europe (except Germany) and a resolution of 1/64° width und 1/64° length for Germany (approx. 2x2 km). All prognostic calculations for the background were based on the German and European emission prognoses for the years 2010, 2015 and 2020. These prognoses were developed within the PAREST project and are related to the emission reference of 2005. They describe the changes of the emissions caused by technical and non-technical measurements that were already decided and initiated (CLE-Scenario „current legislation“). The databases were used for all RCG calculations within the Air Quality Plan for Berlin.

In PAREST, the national data on emissions caused by air transport in 2005 were also allocated to the German airports with the help of an apportionment formula. This formula determines what percentage of the emissions has to be assigned to which airport. The apportionment formula for 2005 was constantly used for all projection years. A shutting down of the airport Tegel and a huge growth of the airport Schönefeld until e.g. 2015 or 2020 are not taken into account in the PAREST data. This fact was considered for interpreting the RCG prognosis results for Berlin’s southern surroundings.

By way of example, Figures 4.13 and 4.14 display the PAREST emissions for nitrogen oxides and particulate matter in a resolution of approximately 2 km used in Berlin’s surroundings in 2005. In Berlin’s surroundings, the emissions caused by motor vehicle traffic at the Berliner Ring are outstanding. The Polish emissions are only available in a coarser resolution. The two PAREST emissions for Berlin city displayed in the figures were only used in the RCG-validation courses. All IMMIS\(^{\text{nit}}\) calculation courses made use of Berlin’s local data on emissions.

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Figure 4.13: Spatial distribution of nitrogen oxide emissions in Berlin and surroundings from the PAREST emission data base in 2005

Figure 4.14: Spatial distribution of particulate matter (PM$_{10}$) emissions in Berlin and surroundings from the PAREST emission data base in 2005
5 Causal analysis

The objective of this causal analysis is to quantify the origins of pollution from nitrogen dioxide and particulate matter and the contributions of individual source groups.

Air pollutants are transported in the atmosphere over long distances. The concentration measured at one site, e.g. at a road, thus consists of contributions from various territorial sources. This is schematically illustrated for particulate matter PM$_{10}$ in Figure 5.1. The difference model can also provide a first indication of the origin of pollution from nitrogen dioxide. Due to the photochemical equilibrium between NO and NO$_2$, however, NO or the sum of NO and NO$_2$ would need to be taken into account for additional consideration. Part of the pollution is carried into Berlin from outside the city. This pre-existing pollution is referred to as the regional background (marked in green). Meteorologically, it is represented by the windward monitoring stations at the city periphery (Luv- or inlet station) and monitoring stations that are far away from sources in the surrounding areas. The air pollutants released within the city area are distributed in all parts of the city, and, in sum form the contribution of the urban background (marked in blue). This share is represented by the difference between the values measured at stations in inner city residential areas and the inlet station. Added to this is the additional contribution on roads caused by local traffic emissions (marked in red). The additional contribution results from the difference between concentrations measured at traffic sites and concentrations in the urban background. These contributions can be determined through measurements, or by using the models described in Chapter 3.1. The model calculations allow for a relatively simple way to determine the contributions from individual source groups, such as installations requiring a permit, domestic fuel or road traffic. This is because the emissions incorporated in the models are broken down into source groups.

Figure 5.1: Schematic illustration of the distribution pattern of PM$_{10}$ pollution by region of origin in Berlin and its surroundings

Location of monitoring stations
1 traffic sites (e.g. Frankfurter Allee)
2 station in residential areas (e.g. Nansenstrasse in Neukölln)
3 station at the city periphery (Hasenholz, Paulinenaue)
4 station in rural surroundings
5.1 Meteorological conditions in the years 2005-2010

As shown in Chapter 2.3, the weather decisively influences the concentrations of air pollutants occurring in a year. To a large extent, annual fluctuations in concentrations levels result from the meteorological conditions. The influence of emission reductions can thus only be detected by long-term observation, i.e. when the influence of the weather conditions is relativised.

Figure 5.2 shows data for the most relevant meteorological parameters for the years 2005 to 2010. 2007 was chosen as the reference year since the PM$_{10}$ short-term limit value and annual mean limit value were met in this year. Furthermore, 2007 was the year before the introduction of the LEZ. The figure shows that there are considerable differences in some cases. The higher the value of the meteorological parameter, the more the air quality deteriorates. This may either be caused by higher emissions due to increased heating demand or by deteriorated conditions for dispersion in the atmosphere. It is only on days with strong gusts of wind that air quality improves despite high values.

The year 2010 in particular was characterized by extreme meteorological parameters, which resulted in increased emissions, a deteriorated dispersion of exhaust gas, and increased pollution from the trans-boundary transport of particulate matter.

In the same year, the highest number of frost days (daily maximum temperature < 0°C) and days with fresh snow occurred since measurements in Berlin began in 1908 and 1892, respectively. The number of frost days (daily minimum temperature below 0°C) achieved its highest level in 14 years. Likewise, the ensued heating demand (measured as heating degree total) was the highest in 14 years. This led to higher emissions from heating, not only in Berlin, but also in its surroundings. The high number of overcast days with a widely closed cloud cover (more than 6.4 eighths coverage) is also worthy of note. On such days with low solar irradiation, the atmospheric turbulence is generally lower, leading to a poorer dispersal of exhaust gas. This is further suggested by the fact that temperature inversions were recorded 20% more often in Lindenberg (around 60 km southeast of Berlin) in 2010 than in 2007. In the event of temperature inversions, air temperature rises with increasing altitude. As a result, the dilution of air pollutants gets much worse on days that are normally dry.

It was rare to find weather situation in which the dilution of exhaust gases was particularly good due to high wind speeds. In 2010, the number of days with wind speeds of more than 10.8 m/s or 6 Beaufort was the lowest recorded since 1997.

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Figure 5.2: Comparison of meteorological parameters for the years 2005-2010, influencing emissions, transport and the dilution of air pollutants (in 2005 there is no evaluation for the wind direction on days with low wind speeds)

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Source: Berliner Wetterkarte e.V. [Berlin Weather Map inc. soc.] (publ.): Beilage zur Berliner Wetterkarte – Klimatologische Mittelwerte von Berlin-Dahlem für die Jahre 2005-2010 [Supplement to the Berlin Weather Map – climatic mean values of Berlin-Dahlem for the years 2005 to 2010].
Besides that, the high occurrence of east winds with low wind speeds further affected air quality in Berlin as they transported highly pre-polluted air – typical for winter months – into Berlin. The frequency of such wind directions with low wind speeds from the sector 90° to 150° was 27% higher in 2010 than in 2009 and 37% higher than in 2007 before introducing the LEZ. The frequency of wind directions for the individual years is presented in Figure 5.3. It is shown that east winds occurred comparatively rare in 2007 and 2008, years with very low concentrations of particulate matter. East winds generally transport highly polluted air masses into Berlin and are associated with poorer dispersion conditions resulting from generally lower average wind speeds.

Figure 5.3: Frequency of the wind directions in percentage (all wind speeds) in 2005 to 2010 on the monitoring site of the Meteorological Institute of the FU Berlin
5.2 Origin of the pollution from nitrogen dioxide

The source contribution of nitrogen dioxide is determined by using the dispersion models described in Chapter 3.1. Although the NO2 limit value in Berlin exceeds the annual mean, it is not necessary to consider concentration peak values as the short-term limit value is not exceeded.

5.2.1 Significance of direct emissions and photochemistry

Nitrogen oxides mainly emerge as secondary product from combustion processes in power plants or combustion engines of motor vehicles when nitrogen oxidises in the combustion air. Nitrogen monoxide (NO) is formed, which oxidises to nitrogen dioxide (NO2) in the atmosphere mainly by reactions with ozone or hydrocarbons. NO2 itself is a chemically active substance which is subject to various reactions with different substances in the atmosphere during which, among others, ozone is formed. Depending on the solar irradiation, a so called photochemical balance is established between NO, NO2 and ozone.

Due to the use of oxidation catalysts in diesel motor vehicles, an increasing proportion of NO is directly transformed to NO2 in the exhaust gas and emitted. While this is referred to as direct emissions from NO2 or direct NO2, the NO2 formed in the atmosphere from NO will be referred to as photochemical NO2 in the following. The oxidation catalyst was introduced for passenger cars with Euro II standard in order to reduce the masse of diesel soot particles through the oxidation of hydrocarbon to CO2. By introducing particle filters, the NO2 formed in the oxidation catalyst is used for the regeneration of the filter, as it promotes the combustion of the deposited soot as a supplier of oxygen.

5.2.2 Proportions of individual source groups

The NO2 concentration in the street canyon is composed of the pre-existing NO2 pollution, the share of the urban background which includes all sources except the emission share of the considered street section, the traffic-induced and directly emitted NO2 in the street section and the NO2 produced by the chemical conversion of the locally emitted NO.

The source proportions have been calculated for all sites on which NO2 is measured with continuous monitoring devices or passive samplers, by using the dispersion model IMMIScb.

Due to its high local emissions compared to particulate matter and its shorter lifespan in the atmosphere, nitrogen dioxide is a rather locally-derived pollutant. About 70 % to 80 % of the pollution in inner city residential areas with little local traffic can be attributed to emissions in Berlin’s urban area. The pollution on main roads is even more dominated by Berlin’s sources, because added to this is the high contribution of the local traffic on the individual roads. Figure 5.4 illustrates the proportions of the individual source groups as a mean of the 27 modelled road sections. The share of local traffic in 2009 was 45 %, and thus lower than in 2002 when the local traffic still caused 54 % of the NO2 pollution on roads. About 40 % of the incremental local contribution can be attributed to direct NO2 emissions; 60 % of it was formed photochemically from local NO emissions. With 68 % the highest additional local contribution was calculated for the monitoring point at Leipziger Straße 32; the lowest, with 31 %, at the monitoring point Friedrichstraße (MP 562). On average a further 31 % was caused by nitrogen oxide emissions of the motor vehicle traffic in the remaining parts of the urban area. Other sources in Berlin such as industry, power plants and domestic heating play only a secondary role. Their share of 10 % of the total is just as low as the 12 % share of the NO2 pollution imported into Berlin from sources outside the city, at.

A reduction of the NO2 concentration thus primarily requires measures addressing motor vehicle traffic.
Air traffic hardly contributes to the air pollution within the city. Given that most emissions from air traffic are not released at ground level (unlike exhaust gases from motor vehicles, for instance), but enter the atmosphere in altitudes of hundreds to thousands of meters, the dilution at ground level is high. At locations where air quality limit values have been exceeded the share of NO\textsubscript{2} pollution generated by air traffic is below 1 %.

The results for all road sections under consideration are shown in Figure 5.5.
Figure 5.5: Calculated source apportionments of the NO₂ pollution at 27 selected street sections for the year 2009

<table>
<thead>
<tr>
<th>Street Name</th>
<th>NO₂ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tempelhofer Damm 148</td>
<td></td>
</tr>
<tr>
<td>Spandauer Damm 54</td>
<td></td>
</tr>
<tr>
<td>Spree str. 2</td>
<td></td>
</tr>
<tr>
<td>Alt Friedrichsfelde 8a</td>
<td></td>
</tr>
<tr>
<td>Alt Moabit 63</td>
<td></td>
</tr>
<tr>
<td>Bad Str.</td>
<td></td>
</tr>
<tr>
<td>Berliner Allee 118</td>
<td></td>
</tr>
<tr>
<td>Beusselstr. 66</td>
<td></td>
</tr>
<tr>
<td>Buschkrugallee</td>
<td></td>
</tr>
<tr>
<td>Eichborndamm 23 - 25</td>
<td></td>
</tr>
<tr>
<td>Frankfurter Allee 86b</td>
<td></td>
</tr>
<tr>
<td>Glienicker Weg 115 - 95</td>
<td></td>
</tr>
<tr>
<td>Leipziger Str.</td>
<td></td>
</tr>
<tr>
<td>Grünauer Str. 4</td>
<td></td>
</tr>
<tr>
<td>Hauptstr. 30</td>
<td></td>
</tr>
<tr>
<td>Hermannplatz</td>
<td></td>
</tr>
<tr>
<td>Hermannstr. 120</td>
<td></td>
</tr>
<tr>
<td>Kantstr. 117</td>
<td></td>
</tr>
<tr>
<td>Karl-Marx-Str. 77</td>
<td></td>
</tr>
<tr>
<td>Landsberger Allee 6 - 8</td>
<td></td>
</tr>
<tr>
<td>Leipziger Str. 32</td>
<td></td>
</tr>
<tr>
<td>Potsdamer Str. 102</td>
<td></td>
</tr>
<tr>
<td>Schildhornstr. 76</td>
<td></td>
</tr>
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<td>Schloßstr. 29</td>
<td></td>
</tr>
<tr>
<td>Silbersteinstr. 1</td>
<td></td>
</tr>
<tr>
<td>Sonnenallee 68</td>
<td></td>
</tr>
<tr>
<td>Spandau</td>
<td></td>
</tr>
<tr>
<td>Spandauer Damm 54</td>
<td></td>
</tr>
<tr>
<td>Spree str. 2</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- Green: Regional background
- Light Blue: Other sources
- Medium Blue: Industry
- Light Cyan: Domestic heating and small businesses
- Medium Cyan: Other traffic
- Dark Blue: Road traffic in the urban background
- Orange: Additional pollution from local road traffic / formed from NO
- Deep Red: Additional pollution from road traffic / directly emitted NO₂
5.3 Origin of the particulate matter (PM$_{10}$) pollution

Atmospheric particulate matter is released into the atmosphere by a variety of natural and anthropogenic sources (so-called primary particles). It is also formed from gaseous substances by physico-chemical transformation processes in the atmosphere (so-called secondary particles). The most important secondary particles are sulphates (from sulfur dioxide) and nitrates (from nitrogen oxides), both usually occur in compounds with ammonium (from ammonia). In Berlin these secondary particles account for a fifth to a third of the particulate mass. Since the formation of secondary particles is inter alia time-dependent, it has to be taken into account especially in the case of large-scale phenomena.

To assess the PM$_{10}$ pollution in Berlin, the contribution of individual source groups was first set for the annual mean value and based on model calculations. The results are outlined in Chapter 5.3.1. Additionally, the origin of PM$_{10}$ was examined by evaluating various measurements and meteorological data. As the air quality limit value for the annual mean of PM$_{10}$ was met, but the short-term limit value was exceeded (more than 35 daily mean values above 50 µg/m³), periods with high daily mean values were examined in more detail.

The general distinction made between local, urban and regional or trans-regional contributions to PM$_{10}$ concentrations measured in Berlin is taken into account pursuant to Figure 5.1.

5.3.1 Mean apportionment of source groups based on models

The apportionment of source groups for the 27 road sections was calculated on the basis of continuous PM$_{10}$ measurements or with RUBIS samplers with the dispersion model IMMIS. The calculated annual mean values for the total PM$_{10}$ pollution (a mean of 31 µg/m$^3$ and values ranging from 28 to 46 µg/m$^3$) at the examined road sections have a considerably smaller margin than the NO$_2$ annual mean values. It is only on Leipziger Straße where the calculated annual mean value of 46 µg/m$^3$ exceeds the limit value of 40 µg/m$^3$ pursuant to 39th BlmSchV (2010). Annual mean values of more than 30 µg/m$^3$ were calculated at 19 of the 27 road sections under consideration. In these cases an exceedance of the short-term values is likely to occur due to the statistical link between the annual mean value and the exceedance of the short-term value.

The share of the PM$_{10}$ pollution generated from various source groups, which results from the mean of 27 street sections at main roads, is shown in Figure 5.6.

![Figure 5.6: Calculated source apportionments of the PM$_{10}$ pollution at main roads in Berlin resulting from the mean of 27 street sections in 2009](image)

Around 64% of the total particulate matter pollution on main roads already arises from the regional and trans-regional background pollution, and thus from sources outside the city. This contribution cannot be influenced by measures taken with the Air Quality Plan of Berlin. The origin of the pre-existing pollution and the influence of trans-boundary long-distance transport will thus be further examined in Chapter 5.3.2.

The “home-made” part of emissions, which can be addressed by local measures in Berlin, is composed of the urban background pollution (17%) and the additional local contribution from traffic on main roads (19%). In sum, the motor vehicle traffic in Berlin (additional local contribution and share of the urban background) causes 26.5% of the total particulate matter pollution, and thus remains a significant source of pollution. The share of road transport has decreased by 35% compared to the 2002 causal analysis carried out in the context of the 2005 Clean Air and Action Plan. This can be attributed to the reduction of exhaust gas emissions (diesel soot). Exhaust particles only account for 4% of the additional local pollution from traffic compared to 11% in 2002. The local contribution of particles generated from abrasion and re-suspension, on the other hand, has remained the same at approximately 15%.

Industry as a source group only accounts for a small share of ambient air pollution, with 0.3% on main roads. Increased contributions may occur in the direct exposure area of plants. However, they are locally limited. The contribution of indoor thermal comfort and of small consumers is slightly larger, accounting for a mean share of 1%. Added to this are contributions from other relevant emittents with a mean share of around 7%.

Air traffic accounts for a maximum of 1% of the particulate matter pollution on streets in which increased values of air pollutants are recorded. Measurements at European hub airports, such as London-Heathrow and Frankfurt Main, also show that the influence of air traffic is low in their surroundings.

Contributions may fluctuate depending on the street section considered, as shown in Figure 5.7. for Leipziger Straße. Due to the narrow street canyon character and higher emissions caused by high traffic-induced pollution and high share of traffic jams, the additional local pollution from transport reaches the highest value at 44%. However, the modelled annual mean value of 46 µg/m³ is well above the annual mean of 34 µg/m³ derived from the RUBIS measurements. Metrologically, however, the RUBIS process only determines the carbon content at the monitoring site. Based on this, the PM₁₀ concentration is derived from comparative monitoring at the continuous PM₁₀ monitoring sites at the kerbside. On road sections with a higher share of particles from abrasion and re-suspension compared to these stations, the RUBIS proceedings thus lead to an underestimation of PM₁₀ concentration as these particles hardly contain carbon. On the other hand, the modelling of particle emissions from abrasion and re-suspension is characterized by uncertainties, as the factors influencing the release of these particles have not been fully identified yet.
Figure 5.7. PM$_{10}$ source contributions for 27 selected road sections in Berlin in 2009 (based on model calculations)

- Alt Friedrichsfelde 8a: 31%
- Alt Moabit 63: 34%
- Badstr.: 31%
- Berliner Allee 118: 31%
- Beusselstr. 66: 32%
- Buschkugalle: 33%
- Eichborndamm 23 - 25: 28%
- Frankfurter Allee 86b: 31%
- Friedrichstr.: 29%
- Glienicker Weg 115 - 95: 29%
- Grünauer Str. 4: 28%
- Hauptstr. 30: 33%
- Hermannplatz: 30%
- Hermannstr. 120: 33%
- Kantstr. 117: 31%
- Karl-Marx-Str. 77: 30%
- Landsberger Allee 6 - 8: 30%
- Leipziger Str. 32: 46%
- Potsdamer Str. 102: 33%
- Schildhornstr. 76: 34%
- Schloßstr. 29: 30%
- Silbersteinstr. 1: 31%
- Sonnenallee 68: 32%
- Spandau: 30%
- Spandauer Damm 54: 32%
- Spreest. 2: 28%
- Tempelhofer Damm 148: 31%

PM$_{10}$ concentration in µg/m$^3$
5.3.2 Reasons of the PM<sub>10</sub> limit value exceedances

The air quality short-term limit value for PM<sub>10</sub> has been exceeded in several years, i.e. daily mean values of more than 50 µg/m³ were measured on more than 35 days per year. The limit value for the annual mean of 40 µg/m³, however, was met in the last few years. In the following, the available monitoring data will thus be assessed with a view to the underlying reasons for high daily mean values. As model calculations have shown, around 65 % of the annual mean of particulate matter originate from sources outside of Berlin. The following evaluation thus focuses on analysing the origin of these high pre-existing air pollution levels and the impact on high daily mean values.

Besides that, exceedances of the daily mean values occur due to the influence of local sources, particularly when the meteorologically-related dispersion conditions are detrimental to local emissions or through high temporal additional local emissions, e.g. through construction works.

5.3.2.1 Influence of the pre-existing pollution on daily mean value exceedances

In order to demonstrate the influence of the pre-existing pollution on days with particulate matter concentrations of > 50 µg/m³, the difference between the PM<sub>10</sub> concentrations on traffic sites and the inlet station, which was chosen according to the wind direction, was taken for each day. It is assumed that the inlet station represents the large-scale air pollution and thus also the long-distance transport.

In Figure 5.8., the thus calculated procentual equity ratio of Berlin, is shown in relation to the measured concentrations.

It is shown that Berlin’s own contribution decreases with increasing PM<sub>10</sub> concentrations at traffic sites and thus increases the influence of the pre-existing pollution. On days with mean values of more than 50 µg/m³, equity ratios of more than 35 % occur less often. Exceptions are New Year’s Eve, on which Berlin’s own share is high because of fireworks. On average, the potential for reducing the own share of Berlin’s sources is thus lower as on days with high concentrations. Therefore, smog alert-related measures, as required in the so-called plans for short-term measures, are not targeted to avoid exceedance days.

The same conclusion was already drawn in the context of the Clean Air and Action Plan 2005 for the years 2002-2004. At that time, Berlin’s own share was considerably higher. The mean equity ratio (black regression line) accounted for 42 % with daily means of 50 µg/m³ between 2002-2004. Between 2005 and 2010 it decreased to 35 %.
For the monitoring station Frankfurter Allee the contributions from the individual source regions were determined for all exceedance days between 2006 and 2010, i.e. the contribution of local traffic, urban background and regional background as a measure of the input from outside the city. As shown in Figure 5.9, in years with many exceedance days the mean entry concentration already reaches 50 µg/m³, i.e. the daily limit value is often already achieved at the city boundaries. Depending on the intensity of the emissions from urban sources and the local dispersion conditions, the PM₁₀ concentration in the city increases by a further 22 to 29 µg/m³.

The contribution of the city (marked in blue) is characterized by the substantial influence of domestic fuel. In cold winters it is normally higher, especially when the dispersion conditions are also detrimental. While the city contribution was higher in 2010 than in 2009 due to the cold winter, the local additional contribution from traffic reached the lowest contribution ever in 2010. Evaluations in the following years will reveal to what extent stage 2 of the LEZ, which resulted in a 50 % reduction of diesel soot particles, contributed to this development.

Figure 5.9: Mean contributions of source regions in µg/m³ at the kerbside monitoring station Frankfurter Allee on days exceeding the daily limit value of 50 µg/m³ for the years 2006 to 2010

<table>
<thead>
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<th>Year</th>
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<th>Urban Background</th>
<th>Local Traffic</th>
</tr>
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<td>71</td>
<td>8</td>
<td>19</td>
</tr>
<tr>
<td>2007</td>
<td>30</td>
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</tr>
<tr>
<td>2009</td>
<td>39</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>2010</td>
<td>54</td>
<td>10</td>
<td>12</td>
</tr>
</tbody>
</table>

5.3.2.2 Origin of the regional and trans-regional background pollution

Particulate matter (PM₁₀) has a retention period in the atmosphere that allows for its transport over hundreds of kilometres. Especially particles with an aerodynamic diameter between 0.1 µm and 2.5 µm may remain in the air for several weeks. Wide-scale movements of air masses ensure that air pollutants from highly polluted areas are transported over long distances. It is exactly in this size range of particles that soot particles (sulphates) damaging to health, but also sulphurous particles formed by gaseous precursors, can be found.

To determine the origin of background pollution, it was first examined to what extent the level of PM₁₀ concentration depends on the wind direction. To this end, the mean PM₁₀ concentration is calculated for each wind direction sector based on the PM₁₀ concentrations measured for each wind direction. Figure 5.10 illustrates the PM₁₀ concentration depending on the wind direction (PM₁₀ compass rose) for the years 2005 to 2010 for the traffic site Frankfurter Allee, divided according to source groups. The PM₁₀ concentration at the inlet station at the city periphery, and thus the pre-existing pollution of the inflowing air from outside Berlin, is highest with southeast wind directions. By contrast, the contribution of the city is widely independent of the wind direction.

The influence of wind directions is slightly higher on the additional local contribution from traffic. With northern to northeastern winds, the contribution from traffic is lowest on
Frankfurter Allee as the monitoring station is less exposed to the exhaust gas trail of the traffic due to the formation of rolling air flow. Furthermore, the wind speed is often higher, thus improving dilution. In case of southern winds, this formation of a rolling air flow results in the opposite effect – an increased additional local contribution from traffic, since the exhaust gases directly drift from the street to the monitoring station.

In the case source areas are further away, dependences on wind directions may lead to misinterpretations, if wind shifts have occurred on the transport way or if the wind field is influenced by topographic barriers such as mountains. Such changes in the wind field can be assessed by means of trajectory models. The way of the air masses arriving in the Berlin area is calculated on the basis of three-dimensional data for wind, temperature and barometric pressure at numerous meteorological stations in Europe. In this way, the air masses can be traced two up to three days back, e.g. starting in Berlin (backward trajectory). This procedure is used to determine the origin of air masses for all days with high PM$_{10}$ concentrations. Of utmost importance is the question whether the pollution results from the trans-boundary long-distance transport of the eastern neighboring countries (Poland, Czech Republic etc.). For a better assessment of the wide scale long-distance transport, further use is made of the maps created daily by the Federal Environment Agency on the interpolated PM$_{10}$ concentration distribution all over Germany.
In the following, this type of assessment will be exemplified for the level of pollution on 10/02/2010. On this day a value of 127 µg/m³ PM\textsubscript{10} was measured at the traffic site Frankfurter Allee.

The mean value of the urban background stations in Berlin’s residential areas was 122 µg/m³ on this day, and the mean of Berlin’s background stations 101 µg/m³.

Figure 5.11 shows the backward trajectories of this day, which were calculated every four hours for different starting points in Berlin and its surroundings. The time-path of the trajectory, i.e. the time period over which the air package was traced back, is indicated by different colours for different hours. It can be seen where the trajectory has been in the hours before reaching Berlin. The lines illustrate the path travelled. It is shown that air masses on 10/02/2010 had their origin southeast of Berlin in Poland, before they traversed Poland over the course of two days and reached Berlin from the northeast in a slight curve.

As shown in the map of the Federal Environment Agency in Figure 5.12, the PM\textsubscript{10} concentration on 10/02/2010 exceeded 100 µg/m³ in wide parts of East Germany. The fact that the concentration strongly decreases towards the west, and that the areas with high concentrations (with the highest concentration at the eastern state boundary) are wedge-shaped, suggests that the pollution originates in trans-boundary transport from Poland.
In order to determine the influence of the trans-boundary long-distance transport on daily limit value exceedances in Berlin, the origin of the air mass was examined for all days between 2006 and 2010 in which the PM$_{10}$ concentrations at the inlet station exceeded 40 µg/m³. 80% of the daily limit value were already attained at the city periphery without any contributions from the city or transport. The exceedance days were classified as trans-boundary cases of long-distance transport, in which the reverse trajectories indicated a clear link to neighbouring countries since the PM$_{10}$ concentration between Berlin and the eastern border were increased. Cases in which the trajectories remained over Berlin or its surroundings for a while, or where no clear transport direction was detectable, as well as days on which the PM$_{10}$ concentration at the inlet station was below 40 µg/m³ were not graded as long-distance transport. The year 2005 has not been evaluated yet due to a lack of trajectory data. Figure 5.13 shows the result of the 2006-2010 evaluation for traffic site stations. Exceedance days arising from regional or local influences, including the local traffic contribution, are marked in yellow. Marked in blue are days on which the exceedance of the 24-hour limit value was caused by trans-boundary long-distance transport, and which could not have been avoided with proportionate measures in Berlin and its surroundings. In 2006 the regional and local emissions were sufficient to meet or to exceed the 35 permitted days with daily limit value exceedances. In 2009 and 2010 by contrast, it would have been very likely that the limit value would have been met without the trans-boundary long-distance transport. In 2010 especially, more than half of the exceedance days could be attributed to long-distance transport. The number of long-distance transport cases varies for the individual monitoring stations because in the event of fulfilling the long-range transport criterion of a PM$_{10}$ concentration of at least 40 µg/m³ at the city periphery, at least one road station, but not all road stations must have had an exceedance. These are days on which the daily limit value of 50 µg/m³ was hardly exceeded at the individual street stations.

The Mariendorfer Damm station was a special case in 2009. In this year, a building was demolished adjacent to the station and a new multi-storey building was constructed. The influence of construction sites will be further examined in Chapter 5.3.2.3.

The significant influence of the wide-ranging transport of particulate matter is additionally underpinned by an examination of the contents of particulate matter. This is because the composition of particulate matter differs depending on the origin of air masses and the transport duration. A good indicator is the proportion of secondary particles which are...
formed from gaseous precursors and basically consist of sulphates and nitrates in combination with ammonium.

The proportion of the particulate matter contents is exemplified for the traffic site Frankfurter Allee (No. 174) as mean values for days with PM$_{10}$ concentrations below 30 µg/m$^3$, for days with moderate concentrations of 30 to 50 µg/m$^3$ and for days exceeding the 24-hour limit value of 50 µg/m$^3$. The percentage of mass concentrations shows the same pattern over years: For low particulate matter concentrations, carbonic particles and the rest that are unidentifiable material-wise (mostly inorganic insoluble components such as whirled-up soil and built-up water) dominate. For high total concentrations on the other hand, inorganic secondary particles dominate which are only formed by a sufficiently long transport in the atmosphere. The year 2010 is unique among the highly polluted years in that it has the highest share of inorganic secondary particles, and, at the same time, the highest carbon share. Diesel exhaust gases, and the combustion of solid fuels both inside and outside Berlin, cause the highest share of soot.

5.3.2.3 Exceedances of the 24 hour limit value due to construction works
Depending on the type of work, high particulate matter emissions may occur on construction sites. In general, however, the influence is of local nature, as the mostly coarse dust particles are not transported over long distances in the atmosphere. This does not include the motor emissions of construction machines, however, whose diesel soot emissions are comparatively high.

The influence of construction sites on the frequency of exceeding PM$_{10}$ daily limit values at monitoring stations can be inferred from the typical course of temporal highly resolved PM$_{10}$ concentrations, i.e. on the basis of ½-h values of the continuous PM$_{10}$ measuring devices. In case of direct influence from construction sites, high concentration peaks and higher concentrations that significantly exceed the concentrations measured at comparable stations, occur temporarily during the working hours. This is emphasised in Figure 5.15. It shows the course of PM$_{10}$ concentrations during daily variation for the station Mariendorfer Damm based on ½-h values between the 19/07 and the 26/07/2009. Concentrations are very high during the working hours on weekdays, which end considerably earlier on Fridays. The mean value of all other traffic sites (red curve) serves as a means of comparison. On weekends, i.e. when there is no construction work, the values at the Mariendorfer Damm station are on the same level as those measured at other traffic sites. In 2009, the construction work lasted from the beginning of March to the end of July. During this time, 44 exceedance days occurred due to the construction work.
Comparable evaluations were carried out for other monitoring stations with construction work in their surroundings. As a result, 17 of the 59 exceedance days at the monitoring station Jannowitzbrücke (e.g. sandblasting works). Despite the enclosure of the working area, the high additional concentrations could not be avoided sufficiently. At the station Hardenbergplatz (No. 115), 2 of the 42 exceedance days in 2006 were caused by construction work. In 2007, one exceedance day occurred for the same reason at the station Karl-Marx-Straße (No. 220).

These exceedances mostly derived from coarse particles. These accrue due to re-suspension, from dredging works and demolition work for example, and account for the bulk of exhaust emissions given their larger particle mass compared to the small and very fine soot particles deriving from the exhaust of machines. The share of particulate matter pollution from pure soot emissions from exhaust of machines is thus difficult to capture solely on the basis of measurements of particulate matter (PM10) concentrations, which contain a significant share of the whirled-up coarse particles.

Within the framework of the on-going examinations by the Federal Environment Agency on reducing environmental pollution from mobile machines, only a preliminary assessment has been conducted so far. The particulate emissions from exhaust pipes of machines that are typically used on larger construction sites were compared with the exhaust emissions of 40,000 motor vehicles that pass daily through a 200 m long section of a main road without construction work. As a result, the contribution from soot particles from the construction machines’ exhaust is in the same range as, or even above, the contribution of motor vehicle traffic. If the share of contributions from other sources within and outside Berlin is taken as a basis (see Figure 5.6), the contribution of exhaust soot from the motors of machines used on construction sites accounts for 10 % of the total local pollution from particulate matter (PM10).

5.4 Origin of the particulate matter (PM2.5) pollution

A special monitoring programme [Pesch58] was conducted in 2007 in order to examine the sources of the PM2.5 immissions in Berlin. Since 70 to 75 % of the particles up to 10 µm (PM10) are smaller than 2.5 µm, thus belonging to the PM2.5 fraction, the causal analysis for PM2.5 also explains part of the origins of PM10. The comparable study for PM10, which was carried out in 2002, was thus not repeated.

On the basis of data on PM10 concentrations measured daily at stations in and outside of Berlin, analysis of the components of particulate matter and data on emissions from particles and precursors such as sulphur dioxide, ammoniac and nitrogen oxides, the significant pollutants were identified and their contribution to the PM2.5 contribution determined. The sources responsible for the PM2.5 immissions in Berlin were broken down into a local traffic contribution and an urban and (trans) regional contribution.

Figure 5.16 presents the contributions of each source group according to their source region.

Of all sources, the exhaust particles of the total road traffic in Berlin contributed most to the PM$_{2.5}$ pollution at 21% (9% local traffic contribution and 12% remaining traffic in Berlin). A further 9% was caused by the exhausts of the road traffic entering Berlin from outside the city. The share of PM$_{2.5}$ concentrations from abrasion and re-suspension from Berlin’s traffic was much lower, at 7%, than for the comparable analysis for PM$_{10}$ (approx. 21%). This is because the major part of the particles formed by these processes are larger than 2.5 µm.
5.5 Origin of the benzo[a]pyrene-pollution

In order to limit the pollution from PAH, a target value of 1 ng/m³ was set for benzo[a]pyrene (BaP), which serves as its main component. The target value has to be met by 2013. In 2006 and 2010 this value was exceeded at two of the five monitoring stations, at which BaP is measured.

An examination of the annual course of the BaP concentration in 2010, as in Figure 5.17, shows that high concentrations occurred solely in the winter months; whereas in summer the values were below 0.2 ng/m³ at all stations. The same applies to stations on roads where few BaP emissions are released by diesel exhaust. Both this annual course and the emission balance for BaP suggest that BaP pollution can be attributed 90% to the combustion of solid fuels such as wood and coal. Around 90% of the emitted BaP in Berlin is derived from these sources. Even on the federal level, around 90% of BaP can be attributed to these sources according to the Federal Environment Agency. In order to ensure compliance with the target value of 1 ng/m³ by 2013, it is thus necessary to reduce the combustion of wood and coal in small heating plants or to reduce emissions during the combustion process by taking measures such as the incorporation of particle filters.

Figure 5.17: Annual course/cycle of the BaP concentration in 2010
6 Assessment of measures implemented to date

6.1 Low emission zone
The causal analysis for the pollution resulting from particulate matter PM$_{10}$ and nitrogen dioxide within the framework of the Clean Air and Action Plan 2005-2010 has shown that the emissions caused by engines in Berlin’s road traffic, with a total share of 21 % in the particulate matter pollution and of 86 % in the nitrogen dioxide pollution, are the largest among the city’s sources. One of the reasons for this is the proportion of old, highly emitting vehicles, which is high in Berlin compared to the national average. Model calculations for emission-based traffic bans show a reduction potential of 40 % in diesel particle emissions and 10 % in total particle emissions (taking into account abrasion and resuspension emissions) and 10 % in nitrogen oxide emissions from traffic, if from 2010, only diesel vehicles with the emission standard EURO 3 and particulate filter were allowed to drive within the inner light train ring [S-Bahn-Ring]. Among all considered measures, the so-called low emission zone (LEZ) was the measure with the largest potential impact. Furthermore, this measure would be effective along the whole road network in the LEZ and beyond.

Implementation
In the context of the Air Quality Plan, the introduction of a low emission zone as an emission-based traffic ban in two stages was adopted in August 2005. For reasons of proportionality, with the introduction dates on 01/01/2008 for stage 1 and on 01/01/2010 for stage 2, the concerned motor vehicle owners were given transitional periods of two and four years respectively.

The labelling of low-emission vehicles for the screening of emission-based traffic bans was governed by means of the 35th Ordinance of the Federal Pollution Control Act [35. BlmSchV] that introduced four emission groups and three coloured stickers. Furthermore, in order to aid compliance, a traffic sign that identifies the low emission zone was created.

The low emission zone was implemented as an ordinance in the form of a traffic ban according to § 40(1) BImSchG in connection with the 35th ordinance with the following criteria:

- traffic ban for vehicles of the emissions group 1 from 01/01/2008
- traffic ban for vehicles of the emissions groups 1 to 3 from 01/01/2010

To reduce the economic and social consequences caused by the traffic ban to concerned vehicle owners, a two-stage introduction was implemented with long transitional periods. Additionally, both stages were granted each 7,000 to 8,000 temporary individual exemptions in cases of economic and social hardship. Furthermore, there is an exemption for stage 2 for diesel EURO 3 vehicles that cannot be upgraded (yellow sticker). In 2010, 12,000 vehicles made use of this.

Due to the traffic ban, the share of vehicles displaying a green sticker was 1.5 to 3 times higher than expected compared to what would have been expected in the trend development without the low emission zone. The highest degree of compliance with the establishment of the low emission zone stage 2 was seen in passenger cars (petrol and diesel engine) with 97 % and diesel engine cars with a 91 % share. Regarding the commercial vehicles, the emissions group 4 (green sticker) shares came to 6 % for small trucks up to 7.5 t and approximately 75 % for light commercial vehicles and 73 % for trucks exceeding 7.5 t. The proportion of vehicles having a green sticker already strongly increased with the introduction of the low emission zone in 2008, as vehicles of the emissions group 1 and 2 were substituted by vehicles of emissions group 4 at an early stage.
In 2010, the proportion of highly emitting vehicles without sticker, compared to the trend development (without low emission zone), increased by 70 to 85 % and the share of vehicles with a red sticker decreased by 50 to 70 %.

The retrofitting with diesel particulate filters made a considerable contribution to the increase in vehicles with green stickers. Until 01/01/2010, there were altogether 41,219 retrofitted vehicles in Berlin, 8,104 of which were trucks. In December 2010, the number of vehicles was 55,541, of which 14,221 were commercial vehicles.

**Environmental effects**

**Effects from the emission of diesel soot and nitrogen oxides**

Based on the changes of the fleet mix – determined by annual licence plate surveys – the impact of the low emission zone on the emission of pollutants was calculated. The same total mileage per vehicle category was assumed for each year, but it was allocated to the changed proportions of the different emission standards in each year. Retrofitting with particulate filters, in so far as is known, was not taken into account. However, the data on this was incomplete, as pertinent information from the licensing authority in Berlin about the retrofitting was available only for vehicles registered in Berlin that hold an 80 % share of the vehicle fleet on the road, whereas the technical information on vehicles not registered in Berlin was delivered by the Federal Motor Transport Authority, which was not able to provide data about retrofitting with diesel particulate filters. In addition to emissions of the actual fleet, which was determined by the licence plate survey, emissions of a trend scenario without a low emission zone were calculated as well.

For the whole fleet, and thus the road traffic in Berlin, stage 1 of the low emission zone showed a decrease of 24 % in soot emissions in the first year and a decrease of 32 % in the second year compared to the trend development without a low emission zone. With the 2nd stage, the emission of pollutants decreased by 173 tons from 299 tons per year (trend development) to 126 tons per year in 2010. This means 58 % less soot particles compared to the trend without low emission zone, and 40 % less compared to the 1st stage having an emission of pollutants of 424 tons in 2009. The emission of nitrogen oxide was also reduced by the low emission zone. With the 2nd stage, approximately 1,517 tons of nitrogen oxide compared with the trend development and 424 tons compared with stage 1 were avoided. The reduction of emissions was achieved by the modernisation of motor vehicles and trucks in equal proportions. This shows the importance of involving motorcars in the low emission zone regulation.

Despite exceptional authorisations, the reduction potential of the 2nd stage was exceeded by about 88 %.

**Effects on air quality**

The low emission zone’s objective is the reduction of air pollution due to PM_{10} and NO_{2} compared to the conditions without low emission zone. This means that even in the case of meteorologically-related increases in large-scale air pollution due to unfavourable dispersion conditions, long-distance transports of air pollutants or emission increases due to other sources such as domestic heating, a reduction in the overall air pollution, especially at highly polluted roads, can still be successful.

Evaluating the impact of the low emission zone on the air quality is based on studies regarding the change of the PM_{10} share of source groups from 2007, which is the year before the introduction of the low emission zone. It is furthermore based on the evaluation of data on air quality for PM_{2.5}, NO_{2} and also carbon-based particles being a characteristic constituent of diesel engine emissions.
The evaluations revealed, with regard to particulate matter PM$_{10}$, that without the existence of a low emission zone, the mean annual value for 2010 would have increased by about 2 $\mu g/m^3$ respectively 7 %. By implementing the low emission zone were avoided 10 exceedance days of the 24-hours limit value on roads. Owing to the low emission zone, the nitrogen dioxide pollution for roads decreased by about 5 %. The decrease in traffic-related incremental pollution caused by soot particles is a significant improvement for human health, as they are an especially toxic source of particulate matter. This incremental pollution on roads decreased by more than 50 %. Due to the low emission zone, the traffic-related pollution for residents on main roads was significantly reduced. Thus the level of pollution continues to approach the level of the urban background.

### 6.2 Improvement of the municipal transport bus fleet

BVG, Berlin’s public transport service operator, runs a bus fleet of approximately 1,320 buses, which consume about 6 % of the diesel fuel sold in Berlin. BVG buses have gradually been equipped with particulate filters since the late 1990s. Before the entry into force of the Clean Air and Action Plan 2005, approximately 72 % of the buses were equipped with particulate filters. These filters reduce particulate emissions by approximately 70-90 %. Besides particulate emission, the buses also contribute to nitrogen dioxide pollution on a local level. In order to reduce bus emissions, the Clean Air and Action Plan 2005 included the following objectives:

- Complete achievement in retrofitting with particulate filters until 2010
- Retrofitting to EURO 5 standard/enhanced environment-friendly vehicle (EEV) standard

These requirements also apply to sub-contractors of the BVG.

### Implementation

For the implementation, the Air Quality Plan objectives were integrated into the local transport plan (NVP) of the federal state Berlin 2006-2009 and also into the most important elements of the NVP 2010-2014.

![Figure 6.1: Fleet mix development of transport busses operated by the Berlin transport company BVG](image)

In the years 2005 to 2010, the BVG purchased altogether 923 buses, 161 of which with emission standard EURO 3, 409 with EURO 4 and 353 with EEV/EURO 5. All those newly purchased diesel engine buses are equipped with closed particulate filters. Four of nine gas-powered buses are fuelled with hydrogen. Figure 6.1 shows the present fleet mix as compounded in spring 2011 compared to the reference year 2004 and the intended objective of the Clean Air and Action Plan 2005.

The target share of EURO 5/EEV-busses has not been achieved. Instead, a higher number of buses with the emission standards EURO 3 and EURO 4 had to be purchased. One reason for this was the delivery of the double-decker bus fleet type A39 (manufacturer MAN), that was delayed by 1.5 years and is still being delivered today. Furthermore, vehicles with EURO 5/EEV from the 3rd delivery lot were supposed to be delivered. For construction-related reasons, only EURO 4 vehicles (with CRT-particulate filter) were delivered.

Within a tendering of articulated busses in 2004, vehicles with EURO 3 (with CRT-particle filter) were put out for tender and quotes for vehicles with EURO 5/EEV standard were requested. According to the BVG, there was no provider back then who would have been able to deliver the required articulate busses with a higher standard than EURO 3 (CRT) in the short-term. The short-term purchase was necessary at that time, as leased vehicles (CharterWay) had to be given back in 2005.

Environmental effect
With regard to the fleet mix, the fleet for 2004 with the HBEFA 3.1 data show a mean emission factor of 0.47 g/km for diesel soot and 18.03 g/km for nitrogen oxide. The fleet of 2011 attains mean emission factors for diesel soot of 0.47 g/km (Air Quality Plan objective: 0.029 g/km) and a nitrogen oxide emission factor of 9.71 g/km (objective: 8.95 g/km).

By means of the fleet that was targeted in the Clean Air and Action Plan 2005, the mean soot emission per km of the bus fleet would have increased by 96%. Yet, by means of the actual fleet modernisation was attained a reduction of 90%. The slightly higher emissions were caused by the remaining EURO 2 buses without particulate filters, at 6% of the total, which will be replaced by new vehicles in the near future. These buses already cause 42% of the specific fleet emissions. However, these buses merely operate in the lightly built-up suburbs outside of the low emission zone. The fleet that operates inside the low emission zone accomplishes mean soot emissions of 0.029 g/km, meeting the targeted value of the Clean Air and Action Plan 2005.

As for nitrogen oxides, the mean specific emissions of pollutants decreased by 46%, the target value was 50%. Thus the objective was nearly attained. Currently, the largest part of the nitrogen oxide emissions originates from buses with emission standard EURO 3.

The annual mileage performance of the BVG busses comes to approximately 88 million kilometres. Thus, by means of the fleet modernisation at the end of 2010 and compared to the fleet of 2004, can be avoided 37 t of diesel soot and 732 t of nitrogen oxide (9 t of which is nitrogen dioxide) annually.

6.3 Improvement of the municipal vehicle fleet
As to the municipal vehicle fleet, the Clean Air and Action Plan 2005 aims at the gradual retrofitting of diesel engine vehicles with particulate filters or their replacement by natural gas vehicles. A complete retrofitting is supposed to be attained in 2012.

Implementation
Specific environmental standards for the purchase of motor vehicles by the Berlin authorities with respect to the emission standard were settled as early as 2003. In this context, the use of particle filters was demanded for the first time. On that basis, the Berlin Police Department purchased motor vehicles with particulate filters to a greater extent already in

61 BVG: personal information about the bus fleet.
2004. In the course of a circular in 2007, the environmental standards were updated and the CO₂ emissions criteria were widened.

In the course of cooperation agreements in addition to climate change objectives were additionally made agreements concerning the vehicle fleet with the BSR (Berlin’s municipal cleaning and waste management company) and the BWB, operator of the city’s water supply and wastewater disposal network, including modernisation and environmentally conscious operations, such as driver trainings. At the end of 2010 was conducted an inspection of the vehicle fleet of the Berlin authorities and public institutions.

In 2005, only a few vehicles, such as newly purchased motor vehicles for the police department, were equipped with particulate filters. By now, however, a large number of the diesel engine vehicles utilise a filter or were replaced by EURO 5/EEV vehicles. Natural gas vehicles were only purchased in a small number.

The following table displays the shares of diesel engine vehicles with a particulate filter or EURO 5/EEV standard, and also the share of pollutant group 4 vehicles of the 35th BlmSchV (green sticker) in the Berlin Administration for the year 2010. Since then, the share of vehicles with a green sticker and of diesel engine vehicles with a particulate filter system was further increased, for instance up to 80 % at the BWB until the beginning of 2012.

Table 6.1: Share of clean vehicles in public institutions (2010)

<table>
<thead>
<tr>
<th>Authority/Institution</th>
<th>Share of diesel engine vehicles with particulate filter or EURO5/EEV standard of the diesel engine vehicles</th>
<th>Share of vehicles (Otto and Diesel engines) pollutant group 4 (green sticker)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senate Departments with subordinate institutions</td>
<td>54 %</td>
<td>77 %</td>
</tr>
<tr>
<td>(without Administration of the Federal State, police,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fire brigade, BSR, BWB, BVG)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>State Administration Department (LVwA)</td>
<td>100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Police</td>
<td>72 %</td>
<td>82 %</td>
</tr>
<tr>
<td>Fire brigade</td>
<td>90 %</td>
<td>87 %</td>
</tr>
<tr>
<td>Berliner Stadtreinigung (BSR)</td>
<td>45 %</td>
<td>73 %</td>
</tr>
<tr>
<td>Berliner Wasserbetriebe (BWB)</td>
<td>53 %</td>
<td>73 %</td>
</tr>
<tr>
<td>BVG</td>
<td>87 %</td>
<td>89 %</td>
</tr>
<tr>
<td>Local authorities</td>
<td>43 %</td>
<td>52 %</td>
</tr>
</tbody>
</table>

Environmental effect
It was not possible to evaluate the emissions of the public vehicle fleet in its entirety, as the required information on vehicle mileage is incomplete. The attained emission reductions concerning the BVG were already presented in Chapter 6.2.

6.4 Support of natural gas vehicles
The city of Berlin has supported natural gas vehicles since 2000. The Clean Air and Action Plan 2005 aimed at the continued support of natural gas vehicles.

Implementation
In the course of the programme “TUT – Tausend Umwelttaxis für Berlin”, supported by the Federal Government, the gas industry and the EU-funded project “TELLUS” was supported the purchase of 1,000 natural gas taxis, about 100 natural-gas powered driving school vehicles and also 150 natural gas delivery vehicles until the end of 2006.
Being one of biggest fleet operators, BSR has purchased about 50 natural gas waste collection vehicles since 2003 and installed its own filling station for fuelling. This investment was supported by the Berlin Environmental Relief Programme64.

Starting with two original natural gas filling stations in Berlin in 2002, the network has grown to 17 filling stations in 2010. In the areas around Berlin, there are 8 more natural gas filling stations. In order to keep promoting the development of natural gas vehicles, this objective was incorporated into cooperation agreements with the GASAG (Berlin’s gas works corporation), aiming at the joint implementation of energy and environmental objectives. This agreement was renewed on 08/12/2010 for a further term from 2011-2020.

Currently, the purchase of natural gas vehicles is supported by the Berlin GASAG in the form of fuel vouchers in the amount of 111 to 1,500 €. Indeed, from 2006 to 2010, the share of natural gas vehicles was doubled due to promotion and favourably taxed fuel prices. However, the share of the 3500 natural gas vehicles registered in Berlin of the total number of 1.2 million vehicles is vanishingly small and only amounts to 0.3 %. With regard to the active fleet on the road, the share is less than one per cent.

Slightly higher is the number of liquefied petroleum gas (LPG) vehicles that increased from 1,163 to 9,134 between 2006 and 2010. Those generally cost-effective retrofittings of gasoline vehicles was also encouraged by tax-advantaged low fuel prices. Nevertheless, this does not cause a reduction of nitrogen oxide and particulate matter emissions, as gasoline and LPG vehicles show similar emissions.

**Environmental effect**

Within the projects mentioned above, altogether 1,250 natural gas vehicles were purchased instead of diesel engine vehicles with the emission standard EURO 4 (taxis and light commercial vehicles)65. On the basis of an annual vehicle mileage of 30,000 km/a for light commercial vehicles and 60,000 km/a for taxis and driving school vehicles, the avoided nitrogen oxide and particulate matter emissions for the urban traffic were calculated by way of the mean emission factors of the HBEFA 3.1. Operating these natural gas vehicles accordingly avoided 3 tons of diesel soot and 35 tons of nitrogen oxide per year. On a local level, however, especially in taxi areas or on roads with a high share of taxi transport, can be expected a higher beneficial effect.

6.5 Promotion of ecological means of transport

A shift of car traffic to ecological of transport ("ecomodes", i.e. local public transport, cycling and walking) is always connected to a reduction of emissions both for air pollutants and also noise and greenhouse gases. Hence, the Urban Development Plan (StEP) Traffic of 2003 aimed at increasing the journeys of ecomodes from 62 % to 66 % in the entire urban area and from 75 % to 80 % in the inner city.

**Implementation**

In its partial “ecomode” strategy, the SteP Traffic 200366 connected measures regarding the settlement structure that are intended to counteract the trend of longer distances with measures that are intended to make local public transport (ÖPNV) and cycle and pedestrian traffic more appealing.

Measures to promote the ÖPNV, such as a further development of the infrastructure, more frequent services during the evening or quality requirements in terms of punctuality and cleanliness, were specified within the local transport plan [Nahverkehrsplan67]. The measures were basically implemented within the transportation contracts, which were made with transport-sector operators like BVG and S-Bahn GmbH. The contracts are subject to a continuous monitoring by the Center Nahverkehr Berlin that publishes the results in quality reports68. As a result, from 2003 to 2009, the number of passengers using local public transport increased by 148 million to 1,351 million per year, which is an increase of 12 %.

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For the promotion of cycle traffic, the Berlin Senate adopted a cycle strategy\(^{69}\) that includes measures such as expanding the cycling network, the provision of bicycle routes and the option to integrate bicycles into the public transport, as well as road safety projects and mobility education in schools and public relations, e.g. the campaign “engine off – head on” [“Motor aus – Kopf an”]. As a result, in 2009 both the length of bicycle routes and the number of bicycle facilities was increased by about 60 % compared to 2002. The monthly bicycle censuses\(^{70}\) at fixed counting stations [cycle traffic-counts] during the last few years showed that bicycle traffic has increased by approximately 34 % since 2004 and continues to show an upward trend.

Different actions to promote pedestrian traffic were implemented in recent years. Since 2001, more than 200 zebra crossings and almost 100 further pedestrian crossing facilities were newly created. Reduced-traffic areas and zones with a speed limit of 30 km/h in residential areas ensure higher road safety for pedestrians. Binding guidelines make sure that new walking paths are sufficiently wide, barrier-free and accessible for disabled persons. Also a signposting system for pedestrians was implemented in the inner city. These approaches are supposed to be extended and complemented within the so-called Fußverkehrsstrategie\(^{71}\), a strategy for pedestrian traffic, which was decided in July 2011. This strategy comprises a number of short-term, medium-term and long-term measures. These include measures to ensure a pedestrian-friendly urban environment, the creation of attractive inter-linked walkways and the enhancement of shopping promenades, tourist attractions and other areas that are highly frequented by pedestrians.

Due to the numerous measures intended to promote ecomodes, and also due to external effects such as increases in fuel prices, the use of environmental-friendly means of transport increased during recent years, whereas the share of the motorised individual traffic (car traffic) declined. As Figure 6.2 shows, the objective of the SteP Traffic with a 68 % share of ecomodes in the whole traffic was attained already in 2008. For the inner city boroughs Friedrichshain-Kreuzberg and Mitte, shares of 17 % and 22 %, respectively, for the MIV were achieved in 2008. Thus, the objectives for the modal split in the inner city traffic have been widely attained.

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From the perspective of clean-air policies, the objective of the modal shift from the MIV to ecomodes means a reduction in car traffic on main roads. As already shown in Chapter 2.5, the car traffic volume on main roads has decreased by 10 to 14 % since 2002. A separate evaluation for motor vehicles shows a decrease in car traffic volume by 12 to 14 % in 2010 compared to 2002, as determined by the mean value of measurements from 36 representative traffic census stations (see figure 6.3).

Environmental effect
The decrease in car traffic volume is taken into account in the traffic model for calculating the emissions and the incremental pollution from road traffic along the whole network. However, in this respect, it was not taken into account at what level the pollution would have been without this decrease in traffic volume. The model calculations from previous years are also not directly comparable due to changed emission factors with regard to road traffic. A simplified estimation of the shift effect is possible by considering the car traffic shares of the local traffic-related incremental pollution in a road (59 % for PM$_{10}$, 52 % for NO$_2$) and the share of the incremental pollution share in the total pollution in a road (16 % for PM$_{10}$, 44 % for NO$_2$). An increase in the car traffic share of 10 to 14 % mathematically leads to a higher total pollution due to PM$_{10}$ by about 2 to 3 % and by 4 to 6 % resulting from NO$_2$.

6.6 Parking space management
The management of parking space reduces air pollution by lowering the considerable traffic caused by searching for a parking space, and supports the commuters’ switching to the ecomodes, which decreases the targeted traffic volume of motor vehicles. Thus, the Urban Development Plan Traffic provides a gradual extension of the management of parking space to all urban areas having high demand pressures and limited parking facilities. In this respect, the amount of the cost charges is differentiated according to the borough.

Implementation
The introduction and operation of parking space management comes under the responsibility of the boroughs, where there are different resolutions reaching from active endorsement to rejection. Thus, a further expansion of the management area requires cooperation with the boroughs. The basis of a uniform handling of parking space management expansion was created by means of the new parking fee regulation and the guide$^{73}$ on parking space management.

In 2010, there was parking space management in 7 out of 10 boroughs. The number of managed parking spaces in Berlin increased from 47,726 spaces in 2002 to 80,980 in 2010. In 2010, the managed area amounted to 2,525 ha and primarily focuses on the area inside the urban rail ring (see Figure 6.4). Most of the managed parking spaces are located in the borough Mitte with a number of 27,900 spaces, followed by Charlottenburg-Wilmersdorf with 20,800 parking spaces.

Environmental effect
The parking space management’s objective is, on the one side, the reduction of car traffic looking for a parking space. Regarding this, censuses showed a decrease of 20 to 40% in motor vehicle traffic on minor roads with a high share of car traffic looking for a parking space. This does not just constitute a significant contribution to air pollution reduction on those roads, but also reduces traffic noise and increases road safety. However, a quantification of the related environmental effects is lacking.

A further objective from the environmental perspective is the moderation of the motorised transport by encouraging a shift to the ecomodes, especially with regard to persons commuting for work and training. This effect is also reflected in the decrease of car traffic and its effect on air quality as already described in Chapter 6.6 (Promoting ecological means of transport). Parking space management is thus also one of the instruments to promote the ecomodes.

6.7 Environmentally sensitive traffic management
The emissions and meteorological conditions that change as well from day to day as also during the course of a day, lead to strongly fluctuating concentrations of air pollutants in street canyons. By means of traffic control measures, such as regulating the flow of traffic entering the city with the help of entry traffic lights or modified traffic light systems in order to improve the traffic flow, emissions in a road section can be considerably lowered by reducing congestion. However, this might happen to the detriment of other road sections, which are then exposed to higher traffic and emissions. It does not make sense to stick to such measures in the long run under those circumstances. Instead, they should only be used in order to avoid peak loads when there is less critical air pollution in other road areas. This is, for example, applicable to intersecting streets, one of which is driven
into across and the other one lengthways. In the street canyon which is driven into lengthways, exhaust gases are more easily diluted. Therefore, a reduction in emissions attained by measures intended to make traffic run more smoothly for the street which is driven into across, in which the dilution is unfavourable at that time, do not lead to a significant increase in air pollutants on the lengthways driven street. Thus, an environmentally sensitive traffic control aims at attaining a selection of the ideal traffic control that is adapted to the particular situation.

**Implementation**

In Berlin, within the pilot project iQmobility, were developed, among other things, the required monitoring and modelling systems to determine traffic conditions and air quality, as tested within a field trial in the Leipziger Straße (see Figure 6.5) from September to December 2007. The project’s objective was the analysis of the influence of different maximum permitted speeds (50 km/h and 30 km/h) and also the testing of two different control programs for the traffic light systems (fixed-time control systems and traffic-related control programs). A speed limit of 30 km/h (Tempo 30) was only operated with a fixed-time control system, which means that the so-called “green wave” was adjusted to tempo 30 and operated depending on the time of the day. As for the traffic-related control, the green wave was oriented to tempo 50 and operated depending on the measured traffic volume.

In one direction of travel, the field trial results were strongly affected by a construction site, which always caused, regardless of the coordination, a backlog during peak hours. The traffic-related effect of the three scenarios can be summarised as follows:

- The traffic-related selection of a signal-timing schedule for the traffic light systems better contributes to the stabilisation of the traffic flow than a fixed-time control of the traffic lights. The optimal coordination speed of the traffic light systems, however, depends on the local conditions.
- Due to the high traffic volume on Leipziger Straße, the mean speed in tempo-50-scenarios was only between 26 and 32 km/h. With a recommended speed of 30 km/h, the mean speed level continued to decrease, however, in a relatively moderate way to only 25 km/h. The recommended speed of 30 km/h with the according traffic light coordination oriented by tempo 30 (only fixed-time controls were tested) over a route section of 1.6 km on Leipziger Straße had, with a longer mean travel time of 12 to 26 seconds, a speed reducing effect, especially on the maximum driven speeds.
- When capacity limits are exceeded due to high traffic volume, traffic flow cannot be influenced by a traffic-related signal timing schedule or speed limits any further.

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The number of stops on the test route was equal to a speed of 30 km/h in the one direction and lower than a speed of 50 km/h in the other one (both with fixed time control).

By a speed of 30 km/h were attained constant travel shares that were on average up to 18 % higher. That means that the acceleration phases in which emissions occur most heavily are shorter at a speed of 30 km/h.

**Environmental effect**

It was examined how the different coordination of traffic light affected emissions and pollution concentrations. For the determination of emissions were measured traffic volumes with automatic counting installations and the driving profile was recorded of vehicles that go with the flow of the traffic. Thus, the emission of pollutants by engines was calculated accurately to the second by an emission model of the German association for technical inspection [TÜV Nord]\(^76\). A calculation of the particulate emission due to abrasion and re-suspension was not possible due to lacking models.

As expected, congestions had the largest influence on emissions. This is illustrated by the diurnal variation of the NO\(_x\) emission in Figure 6.6, that strongly increase during afternoon congestion primarily caused by a construction site. If this congestion was avoided, could be attained an emission reduction of about 10 % over the whole day.

The comparison of the summarised emission of pollutants for the respective scenarios showed that the coordination of traffic light systems to achieve 30 km/h with the measured traffic conditions caused a reduction of nitrogen oxide emissions by approximately 4 % and a 3 % reduction of the diesel soot emissions.

The effect on local air quality along Leipziger Straße was determined by a mobile measurement bus from the Senate Department for Urban Development and the Environment, which was located in Leipziger Straße during the field trial (see Figure 6.5).

Measures provided by the Berlin air quality monitoring network were utilised in order to evaluate the influence of the urban background pollution. According to the calculated changes in emissions of a few per cent in the daily average, only little declines in the air pollution level were to be expected. Actually, the measurements did not show any significant differences between the three scenarios regarding the incremental pollution of NO\(_x\) and PM\(_{2.5}\). The highest air pollution was measured during the times in which traffic disruptions came up due to the construction site in the direction of Alexanderplatz. It was accordingly not possible to identify a categorically significant influence in the statistical analyses. By means of this statistical correlation, model calculations could demonstrate, however, that by means of traffic management measures for congestion reduction, the incremental NO\(_x\) concentrations on Leipziger Straße could be reduced by up to 10 %, and even up to a maximum of 17 %. Also in terms of particulate matter, diesel soot emission decreases by about 8 % up to a maximum of 15 % due to a reduction in congestion.

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6.8 Speed limits on main roads

Speed limits on main roads serve both road safety and the protection against noise and air pollutants. In the beginning of 2009, a speed limit of 30 km/h was ordered\(^7\) for main road sections totalling a length of 130 km for the whole day, and temporally restricted for a further 100 km section (see Figure 6.7). So far, high noise pollution and accident risks have been decisive for the ordinance of speed limits. In a number of cases, the ordinance of 30 km/h speed limits for noise protection reasons was made due to court decisions. High traffic-related pollution has only served as an additional argument so far. The effect of a 30 km/h speed limit on the air quality was tested within three inquiries. The results of the pilot project HEAVEN were already presented in the Clean Air and Action Plan 2005\(^7\). Since, within the project, a speed limit of 30 km/h was only ordered for a short period comprising a few weeks with initially lacking controls, the results had little meaning since the speed limits were hardly complied with. A long-term evaluation of the effects of a speed limit of 30 km/h on the air quality in Berlin was only possible for Schildhornstraße. This evaluation will be described below.

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30 km/h Speed limit for main roads: Schildhornstraße

Schildhornstraße is the continuation of the urban motorway A107 with an accordingly high traffic volume of about 40,000 vehicles per day. It connects the boroughs Wilmersdorf and Steglitz. The air quality monitoring station is located between Gritznerstraße and Lepsiusstraße. Schildhornstraße is in this area a four-lane roadway beside densely built, closed, four-storey roadside structures.

This station has measured particulate matter PM$_{10}$ since 1999. In 2006, the particulate matter concentrations exceeded the short-time limit value, which had been established in 2005. From 2007 to 2009, the PM$_{10}$ limit values were complied with. In 2010, the daily limit value of 50 µg/m$^3$ was reached and the maximum number of 35 transgressions was exceeded. Since 2007, the traffic volume and vehicle speed have also continuously been measured at this monitoring station. Since about 2009, increased construction site traffic on Schildhornstraße due to comprehensive building operations on Schloßstraße has been noticeable.

Besides increased air pollution, Schildhornstraße shows high traffic-related noise pollution. In order to reduce the noise and air pollution, an all-day speed limit of 30 km/h [Tempo 30] was ordered on the basis of two court decisions.

**Implementation**

In the beginning of November, Tempo 30 was implemented on an all-day basis. The compliance with the speed limit is monitored by a stationary radar system.

The mean speed in the area of the air quality monitoring station now comes to 33.6 km/h. Hence, the speed was permanently reduced by around 7 km/h, or 18%. A shift of traffic...
onto the surrounding road network was not noticeable. Since nearby roads predominantly have a speed limit of 30 km/h as well, in addition to having right of way regulation “right over left”, there are - apart from large-scale bypassing - no quicker alternative routes.

Evaluations of the mean hourly speed depending on the number of vehicles (q-v-diagrams) show that in Schildhornstraße, traffic disruptions causing a decrease of speed and traffic volume solely occur over very few hours during the year. Thus, there is an almost permanently smooth traffic flow without disruptions resulting from congestion.

Environmental effect
There are currently not any standardised models either for engine emissions or for emissions due to abrasion or resuspension in order to evaluate the emission reducing effect of speed limitations to Tempo 30 on main roads.

The Handbook Emission Factors for Road Transport [HBEFA] does not contain emission factors for Tempo 30 on main roads. Tempo 30 is only designated for minor roads, on which, however, there occur more disruptions in the traffic flow due to the adopted “right over left” regulation. The application of these emission factors to right of way roads thus leads to exorbitant emissions. According to the evaluation of references in literature, the non-engine based emissions that were caused by abrasion and resuspension are expected to decrease with a reduction of speed, provided that the traffic flow is consistent. With measurements taken directly on a vehicle, Düring81 assessed an achievable reduction in emissions of 20 to 50 % with the higher value applying to actual vehicle speeds of 30 km/h and less.

In order to evaluate the effect of Tempo 30 on the local air quality, long-term measurement series for PM$_{10}$, nitrogen oxides and elemental carbon are available at Schildhornstraße monitoring station. The measurements from one whole year before the introduction of the speed limit were compared with those from the year after the introduction, that is the period 01/11/2004 to 31/10/2005 with the period 01/11/2005 to 31/10/2006. To be able to consider external effects (a changing urban background pollution and dispersion conditions), measurements on Frankfurter Allee, which is a road not implementing any emission reducing measures, and at the urban background station on Nansenstraße in Berlin-Neukölln were used for a comparison.

The evaluation of the measurements for Schildhornstraße showed that after introducing Tempo 30, the traffic-related additional PM$_{10}$ pollution locally decreased by 30 %, nitrogen oxides (NO$_x$) decreased by 18 % and nitrogen dioxides (NO$_2$) by 15 %.

The reduction in the total pollution on a road additionally depends on the contribution of the urban background pollution, which is not affected by this measure. At the monitoring station Schildhornstraße, without the introduction of Tempo 30, the annual mean value for PM$_{10}$ in 2006 would have been by 2 to 3 µg/m$^3$ higher and additional exceedances of the daily limit value on 7 days would have been expected. As for the annual mean value of the total NO$_x$ pollution, the reduction equalled between 5 and 9 µg/m$^3$.

When applying the results to other roads, it must be considered that similar conditions shall be present, which means that the compliance with Tempo 30 must be monitored sufficiently and disruptions due to congestion should occur rarely.

6.9 Traffic ban for trucks in Silbersteinstraße in Berlin-Neukölln
Having a traffic load of around 14,000 vehicles per day in a street canyon with a width of about 19 m and a closed roadside development of 22 m in height, Silbersteinstraße is an important connection between the boroughs Neukölln and Tempelhof-Schöneberg. The monitoring station on Silbersteinstraße was the first station in 2005 to record the 36th exceedance of the PM$_{10}$ daily average value of 50 µg/m$^3$ and to exceed the limit value for particulate matter (on 14/04/2005).
Since the motorway BAB100 is a suitable bypass route without residential development, a traffic ban for trucks on Silbersteinstraße does not necessarily lead to a significant increase of the air pollution in other sensitive areas.

**Implementation**

At the end of April the traffic ban for trucks > 3.5 t was ordered, except for originating and terminating traffic. Compliance with the traffic ban is only monitored sporadically, in individual cases it is difficult to differentiate between transit traffic and access traffic.

As traffic surveys show, the share of trucks could be halved from 6.0 % to between 2.6 % and 3.2 %.

**Environmental effect**

Due to the smaller number of trucks, the particulate matter emission generally decreased by 28 %, whereas regarding the vehicle fleet 2005, the diesel soot emissions declined by 17 % and the emissions caused by abrasion and resuspension decreased by 32 %. The latter is due to the fact that vehicle weight highly influences the abrasion and resuspension of particles, so that trucks resuspend significantly more particles than cars. Nitrogen oxide emissions were reduced by 26 %.

The effect on the air quality was at first calculated by means of the model Immis Luft as an annual mean value. Particulate matter PM10 showed an abatement in the traffic-related contribution of around 30 % to 7.1 µg/m³. In the model calculations, the NO2 share decreased by 10 % to 45.7 µg/m³ (total concentration).

For evaluating the measurements of the Silbersteinstraße monitoring station, the measured values at the traffic stations Frankfurter Allee and Schildhornstraße were also consulted, being reference stations without a traffic ban for trucks. Additionally, the measured values of the urban background monitoring station on Nansenstraße were used in order to be able to take meteorological and pre-pollution influences into account.

The comparison of the measured values between the periods July 2004 to March 2005 and July 2005 to March 2006 showed, with regard to PM10, that the particulate matter concentration without the traffic ban for trucks would have been higher by 3 to 4 µg/m³, respectively 7 to 9 % on average. With the aid of a regression model, it was additionally determined that, due to the traffic ban for trucks, 11 exceedances were able to be avoided during the inquiry period. This means that without the traffic ban, Silbersteinstraße would have been anticipated 44 exceedances from May to December 2005, whereas 33 exceedances were measured with the ban in place. This constitutes a decrease of 25 %.

As for NO2, the measured values on Silbersteinstraße for the period 2005 after introduction of the traffic ban displayed, compared to the reference period, a decline of 4 µg/m³, respectively 7 %. During the same time, however, the NO2 concentration in the urban background, which also affects the measured values on Silbersteinstraße being a pre-pollution factor, rose by 2 µg/m³. Considering this, the reduction of the NO2 concentration due to the traffic ban actually corresponds to 6 µg/m³, respectively 10 %.

**6.10 Communication of sustainable mobility**

**Campaign “Sauberer Fuhrpark“ (clean vehicle fleet)**

In order to support companies when modernising their vehicle fleet, especially with regard to the low emission zone, the Senate Department for Health and Social Services Berlin established a consulting campaign that was executed by the Berlin Energy Agency [Berliner Energieagentur] under the title “Clean Vehicle Fleet” [Sauberer Fuhrpark] from 2006 to 2008. The campaign was promoted by the Senate Administration Berlin and the Energiefonds Berlin (funded by the E.ON Energie AG, a large German electric utility service provider).
Within the campaign, information and decision-making materials promoting the purchase of low-emission and energy-efficient vehicles were developed and provided on the internet. Furthermore, consultations (partly including a driver training) and all-day in-house trainings and workshops were held. The campaign addressed around 1,500 companies, the guide was downloaded about 1,000 times until the beginning of 2008, approximately 60 consultations and trainings took place and the workshops had almost 100 attendees. The campaign was followed up by the EU project “INTERACTION – Reducing energy use in freight transport” with further support by the Energiefonds Berlin (funded by the E.ON Energie AG).

The updated version of the guide and further materials are still available within the project “Buy Smart – Beschaffung und Klimaschutz” at www.buy-smart.info (status 2012). A quantification of a beneficial effect on the environment did not take place.

6.11 Testing of particulate filter retrofitting for passenger ships
The current emission standard for diesel engines in ships lags by about 1 to 2 decades behind the one for road vehicles regarding the limit values of exhaust emissions. Ship’s engines have a lifetime of 30 years and longer, being the reason why there is only slow market penetration by new engines.

Passenger ship transport in Berlin’s inner city has considerably increased in recent years. At the same time, complaints by residents and people walking on the waterfront about the nuisance resulting from ship exhaust become more frequent. The Air Quality Plan aims at reducing ship-related emissions. In this respect, the effect of using shore power for the energy supply of ships while they are in port in order to reduce the running of diesel engines during these times was examined. However, the examination showed that this measure does not make sense in the field, at least for passenger ships, as the time they spend in port is so short that the advantage of a changeover to shore power compared to the effort required would generate only low benefits to the environment. For this reason, the alternative measure of refitting the passenger ships with particulate reduction systems was considered more effective. Thus, particulate emissions can be reduced during the whole operation of the ship, both in port and during the journey.

Implementation
From a technical perspective, the diesel engines of passenger ships are comparable to the engines of heavy trucks, so that a retrofitting with particulate reduction systems similar to the ones used with trucks should be feasible. However, there are differences regarding the exhaust gas temperatures that are usually considerably lower for passenger ships, and also with regard to the diesel fuel used, which can have higher sulphur contents. Thus the filter technology used for trucks is not directly transferable, but rather has to be optimised for the intended purpose.

In this pursuit, with the support of the Senate Department for Health and Social Services, within a pilot project, three passenger ships of the shipping company Stern & Kreis were equipped with different particulate reduction systems with differing regeneration systems. Efficiency and durability were examined by means of exhaust gas measurements carried out by the TÜV Hessen (technical inspection agency) over a period of two years. In addition, practical operational experience was evaluated. From the beginning, the commission of ship inspection [Schiffuntersuchungskommission] was also involved in the project, as the filter retrofitting had to be accepted by them in order to ensure a safe ship operation.

In the field, it turned out that, when installing the filter systems, the exhaust back-pressure in particular has to be considered. In this regard, with the engine at maximum load, sufficient capacity reserve must also be provided, as otherwise the filter may build up excessive back-pressure and a bypass valve for avoiding the filter cartridge has to be opened. It furthermore turned out that the filter could become quite hot, so sufficient insulation is of high importance. Additional fuel consumption due to the filters has not been observed yet.
Environmental effect
In order to determine the effect of the particulate filters, three measurement series were executed: directly after commissioning the filter, after one year of operation and finally after two years.

It turned out that the systems attained soot emission reduction rates of significantly above 90%. Also after two operating years, no deterioration was noticeable. The regeneration of the loaded particulate filters operated reliably. This showed that a highly efficient reduction of diesel particulate emissions of passenger ships is possible in the long term.

For future retrofitting, it is envisaged that the Environmental Relief Programme will provide financial support of 50%, which each shipping company is entitled to receive if they meet the criteria and correspondingly install filters of high quality (see Chapter 9; Measure M 2.8).

6.12 Dust emissions from construction sites
One of the other sources of particulate matter emissions identified were the numerous existing construction sites in Berlin, though not every construction site inevitably causes dust emissions. According to the Clean Air and Action Plan 2005-2010, the following measures are supposed to be implemented in order to reduce the dust emission of construction sites:

- Informing the building owners about how to reduce dust on construction sites,
- checking if construction sites in highly polluted areas can be required to use particle-reduced construction machines and which criteria are applicable in this respect and
- Reducing the dust emission of construction sites by executing the (at that time) new Pollution Control Act of the Federal State Berlin [Landes-Immissionsschutzgesetzes Berlin].

Implementation
In order to raise awareness at an early stage with the involved planners, building owners and companies concerning the avoidance and reduction of dust emissions during construction projects, the Senate Department for Health and Social Services published the practice guide “Vermeidung und Verminderung von Staubemissionen auf Baustellen” in June 2010. The practice guide mentions possible measures to reduce dust emissions. It was first printed with a circulation of 300 copies and is also available for download on the internet. It is distributed during inspections of construction sites if necessary.

For further distribution, the guide was also provided to business associations, chambers of crafts and trades and also universities that offer construction studies.

The Federal Pollution Control Act [Bundes-Immissionsschutzgesetz] and the Pollution Control Act of the Federal State of Berlin [LImSchG Bln] that entered into force in 2005 have not yet been able to ensure that the use of reduced-emission construction equipment could be required against the will of construction site operators. This is due not least to the fact that no example cases were found within Germany, where, with regard to particularly polluted areas like environmental zones, general regulations for the use of particulate filters in construction equipment on a voluntary basis were demanded. Efforts to promote the use of particulate filters in construction equipment on a voluntary basis failed. This also applies to diesel-powered generating sets. A major cause to be considered is the high cost pressure, especially in the construction industry, which induces that the demand for such measures, also with reference to how other Federal States handle the problem, has so far been classified as disproportionate.

In order to reduce the other dust emissions emanating from construction sites due to work like cutting stones, façade and demolition work and the like, the LImSchG Bln provides a well-founded legal basis. A reduction of dust emissions is usually attained by means of...
cooperative agreements with the on-site persons in charge or, if necessary, by ordinances of regulatory authorities, of which the compliance can be sanctioned where required.

**Environmental effect**

An environmental effect cannot be evaluated for the development and publishing of the guide about the avoidance and reduction of dust emissions on construction sites, or for the promotion of the reduction measures described in the guide with the respective professional associations, as the guide was only published in June 2010 and an assessment could at the most only consider an evaluation of the number of complaints over several calendar years.

Between 2005 and 2010, there was virtually no reduction of particulate matter by the increasing use of particulate reduced construction equipment, as only a small amount of the mentioned equipment is in use with construction companies, as well as, presumably, with rental companies of construction site equipment.

The environmental effect caused by measures according to the LImSchG cannot be evaluated quantitatively due to the many sources on construction sites causing dust.

### 6.13 Intensified street cleaning

The particles resulting from the resuspension of road dust that is deposited on the road surface contributes considerably to the particulate matter concentrations on roads. The influencing factors on the extent of suspension have not yet been completely identified. However, examinations taken so far suggest that dust mass deposited on the street has an important role. The less dust available, the less should be the volume of the resuspended particles. It was furthermore observed that during or after precipitations, the share of resuspended particles in the particulate matter is lower. Street cleaning is generally an adequate measure in order to reduce the dust load. For this reason, examinations focus on the question of whether intensified street cleaning would correlate with a significant reduction in the particulate matter concentration at a monitoring station.

**Implementation**

The impact of intensified street cleaning methods was investigated in two measurement campaigns on Frankfurter Allee between Proskauer Straße and Möllendorfstraße\(^5\), where is also located a monitoring station (No. 174) from the air quality monitoring network.

From 10/05/2004 to 10/10/2004, regular street cleanings at intervals of two days (on working days early in the morning and in the afternoon, on Saturdays only in the morning/ before noon) were carried out on all traffic lanes. Within the second campaign, in the time period from 24/10/2006 to 29/03/2007, the road was cleaned by means of a new kind of street sweepers with a particulate filter for the exhaust air and that do not make use of water sprays. All traffic lanes were cleaned each time. Altogether, during the evaluation period, the road was cleaned by this machine on 87 out of 157 days.

**Environmental effect**

For the evaluation of the impact on the particulate matter concentration, the continuous half-hourly values for PM\(_{10}\) and the pollution data on NO\(_x\) from the air quality monitoring network BLUME and local traffic count data that were gathered for that same period were analysed.

It was not possible to prove a relevant reduction of the particulate matter concentration for either of the two procedures of intensified street cleaning. The total PM\(_{10}\) pollution on dry roads with street cleaning did not significantly differ from the days without street cleaning. Thus the measure did not cause the desired effect. Also, more frequent street cleanings with the improved sweeper did not lead to a relevant reduction. As an upper limit of the reducing effect, the evaluations showed a decrease in the particulate matter concentration of 0.4 \(\mu g/\text{m}^3\) for days with street cleaning.


Düring, I., Hoffmann, T., Nitzsche, E.: Auswertungen der Messungen des BLUME während der verbesserten Straßenreinigung am Abschnitt Frankfurter Allee 86 (Analyses of Measurements of BLUME during the improved street cleaning on the section Frankfurter Allee 86) on behalf of the Senate Department for Urban Development Berlin, Radebeul 2007.
7 Pollution forecast 2015/2020 in the absence of additional measures (trend scenario)

In order to determine the extent to which additional measures are required to improve Berlin’s air quality, this Chapter first assesses the air pollution trends over the next few years in the case no further measures are being taken (trend scenario). The forecasts were carried out for the years 2015 and 2020. The year 2015 is of particular importance since by then air quality values for nitrogen dioxide have to be met, even if extending the deadline.

The 2020 forecast seeks to point out the further development paths—considerable improvements in air quality are anticipated due to the Euro 6 emission standard which becomes binding between 2014 and 2016. The trend forecasts take account of the existing legal provisions, and those that have been already adopted and will enter into force by 2020, as well the measures introduced or adopted as a result of the 2005 Clean Air and Action Plan and the Urban Development Plan on Transport, e.g. the LEZ stage 2. The model calculations further include population trends and forecasts on other structural data.

The forecast of the air pollution for the years 2015 and 2020 comprises the following steps:

- An estimation of the pre-existing air pollution within the regional background under consideration of PAREST-data,
- Forecast of the traffic-induced pollution in the network of main roads and trends in the vehicle fleet,
- Modelling of the urban background using projected emission trends for sources in Berlin,
- Calculation of pollution levels and road sections that will potentially be concerned by limit value exceedances and number of the persons affected for nitrogen dioxide and particulate matter on main roads.

In addition, emission reductions in the traffic-induced incremental pollution, which are necessary for achieving the limit values, were calculated for selected sections with projected limit value exceedances in 2015.

The results are depicted for nitrogen dioxide and particulate matter PM\textsubscript{10}. They are not shown for PM\textsubscript{2.5} as the relevant air quality limit values are met.

7.1 Pollution trends in the regional background

As part of the project PAREST, the emissions expected due to existing legal regulations were predicted for the years 2015 and 2020\textsuperscript{86}. Based on this data and the meteorological conditions of 2005, concentrations of air pollutants were calculated for the regional background using the RCG model. Emissions generated in Berlin were not taken into account, since they are included in the calculations of Berlin’s urban share for modelling the urban background and should not be used twice.

For all substances, a decline in the regional background pollution was calculated, which, however, relatively modest with 0.6 µg/m\textsuperscript{3} in 2015 and 1 µg/m\textsuperscript{3} in 2020 for particulate matter, and 1.8 µg/m\textsuperscript{3} (in 2015) up to 2.7 µg/m\textsuperscript{3} (in 2020) for NO\textsubscript{2}. During this period, hardly any legal requirements on reducing emissions will enter into force. The greatest effect on improving air quality is expected from the introduction of the Euro 6 emission standard for passenger cars.

7.2 Pollution trends from traffic and the vehicle fleet

The emission trends from road transport are based on assumptions concerning the development of the mileage performance of individual vehicle categories in Berlin (traffic load),

Regarding the future mileage trend, a VISEVA-supported traffic forecast was prepared for the year 2015. For this purpose, the data contained in the 2025 total traffic forecast for Berlin-Brandenburg [PTV Planung Transport Verkehr AG (PTV Planning Transport Traffic Corp.), TCI Röhling Transport Consultation International: Gesamtverkehrsprognose 2025 für die Länder Berlin und Brandenburg – final report. On behalf of the Senate Department for Urban Development Berlin and the Brandenburg Ministry for Infrastructure and regional development. Berlin 2009.] was adapted. In the process, adjustments were made on the data for population development, employment, school admissions, circulation areas and for changes to the infrastructure, e.g. the parking space management. In the development of the costs relating to traffic, no inflation-adjusted increase was assumed. In this regard, the assumptions rely on the status of information as per the year 2010 concerning the future developments of the population, the economy and the traffic framework conditions. In order to allocate the overall traffic volumes to the individual sections of the main traffic road network and the traffic cells in the secondary network, a traffic network model was used on this basis. While looking at the entire city, the model takes account of the implemented measures until the forecast year 2015. The data basis was thus developed specifically for the present questions. It is neither the basis for the evaluation of projects concerning the entire city and nor for local projects. Due to the complexity and non-linear correlations in the traffic network, significant deviations from the project-specific requirements or from other forecast years can result in some instances.

The following developments were taken into account for the forecast year 2015:

- Opening of the airport Berlin-Brandenburg in Schönefeld,
- Closure of the airport Tegel,
- Establishment of new road links, such as the south-east link (Spreequerung) or the extension of the motorway A 10 in the north of Berlin,
- changed traffic organisation and road deconstruction.

For the forecast year 2020, the construction of the motorway extension of the A100 between the motorway junction Neukölln and Treptow was included in the modelling as an infrastructure change.

The vehicle mileages forecasted for the years 2015 and 2020 are subdivided into vehicle categories and summarized in Table 7.1.

Compared to 2009 the traffic-induced pollution in 2015 is expected to increase slightly by 1 %. By 2020, the transport decreases by 7 % compared to 2015, which is mainly due to assumptions on the total population and its age structure. The share of individual motor vehicle categories changes only marginally. In general, a slight decline in the share of passenger cars and a slight increase in commercial vehicles and buses are forecasted.

<table>
<thead>
<tr>
<th>Category of motor vehicle</th>
<th>2009</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bn km/year</td>
<td>share</td>
<td>bn km/year</td>
</tr>
<tr>
<td>Total motor vehicles</td>
<td>10.16</td>
<td>100 %</td>
<td>10.27</td>
</tr>
<tr>
<td>Passenger cars</td>
<td>8.77</td>
<td>86.3 %</td>
<td>8.86</td>
</tr>
<tr>
<td>Light commercial vehicles &lt; 3.5 t</td>
<td>0.79</td>
<td>7.8 %</td>
<td>0.8</td>
</tr>
<tr>
<td>Trucks &gt; 3.5 t</td>
<td>0.38</td>
<td>3.7 %</td>
<td>0.39</td>
</tr>
<tr>
<td>Buses</td>
<td>0.12</td>
<td>1.2 %</td>
<td>0.12</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>0.1</td>
<td>1.0 %</td>
<td>0.1</td>
</tr>
</tbody>
</table>
In order to forecast the vehicle fleet composition in 2015 and 2020, the trend in the vehicle fleet was updated by means of the exchange rates used in the Handbook Emission Factors based on the results of a survey of registration numbers in 2010, i.e. under consideration of level 2 of the LEZ. The contributions indicated in the HBEFA 3.1 were assumed for the upcoming Euro VI emission standard. The only exception made was for service buses, for which higher contributions were assumed due to the requirements of the Local Transport Plan [Nahverkehrsplan]. As shown in table 7.2., a massive increase in Euro VI vehicles is expected between 2015 and 2020:

<table>
<thead>
<tr>
<th>Year</th>
<th>Type of vehicle</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Passenger cars with otto engine</td>
<td>4 %</td>
<td>21 %</td>
</tr>
<tr>
<td></td>
<td>Diesel passenger cars</td>
<td>8 %</td>
<td>32 %</td>
</tr>
<tr>
<td></td>
<td>Light-commercial vehicles</td>
<td>2 %</td>
<td>47 %</td>
</tr>
<tr>
<td></td>
<td>Heavy goods vehicles</td>
<td>28 %</td>
<td>75 %</td>
</tr>
<tr>
<td></td>
<td>Coaches</td>
<td>14.5 %</td>
<td>50 %</td>
</tr>
<tr>
<td></td>
<td>Service buses</td>
<td>27 % (18 %)</td>
<td>65 % (57 %)</td>
</tr>
</tbody>
</table>

Due to the LEZ the share of vehicles with Euro 3 emission standard (without filter) or lower in Berlin is much lower than in the HBEFA. The share of diesel vehicles with particle filters is irregular, however. Vehicles with the Euro 3 emission standard and filter are much more frequent in Berlin, whereas Euro 4 vehicles are less equipped with filters as shown in the evaluation of vehicle plates. However, since this evaluation is partially based on the incomplete data of the vehicle admission database, it can be assumed that the share of diesel particle filters is also higher in Berlin. The assumptions made are thus a conservative estimation.

On the basis of the forecasted motor vehicle traffic volumes and the updated composition of the vehicle fleet, emissions of the main road network and the network of secondary roads were calculated. The results are shown in table 7.3 along with further data on the sources of pollution in Berlin.

### 7.3 Emission trends of sources in Berlin

In modelling the air pollution within the urban background, assumptions were first made on emission trends from air pollutants in Berlin. The forecasted emissions are shown in table 7.3.

Due to existing legal regulations, no larger changes are expected for most inner city sources. In total, only slight decreases in emissions are expected until 2015.

The largest reductions are expected to occur in exhaust emissions from motor vehicle traffic, with 22 % less nitrogen dioxides and 45 % less particles (diesel soot). These reductions mainly result from level 2 of the LEZ, which stimulated modernization in 2010.

The tightening of emission limit values for residential combustion installations, which will be introduced by the upcoming amendment on these installations, will only affect emission trends after 2015. The replacement of old plants in the power range of 4 to 400 kW equally contributes to emission reductions, especially nitrogen oxide emissions from the domestic sector, as a result of the Energy Saving Regulation [Energieeinsparverordnung (EnEV)].

Due to the advanced technology of industrial plants achieved in Berlin, e.g. power plants and heating plants, and some large-scale facilities such as waste incinerators, coffee-roasting establishments or the asphalt and demolition construction waste recycling plants,

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Table 7.2: Share of vehicles with Euro VI emission standard in the individual type of vehicles
(passenger cars to coaches: values from the HBEFA 3.1; services buses: development in Berlin, HBEFA values in brackets)

<table>
<thead>
<tr>
<th>Year</th>
<th>Passenger cars with otto engine</th>
<th>Diesel passenger cars</th>
<th>Light-commercial vehicles</th>
<th>Heavy goods vehicles</th>
<th>Coaches</th>
<th>Service buses</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>4 %</td>
<td>8 %</td>
<td>2 %</td>
<td>28 %</td>
<td>14.5 %</td>
<td>27 % (18 %)</td>
</tr>
<tr>
<td>2020</td>
<td>21 %</td>
<td>32 %</td>
<td>47 %</td>
<td>75 %</td>
<td>50 %</td>
<td>65 % (57 %)</td>
</tr>
</tbody>
</table>
there are no reasonable and proportionate requirements for further reducing emissions. By installing cloth and fabric filters, for instance, the best available technology is already used. The requirements of the Ordinance on large combustion plants (13. BImSchV), adopted in 2007, were already fulfilled or fell below the requirements before 2007. Nevertheless, as in recent years limited emission reductions are expected because of the fuel switching and further optimisation of fuel technologies.

Table 7.3: Emission inventory for the forecast year 2015 and 2020 in comparison with the basis year 2009

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen oxide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installations requiring a permit</td>
<td>18,619</td>
<td>16,620</td>
<td>13,006</td>
<td>-11 %</td>
<td>-30 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic fuel</td>
<td>6,594</td>
<td>6,400</td>
<td>6,300</td>
<td>-3 %</td>
<td>-4 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small businesses</td>
<td>2,807</td>
<td>2,739</td>
<td>1,595</td>
<td>-2 %</td>
<td>-43 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport (only motor vehicles)</td>
<td>7,510</td>
<td>5,822</td>
<td>3,491</td>
<td>-22 %</td>
<td>-54 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport (other)</td>
<td>641</td>
<td>635</td>
<td>630</td>
<td>-1 %</td>
<td>-2 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other sources</td>
<td>940</td>
<td>900</td>
<td>870</td>
<td>-4 %</td>
<td>-7 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particulate matter (PM$_{10}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installations requiring a permit</td>
<td>3,125</td>
<td>2,993</td>
<td>2,778</td>
<td>-4 %</td>
<td>-11 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic fuel</td>
<td>153</td>
<td>150</td>
<td>145</td>
<td>-2 %</td>
<td>-5 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small businesses</td>
<td>95</td>
<td>90</td>
<td>84</td>
<td>-5 %</td>
<td>-12 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport (only motor vehicles, exhaust pipe)</td>
<td>258</td>
<td>250</td>
<td>240</td>
<td>-3 %</td>
<td>-7 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abrasion and resuspension from motor vehicle traffic</td>
<td>225</td>
<td>124</td>
<td>60</td>
<td>-45 %</td>
<td>-73 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport (other)</td>
<td>669</td>
<td>692</td>
<td>631</td>
<td>3 %</td>
<td>-6 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other sources</td>
<td>1,606</td>
<td>1,568</td>
<td>1,500</td>
<td>-2 %</td>
<td>-7 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particulate matter (PM$_{2.5}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installations requiring a permit</td>
<td>1,828</td>
<td>1,707</td>
<td>1,563</td>
<td>-7 %</td>
<td>-15 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic fuel</td>
<td>89</td>
<td>87</td>
<td>84</td>
<td>-2 %</td>
<td>-6 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small businesses</td>
<td>86</td>
<td>81</td>
<td>76</td>
<td>-5 %</td>
<td>-11 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport (only motor vehicles, exhaust pipe)</td>
<td>197</td>
<td>190</td>
<td>185</td>
<td>-4 %</td>
<td>-6 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abrasion and resuspension from motor vehicle traffic</td>
<td>225</td>
<td>124</td>
<td>60</td>
<td>-45 %</td>
<td>-73 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport (other)</td>
<td>360</td>
<td>374</td>
<td>341</td>
<td>4 %</td>
<td>-5 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other sources</td>
<td>57</td>
<td>68</td>
<td>67</td>
<td>-1 %</td>
<td>-3 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other sources</td>
<td>803</td>
<td>784</td>
<td>750</td>
<td>-2 %</td>
<td>-7 %</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7.4 Pollution forecast for the urban background and on roads

In the following two sections, the results of model calculations for air pollution in 2015 and 2020 will be presented. Meteorological data of 2005 and the emission trend presented above serve as input data.

7.4.1 NO$_2$ pollution trends for 2015 and 2020

The calculated distribution of NO$_2$ concentrations in the urban background is presented as grid maps in Figure 7.1 and 7.2.

Compared to the base year 2009, the NO$_2$ concentration within the entire urban area will strongly decrease. In 2015, no grid areas with values exceeding 25 µg/m$^3$ are expected anymore; values between 22 and 25 µg/m$^3$ will occur occasionally whereas in 2009 large parts of the inner city area were still affected. In 2020, pollution declines to a level reaching NO$_2$ concentrations below 18 µg/m$^3$ in all parts of the city separated from main roads, in many parts of the city even below 14 µg/m$^3$.

The pollution level in the network of main roads was modelled with IMMIS$^\text{surf}$. It is illustrated in Figure 7.3 and Figure 7.4.

The number of road sections with limit value exceedances will fall to 98 sections in 2015. This is a decrease of 77% compared to 2009. As to the length of road sections the decline accounts for 76% and in relation to the number of persons affected it accounts for 74%. It is forecasted that in 2015, exceedances of the NO$_2$ annual limit value will occur on 12.8 km of the network of main roads with around 11,400 residents affected. Concentration levels exceeding 60 µg/m$^3$ are not forecasted any longer. The sections with potential limit value exceedances are focused in the area within the light rail network (S-Bahn Ring), with additional hot spots at south radials and isolated problems in the west and in the southeast (see Figure Figure 7.3). Among the sections with NO$_2$ annual mean values exceeding 40 µg/m$^3$, two sections do not exceed the PM$_{10}$ annual mean limit value of 30 µg/m$^3$. These are two sections on the A100. In both cases, the modelled NO$_2$ annual mean value with 41.4 and 40.1 µg/m$^3$ slightly exceeds the limit value, while the PM$_{10}$ annual limit value reaches 28.1 µg/m$^3$.

In 2020, the NO$_2$ annual limit value of 40 µg/m$^3$ will be achieved at all main roads due to the number of vehicles with an emission exhaust standard of Euro VI achieved by that year (see Figure 7.4). Assuming a modelling error of 10% (36 µg/m$^3$), or of 20% (32 µg/m$^3$), six or 15 sections respectively, may exceed the limit value.

The share of the incremental pollution from individual motor vehicle types in the road space and the reduction gap for compliance with the limit value was determined for 21 selected sections with forecasted NO$_2$ limit value exceedances in 2015. These include seven sections with the highest and medium exceedances and exceedances with up to 3 µg/m$^3$, respectively. The selection of road sections is shown in Table 7.4 and is cartographically illustrated in Figure 7.5.

For the purpose of characterising the traffic load of the individual sections, the annual average number of vehicles travelling along the section, i.e. the average daily traffic volume, was indicated, including the traffic on weekends and on holidays. Furthermore, the Table contains the share of heavy utility vehicles for each section, i.e. trucks with a total permissible weight of more than 3.5 t and the share of buses, since these vehicles have a particularly high specific emissions level. The share of light utility vehicles, i.e. all utility vehicles with a total permissible weight below 3.5 t is between 6.9 and 8.4% at an average share of about 7.5%. At the same time, higher percentages of lighter utility vehicles are observed on sections, with higher shares of heavy utility vehicles.
Figure 7.1: Urban background concentration of NO₂ in 2015

Modelled annual mean concentration of urban background NO₂ in µg/m³
Trend scenario 2015

- 10 up to 14
- 14 up to 18
- 18 up to 22
- 22 up to 25
- above 25

Low emission zone

Figure 7.2: Urban background concentration of NO₂ in 2020

Modelled annual mean concentration of urban background NO₂ in µg/m³
Trend scenario 2020

- 10 up to 14
- 14 up to 18
- 18 up to 22
- 22 up to 25
- above 25

Low emission zone
Figure 7.3: NO₂ annual mean values in the main road network in 2015
Modelled annual mean concentration of NO₂ in µg/m³
Trend scenario 2015 plus action bundle 1, vehicle technology

- 10 up to 38
- 38 up to 40
- 40 up to 42
- 42 up to 44
- 44 up to 60
- above 60

Low emission zone
NO₂ limit value: 40 µg/m³

Figure 7.4: NO₂ annual mean values in main road network in 2020
Modelled annual mean concentration of NO₂ in µg/m³
Trend scenario 2020

- 10 up to 38
- 38 up to 40
- 40 up to 42
- 42 up to 44
- 44 up to 60
- above 60

Low emission zone
NO₂ limit value: 40 µg/m³
Table 7.4: Traffic data and NO₂ values for selected road sections for the year 2015

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Daily average traffic volume [Kfz/d]</th>
<th>Light commercial vehicles [%]</th>
<th>BUS [%]</th>
<th>Total NO₂ [µg/m³]</th>
<th>NO₂ contribution local traffic [µg/m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>7288</td>
<td>Potsdamer Straße</td>
<td>35,360</td>
<td>3.5</td>
<td>3.2</td>
<td>58</td>
<td>36</td>
</tr>
<tr>
<td>10909</td>
<td>A100 (nur Fahrrichtung Nord)</td>
<td>83,216</td>
<td>6.6</td>
<td>0.3</td>
<td>55</td>
<td>33</td>
</tr>
<tr>
<td>7809</td>
<td>Friedrichstraße</td>
<td>14,822</td>
<td>3.4</td>
<td>1.7</td>
<td>53</td>
<td>32</td>
</tr>
<tr>
<td>2046</td>
<td>Wilhelmstraße</td>
<td>19,211</td>
<td>2.3</td>
<td>4.7</td>
<td>52</td>
<td>30</td>
</tr>
<tr>
<td>1982</td>
<td>Dorotheenstraße</td>
<td>14,612</td>
<td>0.3</td>
<td>4.8</td>
<td>51</td>
<td>27</td>
</tr>
<tr>
<td>1617</td>
<td>Potsdamer Straße</td>
<td>35,030</td>
<td>2.3</td>
<td>2.4</td>
<td>51</td>
<td>29</td>
</tr>
<tr>
<td>7861</td>
<td>Leipziger Straße</td>
<td>36,691</td>
<td>2.6</td>
<td>1.7</td>
<td>49</td>
<td>29</td>
</tr>
<tr>
<td>7053</td>
<td>Mariendorfer Damm</td>
<td>42,155</td>
<td>3.4</td>
<td>0.5</td>
<td>47</td>
<td>29</td>
</tr>
<tr>
<td>8942</td>
<td>Elsenstraße</td>
<td>26,003</td>
<td>3.9</td>
<td>2.6</td>
<td>46</td>
<td>28</td>
</tr>
<tr>
<td>2037</td>
<td>Leipziger Straße</td>
<td>34,058</td>
<td>2.5</td>
<td>1.9</td>
<td>45</td>
<td>25</td>
</tr>
<tr>
<td>974</td>
<td>Alt-Moabit</td>
<td>29,102</td>
<td>3.4</td>
<td>0.6</td>
<td>45</td>
<td>25</td>
</tr>
<tr>
<td>7283</td>
<td>Kolonnenstraße</td>
<td>18,527</td>
<td>1.9</td>
<td>3.0</td>
<td>45</td>
<td>23</td>
</tr>
<tr>
<td>8889</td>
<td>Karl-Marx-Straße</td>
<td>24,659</td>
<td>2.5</td>
<td>0.7</td>
<td>45</td>
<td>25</td>
</tr>
<tr>
<td>1606</td>
<td>Hauptstraße</td>
<td>30,379</td>
<td>2.9</td>
<td>3.7</td>
<td>44</td>
<td>22</td>
</tr>
<tr>
<td>9208</td>
<td>Frankfurter Allee</td>
<td>53,026</td>
<td>2.4</td>
<td>0.7</td>
<td>43</td>
<td>24</td>
</tr>
<tr>
<td>7806</td>
<td>Französische Straße</td>
<td>17,227</td>
<td>3.8</td>
<td>1.3</td>
<td>42</td>
<td>22</td>
</tr>
<tr>
<td>2040</td>
<td>Glinkastraße</td>
<td>17,343</td>
<td>4.6</td>
<td>0.5</td>
<td>42</td>
<td>21</td>
</tr>
<tr>
<td>7605</td>
<td>Karl-Marx-Straße</td>
<td>27,662</td>
<td>2.5</td>
<td>1.9</td>
<td>42</td>
<td>22</td>
</tr>
<tr>
<td>8902</td>
<td>Schlesische Straße</td>
<td>20,867</td>
<td>3.3</td>
<td>1.9</td>
<td>42</td>
<td>22</td>
</tr>
<tr>
<td>6318</td>
<td>Budapester Straße</td>
<td>45,841</td>
<td>1.8</td>
<td>1.4</td>
<td>42</td>
<td>20</td>
</tr>
<tr>
<td>7061</td>
<td>Tempelhofer Damm</td>
<td>37,129</td>
<td>3.5</td>
<td>0.1</td>
<td>42</td>
<td>23</td>
</tr>
</tbody>
</table>
At the selected road sections, the additional contribution from local traffic causes between 48 and 62 % of the total NO₂ concentration on these roads, with a mean value of 56 %. Higher traffic contributions generally occur in sections with higher pollution levels.

The mean shares of the incremental pollution from the individual vehicle types are summarized in Table 7.5. Just over half of the incremental pollution is caused by the use of passenger cars. This is induced by the numerical dominance of passenger cars, which account for 85 % of the cars driving on these roads. The second most significant contribution is from trucks with over 3.5 t of total weight (heavy goods vehicles/trucks) with 17 %. With just under 7 %, coaches have the lowest contributions, if the share from motorbikes of 0.1 to 0.2 % is disregarded. The share of individual vehicle types may fluctuate strongly because of the large differences in the traffic volume at local level (see Table 7.4). For this reason, the minimum and maximum share as well as the roads concerned are listed in Table 7.5 (all individual results can be found in Annex Tab. A-1). It can be seen that the contributions are shaped considerably by the position and the functioning of the road. The A100 for instance has the highest share of heavy goods vehicles and light commercial vehicles. This contrasts sharply with the situation in the touristic centre of Berlin, on streets with high traffic volumes of service buses and coaches. In total, buses are responsible for 42.5 % of the NO₂ incremental pollution on Dorotheenstraße (passenger cars 46.7 %). On Wilhelmstraße, the share of buses accounts for 41 % and the share of passenger cars for around 40 %. Buses are thus the most significant source of NO₂ in these road sections. Such differences provide crucial indicators for the planning of measures.
Table 7.5: Mean share of vehicle categories in the traffic induced incremental NO\textsubscript{2} pollution in % of all hot spots and the minimum and maximum shares of each vehicle type for 2015

<table>
<thead>
<tr>
<th></th>
<th>Passenger cars</th>
<th>Light commercial vehicles</th>
<th>trucks</th>
<th>Service buses</th>
<th>Coaches</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean value</strong></td>
<td>52.5 %</td>
<td>11.8 %</td>
<td>16.7 %</td>
<td>12.4 %</td>
<td>6.6 %</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>39.8 %</td>
<td>9.2 %</td>
<td>1.4 %</td>
<td>&lt; 1 %</td>
<td>&lt; 1 %</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Wilhelmstraße</td>
<td>Wilhelmstraße</td>
<td>Dorotheenstraße</td>
<td>Tempelhofer Damm</td>
<td>Tempelhofer Damm und A100</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>61.9 %</td>
<td>16.7 %</td>
<td>30.8 %</td>
<td>27.9 %</td>
<td>14.6 %</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Tempelhofer Damm</td>
<td>A100 (in northern direction)</td>
<td>A100 (in northern direction)</td>
<td>Dorotheenstraße</td>
<td>Dorotheenstraße</td>
</tr>
</tbody>
</table>

For the selected hot spots, the scale of emissions reductions needed to meet the limit values of nitrogen oxides in 2015 was examined in a model calculation. The emission reductions were simulated by decreasing the daily average volume of traffic. Depending on the level of the exceedance, emission reductions in the range of 9 % to 54 % on the road section with the highest NO\textsubscript{2} pollution on Potsdamer Straße (ID 7288) are necessary. For road sections with exceedances of up to 3 µg/m\textsuperscript{3}, emission reduction of 11 %, on average, is sufficient. This can generally be achieved by traffic management measures or moderate technical improvements of the fleet. For road sections with annual limit value exceedances by 4 to 7 µg/m\textsuperscript{3}, emissions reductions of 21 %, almost twice as high, are required. In practice, these can only be achieved to a limited degree. For the sections with the highest pollution levels, 36 to 54 % of the NO\textsubscript{x} emissions would need to be avoided. This cannot be addressed by traffic management measures, but requires technical improvements in the vehicle fleet, e.g. by a high quota of vehicles with Euro 6 emission standard. An adequate proportion will only be forecasted for 2020, because a sufficient penetration of the fleet will only be achieved several years after introducing the exhaust emission standards for motor vehicles.
7.4.2 Pollution forecast for PM$_{10}$ for 2015 and 2020
The spatial distribution of the PM$_{10}$ concentration in the urban background is illustrated in Figure 7.6 and Figure 7.7. Similar to NO$_2$, lower PM$_{10}$ concentrations are forecasted for the years 2015 and 2020. The share of areas with PM$_{10}$ concentrations below 22 µg/m$^3$ will increase, whereas areas with concentrations above 26 µg/m$^3$ will decrease considerably and only occur occasionally. The PM$_{10}$ concentrations in the inner city will remain on a high level, with concentrations of 24 to 26 µg/m$^3$ by 2015.

In 2020, the pollution from particulate matter will decrease to a level assuming that concentrations above 26 µg/m$^3$ on average do not occur in the urban background and that concentrations between 25 and 26 µg/m$^3$ only occur rarely. In most areas of the urban background, concentrations of 24 µg/m$^3$ are forecasted.

The pollution concentrations in the network of main roads are illustrated in Figure 7.8 and 7.9. It is shown that the decrease in the pollution from PM$_{10}$ is not as strong as for NO$_2$. Among the reasons for this are high dependence on regional pre-existing pollution, for which a reduction of less than 1 µg/m$^3$ is forecasted and a high share of particles deriving from abrasion and re-suspension in the traffic-induced incremental pollution, which cannot be reduced by a renewal of the fleet.

In 2015, the number of sections with values above the annual mean value of 30 µg/m$^3$, which corresponds to the daily limit value, only decreases by 30 % from 563 to 373 sections. These sections are mainly located within the light rail network (see Figure 7.8). This means that in 2015, exceedances of the PM$_{10}$ limit value are still likely to occur at 52.1 km of the network of main roads with approximately 43,600 residents. Annual mean values exceeding 32 µg/m$^3$ are forecasted for 15.9 km roads with around 14,000 persons affected. Concentrations of more than 40 µg/m$^3$ in the annual mean are not predicted.

According to the forecast for the year 2020, exceedances of PM$_{10}$ will still occur. The beneficial effect of reductions of the urban pollution shares alone is not sufficient given the low reduction levels of the urban background. 111 sections with a length of 15.3 km and approximately 13,300 persons may be exposed to limit value exceedances.

The share of the traffic-induced incremental pollution from the individual vehicle types was also calculated for particulate matter pollution on main roads, i.e. the 21 road sections outlined in Chapter 7.4.1. The calculated PM$_{10}$ concentrations and the share of diesel soot are summarized in Table 7.6. The PM$_{10}$ share of traffic encompasses soot particles as well as particles from abrasion and re-suspension.
Figure 7.6: Urban background concentration of PM$_{10}$ in 2015

Modelled annual mean concentration of urban background PM$_{10}$ in µg/m$^3$

Trend scenario 2015

- 20 up to 22
- 22 up to 24
- 24 up to 25
- 25 up to 26
- above 26

Low emission zone

Figure 7.7: Urban background concentration of PM$_{10}$ in 2020

Modelled annual mean concentration of urban background PM$_{10}$ in µg/m$^3$

Trend scenario 2020

- 20 up to 22
- 22 up to 24
- 24 up to 25
- 25 up to 26
- above 26

Low emission zone
Figure 7.8: PM$_{10}$ annual mean values in the main road network in 2015

Modelled annual mean concentration of PM$_{10}$ in µg/m$^3$

Trend scenario 2015
- below 28
- 28 up to 30
- 30 up to 32
- 32 up to 34
- 34 up to 40
- above 40

Low emission zone

PM$_{10}$ limit value: 40 µg/m$^3$ annual mean (excess of 24h-limit value to be expected at about 30 µg/m$^3$ and higher)

Figure 7.9: PM$_{10}$ annual mean values in the network of main roads in 2020

Modelled annual mean concentration of PM$_{10}$ in µg/m$^3$

Trend scenario 2020
- below 28
- 28 up to 30
- 30 up to 32
- 32 up to 34
- 34 up to 40
- above 40

Low emission zone

PM$_{10}$ limit value: 40 µg/m$^3$ annual mean (excess of 24h-limit value to be expected at about 30 µg/m$^3$ and higher)
Table 7.6: PM$_{10}$- and diesel soot concentrations at selected road sections for 2015

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Daily average traffic volume</th>
<th>Total PM$_{10}$ [µg/m$^3$]</th>
<th>PM$_{10}$-share traffic [µg/m$^3$]</th>
<th>Diesel soot [µg/m$^3$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>7288</td>
<td>Potsdamer Straße</td>
<td>35,360</td>
<td>40</td>
<td>14</td>
<td>1.6</td>
</tr>
<tr>
<td>10909</td>
<td>A100 (Fahrtrichtung Nord)</td>
<td>83,216</td>
<td>31</td>
<td>6</td>
<td>1.4</td>
</tr>
<tr>
<td>7809</td>
<td>Friedrichstraße</td>
<td>14,822</td>
<td>38</td>
<td>13</td>
<td>1.7</td>
</tr>
<tr>
<td>2046</td>
<td>Wilhelmstraße</td>
<td>19,211</td>
<td>36</td>
<td>11</td>
<td>1.3</td>
</tr>
<tr>
<td>1983</td>
<td>Dorotheenstraße</td>
<td>14,612</td>
<td>34</td>
<td>9</td>
<td>1.2</td>
</tr>
<tr>
<td>1617</td>
<td>Potsdamer Straße</td>
<td>35,030</td>
<td>37</td>
<td>11</td>
<td>1.4</td>
</tr>
<tr>
<td>7861</td>
<td>Leipziger Straße</td>
<td>36,691</td>
<td>37</td>
<td>12</td>
<td>1.4</td>
</tr>
<tr>
<td>7053</td>
<td>Mariendorfer Damm</td>
<td>42,155</td>
<td>35</td>
<td>10</td>
<td>1.6</td>
</tr>
<tr>
<td>8942</td>
<td>Elisenstraße</td>
<td>26,003</td>
<td>36</td>
<td>11</td>
<td>1.2</td>
</tr>
<tr>
<td>2037</td>
<td>Leipziger Straße</td>
<td>34,058</td>
<td>35</td>
<td>10</td>
<td>1.2</td>
</tr>
<tr>
<td>974</td>
<td>Alt-Moabit</td>
<td>29,102</td>
<td>35</td>
<td>10</td>
<td>1.4</td>
</tr>
<tr>
<td>7283</td>
<td>Kolonnenstraße</td>
<td>18,527</td>
<td>34</td>
<td>8</td>
<td>1.1</td>
</tr>
<tr>
<td>8887</td>
<td>Karl-Marx-Straße</td>
<td>24,659</td>
<td>35</td>
<td>10</td>
<td>1.3</td>
</tr>
<tr>
<td>7275</td>
<td>Hauptstraße</td>
<td>30,379</td>
<td>34</td>
<td>8</td>
<td>1.0</td>
</tr>
<tr>
<td>9208</td>
<td>Frankfurter Allee</td>
<td>53,026</td>
<td>33</td>
<td>8</td>
<td>1.4</td>
</tr>
<tr>
<td>7806</td>
<td>Französische Straße</td>
<td>17,227</td>
<td>34</td>
<td>9</td>
<td>1.0</td>
</tr>
<tr>
<td>2040</td>
<td>Glinkastrasse</td>
<td>17,343</td>
<td>34</td>
<td>9</td>
<td>1.1</td>
</tr>
<tr>
<td>7605</td>
<td>Karl-Marx-Straße</td>
<td>27,662</td>
<td>34</td>
<td>8</td>
<td>1.1</td>
</tr>
<tr>
<td>8902</td>
<td>Schlesische Straße</td>
<td>20,867</td>
<td>34</td>
<td>9</td>
<td>1.0</td>
</tr>
<tr>
<td>6318</td>
<td>Budapester Straße</td>
<td>45,841</td>
<td>33</td>
<td>8</td>
<td>0.9</td>
</tr>
<tr>
<td>7066</td>
<td>Tempelhofer Damm</td>
<td>37,129</td>
<td>33</td>
<td>8</td>
<td>1.3</td>
</tr>
</tbody>
</table>

On average and throughout all road sections the local traffic causes 27 % of the total particulate matter pollution. The highest additional contribution from local traffic was seen on Potsdamer Straße with a share of 35 %, the lowest share with 20 % at the considered section of the A100.

Table 7.7 shows the mean contributions of the PM$_{10}$ incremental pollution from the individual vehicle types. These are comparable to the local NO$_2$ contributions. On average, 60 % are caused by passenger car traffic, followed by the contribution of heavy goods vehicles above 3.5 t total weight at 19 %. With an average of around 4 %, coaches have the smallest contribution. The share of individual vehicle types can fluctuate considerably due to local differences in the traffic volume (see Table 7.4). Table 7.7 thus includes the minimum and maximum contributions and the affected roads (for all results see Annex Tab. A-3). It can be seen that the contributions are shaped considerably by the position and functioning of the road. The A100 for instance has the highest share of heavy goods vehicles and light commercial vehicles. This contrasts sharply with the situation in the touristic centre of Berlin, on streets with high traffic volumes of service buses and coaches. In total, buses are responsible for 31.3 % of the PM$_{10}$ incremental pollution on Dorotheenstraße (passenger cars 46.7 %). On Wilhelmstraße, the share of buses accounts for 41 % and the share of passenger cars accounts for around 40 %. Motorbikes have a share of less than 0.1 %.
Table 7.7: Mean share of vehicle types in the traffic-induced incremental PM\textsubscript{10} pollution in % of all hot spots and the minimum and maximum share of each vehicle type in 2015

<table>
<thead>
<tr>
<th></th>
<th>Passenger cars</th>
<th>Light commercial vehicles</th>
<th>trucks</th>
<th>Service buses</th>
<th>coaches</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean value</strong></td>
<td>59.4 %</td>
<td>9.6 %</td>
<td>19.0 %</td>
<td>7.9 %</td>
<td>4.1 %</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>51.5 %</td>
<td>8.1 %</td>
<td>1.9 %</td>
<td>&lt; 1 %</td>
<td>&lt; 1 %</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>A100</td>
<td>Wilhelmstraße/Dorotheenstraße</td>
<td>Tempelhofer Damm</td>
<td>Tempelhofer Damm und A100</td>
<td></td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>68.2 %</td>
<td>11.3 %</td>
<td>35.6 %</td>
<td>20.6 %</td>
<td>10.7 %</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Budapester Straße</td>
<td>A100 (in northern direction)</td>
<td>A100 (in northern direction)</td>
<td>Dorotheenstraße</td>
<td>Dorotheenstraße</td>
</tr>
</tbody>
</table>

The contribution of vehicle types to the pollution from soot on roads differs from the PM\textsubscript{10} contributions, as shown in Table 7.8. This is due to the varying diesel shares of the vehicle types and the varying levels of filter installations. The share of passenger cars thus falls to 46 %, while light commercial vehicles are now the second most important source with a share of 35 %. Service buses account for only 2 %, which can be attributed to filter equipment. In coaches, on the other hand, particle filters have hardly been installed. The soot emissions are thus quite high and account for 7 % of the total local diesel soot contribution, although the number of coaches is around 60 % lower than the number of service buses.

Table 7.8: Mean share of vehicle types in the traffic-induced incremental soot pollution in % of all hot spots and the minimum and maximum share for each vehicle type in 2015

<table>
<thead>
<tr>
<th></th>
<th>Passenger cars</th>
<th>Light commercial vehicles</th>
<th>trucks</th>
<th>Service buses</th>
<th>coaches</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean value</strong></td>
<td>46 %</td>
<td>35 %</td>
<td>10 %</td>
<td>2 %</td>
<td>7 %</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>40.6 %</td>
<td>31.7 %</td>
<td>1.0 %</td>
<td>0.1 %</td>
<td>0.4 %</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Wilhelmstraße</td>
<td>A100</td>
<td>Dorotheenstraße</td>
<td>Tempelhofer Damm</td>
<td>Tempelhofer Damm</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>50.3 %</td>
<td>38.4 %</td>
<td>24.7 %</td>
<td>4.4 %</td>
<td>16.9 %</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Budapester Straße</td>
<td>Glinkastraße</td>
<td>A100</td>
<td>Dorotheenstraße</td>
<td>Dorotheenstraße</td>
</tr>
</tbody>
</table>

The analysis of the emission reductions necessary for complying with the PM\textsubscript{10} limit value by traffic-related measures alone reveals that emissions need to be reduced by 38 % (Tempelhofer Damm) to 70 % (Potsdamer Straße). Since most of the traffic-induced particles derive from abrasion and re-suspension, reductions could be better achieved by lower speeds and a reduction in the traffic volume rather than through technical measures in the vehicles. On the other hand, around half of the particulate matter pollution is already caused by sources outside Berlin. It would thus not reflect the share of pollutants to envisage compliance with limit values solely by making disproportionate emission reductions in Berlin’s road traffic. The PM\textsubscript{10} background pollution will likely remain high in 2015 and 2020, and require effective reduction actions.
8 Scenario calculations for assessing the effectiveness of selected measures

For the modelling of the emission and pollution side effect of measures for 2015, five packages of measures were created. Generally, those measures that are likely to have an emissions reducing effect citywide or at least for a major share of road sections where pollution limits are exceeded were selected as a priority. Moreover, suitable models for the calculation of the effect need to be available.

Some of the measures have been formulated very comprehensively, independent of the concrete implementation ability of the model, e.g. in the demand for a complete ban on the combustion of solid fuels in small firing plants, or the equipment of all construction machines with particulate filters. The reason for this was to start by scoping out the maximum possible reduction potential.

8.1 Definition of measures

The following Table 8.1 offers an overview on the considered packages of measures and their contained individual measures.

Table 8.1: Scope of the five-measure package of measures for scenario calculations in the motor vehicle traffic area

<table>
<thead>
<tr>
<th>Package of measures</th>
<th>Measures included</th>
</tr>
</thead>
<tbody>
<tr>
<td>MB 1</td>
<td>Improved vehicle technology</td>
</tr>
<tr>
<td></td>
<td>• low emission zone without individual exceptions</td>
</tr>
<tr>
<td></td>
<td>• higher share of EURO6-vehicles</td>
</tr>
<tr>
<td></td>
<td>• support for electric vehicles</td>
</tr>
<tr>
<td></td>
<td>• retrofitting with particulate filters (EURO4-cars and trucks) and NO_x scrubbers (EURO4-trucks)</td>
</tr>
<tr>
<td></td>
<td>• retrofitting with particulate filters in passenger ships</td>
</tr>
<tr>
<td>MB 2</td>
<td>Traffic flow optimisation</td>
</tr>
<tr>
<td></td>
<td>Reduction of congestions/traffic backups by:</td>
</tr>
<tr>
<td></td>
<td>• traffic light coordination</td>
</tr>
<tr>
<td></td>
<td>• inflow dosage</td>
</tr>
<tr>
<td></td>
<td>• 30 km/h speed limit</td>
</tr>
<tr>
<td>MB 3</td>
<td>30 km/h speed limit at hotspots</td>
</tr>
<tr>
<td>MB 4</td>
<td>Emissions reduction in the urban background</td>
</tr>
<tr>
<td></td>
<td>• Ban on solid fuel heating for housing</td>
</tr>
<tr>
<td></td>
<td>• Particulate filters for construction machines</td>
</tr>
<tr>
<td>MB 5</td>
<td>Achieving the 2020 fleet early</td>
</tr>
</tbody>
</table>

For the modelling were made the following assumptions.

8.1.1 Assumptions for the package of measures 1: Improvement of vehicle technology

In order to attain a higher share of EURO 6 vehicles in the vehicle fleet, it was assumed that vehicles running in the low emission zone with an exemption would be replaced by EURO 6 vehicles. In addition, 20% of the diesel engine vehicles with emission standard EURO 3 with particulate filters and 20% of the petrol engine vehicles with EURO 1 and less would...
be replaced by EURO 6 vehicles. The resulting mileage performance shares of EURO 6 vehicles are shown by separate vehicle categories in Table 8.2. The shares of EURO 6 vehicles presented by way of comparison for the trend development in 2015 were taken from the HBEFA 3.1.

Table 8.2: Share in mileage of EURO 6 vehicles

<table>
<thead>
<tr>
<th>Motor vehicle type</th>
<th>Share of Euro 6 trend 2015</th>
<th>Share of Euro 6 MB 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel engine motor vehicle</td>
<td>7.6 %</td>
<td>13.8 %</td>
</tr>
<tr>
<td>Light commercial vehicles</td>
<td>2.1 %</td>
<td>12.3 %</td>
</tr>
<tr>
<td>Heavy commercial vehicles</td>
<td>28.2 %</td>
<td>37.7 %</td>
</tr>
<tr>
<td>Coaches</td>
<td>14.5 %</td>
<td>47.8 %</td>
</tr>
</tbody>
</table>

In the trend scenario, there are only little changes regarding the share of EURO-6-vehicles, as already in the trend development the share of older vehicles that could be replaced by EURO-6-vehicles is relatively small. The case is different for commercial vehicles and busses. For this vehicle category, considerable shares of older vehicles are expected in 2015, a significant modernisation of the fleet could accordingly be achieved by means of incentive measures.

As for electric vehicles, a share of 1.2 % of the total mileage is expected for 2015. Within the modelling, in each case 2.5 % of the mileage of diesel engine cars and commercial cars with the emission standards EURO 4 and 5 were replaced by electric vehicles. This represents a relatively optimistic scenario, which is only attainable, if electric vehicles show a dynamic development and competitive vehicles are launched quickly.

For the low emission zone, only diesel engine vehicles had to be retrofitted with particulate filters up to the emission standard EURO 3 so far. In 2015, however, significant shares of the polluting emissions will originate from EURO 4 vehicles without particulate filter. Besides retrofitting systems intended for particle reduction, at least for heavy trucks, systems for the reduction of nitrogen dioxide emissions are increasingly developed and installed. For light commercial vehicles and motor vehicles, however, systems for retrofitting aiming at the reduction of nitrogen dioxide have not yet been developed. This is also not to be expected due to the high technical efforts and related costs. For the scenario, the following assumptions regarding the retrofitting of EURO 4 vehicles that have not yet been equipped with exhaust-side reduction systems were made:

- Retrofitting rates: within the low emission zone 80 %, outside the low emission zone 50 %
- Reduction of emissions:
  - for heavy commercial vehicles: 50 % less diesel soot particles and nitrogen oxides,
  - for motor vehicles and light commercial vehicles: 50 % less diesel soot particles

Additionally, the retrofitting with particulate filters of passenger ships was integrated into the package of measures. A 20 % reduction of diesel soot emissions by passenger ships within the low emission zone and a 10 % share outside the low emission zone were assumed.

8.1.2 Assumptions for the package of measures 2: traffic flow optimisation

The objective of the package of measures is to attain a reduction in emissions from traffic on road segments with NO\textsubscript{2} limit value exceedances by preventing traffic congestion. According to the HBEFA, in the case of stop-and-go traffic, vehicles emit up to twice the amount of nitrogen oxides and diesel soot particles than under normal traffic conditions. The emission reduction can be calculated for an initial assessment by means of the HBEFA by setting the share of the level of service (LOS) 4 (stop-and-go) to zero. The traffic volume did not decrease, except on a section of Frankfurter Allee.
In actual traffic, this ideal situation can only be attained under optimal conditions. Suitable distances between the intersections, optimum traffic light coordination, an adjusted speed and a regulation of the traffic volume on the road section are required. The latter is possible by means of inflow dosage (ramp meter), but causes higher emissions in the areas in which the ensuing back flow is shifted. For the acceleration of bus and urban railway traffic, measures of giving priority to public transport were implemented on numerous roads in Berlin. This disrupts optimum traffic light coordination in cases where a bus requires green light. 65 out of 123 examined sections with transgressions of NO\textsubscript{2} limit values are already subject to the regulation of giving priority to public transport, and it is planned for 21 more sections where it will soon be implemented. Thus only 31 sections can be freely coordinated regardless of public transport. Measures regarding traffic flow optimisation are to be planned and implemented primarily for these sections until 2015. For sections giving priority to local transport, suitable solution strategies must be developed first, and longer implementation periods (until 2020) will be required.

8.1.3 Assumptions for the package of measures 3: 30 km/h speed limit at hot spots
Provided that generally smooth traffic and speed limit monitoring is ensured, the emissions of air pollutants can be reduced, as shown in Chapter 6.8., by reducing the speed limit to 30 km/h. In a model calculation, Tempo 30 was assumed and the share of congestion was set to zero regarding all road sections on which occur limit value exceedances for PM\textsubscript{10} and/or NO\textsubscript{2}. These are 375 sections with a total length of 52.3 km. From the modelling, it was determined that the percentage reductions for the local traffic-related additional contribution amounted to 30 % for particulate matter and 15 % for NO\textsubscript{2}, as was found during the measurements on Schildhornstraße.

Before implementing the measure, it must be examined within a case-by-case review if appropriate conditions are given.

8.1.4 Assumptions for the package of measures 4: emissions reduction in the urban background
In order to reduce the emission of pollutants in the urban background, the ban on the use of solid fuels (coal and wood) in all combustion plants not requiring a permit in Berlin was assumed in the model calculation. This would apply to heating systems, furnaces and chimneys, but also to small combustion plants in factories. As a further measure, the compulsory retrofitting of construction machines with particulate filters was assumed.

8.1.5 Assumptions for the package of measures 5: Achieving the 2020 fleet early
As a further measure, it was evaluated what reduction potential would exist if the traffic performance forecasted for 2015 was accomplished already within the composition of the motor vehicle fleet of 2020. For this purpose, the motor vehicle emissions are calculated on the basis of the traffic forecast for 2015 with the fleet composition of 2020, as contained in the HBEFA. This is intended to show what could have been attained by an ambitious European exhaust emission legislation, if the emission limit values would already have been introduced for the emission standard EURO 5 as was demanded within the consultations by the Federal State Berlin, amongst others. These limit values will become compulsory with EURO 6 only from 2013 to 2016 instead of from 2009.

8.2 Results of the emission calculation
The relative reductions in emissions in relation to the reference case 2015, which can additionally be reached by means of the described traffic-related measures in the whole main road network, are displayed for motor vehicle emissions in Figure 8.1. Regarding the measures in the vehicle technology field, the effect is shown both as a sum of all sub-measures in the package of measures (MB 1) on vehicle technology and the effect of the individual measures.
The largest effect on the emissions of major road traffic is seen in the fictional introduction of the 2020 fleet already in 2015, showing reductions of almost 50% in exhaust particles and 36% in nitrogen oxides. A considerable contribution to the reduction of exhaust particles, at 12%, would constitute retrofitting a major part of the EURO-4-diesel vehicles projected to still run without filters with particulate filters. All the other measures reduce the total emissions on the major road network by less than 5%. The additional retrofitting of EURO 4 trucks with sweepers would reduce the NOx emissions by only 0.7%. That is less than would for instance be attainable by the abolition of exemptions for the low emission zone.

As regards the evaluation of the measures that do not affect the vehicle fleet, but pointedly lead to emissions reductions in individual road sections by traffic management measures, the effect is sorely small. Tempo 30 reduces the emissions by 0.5% for NOx and by 1.1% for PM10. Even by preventing all congestion on highly polluted sections, the emissions for the whole urban area are reduced by only 0.2%. For these measures, however, the local effect is considerably higher. The reduction in emissions for Tempo 30 comes locally in the affected road section to around 30% for PM10, 15% for diesel soot particles and 15% for NOx given fluent to dense traffic. Regarding the measure “traffic flow optimisation”, and given the assumption that no congestion occurs, the nitrogen oxide and particulate matter emissions decreased by about 10% on average, the diesel soot emissions by approximately 7%. With 0% to around 35%, the range is rather high. However, in the case of this emission modelling, it must be taken into consideration that the ideal case of total congestion avoidance is assumed without a decline in the traffic volume. This assumption is de facto hardly achievable, as a large part of the congestion emerges due to the fact that the current traffic volume simply exceeds the capacity of the road section. Then, congestions can only be avoided by traffic reduction. Such a scenario was investigated for Frankfurter Allee. Congestion avoidance and the reduction of the daily traffic volume by 10%, through such means as ramp lights, revealed the highest emissions reductions of up to 43% of NOx and PM10 and 34% of diesel soot particles.

Another significant cause of congestion or traffic flow disruptions are construction sites, big events and unforeseeable behaviour by road users such as double-parking. There is a measure foreseen for the reduction of this kind of disruptions (see Chapter 9 measure M2.14), whose effect, however, cannot be modelled in a general way.

According to this analysis, about 230 t/a nitrogen oxides can be avoided in road traffic, 19 t/a of exhaust particles and 27 t/a of PM10 (exhaust + abrasion + re-suspension) in total, through improved vehicle technology and traffic management measures. By means of the early 2020 fleet mix antedated to 2015, however, 1,687 t/a nitrogen oxides and 48 t/a exhaust particles could be avoided (scenario MB 5). For comparison: With the 2nd stage of the low emission zone, 1,517 tons of nitrogen oxides and 173 tons of exhaust particles were able to be avoided in 2010 compared with the trend development without low emission zone.
For the measures not referring to motor vehicle traffic, only reductions in particulate emissions were assumed. The revealed emissions reductions are displayed in Table 8.3.

Table 8.3: Particulate matter reduction through measures not related to road traffic for the year 2015

<table>
<thead>
<tr>
<th>Measure</th>
<th>Particle reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ban of solid fuels for small combustion plants and additional heating</td>
<td>407 t/a</td>
</tr>
<tr>
<td>Particulate filters for construction machines</td>
<td>105 t/a</td>
</tr>
<tr>
<td>Retrofitting with particulate filters for passenger ships</td>
<td>0.5 t/a</td>
</tr>
</tbody>
</table>

The measure “particulate filters for ships” [Partikelfilter für Schiffe] just slightly contributes to reductions in total emissions with a particulate reduction of 0.5 t/a. The reductions referring to the source group “Shipping” amount to 15 %. The largest contribution, with a reduction in emissions of 407 t/a particulate matter, would be a ban of all solid fuels in small combustion plants and in backup heating systems in private households.

The introduction of particulate filters for construction machines would reduce the particle emission by around 105 t/a, if a mean reduction rate of 75 % is assumed. As outlined in Chapter 4.1.6, there exists a considerable uncertainty with regard to the emissions in the construction equipment sector, and thus also regarding the reduction potential. Even if only taken at the lower limit of 90 t/a, which was indicated by this sector with regard to the level of emission, the reduction potential due to retrofitting with particulate filters would after all come to almost 70 t/a and thus more than double the amount of emitted soot particles avoided from heavy trucks due to the low emission zone. Insofar, following soot filter retrofitting for construction machines, an appreciable reduction of pollution, especially by harmful soot particles, would be expected, which would also contribute to a reduction, albeit a small one, in particulate matter concentration.

8.3 Results of the air quality modelling

Analogous to the total pollution calculations of the status quo 2009 and the forecast 2015/2020, the air pollution in the major road network was calculated. For the packages of measures 1, 4 and 5 the effects in the urban background were first determined, and thus redefined the pre-pollution per road section. For the packages of measures 2 and 3, which...
each solely contain local measures on selected hotspots, the effect on the local additional pollution was just calculated and the urban background was transferred unchanged from the forecast 2015.

The effect of the measures is evaluated by the respective forecasted number and length of the road sections showing limit values exceedances and the number of the affected residents. The results for \( \text{NO}_2 \) are displayed in Figure 8.2, and those for particulate matter (\( \text{PM}_{10} \)) in Figure 8.3, both for the base year 2009, the trend development 2015 and 2020 and for the different scenarios.

The effect on the individual road sections is shown in the Environmental Atlas [Umweltatlas] under the topic Air [Luft]:
http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/dinh_03.htm, diagram 03.11.

**Effect on \( \text{NO}_2 \) pollution**

While there were still exceedances of the annual \( \text{NO}_2 \) limit value on 58 km of the main road network with 47,700 persons affected in the base year 2009, the number of persons affected will decrease independently due to the trend development until 2015 by around 77 % to approximately 13 km with 11,400 persons affected. A considerable share of this decrease is attributed to the emission reductions of the second stage of the low emission zone, which was introduced in 2010. Beyond this, by means of the packages of measures 1 to 3, the polluted road sections can be reduced by more than 40 % to 6.7 to 7.7 km with 6,100 to 7,100 affected persons.

However, virtually complete compliance with the \( \text{NO}_2 \) limit value can only be attained by a considerably higher emissions reduction, achieved by an extensive modernisation of the vehicle fleet with a share of EURO 6 diesel engine vehicles from 32 % (motor vehicles) to 75 % (heavy trucks). For this case, only one single 140 m road section along Potsdamer Straße is forecasted to have an exceedance.

**Effect on \( \text{PM}_{10} \) pollution**

In order to evaluate the limit value exceedance was used an annual mean value of 32 \( \mu \text{g/m}^3 \) in this case, for which a daily limit value exceedance is given with a 90 % certainty. As Figure 8.3 shows, the forecasted decline of \( \text{PM}_{10} \) limit value exceedances, which is forecasted for 2015, is much smaller than the exceedances of the \( \text{NO}_2 \) annual mean limit value. Causal to this is the high share of the supra-regional pre-pollution of \( \text{PM}_{10} \), on which the city of Berlin does not have any influence. Due to the trend development including stage 2 of the low emission zone, the length of the polluted road sections and the
number of persons affected will decrease by about 46% until 2015. Different from NO₂, the PM₁₀ limit value cannot be complied with on each road.

Of all traffic-related measures, the reduction of the speed limit to 30 km/h causes the largest effect, with the number of persons affected by limit value exceedances declining by more than 60% compared with the trend development. This is due to the fact that not just particles from engines have to be reduced, but above all the particulate emission due to abrasion and re-suspension as well. The package of measures for the modernisation of vehicle technology and the measures for optimising the traffic flow lead to a decrease in the persons affected of about 25% each. As for the traffic-related measures, the measures in the vehicle technology field were able to be combined with the measures in traffic management and were thus able to attain a higher relief effect in total.

Also, the reduction of particulate matter pollution in the urban background by the retrofitting of construction machines with particle filters and the renouncement of burning wood and coal in small combustion plants and other small firing systems such as chimneys turn out to be quite effective measures. Due to the low pre-pollution in the urban background, the air pollution on main roads also declines, by which the number of affected persons would decrease by about 40%. In combination with traffic-related measures, an even higher decrease in the number of affected persons would be noticeable. However, there is still an ambiguous legal situation with regard to the question of whether enforcing large-scale retrofitting of construction machines or a substantial renouncement of solid fuels in small combustion plants are enforceable.

When comparing the pollution side-effects of the different packages of measures, it turns out that the traffic flow optimisation measures and the adjusted speed limit measures, that are only effective on a local level, are well-suited for pointedly relieving highly-polluted road sections. The reductions shown herein demonstrate the maximal conceivable effect, if the measures would be implemented on all hot spots showing a full effect. Thus it was postulated for traffic flow optimisation that not a single congestion occurs on the considered road sections, which de facto remains an illusion for obvious reasons. Also with regard to the effect that would result from a reduction of the speed limit would have to be assumed ideal conditions with smooth traffic flow, so the postulated effect cannot be fully attained in practise. Hence, further detailed modelling for individual sections is envisaged before implementing those measures.
9 Measures of the Air Quality Plan 2011-2017

As indicated by the trend forecasts, the air quality limit values are unlikely to be met by 2015 without undertaking additional measures. Therefore, it is key that measures are developed within the Air Quality Plan that ensure long-term compliance with the limit values.

With regard to PM$_{10}$, the causal analysis has shown that – taking into account the principle of proportionality – local measures are not sufficient to abate the problem of PM$_{10}$ short-term limit value exceedances due to the high levels of particles carried into Berlin from outside the city. However, local measures should at least result in minimizing the risk of limit value exceedances and in limiting the extent and the duration of the exceedance.

As outlined in Chapter 6, numerous measures have already been implemented through the 2005 Clean Air and Action Plan and the Urban Development Plan on Transport. The scenario calculations in Chapter 8 have shown that the extent and duration of limit value exceedances of particulate matter and NO$_2$ can be considerably reduced by 2015 through the examined package of measures, but that exceedances will still occur. While the air quality limit value for NO$_2$ will likely be achieved on all roads by 2020, this is deemed unlikely for PM$_{10}$. This is because the PM$_{10}$ pollution increasingly derives from the input of particulate matter from outside Berlin.

Besides the package of measures examined in Chapter 8, further potential measures which can be taken at the level of Berlin to reduce air pollution will be presented in the following. It may be difficult, however, to quantify the effect of these measures by means of the available models.

The measures can be classified in five fields of measures:

- Land-use, urban- and landscape planning
- Transport
- Heat supply
- Building/construction sector
- Installations in industry and business

The variety of the fields of measures already illustrates that the Air Quality Plan should not be considered as a standalone plan. Instead, it requires concerted action along with other planning areas. The following table of measures thus includes the objectives of existing plans. This especially concerns the measures in traffic, which basically build upon the planning and the package of measures of the Urban Development Plan on Transport 2025. The heat supply sector is closely linked with climate protection measures and objectives that can contribute considerably to reducing emissions by limiting the heat requirements. On the other hand, possible conflicts of interest need to be taken into account in this area, e.g. the combustion of biomass.

The envisaged measures are summarized in the table below together with a broad estimate on their impact. A closer description follows in the subsequent package of measures.
### Table 9.1: Compilation of the measures of the Air Quality Plan 2011-2017

<table>
<thead>
<tr>
<th>No.</th>
<th>Measure</th>
<th>Impact</th>
<th>Implementation and entry into force</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
<td><strong>Measures regarding planning instruments</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 1.1</td>
<td>Land-use planning with due allowance for urban climatology and air exchange</td>
<td><img src="no/2" alt="spatial" /> <strong>local</strong> to citywide <img src="no/2" alt="on air quality" /> +/++</td>
<td>long-term</td>
<td>Senate Department for Urban Development and the Environment [SenStadtUm] boroughs</td>
</tr>
<tr>
<td>M 1.2</td>
<td>Avoid new pollution hotspots</td>
<td><img src="no/2" alt="spatial" /> <strong>local</strong> <img src="no/2" alt="on air quality" /> ++</td>
<td>long-term</td>
<td>SenStadtUm Boroughs</td>
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<tr>
<td>M 1.3</td>
<td>Greening of streets</td>
<td><img src="no/2" alt="spatial" /> citywide <img src="no/2" alt="on air quality" /> +</td>
<td>long-term</td>
<td>SenStadtUm Boroughs</td>
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<tr>
<td>M 1.4</td>
<td>Pollution-sensitive development of sites of the Urban Development Plan on Industry and Business</td>
<td><img src="no/2" alt="spatial" /> <strong>local</strong> <img src="no/2" alt="on air quality" /> 0/++</td>
<td>long-term</td>
<td>SenStadtUm Boroughs SenWiTechForsch</td>
</tr>
<tr>
<td>M 1.5</td>
<td>Urban Development Plan for city centres</td>
<td><img src="no/2" alt="spatial" /> <strong>local</strong> <img src="no/2" alt="on air quality" /> 0/+</td>
<td>long-term</td>
<td>Boroughs SenStadtUm SenWiTechForsch</td>
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<tr>
<td>M 1.6</td>
<td>Traffic reducing spatial development</td>
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<td>long-term</td>
<td>SenStadtUm Boroughs</td>
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<tr>
<td>M 1.7</td>
<td>Participation in urban land-use planning and planning permission procedures</td>
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<td>long-term</td>
<td>Boroughs (TÖB)</td>
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<tr>
<td></td>
<td><strong>Measures Vehicle Technology</strong></td>
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</tr>
<tr>
<td>M 2.1</td>
<td>Low emission zone without individual exemptions</td>
<td><img src="no/2" alt="spatial" /> <img src="no/2" alt="on air quality" /> citywide +</td>
<td>until 2015</td>
<td>SenStadtUm</td>
</tr>
<tr>
<td>M 2.2</td>
<td>Promotion of EURO 6 vehicles</td>
<td><img src="no/2" alt="spatial" /> <img src="no/2" alt="on air quality" /> citywide +</td>
<td>until 2015/16</td>
<td>SenStadtUm Federal Government</td>
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<tr>
<td>M 2.3</td>
<td>Promotion of natural gas vehicles</td>
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<td>M 2.4</td>
<td>Electric vehicle network</td>
<td><img src="no/2" alt="spatial" /> <img src="no/2" alt="on air quality" /> citywide uncertain</td>
<td>medium- to long-term</td>
<td>SenStadtUm SenWiTechForsch Federal Government Boroughs</td>
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<tr>
<td>M 2.5</td>
<td>Clean vehicles in public transport</td>
<td><img src="no/2" alt="spatial" /> <img src="no/2" alt="on air quality" /> citywide +/local ++</td>
<td>short- to long-term</td>
<td>SenStadtUm BVG</td>
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<td>M 2.6</td>
<td>Clean municipal vehicle fleet</td>
<td><img src="no/2" alt="spatial" /> citywide 0</td>
<td>short- to medium-term</td>
<td>all municipal companies</td>
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<tr>
<td>M 2.7</td>
<td>Retrofitting of EURO 4 diesel vehicles</td>
<td><img src="no/2" alt="spatial" /> <img src="no/2" alt="on air quality" /> citywide +</td>
<td>medium-term</td>
<td>SenStadtUm Federal Government</td>
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<tr>
<td>M 2.8</td>
<td>Particle reduction for passenger ships</td>
<td><img src="no/2" alt="spatial" /> <img src="no/2" alt="on air quality" /> citywide 0/+</td>
<td>short- to medium-term</td>
<td>SenStadtUm Boroughs</td>
</tr>
<tr>
<td>No.</td>
<td>Measure</td>
<td>Impact</td>
<td>Implementation and entry into force</td>
<td>Responsibility</td>
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<td>M 2.9</td>
<td>Environmental standards for diesel locomotives</td>
<td>Q local 0/+</td>
<td>medium- to long-term</td>
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<tr>
<td>M 2.10</td>
<td>Communication campaigns for the purchase of clean vehicles</td>
<td>Q citywide 0</td>
<td>medium-term</td>
<td>SenStadtUm associations</td>
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<tr>
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<td><strong>Measures Traffic Control</strong></td>
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<td>M 2.11</td>
<td>Stabilisation</td>
<td>Q only local +/+</td>
<td>short- to medium-term</td>
<td>SenStadtUm</td>
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<tr>
<td>M 2.12</td>
<td>City-compatible speed level on main roads</td>
<td>Q only local +/+</td>
<td>short- to medium-term</td>
<td>SenStadtUm</td>
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<tr>
<td>M 2.13</td>
<td>Environmentally sensitive transport management</td>
<td>Q only local 0/+</td>
<td>medium-term</td>
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<td>M 2.14</td>
<td>Concepts for events and incidents</td>
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<td>M 2.15</td>
<td>Traffic control concepts for transit traffic of heavy goods vehicles</td>
<td>Q local to citywide +</td>
<td>medium-term</td>
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<tr>
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<td>Environmentally sensitive traffic control concepts related to the urban traffic</td>
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<td>M 2.17</td>
<td>Reorganisation of coach traffic</td>
<td>Q local to citywide 0/+</td>
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<td><strong>Measures Traffic Displacement and Prevention</strong></td>
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<td>Q citywide +/+</td>
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<td>medium- to long-term</td>
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<td>M 2.20</td>
<td>Parking area management</td>
<td>Q local to citywide +</td>
<td>medium- to long-term</td>
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<td>M 2.21</td>
<td>Mobility management</td>
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<td>medium- to long-term</td>
<td>all administrations</td>
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<td>Promotion of car-sharing</td>
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<td>medium- to long-term</td>
<td>SenStadtUm Boroughs</td>
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<tr>
<td>M 2.23</td>
<td>Integrated economic concept</td>
<td>Q citywide +</td>
<td>medium- to long-term</td>
<td>SenStadtUm SenWirtschaft</td>
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<td><strong>Measures Infrastructure Traffic</strong></td>
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<td>M 2.24</td>
<td>Rehabilitation of road surfaces</td>
<td>Q local +/+</td>
<td>medium- to long-term</td>
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<tr>
<td>M 2.25</td>
<td>Redistribution of public road space</td>
<td>Q local +</td>
<td>medium- to long-term</td>
<td>Within Noise Reduction Plan</td>
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<tr>
<td>M 2.26</td>
<td>Promotion of public means of transport that are low in emissions on local level (local rail passenger transport)</td>
<td>Q local to citywide +</td>
<td>medium- to long-term</td>
<td>SenStadtUm</td>
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<tr>
<td>No.</td>
<td>Measure</td>
<td>Impact</td>
<td>Implementation and entry into force</td>
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<td>Measures Heat supply for buildings</td>
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<td>M 3.1</td>
<td>Reducing heat requirements of buildings</td>
<td>☀️ citywide 0/+</td>
<td>medium- to long-term</td>
<td>SenStadtUm Boroughs</td>
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<tr>
<td>M 3.2</td>
<td>Clean energy for heat supply and the reduction of emissions from small combustion plants</td>
<td>☀️ citywide +</td>
<td>medium- to long-term</td>
<td>SenStadtUm Boroughs</td>
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<td>M 3.3</td>
<td>Clean Mini CHP</td>
<td>☀️ local to citywide 0/+</td>
<td>medium- to long-term</td>
<td>SenStadtUm Boroughs</td>
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<td>Measures Construction sector</td>
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<td>M 4.1</td>
<td>Particle filter for construction machines</td>
<td>☀️ local to citywide 0/+</td>
<td>short- to medium-term</td>
<td>SenStadtUm Federal Government</td>
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<td>M 4.2</td>
<td>Reducing fugitive dust emissions from construction sites</td>
<td>☀️ local +</td>
<td>medium-term</td>
<td>SenStadtUm Boroughs</td>
</tr>
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<td>M 4.3</td>
<td>Reduzierung transportbedingter Emissionen bei Bauvorhaben</td>
<td>☀️ local +</td>
<td>medium-term</td>
<td>SenStadtUm Boroughs</td>
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<td>Measures Industry and business</td>
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<td>M 5.1</td>
<td>Requirements for installation permits</td>
<td>☀️ local 0/+</td>
<td>short- to medium-term</td>
<td>SenStadtUm</td>
</tr>
</tbody>
</table>

9.1 Land use, urban and landscape planning
The topology of the urban agglomeration zone Berlin has an influence on air quality in a number of ways – ranging from possibilities to provide entire urban areas with fresh air to conditions for the dilution of air pollutants in individual road sections, from the geographical situation of sensible use and individual sources to the generation of emissions from influencing the demand of motorized traffic. The objectives of the air quality planning have an important strategic role to play in the urban development planning, since the land-use structure creates long-term conditions which cannot be compensated by other clean air measures in the individual case.
**M 1.1 Land-use planning with due allowance for urban climatology and air exchange**

<table>
<thead>
<tr>
<th>Timetable for implementation</th>
<th>Competent authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>ongoing in the planning process</td>
<td>SenStadtUm, Boroughs</td>
</tr>
</tbody>
</table>

**Potential for reduction**

n.a.

**Costs**

n.a.

Urban development planning, open space planning and land-use planning have an influence on the spatial structure of the city in the long term and thus influence the urban climatological conditions for air quality. Important factors are the building density, the distribution of open spaces and the positioning and development of potential sources of air pollutants (e.g. by providing sites for industries or transport-intensive retail concentrations) in relation to sensible/sensitive uses. As part of the climate model Berlin, assessment maps were created (status as of 2009) illustrating green areas and open spaces of high climatological relevance for the city and areas relevant for air exchange. They also evaluate residential areas with regard to their bioclimatical situation and identify load ranges.

On this basis, planning notes advice arises for measures to improve the climatological situation and air exchange. In the planning practice, however, these notes are not binding. The guiding principle of these planning notes is to protect, develop and restore surface structures relevant for the climatic and ecological impacts of immissions [Environment Atlas map 04.11.2 textual explanation].

With regard to air exchange, for example, the planning instructions include avoiding barriers such as construction barriers, low construction heights, alignment of buildings along interconnection paths, preservation and interlinkage of open areas. With regard to areas with already high pollution levels, further densification should be avoided, ventilation improved and the share of vegetation enhanced. This measure is closely linked to the objectives of the Urban Development Plan on Climate Protection, adopted by the Senate on 31/05/2011.

**Objective of the measure:**

Preserve and, if possible, improve the current conditions for dispersal for air exchange. To this end, the planning notes of the climate model should be taken into account in future planning. No additional barriers for air exchange should arise, the cross-linking of open spaces should be improved, and sealed and unused areas should be unsealed and grassed. If an impairment of the air exchange conditions is not avoided in the individual case after balancing other interests, compensation measures will be necessary.

**Implementation:**

- Implement the Action Strategy of the Urban Development Plan on Climate
- Maintain climate protection as a priority in the landscape programme
- Balance and consider urban climatological concerns when determining urban land-use plans

**Effect:**

Not quantified.

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89 [http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/da411_05.htm](http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/da411_05.htm)

M 1.2 Avoid new pollution hotspots

<table>
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<tr>
<th>Timetable for implementation</th>
<th>Competent authority</th>
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<tbody>
<tr>
<td>until the end of 2013</td>
<td>SenStadtUm, Boroughs</td>
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<table>
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<tr>
<th>Potential for reduction</th>
<th>Costs</th>
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<tr>
<td>to be modelled for the individual case</td>
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Changes in the urban development must be examined with regard to their impact on potential limit value exceedances. Particular attention should be given to street canyons, which are characterized by largely enclosed roadside structures on both sides of the street. The narrower and the more closed the canyon is, the worse is the dilution of exhaust gases from vehicles. High air pollution levels thus occur particularly on roads with high traffic volumes, and concurrently, a low width/height ratio.

**Objective of the measure:**
No additional road sections or pollution hotspots as a result of urban development changes.

**Implementation:**
- Development of guidelines and recommendations on the preservation of wide road spaces and the avoidance of new pollution hotspots due to urban development changes
- Guidelines on modelling air quality
- Consideration of the guidelines in the context of mandatory urban land-use planning
- Examination of the effects of ventilation passages in areas with high pollution levels and poor ventilation

**Effect:**
Locally high – depending on the initial situation, the traffic-induced incremental pollution on a local level can more than double through the creation of a street canyon. The shorter the distances to the next building and the higher the buildings are, the higher is the air pollution from traffic. Gaps between buildings in the development of road spaces reduce the traffic-induced local incremental pollution through a better dilution. The share of empty sites/gaps between buildings at 20 % leads to an incremental pollution that is approximately 10 % lower than of enclosed road spaces.

M 1.3 Greening streets

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<th>Timetable for implementation</th>
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<td>ongoing</td>
<td>SenStadtUm, Boroughs</td>
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<table>
<thead>
<tr>
<th>Potential for reduction</th>
<th>Costs</th>
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<tbody>
<tr>
<td>approximately 1 to 10% of the total pollution, rather coarse particles &gt; 2.5 µm</td>
<td>approximately 1.000 to 2.000 € per tree + annual cultivation costs</td>
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</tbody>
</table>

A certain share of the particulate matter contained in leaves or needles of wood is filtered out when these are swept by air. The larger the particles, the larger is that filter effect. Ultrafine particles such as diesel soot are thus hardly captured, but particles from abrasion and re-suspension are included. In addition to particulate matter, plants also absorb corrosive gases from the atmosphere, such as nitrogen oxides, and thus reduce their concentrations in the atmosphere. However, plants can – depending on the species – also release organic substances that serve as precursors for the formation of ozone and ultrafine particles.

The filtration capacity depends on the wood species, the shape of the treetop, the structural planting (distance between the trees and between tree and buildings for instance) and the period of vegetation. This should be taken into account in the selection.

Air-permeable plantings that are, for example, structured in height filter better than dense woods. When planting trees on streets, especially on narrow ones, it has to be taken into account that air exchange should not be hindered, since in that case the stock of trees would result in an increase in pollution.

In winter months, the dust formation effect only occurs in evergreen plants not yet planted in streets. It should therefore be tested whether evergreen conifers are suitable for trees in streets. According to the literature, pines and yews are particularly effective with a view to the filtration of particulate matter. However, they are not considered suitable for streets in the inner city area. Most deciduous trees have a medium effectiveness, but are more capable of degrading nitrogen oxides. In addition to or instead of street trees, façade greenings generally serve as filter for particulate matter.

Objective of the measure:
- Preserve the stock of street trees and plant 10,000 new street trees particularly on roads with high pollution levels with particular consideration for the reduction of particulate matter (selection of the tree species should be subject to health and allergological aspects)
- Test greenings of facades and rooftops

Implementation:
- Campaign on street trees aimed at planting new trees and a sustainable cultivation
- Support cooperations between public authorities and private actors
- Guidelines on the greening of facades and rooftops

Effect:
Under certain conditions, plants can filter particulate matter contained in the air to a certain degree. Plants may thus contribute to reducing air pollution. Examinations have shown that the particulate matter pollution is considerably higher in streets without tree stocks and in areas with a deficit of green spaces than in streets with tree stocks and in areas with green spaces (see: Positionspapier Feinstaub, Arbeitskreis Stadtbäume der Deutschen Gartenamtsleiterkonferenz, 2008). There is still great need for research, however, with regard to the exact quantification of filter performances for wood species. Model calculations using different deposition speeds and different conditions (e.g. surface coverage with trees) resulted in reduction rates of < 1% to 10%, maximum approximately 30%.

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M 1.4 Pollution-sensitive development of sites of the Urban Development Plan on Industry and Business

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<tr>
<th>Timetable for implementation</th>
<th>Competent authority</th>
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<td>ongoing</td>
<td>SenStadtUm, SenWiTechForsch, Boroughs</td>
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<th>Potential for reduction</th>
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By adopting the Senate decision of 25/01/2011, the Senate of Berlin has agreed to an integrated development concept for the most important industry parks with the Urban Development Plan (StEP) „Industrie und Gewerbe – Entwicklungskonzept für den produktionsbedingten Bereich“™. 40 selected sites of the StEP with a total area of approximately 3000 ha are particularly reserved for commercial use. For each of those sites, the StEP compiles profiles containing information on the location, pattern of use, planning laws and particular suitability. The information on the impacts of the establishment of additional industrial businesses on air quality is confined to very general notes regarding additional traffic volumes. Five sites of the StEP are specifically in frame for the establishment of business companies that may entail enhanced impacts or risks due to noise nuisance, air pollutants or hazardous substances. These sites should be protected against approaching sensitive uses to avoid neighbourhood conflicts and to preserve the existing degree of freedom for the economy.

In order to avoid or limit additional limit value exceedances through the establishment of new businesses, it is necessary to assess the impacts on air quality for the approval of firms, and, if necessary, to provide for emissions-curbing requirements. To facilitate the development of these sites, the additional but still acceptable emissions from air pollutants (and also noise) may be modelled for each location in advance and be included in the profile.

In addition, the sensitivity of the concerned traffic routes should be evaluated with a view to additional traffic volumes caused by the establishment of new businesses.

**Objective of the measure:**
No additional exceedances of air quality values deriving from the development of sites of the StEP industry and business. If this is not possible to avoid for reasons of planning or emission control, compensation measures and emission reduction concepts should be developed in coordination with the relevant Senate Department.

**Implementation:**
- Prepare an air quality evaluation of the sites of the StEP industry and business.
- Develop emission reduction concepts for locations where limit value exceedances already occur or where these are probable with the establishment of further pollutants. Within the framework of such concepts it should be examined whether the concept of noise quota could be applied to air pollutants.
- Consider traffic loads deriving from new settlements

**Effect:**
The measure takes effect locally, its impact can only be quantified if detailed information on future emissions from businesses is available; avoiding limit value exceedances is possible in individual cases.
### M 1.5 Urban Development Plan (UDP) for city centres

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<th>Timetable for implementation</th>
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<td>Boroughs, SenStadtUm, SenWiTechForsch</td>
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<th>Potential for reduction</th>
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Berlin’s urban structure is characterized by a pronounced polycentricity. This polycentricity facilitates the local availability of services, retailing, cultural and gastronomy services and allows for short distances. It prevents motorized traffic and thus contributes to preventing traffic-induced air pollution.

The objective of the Urban Development Plan (UDP) for city centres[^395] adopted on 12/04/2012 is to ensure and further develop this polycentricity in order to reinforce the functional mix in centres and to ensure local services. Emphasis is placed on a “city-friendly” development of retailing which is significant for the functionality of centres. In addition, large retail establishments should be integrated in a “city-friendly” manner. On the basis of the UDP for city centres, matters concerning air pollution control are taken into account with regard to the settlement and development of retail establishments, i.e. by evaluating the origins of traffic and those roads possibly affected by increasing traffic levels. New limit value exceedances should be prevented especially on road sections that have not been affected so far.

**Objective of the measure:**
- Ensure short distances by strengthening local supply (e.g. food and such, basic medical care)
- Reduce motorized shopping traffic
- No further limit value exceedances in cases of new retail establishments

**Implementation:**
- Implementation of the guidelines of the UDP for centres[^3]
- Air-hygienic evaluation of the origins of traffic for new settlements of large retail establishments
- Initiation of a model project in cooperation with the retail sector to develop strategies to reduce motorized shopping traffic
- With regard to new establishments transport loads have to be taken into account under application of the „Leitfaden zur verkehrlichen Standortbeurteilung und Verkehrsfolgenabschätzung für verkehrsintensive Vorhaben“[^96] (gemäß StEP Verkehr)

**Effect:**
The measure has primarily a local effect. Its effect can only be quantified if detailed information on the traffic effects of new retail locations is available. In individual cases it is possible to prevent limit value exceedances.

Traffic reducing spatial development

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<th>Timetable for implementation</th>
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<th>Potential for reduction</th>
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The demand for motorized transport services is closely linked to the spatial structures. When distances to a desired destination are short, emissions are lower and it is easier to reach the destination by foot or by bike. Sophisticated local public transportation services are equally important for preventing motorized private transport. Berlin offers great conditions in this respect due to its polycentric structure with a fragmented mix of uses and a historically less developed suburbanization compared to other large cities for historical reasons.

To ensure and optimize this in the long term, the objective of a traffic reducing spatial development has already been integrated into the spatial planning, e.g. by the strategic approaches of the land-use planning and in the requirements of the Joint Regional Planning with Brandenburg. This allows to control (in terms of reducing traffic) the development of residential areas, a mix of functions for shorter distances to workplaces and a good local supply as well as the settlement of traffic-intensive businesses.

One measure for the development of locations is the retroactive densification of under-used or unused areas, e.g. by the regeneration of disused, developed areas, the closure of empty sites between buildings or by adding new storeys to buildings. This requires examinations in each case on whether such building operations adversely influence the exchange conditions for air pollutants or the supply of fresh air.

**Objective of the measure:**
- Reduce the demand for transport, i.e. more mobility with less motorized traffic
- Consider the length of distances as a criterion in the spatial planning
- No new residential areas without efficient connections to the public transport system

**Implementation:**
- Concentration of settlements along rail corridors
- Develop strategies for redensification under consideration of effects on air quality
- Strengthening and ensuring the local supply of services
- Create balanced job offers in all parts of the city, e.g. by reducing the structural employment deficit in the eastern parts of the city envisaged in the UDP transport with the objective of preventing traffic by spatial prioritization of business and research promotion
- Integrated location planning (for settlements of businesses causing high volumes of traffic the Guidelines (Leitfadenzur verkehrlichen Standortbeurteilung und Verkehrsfolgenabschätzung für verkehrsintensive Vorhaben98) should be taken into account pursuant to the UDP.

**Effect:**
The measure supports the creation of general conditions for preventing emissions from road traffic. A quantification of the effect is only possible in individual cases in the framework of the assessment of several planning alternatives.

97 **“*** denotes measures that were extracted from the Urban Development Plan Traffic 2025.
M 1.7 Participation in urban land use planning and planning permission procedures

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<th>Timetable for implementation</th>
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<td>ongoing</td>
<td>SenStadtUm</td>
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<tr>
<td>Potential for reduction</td>
<td>Costs</td>
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In March 2011, the competent authority for Pollution Control was admitted to the register of authorities and other bodies, which, as representatives of public interests, should be involved in the mandatory urban land-use planning pursuant to §§ 4/4a BauGB. Since then, all urban land-use plannings of districts and the Senate Department for Urban Development have been examined with a view to air pollution and noise control matters. This aims to avoid possible deficits in balancing different interests with a view to limit value exceedances and strategic objectives of clean air and noise action planning. Other authorities have already participated in planning permission procedures before. Since March 2011, notes on pollution level control were submitted in almost 70% of the 74 concluded cases with participations. Insofar as conflicts with the objectives of air quality planning, i.e. limit value exceedances occur as a result of the planning, compensation measures have to be integrated into the plan to prevent limit value exceedances. If not possible with appropriate measures, the extent and duration of the exceedance should be reduced. The measure aims to implement the measures described above, since in practice these generally only take form through the drafting of urban land-use plans and planning permissions.

**Objective of the measure:**
- Avoid additional limit value exceedances due to plan contents

**Implementation:**
- Continuous activity of public agencies
- Evaluation of the planning and developed notes on air quality planning to identify key problem areas
- Experience exchange with the planning authority

**Effect:**
The measure has primarily a local but long-term effect. Its effect can only be quantified case-related. In individual cases it is possible to avoid limit value exceedances.
9.2 Road, rail and waterborne traffic

Traffic-related pollutants, especially from motor vehicles in road traffic, continue to be the most significant source of high particulate matter and nitrogen dioxide pollution in Berlin. As shown in Chapter 5, around 27% of the particulate matter pollution and 77% of the nitrogen dioxide pollution on main roads originate from motor vehicle traffic. Thus the reduction of these emissions continues to be the central objective of the Air Quality Plan. As the reduction potential due to improved vehicle technology has already been exploited to the greatest extent within the scope of the given administrative regulations after introduction of the low emission zone, a comprehensive package of measures has been examined. These measures are intended to lead to further technological emission reductions of vehicles, but shall also include emission reductions by means of traffic control, displacement of traffic and traffic prevention and also infrastructure measures. Regarding individual measures, the attainable reductions are often only low, but when interacting with each other, considerable improvements can be achieved as shown in the scenario calculations in Chapter 8. Additively also, technical improvements in the vehicle fleet and traffic control measures such as the prevention of congestions are effective. Attention should be paid to the fact that measures regarding the modernisation of the vehicle fleet, traffic prevention and displacing the motor vehicle traffic to modes of traffic of the eco-mobility type work on a large-scale level in the road network and thus reduce both the local incremental pollution in highly polluted road sections and the city-wide background pollution. In contrast, measures regarding traffic control and the stabilisation of traffic by means of phased traffic lights (“green wave”), traffic inflow control or a modified traffic management are predominantly only effective on a local level in those sections that were relieved by the measures. In other road sections, however, a higher emission level can be observed. In this case, traffic control measures have to be conceptualised in a way that no displacement of traffic into other areas that need to be protected, or even into the side roads network occurs. For this reason, the measures should be checked and weighed for each individual case before implementation.

The road traffic measures that are marked with “*” in the following are mainly based on the Urban Development Plan Traffic 2025, which strives for a sustainable development of the mobility in the city and targets a reduction of the traffic-related air pollution.

The emission of pollutants by rail vehicles (abrasion and diesel exhaust gases) and also by ships is comparatively low, but can locally cause pollution on rail and waterways.
9.2.1 Vehicle technology

M 2.1 Low emission zone without individual exemptions

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<th>Timetable for implementation</th>
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<tr>
<td>01/01/2015</td>
<td>SenStadtUm</td>
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<tr>
<th>Potential for reduction in 2015</th>
<th>Costs</th>
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<tbody>
<tr>
<td>3.6 t/a resp. 3.6 % diesel soot emissions</td>
<td>Investments for substituting or retrofitting older vehicles (mostly older than 10 years)</td>
</tr>
<tr>
<td>55 t/a resp. 1.1 % NOx emissions</td>
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In Berlin, exemptions from the traffic ban due to Federal Law (Appendix 3 of the 35th BlmSchV) on the one side and due to general orders99 and grants of individual exemptions are valid for the Low Emission Zone. As a result, not all vehicles in the Low Emission Zone meet the required exhaust criteria. In 2010, still about 35% of the diesel soot emissions originated from vehicles without a green sticker. If these vehicles would have also met the green sticker criteria, about 24 t/a less diesel soot particles would have been emitted, that is just 192 t instead of 126 t per year. This reduction only refers to the minimum criteria of EURO 3 with a particulate filter. Many vehicles that are subject to the traffic ban, however, would be replaced by newer vehicles, so that an additional reduction of the nitrogen oxide emissions would be attained as well.

The specified regulations in Berlin for individual exemptions and EURO 3 diesel vehicles not being retrofittable shall expire with a five years transition period since the beginning of Stage 2 of the Low Emission Zone that became effective in 2010 until 01/01/2015. A longer period is not justifiable in view of the fact that the deadline extension for the compliance with the NOx limit values is only possible until 01/01/2015. Whether and how exemptions for special purpose vehicles with minor mileage/driving performance can be conceded beyond that needs to be assessed.

Due to the most widely termination of granting individual exemptions, human resources in the districts can be economised.

Objective of the measure:
Traffic ban exemptions shall be limited to the cases defined in appendix 3 of the 35th BlmSchV from 2015.

Implementation:
- From 2013, individual exemptions can be granted for the last time, all of which need to be restricted until 31/12/2014.
- Integration of the Senate Department for Economics, Technology and Research when formulating the results of the review, whether and if yes, due to which criteria exemptions for special purpose vehicles with minor mileage/driving performance can be granted beyond 31/12/2014.
- The exemption clause for EURO 3 vehicles that cannot be retrofitted could be limited until 31/12/2014 via general direction.

For this purpose, the guideline “individual exemptions” [Ausnahmegenehmigungen] would need to be adapted. The general direction for EURO 3 vehicles would need to be replaced by a limited general direction after review on proportionality from social and economic points of view.

Effect:
The effect of this measure was calculated within network-wide modelling, based on the assumption that all diesel vehicles of the emission group 1 to 3 remaining in 2015 will be replaced by EURO 6 vehicles. As a result, this makes up a reduction of the diesel soot emissions of about 3.6 t/a resp. 3.6 % and about 55 t/a resp. 1.1 % of the nitrogen oxide emissions in the main road network. Additional reductions appear/arise on minor roads. These, however, have not been quantified.

The effect on air quality was calculated within the package of measures “Vehicle Technology”. In total, the number of main road residents affected by limit value exceedances can be reduced by approximately 25 %.

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Promotion of EURO 6 vehicles

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<th>Timetable for implementation until 2015</th>
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<tbody>
<tr>
<td>Potential for reduction</td>
<td>SenStadtUm, SenWITechForsch, Federal Government</td>
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<tr>
<td>Costs</td>
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The emission standard 6 needs to be met by 01/01/2014 by heavy trucks and buses, from 01/01/2015 by motor vehicles and from September 2016 by all light commercial vehicles. In contrast to EURO 5 vehicles, reductions of the NOx and diesel soot emissions in the urban traffic of 60 to 90% are forecasted for heavy trucks and buses. Regarding motor vehicles, the nitrogen oxide emissions are expected to decrease by more than 60% (HBEFA 3.1). Whereas, the transition from EURO 4 to the current standard EURO 5 only achieved a reduction of up to 25% in terms of nitrogen oxide. This low decrease of the NOx emissions up to EURO 5 is the most significant cause why in the trend scenario the NOx air quality limit value is still being exceeded in 2015. Only in 2020, when a higher share of the vehicle fleet attains the EURO 6 standard, the limit values are expected to be met. It is thus desirable, that EURO 6 vehicles are put on the market and bought ahead of schedule, that means distinctly before the official introduction date. User benefits and financial incentives could reinforce this.

Objective of the measure:
It is pursued that in 2015, the share of EURO 6 vehicles in the vehicles registered in Berlin will be higher than the German average in the fleet mix indicated in the Handbook Emission Factors.

Implementation:
- Berlin is going to examine whether user benefits and a labelling of EURO 6 vehicles are both reasonable and realizable.
- Promotion by a reduced vehicle tax: In the Federal Council, Berlin is going to take a stand for the cause that not only EURO 6 motor vehicles, but also EURO 6 commercial vehicles and buses are tax-supported.
- Promotion by means of reduced toll charges for EURO 6 trucks: Berlin is going to continuously encourage this matter in the Federal Council.
- Berlin is going to work to ensure that after entry into force of the EURO 6 standard, little exceptional permissions for the stock sales of EURO 5 vehicles are granted by the Federal Road Transport Authority (Kraftfahrtbundesamt).
- Vehicle purchasers should be encouraged to make early purchases of EURO 6 vehicles. For this purpose, an information campaign – if possible in cooperation with organisations and the automotive industry – shall be started off.
- When purchasing diesel vehicles, the public sector is going to purchase EURO 6 vehicles with immediate effect, insofar as these vehicles are available for the respective purpose.

Effect:
By means of the assumptions made in Chapter 8.1.1 regarding the EURO 6 vehicles share in the whole vehicle fleet, if applied to the whole main road network, reductions in diesel soot emissions by 1.5 t/a resp. 1.5% and nitrogen oxide emissions by 42 t/a resp. 0.8% of the emissions on main roads are calculated. There are additional reductions on minor roads, which, however, were not quantified.

The effect on air quality was calculated within the package of measures entitled “vehicle technology”. In total, the number of main road residents that are affected by limit value exceedances can be reduced by about 25%.
Natural gas engine vehicles are characterised by the fact that on the one hand, they feature very low nitrogen oxide emissions and virtually no particulate emissions, but on the other hand, they reach the low CO₂ emission level of diesel vehicles. Also compared to modern EURO 5 diesel vehicles, an advantage for the reduction of NOₓ air pollutants and particulates in the urban transport can be assumed. Earlier experience shows that pollutant emission control systems that are utilised in diesel vehicles in order to meet the EURO 5 and 6 requirements often don’t show the desired effect under urban traffic conditions, as the exhaust temperatures are too low. For this reason, natural gas technology as a clean alternative should be further supported. The CO₂ balance of natural gas vehicles in Berlin will continue to improve in the future, as the GASAG Berlin increasingly feeds biogas into the natural gas network, from which vehicles can be refuelled. Natural gas as a fuel is currently being promoted nationwide due to the exemption from the mineral oil tax/fuel tax. This promotion, however, is limited until 2018. In Berlin, natural gas vehicles were promoted by the GASAG via a unique petrol voucher in the amount of 111 to 1.500 €. Nevertheless, the share of natural gas vehicles remains static at a very moderate level.

It is thus desirable to at least maintain the natural gas vehicles share in the fleet and to increase it as far as possible. This should not only affect motor vehicles and light commercial vehicles, but also the use of heavy goods vehicles, for which are increasingly offered with natural gas motors. Structures for the use of natural gas in vehicles also allow using hydrogen for propulsion, as already it is permitted to admix hydrogen with conventional natural gas up to a share of 5 %. With the motor technology, higher shares would be possible, but there is hardly any experience in this regard.

Objective of the measure:

At least retention of the share of natural gas vehicles in the vehicles registered in Berlin of 0.3 %, preferably increase to more than 1 %.

Implementation:

- Continuation of the GASAG funding for natural gas vehicles: This is already part of the climate protection agreement 2011-2020 that was negotiated with the GASAG.
- Vehicles of the public sector: for the purchase of public sector vehicles it is further recommended to purchase of natural gas vehicles. The opportunities given by the use of natural gas vehicles by BSR and BVG have to be examined on a regular basis.
- Update of the exemption from energy taxes: Berlin is going to encourage the continuation of tax benefits for natural gas as fuel after 2018 in the Federal Council.
- Communication: It is intended to widely communicate the advantages of natural gas vehicles, especially for commercial transport purposes, to a broad public.

Effect:

The effect of a higher share in natural gas vehicles has not been quantified yet. If older diesel vehicles are replaced by natural gas vehicles to a similar extent like in the scenario regarding the support of EURO 6 vehicles, a comparable effect can be assumed.
Electrically driven motor vehicles are characterised by the fact that they do not emit engine-related air pollutants at the locations they are operating. As to tyre debris and re-suspension, there are no differences compared to combustion engine vehicles. Electronically driven commercial vehicles in particular offer a high potential for reducing the pollution load at the most sensitive places in terms of air-hygiene, such as highly polluted street canyons. Hybrid vehicles, whose share will widely outweigh that of pure electric vehicles, possess distinctly lower reduction potentials. The propulsion-related emission of pollutants of the vehicles depends on the type of power generation and is displaced to the places where the power plants are located. Because of the high chimneys, the pollutants are dispersed over a relatively wide area and they are better diluted than the exhaust gases from the combustion engines of motor vehicles. For the future it is intended that the power for electric vehicles originates from renewable energy sources, whose generation has to be expanded accordingly. However, it has to be noted that during the power generation from biomass, similar particulate matter and nitrogen oxide emissions like those in power plants might occur.

Berlin is – jointly with Potsdam – one of the pilot regions for electromobility within the promotion project of the Federal Ministry of Transport, Building, and Urban Development (BMVBS) and was chosen, in cooperation with the Brandenburg capital region, as “Schaufenster Elektromobilität” within the national promotion programme. Besides the promotion of electro cars, the strategy also includes the promotion of electric bicycles as well as the intermodal linkage of electric vehicles with the public regional and long-distance transport. In order to communicate Berlin as an important business location for electromobility, the Berlin agency for electromobility [Berliner Agentur für Elektromobilität] was founded.

**Objective of the measure:**
It is intended to continuously increase the mileage share of electric vehicles in motorised road traffic.

**Implementation:**
- Implementation of the action programme “Elektromobilität Berlin 2020”\(^{101}\)
- Development of the charging stations infrastructure and also creation of charging facilities for electro bikes.
- Berlin will check if user incentives can be created for electrical vehicles, especially electrically driven utility vehicles.
- Consideration of electric vehicles by the Administration of Berlin and its companies when purchasing vehicles.

**Effect:**
Assuming that until 2015 will be obtained the mileage share of about 1 %, result reductions in emissions resulting from engine related particles of about 1.2 t/a resp. 1.2 % and in nitrogen oxide emissions of approximately 67 t/a resp. 1.4 % for the whole main road network. This emission reduction is effective to the whole road network.

The effect on the air quality was calculated within the package of measures “Vehicle Technology” and has not been quantified separately. Accordingly, the number of main road residents subject to limit value exceedances can thus be reduced by about 25 % in total.

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Clean vehicles in public transport

<table>
<thead>
<tr>
<th>Timetable for implementation</th>
<th>Competent authority</th>
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</thead>
<tbody>
<tr>
<td>until 2013</td>
<td>SenStadtUm, BVG</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Potential for reduction</th>
<th>Competent authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 t/a NO\textsubscript{x} emissions</td>
<td>SenStadtUm, BVG</td>
</tr>
<tr>
<td>5 to 45 % of the local NO\textsubscript{x} incremental pollution</td>
<td>SenStadtUm, BVG</td>
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<table>
<thead>
<tr>
<th>Costs</th>
<th>Competent authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>approx. 1.5 to 2 Mio. € for retrofitting with SCR systems</td>
<td>SenStadtUm, BVG</td>
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</tbody>
</table>

While the diesel soot emission by Berlin buses was reduced by more than 90 % due to the retrofitting with particulate filter systems, there is still potential for the reduction of nitrogen oxide emissions. Transport buses cause about 13 % of the nitrogen oxide emissions from motor vehicle traffic in Berlin (see Table 4.6). On road sections with a high volume of bus transportation, buses disproportionately contribute to nitrogen oxide pollution. The highest contribution to air pollution by buses was assessed at the monitoring station Hardenbergplatz, since this is located directly in the driveway area of the bus station Hardenbergplatz. This station obtained the highest NO\textsubscript{x} concentration of the six urban background monitoring stations.

The retrofitting with nitrogen oxide reduction systems of EURO 3 transport buses has already been tested within an ongoing pilot project since the beginning of 2011, within which two vehicles were retrofitted with SCR systems. The nitrogen oxide reduction effect was already proven in the course of several drive tests by means of an on-board measurement system used by the technical inspection agency TÜV Nord. Since the end 2011 the retrofitting of a double-decker bus with the emission standard EURO 4 with a SCR system has also been tested.

Objective of the measure:
- Retrofitting of about 120 busses with denitrification systems in 2013 and of 50 to 100 busses in 2014.
- Compliance with the EURO 5 emission standard preferably by 2014 in the whole vehicle fleet.
- When purchasing new buses, the emission standard EURO 6 shall be defined in such a way that unlike EURO 5, the intended emission reduction is also effective in the urban traffic.
- Quick replacement of buses that cannot be retrofitted by EURO 6 buses or biogas powered buses.

Implementation:
- Definition of emission standards in the Nahverkehrsplan (local transport plan). In this respect, essential facts were determined already in July 2010 by the Berlin Abgeornetenhaus (“House of Representatives”) that now need to be further developed.
- Retrofitting of buses with SCRT systems (using subsidies from the Environmental Relief Programme is intended).
- Mandatory high requirements for subcontractors.
- Monitoring and periodical reporting by the BVG (Berlin public transport services).

Effect:
The effect resulting from the changeover of the whole bus fleet to emission standard EURO 5 compared to the fleet mix in 2008 was calculated for the Hardenbergplatz and selected surrounding roads with bus transport by means of a detailed dispersion model (MISKAM). While the particulate emissions largely remain unchanged due to the already achieved high degree of retrofitting with particulate filter systems, the nitrogen oxide emissions of the bus fleet decreased by about 50 to 60 %, and the nitrogen oxide emissions of the whole local road traffic on roads with bus routes, according to the local contribution of the bus emissions, decreased by about 5 to 45 %. The modelled NO\textsubscript{x} concentration at the monitoring station Hardenbergplatz thus decreased by more than 13 µg/m\textsuperscript{3} or about 20 %. For all other locations, the reduction of the air pollution according to the NO\textsubscript{x} emission share of the buses was usually lower.

In contrast to the bus fleet of 2011, the nitrogen oxide emissions, given that all busses were complying with the EEV standard (Enhanced Environmentally-friendly Vehicle), were reduced by about 300 t/a. This is equivalent to 35 % of the nitrogen oxide emissions of the BVG busses in 2011.

The effect of the measure is most widely limited to road sections with bus transport, but due to its extent of emission reduction also contributes to the reduction of the NO\textsubscript{x} pollution all over the urban area.
**Objective of the measure:**
- Upgrade of all retrofittable diesel vehicles with particulate filters until end 2012 (according to the Clean Air and Action Plan 2005-2010).
- Gradual replacement of the vehicle fleet to emissions standard EURO 6.
- Retrofitting with nitrogen oxide reduction systems for heavy goods vehicles having a lower standard than EURO 5, as far as available and making sense under the given operating conditions.
- As far as possible, EURO 5 diesel vehicles additionally need to be equipped with a sealed particulate filter.

**Implementation:**
- Specification of environmental standards for the purchase within the „Allgemeine Verwaltungsvorschrift für die Anwendung von Umweltschutzanforderungen bei der Beschaffung von Liefer-, Bau- und Dienstleistungen (Verwaltungs- vorschrift Beschaffung und Umwelt – VwVBU)“ and regularly adapting the technological progress.
- Considering the life cycle costs incl. environmental costs when evaluating tenders.
- Determination of vehicle requirements within the scope of climate protection agreements with municipal companies such as the waste management company BSR or waterworks.
- Information campaigns for the purchasing bodies dealing with facts about vehicle technologies.

**Effect:**
Compared to the total emission of road traffic, a reduction of the municipal fleet emissions is minor and cannot be evaluated with regard to the air quality. Noticeable effects are locally expected at such places, where there is a high share of waste disposal traffic.
M 2.7 Retrofitting of EURO 4 diesel vehicles

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<tr>
<th>Timetable for implementation</th>
<th>Competent authority</th>
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<tbody>
<tr>
<td>until 2015</td>
<td>SenStadtUm, Federal Government, European Commission</td>
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</table>

**Potential for reduction**
- 12 t/a resp. 12.1 % diesel soot emissions
- 33 t/a resp. 0.7 % NO\textsubscript{x} emissions

**Costs**
- approx. 10,000 to 20,000 € for particulate filters each motor vehicle/light commercial vehicle
- approx. 10,000 to 15,000 € for denitrification systems each truck or bus

Diesel vehicles having emission standard EURO 4 that are not equipped with a particulate filter show considerable particle reduction potential. Also, the nitrogen oxide emissions of these vehicles are still relatively high. Meanwhile, for heavy goods vehicles, increasingly combined exhaust gas reduction systems for retrofitting are being developed, that both reduce particles and nitrogen oxides. However, the required eligibility criteria for denitrification systems are still lacking in the German Road Traffic Licensing Regulations, so that an individual approval for retrofitting vehicles is required. Retrofitting the fleet is thus strongly limited. Homogeneous regulations on European level for retrofit systems in Europe are desirable, which would also improve the supply.

As regards motor vehicles and light commercial vehicles, there are limited particle reduction systems on the market for cost concerns. Since it is sufficient for diesel vehicles to have emission standard EURO 4 without additional particulate filter in order to get the green sticker according to the 35th BImSchV, by means of the Low Emission Zone, no further retrofitting can be attained. For this purpose, different incentive instruments must be conceived.

In 2015, in Berlin there will presumably be registered 75,000 diesel motor vehicles, 22,000 light commercial vehicles and 8,000 heavy goods vehicles of more than 3.5 t with the emission standard EURO 4. There is no sufficient data concerning the proportion of EURO 4 diesel vehicles that have not yet been retrofitted with a particulate filter or a denitrification system, as these features are not completely captured at the time of the vehicle’s registration. As regards diesel motor vehicles, it is estimated that about one third has not yet been equipped with a particulate filter.

**Objective of the measure:**
- For 2015 it is intended that more than the half of the at that time still present heavy commercial vehicles and buses with the emission standard EURO 4 (without SCR and DPF) will attain an additional reduction of 50 % of the particulate and nitrogen oxide emissions, inasmuch as suitable reduction systems that are operational in the urban traffic are available.
- For 2015, it is intended that more than the half of the present motor vehicles and light commercial vehicles with the emission standard EURO 4 (without DPF) additionally decrease by 50 % in particulate emissions.

**Implementation:**
- Berlin is going to ensure in front of the Federal Government and the EU commission, that the legal framework for the retrofitting with nitrogen oxide reduction systems will be created.
- The city of Berlin is going to evaluate if the creation of user benefits for retroffited vehicles stands to reason.
- It has to be evaluated in what way retrofitted vehicles can be considered within the tendering of transport services by the public sector.
- Berlin is going to campaign for promotion programmes in the Federal Council.
- In the Federal Council, Berlin is going to take a stand for the consideration of denitrification systems in terms of the motorway toll.

**Effect:**
Assuming the objectives mentioned above, reductions in diesel soot emissions of 12 t/a, 12.1 %, and in nitrogen oxide emissions of 33 t/a, 0.7 %, arise as a result. This emission reduction is effective on the whole road network. The effect on air quality was calculated within the package of measures “vehicle technology” and was not quantified separately. In total, the number of main road residents affected by limit value exceedances can be reduced by about 25 %.
Passenger ships are often characterised by high specific exhaust emissions, as the exhaust standards for ships are less demanding than those for motor vehicles. Furthermore, the engines are often in use for a very long time. Within a model project (see Chapter 6.11) the retrofitting with particulate filters was thus examined. This project has shown that high emissions reduction efficiency (> 90 %) is reached and that the systems have a high durability. Retrofitting a passenger ship costs between 20,000 and 30,000 €. Moreover, the reduction of the particulate emissions of inland vessels was attained by means of introducing sulphur-free diesel fuel (sulphur content less than 10 ppm) for inland ships.

**Objective of the measure:**
A reduction in the particulate emissions caused by passenger ships of 20 % within and of 10 % outside the Low Emission Zone area by retrofitting up to 30 % of the approximately 100 passenger ships in Berlin is intended.

**Implementation:**
- Incentive programmes for the retrofitting of already existing passenger ships in Berlin: Funding of 50 % of the costs via UEP (Environmental Relief Programme for Berlin) is intended.
- Review on user benefits, such as benefits with regard to costs for berths or locks.

**Effect:**
Reduction of diesel soot emissions on waterways by about 0.5 t/a, which is equivalent to 15 % of the particulate emissions of Berlin shipping traffic.
M 2.9  Environmental standards for diesel locomotives

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<th>Timetable for implementation</th>
<th>Competent authority</th>
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<td>ongoing</td>
<td>SenStadtUm, VBB, Federal Government</td>
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<table>
<thead>
<tr>
<th>Potential for reduction</th>
<th>Costs</th>
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<tbody>
<tr>
<td>• approx. 4 t/a diesel soot</td>
<td>n.a.</td>
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<tr>
<td>• approx. 125 t/a nitrogen oxides</td>
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Diesel-powered rail systems (motor train units and locomotives) are crucial to regional transport in Berlin-Brandenburg, as some lines in Brandenburg are not fully electrified. These engines are often characterised by a high level of specific emissions, as the emission limit values have not been very demanding so far and the engines can attain a great age. In Berlin in 2009, about 5 t/a diesel soot and 250 t/a nitrogen oxides came from rail transport, and are not very likely to have decreased to a large extent since. Due to the reductions owing to the Low Emission Zone, the particulate emissions in rail transport per kilometre are thus higher than in road transport by now. The emissions deriving from rail transport, however, are usually better diluted, as only a few railways are bordered by buildings. They add to the increase of the pollutant level in the urban background, though.

As examples, especially in Switzerland have shown, diesel locomotives and diesel railcars can be retrofitted with particulate filters and nitrogen oxide reduction systems. In Germany, however, these systems have been applied only very sporadically. Within the European project ECORails102, the Senate Department for Health and Social Services developed proposals for environmental standards for the tendering of local rail passenger services. As the regional railway lines being subject to diesel locomotion are at all times organised jointly with other Federal States, especially jointly with Brandenburg, the environmental standards have to be agreed upon with these Federal States. That is why the Air Quality Plan Berlin cannot establish binding requirements in this case.

**Objective of the measure:**
A gradual reduction of the pollutant emissions by diesel locomotives and railcars through the use of new cars and retrofitting measures.

**Implementation:**
- Standards when tendering local rail passenger services: existing stock shall have at least the emission standard Stage III A, new vehicles the emission standard III B according to Directive 2004/26/EG. It shall be intended to retrofit or replace existing vehicles in stock.
- Towards the Federal Council, Berlin is going to campaign for the development and implementation of a national retrofitting strategy.

**Effect:**
About 5 t of diesel soot particles and 250 t nitrogen oxides annually derive from rail transport with none of the diesel engines presently utilised complying with the emission standard Stage III B. By retrofitting with a closed particulate filter, the particulate emissions can be reduced by up to 90 %. Retrofitting all diesel engines could thus prevent approximately 4 t/a of diesel soot emissions in Berlin. Indeed, retrofitting in order to reduce nitrogen oxide has only been tested to a limited extent yet, but is expected to have an efficiency of 50 % or more, which would equal an emission reduction of about 125 t NOx per year. Due to long-term contractual commitments, higher environmental standards in rail transport are only convertible in a slow manner when newly awarding contracts. That is why until 2015, only a part of the theoretically possible emission reduction can be attained. It would be more favourable if there were national requirements for retrofitting. However, if that was the case, such regulations would take effect only after 2015 due to the transition periods that are required for technological and economical reasons.

### M 2.10 Communication campaigns for the purchase of clean vehicles

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<tr>
<th><strong>Timetable for implementation</strong></th>
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<td>ongoing</td>
<td>SenStadtUm</td>
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<thead>
<tr>
<th><strong>Potential for reduction</strong></th>
<th><strong>Costs</strong></th>
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</thead>
<tbody>
<tr>
<td>n.a.</td>
<td>n.a.</td>
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</table>

Purchase decisions regarding very low in emission vehicles, as well as the environmentally sensitive use of vehicles require a sufficient supply of information and education for vehicle owners and users. Also, the automotive trade and motor vehicle industry play a major role in giving advice in terms of the purchase of clean vehicles or for the retrofitting of end-of-life vehicles. The current campaigns for “green cars” are often waged in a one-sided manner under climate protection viewpoints. In this respect, there arise opportunities to combine several environmental aspects and synergies. Thereby, in the future, information especially on the advantages of purchasing EURO 6 vehicles, natural gas vehicles and electric vehicles shall be provided and thus support the measures M 2.2 to M 2.4.

**Objective of the measure:**
Set-up of continuous counselling services for specific target groups.

**Implementation:**
- Cooperation with associations
- Target group specific campaigns: Already in 2001 was launched the EU-funded initiative “Clean Drive”\(^{103}\) that primarily addresses car dealers.

**Effect:**
The effect of such campaigns cannot be quantified directly, they rather promote the early purchase of low emission vehicles, which then shows up in registration statistics. The effect of the initiative “Clean Drive” has been calculated by the reduction of CO\(_2\) emissions with regard to the vehicle fleet sold by the participating dealers. This does not allow for drawing conclusions regarding potential emission reductions for NO\(_x\) and particulate matter in the road network, since to do so the driving performance would have to be known.

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\(^{103}\) [http://www.clean-drive.eu/](http://www.clean-drive.eu/)
9.2.2 Traffic control

M 2.11* Stabilisation

<table>
<thead>
<tr>
<th>Timetable for implementation</th>
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<tbody>
<tr>
<td>ongoing testing of the coordinates</td>
<td>SenStadtUm</td>
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<tr>
<td>Pilot project until end 2013</td>
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</tbody>
</table>

Potential for reduction
- locally approx. 10 % less emissions
- locally on average 2 µg/m³ less NO₂
- approx. 38 % less persons affected by NO₂ limit value exceedances

Costs
- approx. 5,000 € per fine modelling per section
- approx. 100,000 € for flanking studies
- approx. 5,000 to 25,000 € for adjustments of the traffic light systems per traffic intersection

Congestion and stop-and-go traffic lead to an increased emission level and thus higher air pollution on the affected road sections. One objective of traffic control measures is thus to stabilise the traffic flow, to reduce the share of times spend in congestion and to enable, where possible, a “green wave” for the majority of the traffic flow. Especially for the coordination of a “green wave”, however, the interests of all road users, that is pedestrians and cyclists, the local public transport and also the crossing motor traffic, have to be taken into consideration. Due to the limited geometric constraints, usually only one direction of travel can be duly coordinated, whereas in the opposite direction, according to the distance between the intersections, a degradation of the transport quality can occur. In order to prevent congestion, besides the optimal coordination of traffic light systems, traffic inflow control (e.g. a ramp meter) might also be required. Since when the capacity limitation is exceeded, that is when there is too high traffic volume in the upstream section, even an optimal coordination of the traffic light systems cannot prevent congestion. The effect of modified traffic light coordination on traffic flow and air quality has to be evaluated within fine modelling for the directly affected road section and for implicitly affected parts of the surrounding road network in order to avoid negative side effects or to minimise these to a tolerable level. The measure is closely linked to the measures M 2.12, M 2.13 und M 2.14.

Objective of the measure:
Reducing the shares of congestion, defined as share of the transport quality category (LOS) 4, in mileage performance with limit value exceedances in 2015.

Implementation:
- Testing of congestion prevention potentials for about 90 sections with NO₂ limit value exceedances. This includes among others fine modeling for selected sections, with sections without priority for public transport being preferably considered, as this makes the coordination easier.
- Pilot project regarding traffic inflow control and change of green-light time for the Schildhornstraße when there is the risk of imminent congestion due to expected transport growth after opening of the “Boulevard Berlin” in 2012. Within flanking studies, the transferability to other roads that are threatened by congestion shall be tested.
- Pilot projects for the examination of traffic avoidance potentials considering the priority of public transport for Potsdamer Straße and testing of transferability.

Effect:
The measure is only effective locally on the respective road section. Theoretically, assuming the objective of completely avoiding stop-and-go traffic, the attainable emission reductions locally and on average amount to 10 %, in reference to the total emission of the motor vehicle traffic only 0.2 %. Hence the NO₂ concentration decreased locally on average by 2 µg/m³ (max. 9.5 µg/m³) and the particulate matter concentration by 0.2 µg/m³ (max. 3.5 µg/m³). This reduces the number of persons affected by NO₂ limit value exceedances by roughly 38 % (particulate matter: circa 25 % less affected persons).

The measures marked with „*” were taken from the Urban Development Plan Traffic 2025.
M 2.12*  City-compatible speed level in main roads

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<tr>
<th>Timetable for implementation</th>
<th>Competent authority</th>
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<tbody>
<tr>
<td>ongoing</td>
<td>SenStadtUm, VLB [traffic management Berlin], Boroughs (set-up of traffic signs)</td>
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<table>
<thead>
<tr>
<th>Potential for reduction</th>
<th>Costs</th>
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<tbody>
<tr>
<td>• decrease of the local incremental pollution: -15 % NO&lt;sub&gt;2&lt;/sub&gt; and -30 % particulate matter;</td>
<td>• approx. 10,000 € per road section for the installation</td>
</tr>
<tr>
<td>• locally up to 2 to 3 µg/m³ less NO&lt;sub&gt;2&lt;/sub&gt; and particulate matter PM&lt;sub&gt;10&lt;/sub&gt;</td>
<td>• 100,000 € for flanking studies</td>
</tr>
<tr>
<td>• up to approx. 40 % less affected persons by limit value exceedances (PM&lt;sub&gt;10&lt;/sub&gt; and NO&lt;sub&gt;2&lt;/sub&gt;)</td>
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The strategy of a sustainable urban mobility speed level that has been successful in Berlin for years, such as Tempo 30, with the objective of improving road safety also serves the reduction of air and noise pollution. This strategy shall be further developed according the requirements of road safety, noise reduction and air pollution control (“Stadttempo Berlin”). Impact and efficiency of speed limits in the main road network shall be checked regularly.

The analysis of the Tempo 30 measure on a main road in the area of an air quality monitoring station has shown that by means of this measure, the local, traffic-related incremental pollution for NO<sub>2</sub> can be reduced by up to 15 % and for particulate matter PM<sub>10</sub> by up to 30 %, provided that suitable boundary conditions are given. These include a steady traffic flow with minimal congestion and sufficient control. Besides a reduction in air pollution, by means of an adjusted speed in the city is also attained a noise reduction of up to 3 dB(A).

Tempo 30 speed limits are thus not scheduled for the whole network, but rather have to be synchronised with the requirements of an efficient main road network, especially with the interests of the local public transport as well in order not to dampen its appeal. Furthermore, the traffic shall not be displaced to other areas that are likewise worth protecting or even to the minor road network.

Objective of the measure:
Introduction of city-compatible speed levels on main road sections that are expected to have NO<sub>2</sub> limit value exceedances still in 2010, inasmuch as a largely steady traffic flow is ensured and the interests both of the local public transport and other road users are sufficiently considered.

Implementation:
- Ordinance of speed limits in order to reduce the air and noise pollution on a case-by-case basis.
- Promotion of and involvement in initiatives for the locally targeted reduction of the inhabited area speed on national level.

Effect:
For the affected road section, the local incremental pollution can be reduced by up to 15 % for NO<sub>2</sub> and up to 30 % regarding particulate matter. The impact on the total pollution by NO<sub>2</sub> and PM<sub>10</sub> depends on the pre-pollution. Assuming optimal conditions, the number of affected persons by limit value exceedances both for PM<sub>10</sub> und NO<sub>2</sub> can be reduced by about 40 % by means of speed reductions.
M 2.13* Environmentally sensitive transport management

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<th>Timetable for implementation</th>
<th>Competent authority</th>
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<tr>
<td>ongoing</td>
<td>SenStadtUm, VLB</td>
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<thead>
<tr>
<th>Potential for reduction</th>
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<tbody>
<tr>
<td>locally and temporily medium to high</td>
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<table>
<thead>
<tr>
<th>Costs</th>
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<tbody>
<tr>
<td>Costs for set-up/installation, not yet quantified</td>
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<tr>
<td>approx. 100,000 € for flanking studies</td>
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</table>

In order to reduce concentration peaks due to a high traffic volume with unfavourable meteorological conditions at the same time, traffic management measures (adjusted traffic control programs for traffic light systems, informing the road users of by-pass options) shall be used in particularly affected road sections. For this purpose, the traffic information centre is currently about to implement a forecasting tool in order to calculate and forecast the air pollution within the upcoming hours on the road network by means of traffic, meteorological and air quality data. In case limit values are exceeded, the traffic management programs developed for this purpose shall be operated and the road users shall be informed via indicator panels in public roads as well as via internet and radio.

**Objective of the measure:**
Set-up of an environmentally optimised traffic management, i.e. for Frankfurter Allee or Invalidenstraße, in order to meet the NO₂ limit value and to reduce the daily PM₁₀ limit value exceedances from 2015. Testing the transferability to other highly polluted road sections.

**Implementation:**
- Installation of the required hard- and software for the control has already been launched by placing of an order for the set-up of a traffic information centre.
- Development of the required traffic signal control plans and implementation.
- Examination of the traffic control strategy effect and the transferability to other highly polluted road sections.

**Effect:**
The emission reducing effect strongly depends on to what extent congestion and traffic volume can be reduced. Assuming complete congestion avoidance with a decrease in traffic volume of 10 %, for Frankfurter Allee an emission reduction in considered road sections by up to 26 % in nitrogen oxides and 35 % in soot particles is shown. This, in proportion to traffic volume high emission reductions, results from the thus attainable congestion avoidance. The impact on the total pollution due to NO₂ und PM₁₀ depends on the pre-pollution.
### M 2.14* Concepts for events and incidents

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<tr>
<th>Timetable for implementation</th>
<th>Competent authority</th>
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<tbody>
<tr>
<td>from now on</td>
<td>SenStadtUm, Boroughs, BWB, Vattenfall, GASAG, Organisers</td>
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<table>
<thead>
<tr>
<th>Potential for reduction</th>
<th>Costs</th>
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<tr>
<td>locally and temporarily</td>
<td>n.a.</td>
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<td>medium</td>
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Huge events with road closures or high traffic volume can locally cause increased air pollution due to additional congestion. Moreover, considerable disruption potential for the traffic flow is caused by construction sites and traffic disruptions that are due to Berlin being the capital, which cannot be influenced by environmental law or traffic management (demonstrations, state visits, etc.), as well as by accidents. As a result, the transport quality on the affected sections and relevant roads running parallel is considerably impaired. This does not only go along with increased pollutant emissions, but also with an increased energy and fuel consumption, increased risks of accidents, unreliability and unpunctuality of the local public passenger transport and also longer journey times and loss of convenience with a negative impact on economic development, urban qualities and quality of life. By means of suitable traffic control measures, these additional burdens shall be reduced.

In order to reduce disruptions owing to construction sites, it is intended to reduce the duration of the construction works. By further developing the construction site coordination, events shall be combined, if possible, in order to minimise traffic restrictions.

**Objective of the measure:**
Reduction of congestions due to huge events and incidents (Action Plans).

**Implementation:**
- Further development of the control strategies tested within the pilot project iQMobility.
- Set-up of a disruption and congestion management.
- Set-up of an information and incident management for the transport to the future international airport Schönefeld (AIRVIS).
- Extension of the traffic information panels.
- Further development of construction site coordination.
- Testing if information concepts for organisers of huge events can contribute to the reduction of traffic volume and if applicable, to the development of planning aids.

**Effect:**
On the day of the huge event, emissions can be locally avoided to the extent that it is possible to prevent congestion.
**M 2.15**  Traffic control concepts for transit traffic of heavy goods vehicles

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<th>Timetable for implementation</th>
<th>Competent authority</th>
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<tr>
<td>ongoing</td>
<td>SenStadtUm, Federal Government (truck toll)</td>
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<table>
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<tr>
<th>Potential for reduction</th>
<th>Costs</th>
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<tr>
<td>locally low to medium</td>
<td>without cost approach</td>
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A quantification of the large-scale heavy truck transit traffic via the urban motorways of Berlin is not possible at present, as the respective data basis does not yet exist. It is assumed that during off-peaks, the marginally shorter run via the urban motorway and thus through the city is preferred to the Berlin outer ring. During rush hours, the traffic volume and the resulting losses of time are so high that this should not constitute an attractive option. Within the implementation of the StEP Traffic 2025 are thus planned respective examinations regarding the transit traffic of trucks. In this respect, it shall be tested, among others, to what extent the urban motorway meanwhile passing from Kreuz Oranienburg to Kreuz Schönefeld is used as abridgment by trucks in order to reduce the toll costs. The reduction of costs, depending on emission standard and number of axles of the truck being subject to toll, amounts to approximately between 3.90 to 7.25 € per transport way, as the way through Berlin is about 25 km shorter than the comparable connection via the Northern and Eastern Berlin outer ring/A 10.

Further, due to its economic structure, Berlin is target but also source of numerous supply trips. The pollution in the subordinate road network thus primarily results from the terminating journeys in the urban area. Questions deriving from this circumstance have to be compensated with the other scopes of measures.

**Objective of the measure:**
Testing of truck transit traffic share via the urban motorway and testing of probable displacement potential to the Berlin outer ring. Is must be ensured that potential measures do not counteract the objective by unnecessarily shifting the truck transports to the urban road network.

**Implementation:**
- Adjustment of the road guidance with orientation towards the Berlin outer ring.
- Traffic telematics.
- Reorganisation of the superior road network in the inner city.
- Road construction measures in the course of the “Mittlerer Ring” (further extension of the A100).
- Road construction measures in order to relief residential areas.
- Testing if the truck transit traffic on the A100 can be reduced by means of an amendment of the toll regulation (temporal and spatial toll differentiations) without displacement into the subordinate urban road network; possibly initiation of an initiative in the Federal Council.

**Effect:**
This measure targets the displacement of traffic flows, so that emissions are basically only dislocated, but not avoided. Usually, the relief effect thus merely occurs on local level, minor reduction potentials only arise due to changed driving profiles (more constant and efficient speed profiles when using the motorway A10). Potential additional traffic loads at other locations have to be examined in detail and analysed as regards their impact.
M 2.16*  Environmentally sensitive traffic control concepts related to the urban traffic

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<tr>
<th>Timetable for implementation</th>
<th>Competent authority</th>
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<tr>
<td>ongoing</td>
<td>SenStadtUm</td>
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Potential for reduction: locally low to medium  Costs: without approach

A quantification of the transit traffic running through the Berlin inner city is difficult. Certain individual areas will always be subject to transit traffic, for instance through single districts, due to the urban terminating traffic. In the Urban Development Plan Traffic different measures for the reduction of transit traffic through urban quarters, urban districts or individual areas, whose implementation is also significant to air quality management, are thus included. However, when displacing traffic, for example, the impact on the air pollution of the by-pass routes must also be assessed. Provided that displacements of transit traffics through districts by means of new road links construction such as the extension of the A100 or the Eastern tangential connection shall be implemented, the potential emergence of new traffics has to be considered in the assessment.

Objective of the measure:
Reduction of the traffic (particularly heavy goods vehicles) in sensitive areas (such as residential areas, urban district centres, inner city), without the emergence of new limit value exceedances on other road sections. Given the case that this is inevitable, for instance on new motorway sections or new main roads, compensatory measures have to be set in the planning permission resolution.

Implementation:
- Reorganisation of the main road network in the inner city
- Adjustment of the road signing
- Traffic telematics
- Modification of traffic signal coordination
- Road construction measures in the course of the “Mittlerer Ring” (further extension of the A100)
- Road construction measures in order to relief residential areas

Effect:
This measure targets the displacement of traffic flows, so that also emissions are basically only dislocated, but not avoided. Usually, the relief effects thus merely occur on local level. Potential additional traffic volumes at other locations have to be examined in detail and analysed with regard to their impact. This contrasts with the situation of newly constructed roads such as the extension of the A100 that serve a pooling of traffic, however, with high pollution levels being possible on these roads. This requires an assessment within the planning permission.
M 2.17*  Reorganisation of coach traffic

<table>
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<tr>
<th>Timetable for implementation</th>
<th>Competent authority</th>
</tr>
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<tbody>
<tr>
<td>from 2012</td>
<td>SenStadtUm (StEP measure), Boroughs (among others public order offices)</td>
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<table>
<thead>
<tr>
<th>Potential for reduction</th>
<th>Costs</th>
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</thead>
<tbody>
<tr>
<td>locally low to medium</td>
<td>• approx. 70,000 € for concept development</td>
</tr>
<tr>
<td></td>
<td>• approx. 500,000 € for implementation in the Museum Island area</td>
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</table>

Tourism is a relevant economic factor for Berlin, being of increasing importance. This also results in an increase in coach traffic, which is an important mainstay of tourism, but can locally cause usage conflicts and environmental pollution. The objective of this measure is thus definitely not to fundamentally reduce the coach traffic, but to turn it to be more compatible with the city and the environment.

A high volume of coaches at attractive tourist destinations (such as the Museum Island area) and urban locations with a number of hotels can locally lead to high contributions to pollution due to these vehicles. A differentiated analysis of the model calculations for a random sample of road sections showed contributions to the traffic-related local incremental pollution in public road space made by coaches of up to 17% of diesel soot and up to 15% of nitrogen oxide. In addition, obstructions due to halting coaches in order for passengers to get in and out can cause traffic disruptions that in turn lead to increased pollutant emissions of the traffic. The model calculations do not consider emissions that arise from the halting for a long period with the engine running, which is commonly observed with coaches. This is often justified with the operation of the air conditioning – nevertheless, keeping the engine running is legally not permissible. In the Air Quality Plan for London, this issue is addressed in an exemplary manner by requiring a significant increase of the fine from 10 to 120 £ and reinforced controls.

**Objective of the measure:**
Reduction of the contribution to air pollution from coaches by developing and implementing a coach concept for the entire urban area taking into account the interests of air pollution control (and noise protection) and measures against the impermissible running of the engine when standing.

**Implementation:**
- Development of a coach concept, prioritizing the inner city with focus on the Museum Island, among others for the improved coordination of transfer and collection journeys and organisation of parking coaches
- Parking space information about major parking facilities including coaches
- Promotion of the efficient handling of traffic (flowing and stationary coach traffic) by means of communication measures such as the “BusStop” Berlin (prevention of traffic searching for a parking space, indication of stops reserved for buses)
- Site investigation for a second central bus station
- In order to reduce the emissions resulting from non-authorised running of engines, as a first step an awareness campaign for drivers under involvement of associations is envisaged, as a second step a reinforced control on the part of public order offices.

**Effect:**
The measure allows local relief effects in areas having a high volume of coach traffic by means of primary (directly applied to the coach) and secondary (having an impact on the rest of the traffic) effects.
### 9.2.3 Traffic displacement and prevention

**M 2.18** Promotion of the ÖNPV

<table>
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<th>Timetable for implementation</th>
<th>Competent authority</th>
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<tbody>
<tr>
<td>ongoing</td>
<td>SenStadtUm, VBB, BVG, S-Bahn Berlin GmbH, DB, other providers of the ÖPNV</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Potential for reduction</th>
<th>Costs</th>
</tr>
</thead>
</table>
| for the whole urban area high, not further quantified | • Finance volume ÖPNV Berlin approx. 800 Mio. € in 2010, 835 Mio. € are planned for 2014\(^{106}\)  
• Additional needs for acceleration of ÖPNV approx. 27 Mio. € |

An attractive supply of local public passenger transport services (ÖPNV) is essential in order to be able to further decrease, according to the objectives of the StEP Traffic, the low degree of motorisation attained in Berlin and the contribution of the motorised private transport to the 32 % modal share of journeys, which is very low compared to other cities. The ÖPNV contributes to the clean air management by preventing car journeys and the resulting emissions. In this respect, the electrically operated rail traffic is a particularly clean mode of transport, whereas buses have to comply with sufficiently demanding emission standards in order to avoid air pollutants in relation to the fleet standards of the motor vehicle transport.

The efficiency and attractiveness of the ÖPNV has been improved for buses and tramways by means of a „bus priority system“. By means of the creation of new pilot lines shall be tested an integrated approach for acceleration, considering measures as regards distance, stops and traffic lights. Further measures for the promotion of the ÖPNV were implemented within the local transport plan for Berlin 2006-2009 [Nahverkehrsplan]. This includes for instance standards in terms of punctuality, connection synchronisation and accessibility of centres. The plan is currently being updated for the period 2018, basing among others on its cornerstones as regards the local transport that already been approved by the house of representatives [Abgeordnetenhaus]. By means of the new Urban Development Plan Traffic 2005, a number of further measures intended to enhance the attractiveness were voted passed and shall be gradually implemented within the future years.

**Objective of the measure:**
Ensuring attractive, environmentally friendly local public passenger transport services in order to increase, jointly with pedestrian and cycle transport, the share of the ecomodes in the modal split of journeys in the whole urban area and in commuter traffic.

**Implementation:**
The StEP Verkehr 2025 (Urban Development Plan Traffic) and the Nahverkehrsplan Berlin (local transport plan for Berlin) contain numerous measures promoting the ÖPNV. This can be additionally enhanced by the following activities:

- Initiatives on national level in order to ensure the financing of the ÖPNV and the public regional transport by means of respective orders of the environmental committees (Conference of Environmental Ministers, Bund-Länderausschuss Immissionsschutz)
- Further development of the acceleration programme for buses
- Communication campaigns

**Effect:**
By relocating motor vehicle journeys to the ÖPNV, pollutant emissions can be avoided, the emissions by the ÖPNV (buses) being considered in the balance. The importance of the ÖPNV is exemplarily shown, when the services are drastically limited due to strikes or technical problems. An evaluation of traffic data during a strike by the BVG in spring 2008 have shown an increase of the motor vehicle transport of 7 to 12 %, associated with an increase in particulate emissions of 2 to 9 %. The nitrogen oxide emissions, however, only increased at locations where there is no bus service, whereas on routes with bus transport, the surplus of emissions due to the automobile traffic was compensated owing to the omission of emissions by buses/because there were no emissions by buses.

\(^{106}\) Berlin House of Representatives, official documents Nos. 16/2772 and 16/3370: Eckpunkte für den Nahverkehrsplan 2010-14 (Key Points of the Local Transport Plan 2010-2014. Decision dated 01.07.2010.)
Promotion of pedestrian and cycle traffic

Walking and cycling are the only main transport modes not emitting air pollutants due to combustion processes. The replacement of motor vehicle journeys by pedestrian and cycle transport thus contributes to the clean air management. In Berlin, about 28% of all motor vehicle journeys made by the Berlin citizens (i.e. without commuters) were shorter than 3 km, roughly 50% shorter than 6 km and approximately 70% shorter than 10 km in 2008. Such distances are certainly suitable for being shifted to non-motorised modes of transport, provided that this is possible in an attractive manner, i.e. particularly safe, comfortable and without detours. Since by bicycle much longer distances can be travelled than by foot in the same period of time, by promoting the cycle traffic, higher reductions in emissions are achievable. Interesting new potentials arise from electric bicycles, since those on the one hand increase the operating radius, and on the other hand address new circles of users, for instance less sporty persons.

When going by bicycle, local dust emissions – primarily on unpaved or usually waterlogged cycle paths when they are dry – can come up due to the re-suspension of coarse particles (> 2.5 µm). There are, however, no quantitative studies of these particles, but they are easily visible and can bother other cyclists and pedestrians. For this reason, from the clean air management perspective, asphalt covers are generally preferable, as they ensure the highest ride comfort with minor dust re-suspension. Contrary to common notions, as studies revealed, asphalt covers are even more favourable regarding water management than unpaved or usually waterlogged cycle routes, since after set-up, those are subsequently sealed due to riding on them, which results in the fact that the water absorption of the whole path structure is less favourable than in terms of asphalt, concrete or paving stone covers. However, due to their low ride comfort and a significantly higher rolling resistance and thus losses in terms of attractiveness, paving stone covers are less advisable.

Objective of the measure:
Achievement of a 75% share of the ecomodes in relation to 25% of motorised individual transport in the whole urban area, with a higher share of cycle traffic compared to the present share.

Implementation:
Der StEP Verkehr 2025 enthält zahlreiche Maßnahmen zur Förderung des Fuß- und Radverkehr. Dazu gehören:

- Implementation of the “Berliner Fußverkehrsstrategie” [pedestrian traffic strategy for Berlin]
- Update and implementation of the “Berliner Fußverkehrsstrategie” including among others the following measures:
  - Retention, maintenance and extension of the bicycle facilities as a comfortable, dense, comprehensive and safe network using reliable and cost-effective components such as cycle lane markings, the opening of one-way roads and bicycle streets
  - further extension of the intermodal connection with the local public passenger transport (ÖPNV)
  - further extension of bicycle parking facilities
  - target group orientated communication campaigns
  - Adjustment of bicycle facilities to a higher number of users and higher speeds by means of electric bicycles
- In the Federal Council, Berlin is going to campaign for the maintenance of financing instruments and financial resources for cycle transport by the Federal Government.

Effect:
The potential reduction of air pollutants can be estimated by means of the statistics regarding the length of distances travelled by the motorised private transport by displacing distance-related proportions to the non-motorised transport. For this assessment of the potential it was assumed that 50% of the journeys up to 3 km, 30% of the journeys up to 6 km. 15% of
the journeys up to 9 km, 10 % of the journeys up to 12 km and 3 % of the journeys of more than 12 km are displaced. Using the average emission factor for motor vehicles for the urban traffic in the reference year 2015, thus arise emission reductions of approximately 8 t/a of diesel soot, 36 t/a of particles from abrasion and re-suspension and 413 t/a of nitrogen oxides. This equals a reduction rate of 10 to 13 % referred to the urban motor vehicle emissions. The effect on the air quality has not been determined, since this would require complex modelling in order to figure out at which locations in the road network motor vehicle journeys are omitted.

Source: Mobilität in Städten – SrV [Mobility in Cities – SrV].

M 2.20*  Parking area management

<table>
<thead>
<tr>
<th>Timetable for implementation</th>
<th>Competent authority</th>
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<tbody>
<tr>
<td>until 2015</td>
<td>SenStadtUm, Boroughs</td>
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<table>
<thead>
<tr>
<th>Potential for reduction</th>
<th>Costs</th>
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</thead>
<tbody>
<tr>
<td>not quantified</td>
<td>to a great extent cost-neutral for administration</td>
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</table>

Parking area management decreases air pollution by reducing the traffic in search for a parking space and supports the switch-over of commuters to ecological transport modes. Especially the motor vehicle terminating traffic can be diminished that way.

Within the ongoing project “Masterplan Parken Berlin” [master plan for parking in Berlin], the “regional scenario for potential extensions” that is roughly shown in the Urban Development Plan Traffic is examined in further detail. The objective is to achieve a considerable extension of the parking space management, particularly in the inner city, until 2015. Beyond, it is intended to adopt regulations for the limitation of additional private parking space facilities within construction projects. The essential objectives of this “parking space limit ordinance” are the usage-dependent limitation of the new construction of parking facilities in the central urban area to the required level and also the limitation of the additional motor vehicle volume on main roads and the related impairments for the environment and residential areas.

**Objective of the measure:**
The STEP Traffic intends to expand the parking space management to all inner city target areas of the motor vehicle traffic having a strong demand for parking space and competition for uses and also to the adjacent residential areas.

**Implementation:**
The extension and further development of the parking space management takes place in cooperation with the Berlin districts.

**Effect:**
The sensitivity analyses of the forecasts for the whole traffic in Berlin-Brandenburg have shown a decrease in the traffic performance in passenger transport when extending the parking space management. The effect, however, depends on the spatial expansion and disposition of the areas subject to management and the amount of the parking fees. A modelling of the effect on the emission and air pollution on main roads is thus only possible after elaboration of the “Masterplan Parken Berlin”.

Mobility management

<table>
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<th>Timetable for implementation</th>
<th>Competent authority</th>
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<tbody>
<tr>
<td>from 2012</td>
<td>SenStadtUm as initiator</td>
</tr>
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<table>
<thead>
<tr>
<th>Potential for reduction</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>not quantified</td>
<td>open, Costs for development and implementation of campaigns</td>
</tr>
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</table>

The improvement of the infrastructure and the supply for ecological means of transport are not self-sufficient to induce a change in travel behaviour. The mobility management’s objective is to influence the transport demand and especially the choice as regards means of transport towards a stronger use of the ecomodes by means of information, organisation, communication and coordination measures. Especially in recent years it has became clear, that newcomers to Berlin show a distinctly different behaviour and also retain this. Beyond this, when getting older the question arises concerning the participation in traffic, which depends on personal conditions (place of residence, possession of a driver’s licence, physical and financial capabilities). In this respect, within the implementation of the Urban Development Plan 2025 shall be developed a strategy supporting the mobility management as target group specific mobility advisory (commuters, senior citizens, newcomers to Berlin, relocating persons). The largest reduction effect can be attained by means of mobility management in companies, enterprises, authorities etc., since on the one hand, the motorised private transport (as self-driver) continues to be dominant in commuter traffic, and on the other hand, the accessibility to a target group with fixed start-destination-relations is provided. In addition, particularly in the corporate mobility management can be developed potentials as regards occupational journeys, which are both economically efficient to the companies and at the same time also stimulate improvements in terms of traffic and emissions in the whole system.

Mobility management is not only important to the clean air management, but is also part of measures within the Noise Reduction Plan Berlin.

**Objective of the measure:**
Reduction of the motor vehicle traffic by avoiding or shortening journeys and by relocating to the ecological means of transport.

**Implementation:**
Der Lärmaktionsplan enthält bereits folgende Vorschläge für die Förderung von Mobilitätsmanagement:

- Implementation of pilot projects having different structures and operational frameworks, such as public administration, industrial companies, industrial parks (pool solutions), hospital, educational institutions
- Implementation of a widely reported information campaign (target group companies), for instance in connection with VBB (traffic association Berlin-Brandenburg), industrial associations
- Implementation of a widely reported information campaign (target group employees)
- Publishing of action guidelines for different target groups
- Implementation of pilot and image campaigns
- Implementation of measures in the own administration (departments)

Respective pilot projects have partially already been implemented in Berlin companies and authorities and thus illustrated the high existing reduction potentials. This has to be taken into account.

The StEP Traffic 2025 provides apart from the promotion of the corporate mobility management also measures for target group specific mobility advisory (also multilingual) for senior citizens, persons moving to Berlin or changing their domicile and persons from a migrant background.

Essential actors are companies, the residential housing industry and providers of transport services.

**Effect:**
Impact studies of measures regarding the corporate mobility management have shown that a 20 % reduction of the motorised private transport share in commuter traffic to particular companies is possible. Partly considerable reduction potentials also exist with regard to occasional journeys, with the tangible extent strongly depending on the economic activity.
**M 2.22* Promotion of car-sharing**

<table>
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<tr>
<th>Timetable for implementation</th>
<th>Competent authority</th>
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<tbody>
<tr>
<td>from 2011</td>
<td>Boroughs, SenStadtUm</td>
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<table>
<thead>
<tr>
<th>Potential for reduction</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>not quantified</td>
<td>Boroughs: administrative expenses, signposting</td>
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</table>

Car-sharing makes it easier to decide not to purchase a personal car and leads to a more conscious choice regarding means of transport with a higher share of journeys within the ecomodes. As yet, there have been 219 car-sharing stations by 6 providers in Berlin that are to a great extent concentrated on the inner city area.

Entering the market are flexible car-sharing offers without fixed stations, which are first of all initiated by large automobile companies (“Drive Now”, “car2go” among others), in part connected with the introduction of electric vehicles.

**Objective of the measure:**
- Provision of approx. 1,000 spaces for car-sharing vehicles
- Promotion of the introduction of car-sharing systems (depending on the experience)

**Implementation:**
- Development of a guideline for the responsible districts
- Promotion of Federal State initiatives on a national level for a draft legislation on national level regarding the modification of the StVG [road traffic act] and StVO [road traffic regulations] that opens the possibility for the local authorities to establish car-sharing spaces in public road space and creates a uniform framework on the national level for the marking of the spaces and vehicles as well as for charging.
- Implementation of associated studies on the (environmental) effects of flexible car-sharing systems
- Set-up of a charging infrastructure for electric vehicles within the car-sharing fleet

**Effect:**
A car-sharing vehicle replaces on average 5 to 7 private cars. The usage-based and transparent billing (a combination of kilometre and time-dependent fees) brings about a distinctly more conscious usage, i.e. lower motor vehicle mileage and thus a reduction of pollutant and noise emissions. A tangible quantification of the effects is complex and has not been performed so far.

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The commercial vehicle transport highly contributes to the air pollution. In this respect, light commercial vehicles cause higher shares of traffic-related incremental PM$_{10}$ pollution than heavy commercial vehicles, as the contribution due to re-suspended particles is higher since the mileage shares of light commercial vehicles is higher. Regarding nitrogen oxides, heavy commercial vehicles are dominant owing to their high vehicle-specific nitrogen oxide emissions.

By means of updating the integrated economic concept that is included in the Urban Development Plan StEP 2025 shall be developed approaches that are scheduled to reduce these pollutions as well. By a number of measures the grounds for a city-compatible goods transport shall be elaborated and the tangible implementation shall be pushed by the respective participants (i.e. Federal State of Berlin, boroughs, companies). This includes for instance the reduction of heavy goods vehicle transit traffics, route concepts for trucks in order to relief particularly sensitive areas, the displacement from transport on roads to rail and waterways or an integrated land use planning when dealing with companies causing a high amount of traffic.

**Objective of the measure:**
Reduction of the air pollution by commercial transport.

**Implementation:**
Within the implementation of the StEP Traffic 2025 is just being revised the integrated economic concept, which is expected to be accomplished by 2014. Measures, that are both city-friendly and compatible with business interests, intended to reduce the emission of pollutants constitute a significant emphasis of the concept and are agreed upon in the course of a participatory procedure (among others Senate Departments, boroughs, chambers and associations).

The following measures are supposed to be tested within the concept development:

- Transport concepts for the sites/locations mentioned in the Urban Development Plan (StEP) Commerce and Industry
- Maintenance of the rail sidings and water supply for the commercial transport
- Control concepts for the possible concentration of heavy goods vehicle traffic to less congested routes
- New city-friendly concepts for supply and disposal (urban logistics, alternative propulsion systems, the use of off-peak hours)
- Set-up of an urban and regional information system for the commercial transport

**Effect:**
Tangible effects cannot be estimated yet since the approaches and measures are being elaborated and agreed upon at present. Particularly by the possible displacement of individual traffics from the road to railway or waterway transport, considerable relief effects can be attained on local level.
9.2.4 Infrastructure

M 2.24 Rehabilitation of road surfaces

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<th>Timetable for implementation</th>
<th>Competent authority</th>
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<tr>
<td>ongoing</td>
<td>SenStadtUm, Boroughs</td>
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<table>
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<tr>
<th>Potential for reduction</th>
<th>Costs</th>
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<tbody>
<tr>
<td>locally, primarily less particulate matter from abrasion and re-suspension (not quantified)</td>
<td>only quantifiable after testing of the individual case</td>
</tr>
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</table>

The condition of the road surface affects the particle formation due to abrasion and re-suspension. On the average about 14% of the PM$_{10}$ pollution originates from this source. Given a bad roadway condition with mainly cracked or holey road surfaces or with paved surfaces, these particle emissions, however, can be twice to five times higher than with roads having a smooth asphalt surface in good condition/state. For this reason, already the executed rehabilitations of damaged asphalt road surfaces or the exchange of random paving – funded within the governmental economic recovery plan “Konjunkturprogramm II” [Economic Recovery Plan] – for grounds of noise control (and the road infrastructure retention and road safety) also made contributions to air pollution control. The same applies to the plan intended to rehabilitate potholes by the Senate Department for Urban Development and the Environment Berlin. Both activities shall be continued also for grounds of air pollution control.

The use of road surfaces that were subject to a treatment for the drawdown of nitrogen oxides with photoactive titanium dioxide particles (TiO$_2$) is still in experimental stage. To this end, projects are being performed at the Federal Highway Research Institute [Bundesanstalt für Straßenwesen]. Thus the use cannot yet be recommended.

Objective of the measure:
Reduction of particle emissions by abrasion and re-suspension by means of rehabilitation of damaged roads with priority to the road sections where PM$_{10}$ limit value are exceeded.

Implementation:
- Coordination with road renovations within the Noise Reduction Plan: all road sections showing PM$_{10}$ limit value exceedances are likewise subject to a higher noise pollution.
- Coordination with the boroughs when selecting road sections that are given priority in terms of maintenance/renovation.
- Evaluation of the results of projects for the use of TiO$_2$ (titanium dioxide) in road surfaces as regards the reduction potentials, taking into account the durability and costs and also excluding health and ecological risks (e.g. by the abrasion of nanoparticles).

Effect:
The processes of particulate emissions due to abrasion and re-suspension are largely unknown so far and can only be modelled with significant uncertainties. A quantification of the effect is thus problematic. The largest effect owing to road pavement rehabilitation was reported from the city Nauen in the Federal State Brandenburg$^{110}$, where the traffic-related incremental pollution by PM$_{10}$ was halved by means of road surface rehabilitation. The effect on the PM$_{10}$ pollution concentration depends on the share of this source in the total PM$_{10}$ pollution. It is anyway limited to local contexts, since due to their size (mostly several micrometers or even bigger than 10 $\mu$m), the particles from abrasion and re-suspension are not transported over such great distances in the atmosphere as the much smaller diesel soot particles. Thus the effect of rehabilitating roads should be measured by means of selected model distances in order to be able to evaluate this measure in a more detailed way for further planning.

### M 2.25 Redistribution of public road space

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<th>Timetable for implementation</th>
<th>Competent authority</th>
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</thead>
<tbody>
<tr>
<td><strong>Potential for reduction</strong></td>
<td><strong>SenStadtUm, Boroughs</strong></td>
</tr>
<tr>
<td>locally 5 to 10 % of the incremental pollution</td>
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<table>
<thead>
<tr>
<th>Costs</th>
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<tbody>
<tr>
<td>• approx. 50,000 € and more per section for construction works</td>
</tr>
<tr>
<td>• approx. 10,000 € per section for modelling</td>
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</table>

The action strategy of redistributing public roads originates from the Noise Reduction Plan Berlin\(^{111}\). It intends for the start to extend the distance between road traffic and the housing on roads by up to 3 m, in order that the vehicle emissions can be better diluted until they reach the housing. Additionally, this generates more space for the non-motorised transport and where applicable for the local public passenger transport (bus line) and thus increases the attractiveness of the means of transport provided by ecomodes. Qualified are roads with multiple lanes that can also handle the traffic volume with a lesser number of lanes that are concentrated in the middle of the street canyon. The redistribution of roads is also possible on locations where traffics can be relocated by newly constructing main road connections (e.g. after extension of the urban motorway A100). The limit of the possible traffic performance in case of extending a four-lane road to a two-lane road (with an extra wide lane each direction) amounts to approximately 18,000 to 20,000 vehicles per day.

Figure 9.1: Brandenburgische Straße, Hohenzollerndamm to Berliner Straße: the left side shows the spatial road distribution before implementing the measure and the right side shows the spatial road distribution after implementation of the measure [Noise Reduction Plan Berlin 2008]

**Objective of the measure:**
Further development of measures regarding road space included in the noise reduction planning in order to reduce the air pollution of residents in highly polluted main roads.

**Implementation:**
- Micro-scale modelling of the air pollutant concentration for a modified road section within the Noise Reduction Plan using the traffic-related data collected within the flanking studies and derivation of the reduction potential.
- Evaluation of the air-hygienic reduction potential for potential qualified roads that were identified within the course of the current updating of the Noise Reduction Plan.

**Effect:**
It has not been possible to carry out micro-scale modelling for the model sections mentioned above yet. Micro-scale modelling for other road sections, such as for Frankfurter Allee at the same height as the monitoring station, have shown that when extending the distance to the source of emissions by 2 to 3 m, a decrease of the local traffic-related incremental pollution in the area of the footpath resp. house front of about 5 to 10 % is to be expected.

M 2.26  Promotion of public means of transport that are low in emissions on local level by maintenance and extension of local rail passenger transport lines (in particular tram lines)

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<th>Timetable for implementation</th>
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<tr>
<td>ongoing</td>
<td>SenStadtUm</td>
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**Potential for reduction**
local nitrogen oxide reductions when replacing bus journeys/lines, not quantified

**Costs**
n.a.

Buses considerably contribute to the nitrogen oxide air pollution on lines with a high share in local traffic due to their diesel engines, since relatively modern buses with the emission standard EURO 5 still show a high level of nitrogen oxide emissions. Even regarding the bus fleet 2015, buses cause up to 28% of the traffic-induced local NO₂ incremental pollution as shown by model calculations. Tramways in contrast have as advantage in that they hardly cause local air pollutants when being operated (only abrasion of tracks and current collectors). Indeed, emissions arise depending on the way of producing electricity, however, only make their contribution to the general rather than local air pollution and are better diluted. Provided that tram lines exist or are subject to extension, it should thus be examined if there are possibilities to make reductions in bus transport. Replacing existing tram lines should also be avoided, or at least the effects on the air quality should be considered when planning to do so.

**Objective of the measure:**
Extension of the electrically operated local rail passenger transport in order to avoid nitrogen oxide emissions by buses.

**Implementation:**
The projects to extent the local public rail passenger transport which were agreed within the coalition agreement of the SPD/CDU senate should be implemented as soon as possible on grounds of air pollution control. These are the following:

- Road connecting Nordbahnhof (Northern railway station) and Hauptbahnhof (central station)
- Bridging the gap of the metro line U5 from Alexanderplatz to Hauptbahnhof
- Planning and construction of the S-Bahn line S21
- Construction of the new tram line from Alexanderplatz to Kulturforum (after completion of the metro line 5)
- Construction of the new tram line from Hauptbahnhof to Turmstraße
- Construction of the new tram line from WISTA to Sterndamm/Schöneweide
- The tramway connection of Ostkreuz station
- Extension of the S-Bahn from Bahnhof Spandau in Western direction to Hackbuschstraße/Albrechtshof and
- New construction of an S-Bahn station Tempelhofer Feld

**Effect:**
Basically, the effect is locally restricted to road sections in which bus lines are replaced. In addition, there is an emission reduction potential if passengers can be encouraged to change their transport mode from motor vehicle to the ÖPNV (local public passenger transport) as a result of the new rail transport connections.
9.3 Heat supply for buildings
Supplying heat to buildings generally releases emissions of certain air pollutants and greenhouse gases. The source group ‘domestic fuel’ for instance is responsible for 15 % of nitrogen oxide emissions and for up to 15 % of particulate matter emissions (see Chapter 4). Unlike other source groups, these emissions primarily occur during winter months when high initial levels of particulate matter concentrations occur anyway. In this respect, the highest particulate matter emissions derive from the combustion of wood and coal, while almost no particles arise from the combustion of natural gas. In addition to particulate matter, polycyclic aromatic hydrocarbon such as benzo[a]pyrene is formed during the combustion of coal and wood. To a large extent these substances have a considerable carcinogenic potential. Besides reducing the energy use for heat supply, the choice of the source of energy is thus important to reduce pollutant emissions from this source group. Other influencing factors are the technical equipment and the state of maintenance of the combustion plant. With the tightening of requirements regarding emissions from the combustion of solid fuels in 1st BlmSchV emission reductions are expected. However, these reductions will only progressively have an effect from 2015 on.
Reducing heat requirements not only serves to protect the climate and natural resources, but also curbs air pollutant emissions.

Objective of the measure:
Reduce the average specific heat requirements for all buildings. Quantitative targets will be developed in the context of Climate Protection Policy.

Implementation:
Continuation and further development of the climate protection instruments used in Berlin so far, especially:
- Energy saving contracting and energy saving partnerships
- Offers tailored to target groups as well as energy and climate related advisory services for households and small and medium-size firms
- Energetic renovation of the existing building stock of owner-operated companies of the Land Berlin and of urban housing companies
- An initiative of the Federal Council to promote energetic renovation of buildings such as the apportioning of energetic restorative measures; promotion of contracting-models and tax incentives

Effect:
Reducing emissions from the source sector domestic fuel and thus reducing the urban background pollution throughout Berlin, particularly during winter months. The implementation is over the long-term, and the level of effect is dependent on the reduction of the heating requirements and the respective heating system.
Clean energy for heat supply and the reduction of emissions from small combustion plants

**M 3.2**

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<th>Timetable for implementation</th>
<th>Competent authority</th>
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<td><strong>Long-term</strong></td>
<td>SenStadtUm</td>
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**Potential for reduction (together with M 3.3)**

- 407 t/a PM$_{10}$ emissions
- 34 % less persons exposed to PM$_{10}$

**Costs**

n.a.

As early as 1984, Berlin’s land use plan defined a priority area for air pollution control. Today this priority area covers in essence the inner-city areas of Berlin totalling a surface of 100 square kilometres. To improve air quality, any planning concerning this area should include measures on reducing emissions. This is achieved by regulations for building plans, for which the land use plan sets requirements as preparatory urban land-use planning. For achieving clean air it is important to determine emission requirements for heating installations.

In new buildings situated in the priority area, for instance, it is only permitted to use installations whose emissions are not higher than those from heaters operated with heating oil. The use of district heating is also permitted. The regulations for combustion plants requiring permits remain unaffected by the building plan.

Although sometimes promoted for climate protection reasons, the use of wood as combustible material in small combustion plants is problematic from a clean air perspective. This is because it generates comparatively larger quantities of dust emissions. Compared with oil heaters, wood heating systems release dust emissions that are up to 10 times higher. Since solid fuel heaters are increasingly installed in buildings on the city periphery, which cause higher particulate matter emissions than permissible in the clean air priority area in the inner city, a possible extension of the priority area has to be examined.

Limit values that are locally more stringent than those set in 1st BImSchV can be determined for installations – making it possible in this way to achieve a retrofitting or an exchange of old sites. This is practiced in Aachen for instance. Furthermore, solid fuels such as wood and coal are the most significant source of benzo[a]pyrene, for which the target value (effective as of 2013) was still exceeded in Berlin during years with cold winters.

**Objective of the measure:**

Reduce particulate matter and benzo[a]pyrene emissions from the combustion of solid fuels in small combustion plants in Berlin.

**Implementation:**

- Preserve existing district heating areas
- Quantify the contribution from wood combustion to the particulate matter pollution in Berlin by analysing the components of particulate matter [Staubinhaltstoffanalysen] (Levoglucosan)

Insofar as the examinations result in a noticeable potential for reduction, the following measures should be implemented to the extent necessary:

- Extension of the priority area defined in the land-use plan with requirements for heating systems for the required territories (insofar as this is feasible within the system of presentation of the land use plan with simultaneous scrutiny of whether appropriate emission limit values for particulate matter and NO$_x$ can be defined instead of taking the emissions from oil heaters as the benchmark).

- Or, alternatively for the entire city area: adopt a regulation on solid fuels for Berlin which determines emission limit values for solid fuel firing systems that are below the values of the 1st BImSchV for new and old installations, if feasible and proportionate. So far as appropriate retrofitting of particle filters of combustion plants is possible, funding in the framework of the Environmental Relief Programme should be examined.

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Effect:
In the framework of the model calculations for 2015, the maximum reduction potential of these measures was examined in a scenario in which particle emissions from these small combustion plants with solid fuels and supplementary heaters such as fireplaces were fully reduced to zero, i.e. these firings would need to be replaced by particle-free heat supply such as gas (prohibition of solid fuels). In sum, this would mean a reduction of PM$_{10}$ emissions by 407 t/a. The impact of the measure on air quality was modelled within the package of measures 3. By reducing air pollution in the urban background, the concentration of pollutants also decreased on main roads. For the year 2015, a decrease of the number of residents affected by PM$_{10}$-limit value exceedances by 34 % is forecasted.
High levels of energy efficiency can be achieved by the co-generation of heat and electricity in combined heat and power plants (CHP), saving 30% of the primary energy compared to the separate generation of heat and power. CHP-installations are increasingly developed as so called mini- or micro-CHP with capacities of up to 50 kW\textsubscript{el} (partially up to 1 MW\textsubscript{el}) to heat building complexes. For reasons of climate protection they are supported by public means.

The extent to which mini-CHP plants will contribute to reducing particulate matter and NO\textsubscript{X}-emissions as well as improving air quality depends to a large extent on the energy source used and the technical standard of the installation, e.g. the use of emission reduction systems and the discharge conditions of exhaust gas emissions. Occasional complaints demonstrate that oil-operated CHP plants with unfavourable smokestacks may lead to nuisances in upper storeys.

Currently there are around 300 CHP plants\textsuperscript{113} in Berlin, of which approximately two thirds have a capacity below 50 kW\textsubscript{el}. As a possible future scenario a dynamic development of up to 100,000 CHP with a total power of around 2,000 MW\textsubscript{el} (so called „Schwarm-Kraftwerk“) is discussed. This would correspond to two larger power plants. While for large power stations stringent emission limit values and monitoring requirements of the Ordinance on Large Combustion Plants [(13th BImSchV)] and the Regulations on Exhaust Gas Lines [Abgasableitungsvorschriften] of the Technical Instructions on Air Quality Control [Technische Anleitung zu Reinhaltung der Luft (TA Luft)] are applicable; CHP plants may have significantly higher specific emissions (in g/m\textsuperscript{3} or in g/kWh). When replacing large power stations with CHP, ambitious emission standards are required particularly in urban areas in order to prevent an increase of the pollutant emissions, especially from particulate matter and nitrogen oxide. These emissions standards must be in line with the precautionary principle.

In general, combustion engines are used in mini-CHP plants that are operated with gas and oil. For combustion engines in CHP plants with a Rated Thermal input of less than 1 MW, no particular emission limit values have been determined so far. However, the general requirements pursuant to § 22 BImSchG are applicable. According to these requirements, installations not requiring permits have to be established and operated in such a manner that averts environmental effects that may have been prevented with the technical state-of-the-art. For larger CHP plants with combustion engines, the emission limit values of the TA-Luft 2002 Number 5.4.1.4. are applicable. Since emissions from small engines may also meet or even significantly fall below these limit values, they are applied analogously, e.g. in the Funding Guidelines of the Mini-CHP-impulse programme of the Federal Government. For funding in the framework of the Environmental Relief Programme of Berlin (which has meanwhile expired), the values of the installations had to fall 50% below the values of the TA-Luft. The lowest emissions requirements for gas-operated installations can be found in the tender recommendations\textsuperscript{114} of the Federal Environment Agency whereas the requirements for awarding the eco-label “blue angel” [Blauer Engel] are less ambitious and partially lag behind the TA-Luft and all the more behind the requirements for large power stations. They correspond to the technical standard of 2004 and should be revised in 2012.

The inconsistency of these recommendations show that it is necessary to determine limit values which reflect the current state-of-the-art of these engines when using combustion engines for heat generation in CHP plants. Cleaner than any combustion engines are fuel cells. However, they are still very expensive and thus have to be rather classified as a technology of the future.

\textsuperscript{113} Behrends J.: Leise, kraftvoll, effizient – Kleinkraftwerke im eigenen Keller [Small, Powerful, Efficient – small power plants in private basements]. Energie-Impuls\textsuperscript{E} 4/09.

Objective of the measure:
- Within the priority area of Berlin’s land use plan, only gas-operated installations or installations with fuel cells should be installed in residential and office buildings.
- Newly installed Mini-CHP plants with operation on gas fulfil at least the tender recommendations of the Federal Environment Agency.
- Newly installed Mini-CHP plants for liquid fuels are equipped with a particle filter and comply with the nitrogen oxide emission limit values of the TA-Luft.
- In case of neighbouring conflicts caused by existing oil-operated installations, a retrofitting with particle filters should be strived for.

Implementation:
- Put into effect the Environmental standard for public procurement which already imposes high requirements for oil-operated CHP plants and amending standards for gas-operated installations
- Initiatives on the federal level to create ambitious emission standards for combustion engines in CHP plants with a Rated Thermal Input < MW
- Adapt the formulation for heating installations in the priority area in the land-use plan Berlin
- Take into account high environmental standards in accordance with the recommendations of the Federal Environment Agency in future Funding programmes, e.g. in the case of a funding in the framework of the Environmental Relief Programme Berlin
- Recommendations for the competent district authorities on definitions in land-use plans and building permits as well as on the handling/on how to handle with neighbouring conflicts

Effect:
The measure contributes less to the reduction of existing emissions than to the reduction of future emissions. The reduction has not only a local effect in the surroundings of the CHP plant but also affects the urban background pollution. The application of the Tender Recommendations of the Federal Environment Agency means a reduction of the permitted nitrogen oxide emissions by 60 % for gas-operated CHP plants compared to the previously used standards of the Environmental Relief Programme Funding conditions.
9.4 Construction sector

Construction sites may cause significant increases in particulate matter pollution levels, as construction sites in the vicinity of monitoring stations have demonstrated in recent years. Depending on the type of construction works, high exceedances of the daily limit value have occurred. Particulate matter from mechanical comminution processes or from resuspension of dust and drifts consist of comparatively coarse particles with diameters of more than 2.5 µm, partially also more than 10 µm. In most cases such particles are only transported over short distances in the atmosphere thus rather leading to local and additional temporarily pollution levels. Diesel soot emissions from construction machines with a size below 1 µm, however, have a local and city-wide significance since they are distributed city-wide. Due to the high amount of construction works, these machines contribute to the increase of the urban background pollution caused by particulate matter. With the measures described in the following, certain particulate matter emissions from construction works should be reduced in order to reduce limit value exceedances caused thereby.
M 4.1 Particle filter for construction machines

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<th>Timetable for implementation</th>
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<td>from 2012 ongoing</td>
<td>SenStadtUm, public procurement agency issuing the tender</td>
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<table>
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<tr>
<th>Potential for reduction</th>
<th>Costs</th>
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<tbody>
<tr>
<td>Reduction of approx. 100 t/a diesel soot</td>
<td>approx. 1,000 to 15,000 € per construction machine</td>
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<tr>
<td>Local and city-wide effects</td>
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Engines of construction machines often cause high emissions of certain pollutants since the exhaust emission standards for these machines are much less stringent than for normal road vehicles. On a local level, construction machines may thus lead to increased pollution levels, particularly because some machines on construction sites run continuously for many hours. In sum, diesel soot emissions from construction machines (with 140 t/a) almost reach the emission level from road traffic in Berlin. This is because an emission reduction of almost 60% was achieved in the road transport sector through the low emission zone. Since mobile devices and machines as well as self-propelled working machines are excluded from traffic bans within low emissions zones according to 35th BImSchV, there is no possibility of enforcing an emission reduction of construction machines by means of a low emission zone. However, almost all construction machines of more than 19 kW from the construction year 2000 are retrofittable as shown by the example of Switzerland. Switzerland introduced a nationwide obligation to retrofit construction machines.

Objective of the measure:
Retrofit construction machines with particle filters in order to reduce particle emissions from this source group by 75% by 2015.

Implementation:
- Continuation of the model project that started in December 2011 to test particle filter retrofitting systems for different types of construction machines. With the conclusion of the model project, the results will be assessed and evaluated and, where appropriate, lead to appropriate actions with integration of the economic groups concerned and the Senate Department for Economic, Technology and Research.
- Information for building companies and lenders of construction machines and establish a list of appropriate retrofitting systems and retrofittable construction machines.
- Set environmental standards for construction sites of public contracting authorities: Machines of ≥ 37 kW should comply with the particle limit value of the exhaust emissions standard III B and machines of ≥ 19 kW should comply ex works with the standards III A pursuant to Directive 97/68/EC or by retrofitting with an efficient regulated filter. These Tendering requirements take effect in 2014 with the administrative Act for public procurement adopted in October 2012.
- As far as technically feasible, municipal mobile devices and work machines shall be retrofitted.
- Berlin will advocate the introduction of national requirements for public building plans analogous to the Berlin procurement requirements in the Federal Council. Whether or not this initiative will include a general national filter obligation for construction machines will be assessed after the conclusion of the model project for testing retrofitting systems for particle filters.

Effect:
Assuming the above-mentioned emission reduction, diesel particle emissions can be reduced by around 105 t/a with this measure. For comparison, soot emissions of heavy trucks were reduced by 30 t/a with level 2 of the low emission zone. With this in mind, filter retrofitting in construction machines even seems reasonable if the reduction potential was deemed lower due to given uncertainties. The effect of the measure on air quality was modelled as part of the package of measures 3, which additionally includes the reduction of particulate matter emissions from small combustion plants (M 3.3).

In sum, by reducing particulate matter emissions city-wide the urban background concentration of particulate matter will be reduced to such a level that the number of persons affected by limit value exceedances on main roads will be reduced by around 40% compared to development trends by 2015. Approximately one fifth of this improvement can be assigned to the retrofit of construction machines with filters. The measure is independent from traffic measures which would further reduce the number of persons concerned.
Reducing fugitive dust emissions from construction sites

**Timetable for implementation**
from 2012 ongoing

**Competent authority**
SenStadtUm, Boroughs

**Potential for reduction**
locally high

**Costs**
- for the construction industry: approx. 1 to 5 % of construction costs
- Information campaign approx. 30,000 €
- Personnel costs for controls

Construction sites may cause high emissions of dust that not only lead to air quality limit value exceedances in the surrounding area, but that may also provoke numerous complaints from residents in the neighbourhood. In addition to diesel particle emissions from construction machines and construction vehicles, there are numerous processes on construction sites that generate fugitive dust emissions. Such processes include demolition works, the handling of dusting materials, lapidary works or the resuspension of dusts of soiled working spaces by wind or vehicles. In Berlin’s emission balance these dusts account for a share of approximately 8 % (see Chapter 4.1.7).

The Pollution Control Act of the Land of Berlin in § 9 regulates that dust emissions should be prevented by appropriate measures. The Department of Berlin has established guidelines and a leaflet to put the appropriate measures in concrete terms. However, the proposed measures have not been applied sufficiently for diverse reasons. The reasons range from insufficient knowledge of builders and unclear obligations to lacking control capacities of authorities.

**Objective of the measure:**
- Reduce fugitive dust emissions by complying with the Guideline on Preventing and Reducing dust emissions on construction sites [Leitfaden „Vermeidung und Verminderung von Staubemissionen auf Baustellen”]

**Implementation:**
- Information campaign for building contractors
- Information for building owners
- Advanced training for architects and civil engineers
- Cooperation agreements with the construction industry for Good Practice on Construction Sites
- Examination of whether requirements can be integrated into building permits, building plans and planning permissions
- Set environmental standards for construction sites of public procurement authorities
- Additional staff for controls, training courses or other inspection staff

**Effect:**
Significant effects are expected in the surroundings of construction sites. However, the effect cannot be quantified since the data basis on achievable emission reductions is not sufficient to model the effect of the measure on air quality.
**M 4.3 Reduction of transport-induced emissions in building projects**

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<td>Logistic concepts since 2012</td>
<td>SenStadtUm, Planning authority and Approval authorities of the Senate and in the Boroughs</td>
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<tr>
<td>Modernization of construction vehicles until 2014</td>
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**Potential for reduction**
- Locally medium to high effects

**Dust emissions** are not only caused by the working processes on a construction site itself – significant transport emissions also arise from the supply and waste management services of the construction site. These transport emissions depend on the means of transport that are used, the cleanliness of vehicles as well as the number and duration of transport operations in the city. Increased air pollution levels on roads may particularly occur in the surroundings of construction sites as demonstrated for instance by monitoring stations in Schildhornstraße in 2010 and 2011. In this case, a significant share of the truck traffic of the construction sites on Schloßstraße in Berlin-Steglitz (road works, renovation and new construction of shopping centres) occurred and will occur.

Truck transport is particularly important in the building sector since a comparatively high share of vehicles is used that do not yet fulfil the criteria of the low emission zone. Exemptions are granted to numerous construction vehicles, partly because of national law (e.g. road works pursuant to the nationwide exemption of 35th BlmSchV). The number of truck journeys can be reduced by logistics concepts. This may be achieved by the bundling of transports as well as by shifts from road to rail or ship transport, if possible. Such concepts, including e.g. centres providing goods could be developed in the framework of the envisaged integrated economic trade concept.

Further emissions that may be prevented easily arise from the continuous running of engines on waiting trucks.

**Objective of the measure:**
- Reduction of truck emissions from construction sites by using cleaner vehicles and less journeys
- Reduction of pollution levels on roads caused by construction vehicles

**Implementation:**
- Environmental standards for construction sites of public contracting authorities: Construction Tendering using vehicle mileages of vehicles that do not fulfil the criteria for the green label is not admitted. These environmental standards take effect in 2013 with the administrative Act for public procurement adopted in October 2012.
- For large construction sites, transport by rail and by water is to be examined, and, as far as possible, to be determined in the planning approval decision or in the building permit.
- Development of logistic concepts to reduce the number of transport operations in the framework of the integrated economic traffic concept. In this context, the establishment of a freight centre for construction materials (distribution centre for construction materials) in cooperation with the building sector has to be examined.

**Effect:**
In London\textsuperscript{115} around 40% of the otherwise necessary truck journeys and the thus caused emissions were avoided by a freight centre for construction materials that supplies four large construction sites in London. This particularly relieves congestion on roads in the surroundings of the construction site. There is no data for the emission reducing effect of tyre washing systems. From comparisons with other polluted roads however, e.g. grit in winter, it can be assumed that the particle pollution will increase by 50% or more on highly polluted roads due to resuspension. Since pollution from construction sites occurs in the surrounding areas of construction sites, high reduction effects may only be achieved around the site itself.

9.5 Industry and trade

In Berlin, industry, power plants and businesses cause around 36% of the nitrogen oxide emissions and 13% of the particulate matter emissions (PM$_{10}$). In addition, certain mobile machines that account for around 12% of the particulate matter emissions in Berlin are used in industry and business. More than 90% of the nitrogen oxides in these sectors arise from large combustion plants, i.e. from power plants. Exhaust gas concentrations have already fallen significantly below the prescribed limit values and reflect the best available technique. There are no other reasonable measures for these installations. Since the exhaust emissions of these installations are discharged through high stacks and are thus well diluted, the share of nitrogen dioxide pollution in the urban background and on roads is low and achieves only around 2% on main traffic roads.

Particulate matter emissions from industry and business only slightly contribute to air pollution on main roads, with less than 2% of the total, because of increased urban background concentrations. At local level, particulate matter emissions, especially those from mechanical and diffuse processes such as recycling building rubble, producing concrete or the handling of dusting materials, but also exhaust gases of continuously running mobile machines, may lead to increased particulate matter concentrations in the immediate area of such installations. In unfavourable weather conditions, this may contribute to exceedances of the daily limit value. The primary aim of the measure described in the following is to reduce the local pollution of diesel soot emissions from mobile machines and stationary engines. Part of the planning measures is to develop concepts of measures to avoid neighbour conflicts in cases of settlements of new installations.
M 5.1 Requirements for installation permits: Reducing emissions from mobile machines and devices

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<th>Timetable for implementation</th>
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<td>with immediate effect</td>
<td>Approval authority</td>
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Potential for reduction
- 21 t/a Diesel soot emissions

Costs
- for particle filters approx. 1,000 to 10,000 € per engine

Diesel engines for use in mobile machines and devices or stationary machines are among the emission sources in installations requiring permits. Since the emission limit values for these engines are less stringent than for instance in the vehicle sector according to 28th BImSchV or the TA Luft, emission reductions can be achieved by prescribing achievement of the technological state of the art. Today it is the technical state of the art that such engines are fitted with closed particle filters with efficiencies of more than 90%.

**Objective of the measure:**
Reducing particle emissions from diesel engines in mobile machines, devices and stationary installations in facilities requiring permits.

**Implementation:**
An obligation to fit diesel engines with closed particle filters in mobile machines and devices that are used in the facility is to be introduced in the permission for new installations and in the permits for alteration.

**Effect:**
Together with measure M 4.1, this measure serves to reduce emissions from construction and other mobile machines and devices. In sum, these two measures allow for the reduction of 126 t/a diesel emissions, of which 21 t/a can be reduced in installations requiring permits.

The impact of this measure on air quality has been modelled in the measure package 3, which additionally comprises the reduction of particulate matter emissions from small combustion plants (M 3.3). In sum, the urban background concentration from particulate matter will be lowered to a level, which allows for a reduction in the number of persons affected by limit value exceedances on main traffic roads by 2015 compared to the development trend by around 40%.
9.6 Measures not being pursued

Before identifying the measures outlined in Chapter 9.1 to 9.5, several other options were evaluated. After balancing different interests with regard to the polluter-pays principle as well as the proportionality, effectiveness and feasibility of the measures in legal and regulatory terms, the following measures were not included in this package of measures. As far as the measures described below are still in an early stage or not yet feasible for legal reasons, further developments will be observed in order to examine their applicability at a later time, if necessary.

Extending the low emission zone to the total area of the Land Berlin

The traffic restriction of the low emission zone (LEZ) is limited to Berlin’s inner city areas situated within the local railway ring (S-Bahnring). The LEZ covers around 10% of the surface of Berlin. Outside of this area, all vehicles are permitted irrespective of their exhaust emission standards. The decision on limiting the LEZ to the inner city was taken for reasons of proportionality with the 2005 Clean Air and Action Plan. While limit value exceedances occurred on most major traffic roads within the inner light train ring [S-Bahnring] and were forecasted for upcoming years, limit value exceedances on main roads outside the area of the low emission zone are constrained to the minority of main roads in this area. In essence, there are some large radials with high volumes of traffic and high shares of trucks as well as some roads in densely built city areas close to the light train ring that are concerned. A traffic ban for such areas, in which limit values for air quality are met in most of the main roads due to better conditions for dispersal, was deemed disproportionate. With a view to the question of a possible extension of the area of the current low emission zone, this situation still persists.

Additionally, it has to be noticed that the vehicle fleet in city areas outside the LEZ was modernised to an extent comparable to areas within the LEZ. This is determined from the evaluation of license plates carried out at up to four road sections within and three outside the LEZ between 2007 and 2010. In practice, the attainment rate of the green label for passenger cars was at the same level with 97.3% within and 96.6% outside the LEZ. In the absence of the LEZ regulation this rate would have only reached around 49% in 2010. Similarly, the difference is also small for commercial vehicles: 75.5% of the vehicles within the LEZ and 71.8% outside have a green label – without the LEZ the label would have been issued to only 26% of the vehicles. The LEZ thus influences the composition of the vehicle fleet all over Berlin. Therefore, an extension of the traffic ban to the total surface would not stimulate further modernization. The effect on vehicle emissions would be very little. The extension is thus not followed-up.

Low emission zone „Stage 3“

Stage 3 of the LEZ in this context means the tightening of technical vehicle criteria for the LEZ. Possible criteria are determined in 35th BImSchV in the form of four groups of pollutants; as of yet. Pollutant group 4 (green label) is the most demanding. Since 2010 this pollutant group is required for the LEZ. A further tightening is thus not possible on the basis of the existing 35th BImSchV. It would first require the determination of a new pollutant source group and a label. Given that the vehicle technique has further developed this would be conceivable in general and would also facilitate significant emission reductions. However, in order to respect the proportionality and the legitimate expectations when banning traffic, suitable transition periods would need to be kept. In particular, investments that were made to achieve the currently best pollutant group 4, have to be written off, i.e. they should bring benefits for five to eight years. This includes for instance the retrofitting of particulate filters or the procurement of newer vehicles. The criterion for entering the low emission zone has to be defined in a way that the required exhaust emission standard is available on the market for a sufficient period of time and is achievable by retrofitting. In addition, a new source group with a new label should be defined in a way that only future exhaust emission standards would be concerned in order to prevent the re-labelling of already permitted vehicles that already have a label. Thus, only exhaust emission standard
6 would be eligible for the next pollutant group. This standard comes into force in 2014. A traffic ban for vehicles that do not meet this emission exhaust standard, would only be reasonable from 2020 at the earliest. Since in Berlin no limit value exceedances for nitrogen dioxide can be expected and the contribution of exhaust particles only represents a marginal share of the particulate matter pollution, a traffic ban would presumably not be necessary regarding NO, or would not reflect the source of pollution (PM$_{10}$) in 2020. This assessment is based on the currently applying limit values and on forecasts carried out on the basis of the available emission factors.

**Extending local truck bans to main roads**

The truck traffic ban on Silbersteinstraße has lead to significant emission reductions and a reduction in air pollution (see Chapter 6.9). Traffic bans are a useful means when the traffic volume of trucks in the roads concerned is high and when appropriate alternative routes are available. Alternative routes would need to cope with truck traffic caused by a ban without causing untenable increases of air pollution levels and of the number of persons affected. In Berlin, these criteria were already tested in 2005. Silbersteinstraße fulfilled these criteria, since the share of transit traffic was high, and the city motorway (“Stadtring”) A100 served as an appropriate alternative route. For other streets however like Mariendorfer Damm or Tempelhofer Damm no appropriate alternative routes are available in the surroundings. Therefore, solutions for these roads have to be found in the framework of the integrated economic trade concept (M 2.22).

A large-scale ban of truck through traffic as introduced in Stuttgart or since the end of 2011, where the entire city area or large parts of the inner city are closed to traffic is not possible in Berlin. This is because the volume of truck traffic completely passing through Berlin is not relevant, off the motorway A100. Federal motorways like the A100, where notable shares of transit truck traffic are suspected, cannot be closed to truck transit traffic. Solutions to reduce air pollution from this type of traffic should be developed as part of measure M 2.15.

**City tolls**

A city toll is a road charge for a predefined city area. The charge can take different forms, e.g. depending on the frequency of use, the driving performance or the size of the vehicle and its emissions standards.

In Germany there is currently no legal basis for the introduction of a city toll. Road charges are only imposed in the framework of the truck toll on the basis of the Act of the motorway toll [Autobahnbenutzungsgebührenverordnung], for privately financed road construction projects such as tunnels (e.g. Lübecker Herrentunnel) on the basis of the Act on Private Financing for Transport Infrastructure [Fernstraßenbauprivatfinanzierungsgesetz] and for some private roads, e.g. in the Alpine region.

The most prominent examples for toll regulations are the Congestion Charge for the city of London\textsuperscript{116} (since 2003) and the city toll for the inner city of Stockholm\textsuperscript{117}. The latter was permanently established in 2006 following a positive outcome of the referendum by the people. In Norway a city toll was already introduced in Oslo, Bergen and Trondheim as early as 1986. The city toll serves both the municipal financing of traffic projects and the reduction of the traffic volume and thus traffic congestion. In London\textsuperscript{118} and in Stockholm were observed a 20 % decrease in motorised private transport and a reduction of the journey time by around 30 %. Decreases by 10 % in the traffic-induced air pollutant emissions were calculated.

In general, a city toll is a useful steering instrument for reducing motorized private transport if designed carefully. From an economic perspective, it is an instrument for internalising external costs of road traffic, since a charge depending on emissions allows for purposefully charging those that cause the highest pollution and thus the highest external costs.
environmental costs. When designing a city toll, it has to be ensured that a shift to other transportation means takes place and no shift of journeys in areas outside the city toll area. This implies that the area must have a sufficient size and attractiveness in order to prevent evasive actions to other areas. Otherwise there would be a risk of causing additional traffic and additional emissions from longer distances, e.g. in the hinterland (“shopping in the open countryside”).

In general, the aim of reducing motorized private traffic and traffic-induced emissions can also be achieved by other means as Berlin’s transport policy has demonstrated in recent years. This may include the management of parking spaces, support for ecological transport modes or speed limits. A low emission zone cannot be replaced by a city toll, since emission reductions achieved by low emission zones are significantly higher than of city tolls. Therefore, in both cities, London and Stockholm, a low emission zone was introduced in addition to the city toll. Due to the difficulty of assessing the impact and the lacking legal ground, a city toll is currently not included in the measures of the Air Quality Plan of Berlin.

**Intensified street cleaning and winter road maintenance with fine dust glue**

Road dust whirled up by passing motor vehicles significantly contributes to the traffic-induced total pollution from particulate matter (PM$_{10}$) (see Chapter 5.3).

Two investigations on reducing dust by intensified street cleaning processes have not resulted in a measurable reduction of air pollution in Berlin however (see Chapter 6.13). Therefore, the measures will not be followed-up.

In the hope that road dust may be bound on the road surface and may thus lead to a significant reduction in resuspension, many European cities applied liquid Calcium-Magnesium-Azetat (CMA) on road surfaces of highly frequented roads on a trial basis. These trials were accompanied with measurements of the particulate matter concentrations and other pollutants. CMA which may also be used as de-icing agent has the characteristic of binding dust to road surfaces. However, the substance is abraded relatively quickly from the surface by passing vehicles. The possible reduction effect thus only lasts three to four hours especially on roads with high traffic volumes. Soon afterwards, CMA needs to be applied again to ensure the adhesive effect. Its de-icing effect is significantly poorer than the damp salt used in Berlin in case of imminent icy road conditions. Winter road maintenance services can also only use CMA preventively. Since high levels of particulate matter not only occur during wintry frost periods, CMA as a dust-binder would need to be applied over longer periods and much more frequently than pre-wetted salt due to its rapid abrasion. CMA has to be dosed accurately and applied evenly in order not to deteriorate the adhesion properties of the road surface. This in turn requires specific additional devices on the winter road maintenance service vehicles.

While a reduction effect of 10% on average and up to 30% on certain days was observed during test applications in Austria and a first trial in London, no reduction effect occurred at the highly polluted and traffic-exposed measuring point Neckartor in Stuttgart during a trial. The city of Stuttgart thus decided to no longer use CMA. There is no plausible explanation yet for these contradictory results. It is suggested that the traffic volume in Stuttgart is significantly higher compared to the test tracks in Klagenfurt, Linz and Bruneck and thus the related rapid abrasion of CMA by the numerous motor vehicles marginalised the adhesive effect of particulate matter.

Since the traffic volume on Berlin’s main roads is rather comparable to Stuttgart than to Austrian test cities, a similarly poor effect of the use CMA is expected in Berlin as was seen in Stuttgart. Therefore, in light of the substantial and quantity-related costs for using CMA and the conversion of Berlin’s cleaning service (“Berliner Stadtreinigung”) fleet necessary for the CMA dosage, the use of CMA for reducing particulate matter is not taken into consideration.
9.7 Supportive measures on national and European level

In many cases, local measures cannot be implemented effectively or are generally not sufficient to ensure compliance with the emission limit values, especially those for particulate matter (PM$_{10}$) and nitrogen dioxide (NO$_{2}$), without an adequate legal framework at European or national level in place. For this reason, the Clean Air and Action Plan 2005-2010 already contained additional measures to be implemented on national and European level.

With regard to the difficulty of compliance with the particulate matter limit values, it was comprehensively explained already in past years that measures considerably decreasing the particulate matter pollution being imported into the Berlin agglomeration are also necessary, and that those measures have to be taken primarily on a European level or at least have to be initiated by the European Commission because of the substantial share in sources in the Eastern neighbouring states. This included the testing of the comparatively permissive transition period until 2017 for the compliance with the European emission limit values by coal-fired power plants in Poland as well as the extension of the directive on national emission ceilings for certain atmospheric pollutants (NEC Directive 2001/81/EG), that had already been announced in the thematic clean air strategy in 2005 in order to set a limit value for particulate matter emissions and to create additional objectives regarding the reduction of nitrogen dioxide, nitrogen oxide and ammoniac emissions, out of which evolves particulate matter via atmospheric chemical reactions in the atmosphere.

However, since 2005, no considerable progress could be attained with regard to these measures intended to reduce the high particulate matter import. Also the initiated conversations with the Polish Government under the leadership of the Federal Environment Ministry on the initiative of the Federal States Berlin, Brandenburg, Sachsen, Sachsen-Anhalt and Mecklenburg-Vorpommern within the scope of Article 25 of the air quality directive about cross-border transport of particulate matter did not lead to a resounding success/progress in terms of additional measures on the Polish side., apart from an intensive exchange of information about the causes of the particulate matter pollution in both countries. For this reason, the percentage of the urban particulate matter pollution due to non-Berlin sources and especially polluters beyond the German border has not decreased, but rather increased by about 50% to almost 65%, as described in further detail in Chapter 5.3. Conversely, the Berlin share of the particulate matter issue has correspondingly decreased. However, this is not sufficient to be able to comply with the 24h-limit value also in years during which the weather conditions are unfavourable for the expansion of air pollutants.

The demands for measures regarding the emission reduction at fixed sources in the Eastern neighbour states made in the Clean Air and Action Plan 2005-2010 remain highly relevant. As became evident by German-Polish consultations, measures in the power plant sector and in the industry were indeed adopted, but in Poland there has so far been a lack of regulations for the limitation of emissions by small combustion plants, which significantly contribute to the cross-border particulate matter transport.

In this context it is regarded positively that within the Ecodesign Directive, the European Commission has elaborated a European regulation intended to restrict the pollutant emissions of small combustion plants and to close the gaps in regulatory framework at least for new ovens and firing systems in the European member states such as Poland. However, the German Federal Government shall, within its empowerments, ensure that future European regulations do not take a back seat to the German standards regarding the emissions of small combustions in the 1st implementing Regulation to the Federal Pollution Control Act or that these regulations won’t be downgraded by less demanding European regulations.

The city of Berlin is going to support this via the Federal Council [Bundesrat] and its empowerments within the development of the European legal framework. This also applies to the requirements addressed to the German Government and the European legislature that
were drafted within the measures 2.2, 2.3, 2.9 and 4.1 regarding the emission of pollutants by vehicles and machines, and also in the measures 2.18, 2.22 und 3.1 with regard to traffic and building refurbishment.

Unlike particulate matter, the contribution of sources outside of the Berlin urban area to the limit value exceedances of nitrogen dioxide (NO₂) are negligibly small. As properly shown in Chapter 5.2, the Berlin road traffic has a share of about 75 % responsibility for the traffic-induced NO₂ concentration in the inner city, so that the responsibility to take measures seems to be on local level. In the present list of planned measures, 26 of which directly affect the traffic in Berlin, this circumstance is taken into account.

Nevertheless, an additional external need for action, especially on the European level, exists, as the pollutant emission of motor vehicles essentially depends on the emission standards that were specified and decided by the European legislature. The gradual decrease of the nitrogen oxide emissions, as was compulsory within the European emission standard legislation, up to the present emission standard in force with EURO 5, proved to be too modest. In practice, it turned out that the intended emission reductions for nitrogen oxides cannot be met in many cases, especially regarding urban transport, and that the exhaust of directly emitted nitrogen dioxides (NO₂) even partially increased. As a result, the NO₂ pollution on roads also decreased less than expected. Thus, prospectively, the legislation on emission behaviour in urban transport should be reconsidered.

The insufficient emission reductions and the problems with NO₂ direct emissions were also mentioned already in the Clean Air and Action Plan 2005-2010, including the demand for a tightening of the EU emission standards for motor vehicles and trucksthat are also supposed to address the “problem of the increasing NO₂ emissions share in the NOx emissions of diesel vehicles”.

Therefore, Berlin participated in the stakeholder consultation in September 2005, which was initiated by the European Commission and pursued the elaboration of new EURO 5 standards for motor vehicles and light commercial vehicles. Berlin’s suggestion included a tightening of the upcoming EURO 5 standard for diesel motor vehicles, which was targeted for 2009/2010, to an emission level that equals the limit value of the new EURO 6 standard, which was later resolved. That new obligatory standard, however, is going to enter into force only from 2014. Thus the introduction of the EURO 6 standard, which is presently also advertised by the automotive industry as the essential solution for the nitrogen oxide problems with diesel vehicles, would have occurred about 5 years earlier and, as shown in Chapter 8.3, would have made a considerable contribution to the compliance with the NO₂ air quality limit values until the final expiry of the compliance deadline in 2015. However, the European Commission has not followed the proposal. Subsequent initiatives on the part of Berlin during the Conference of the Environmental Ministers [Umweltministerkonferenz] and in the Federal Council were of no effect, too.

Hence, the considerable reduction potential included in the EURO 6 standard will only contribute to the compliance with the NO₂ limit values until 2015 in a significant manner if the automobile manufacturers offer EURO 6 vehicles distinctly before the obligatory introduction date in 2014, and those vehicles are thus launched with enhanced sales appeal in the form of a nationwide promotion.

The latter is the Federal Government’s duty, as it has the required instruments such as motor vehicle taxes, the truck toll system and additional promotion programmes that can be funded by these revenues at its disposal. In this respect, the support shall not be restricted to only EURO 6 vehicles that conventionally run with petrol or diesel, but shall also consider vehicles with alternative propulsion systems/drive concepts. As announced in measures 2.2 and 2.3, Berlin is going to claim this via the Federal Council by means of corresponding initiatives.
As indicated above, besides the delayed introduction of ambitious emissions standards a problem exists that, especially in inner city roads with a high traffic volume and numerous acceleration and deceleration processes, the NO\textsubscript{x} emissions of diesel motor vehicles up to the current emissions standard are roughly high as those of ten years older EURO 1 vehicles. With a motor vehicle fleet having a high share in diesel vehicles, as it is common in Germany and likewise in Berlin, the NO\textsubscript{x} emissions in inner city roads with a high traffic volume thus decreased only to a little extent in the past years. However, after the type testing stipulated by the European emissions legislation, the NO\textsubscript{x} emissions of diesel motor vehicles should have been about 60 % lower compared to older vehicles.

Such a failure on behalf of the European emissions legislation, especially on urban roads with a high traffic volume and with many residents exposed to a high concentration of pollutants, where the air quality limit values must be complied with in particular, should not happen again in the future.

Even if the problem of lacking consideration of urban driving conditions when registering new motor vehicles has by now been recognised by the European Commission and a resolution has been announced, it remains to be seen whether the first EURO 6 diesel vehicle generation meets the expectations regarding a considerable reduction in emissions especially in urban driving mode. The Federal Government is called upon to accordingly influence the elaboration of respective regulations on European level or within the UNECE (United Nations Economic Commission for Europe).

In any case, the number of EURO 6 vehicles pervading the fleet until 2015 remains limited. More important is the exhaustion of technological potentials regarding the retrofitting of a part of the existing motor vehicle fleet. At least regarding buses and heavy commercial trucks, it is technologically possible to attain an essential reduction of the nitrogen oxide emissions due to retrofitting with NO\textsubscript{x} reduction systems. Like in the case of particulate reduction systems in the past, the Europe-wide establishing of technical criteria for the subsequent fitting of nitrogen oxide reduction systems remained undone. In view of the Europe-wide necessary efforts regarding the compliance with the NO\textsubscript{x} pollution level limit values, also a quick market launch of such systems should take place all over Europe. This would also reduce the system costs and should facilitate the promotion of retrofitting that is co-ordinated among the member states. Without the determination of such technological criteria, measure 2.7 is not convertible.

The discrepancy with regard to PM\textsubscript{10}, which already existed in the past, between the emission reduction required for the compliance with the limit values and the possible reduction potential due to local measures and European (especially technological) regulations also applies to NO\textsubscript{2} for the reasons mentioned above.

The extent to which this potential for the Berlin agglomeration is limited is illustrated by the reduction margins of measures on local level shown in Chapter 8.

In Berlin, the gap between the NO\textsubscript{2} pollution in the starting year 2009 and the end of the extended compliance date in 2015 amounts to more than a third, on average of the measuring stations on main roads, about the half of which can be closed because of introduced measures such as the implementation of the Low Emission Zone and the transport policy part of the Urban Development Plan Traffic. This package of additional measures has been developed in order to close the remaining gap.

In order to effectively implement this package of measures, support from the mentioned accompanying measures on European and national level is necessary. This is the only way to ensure early compliance with the limit values for particulate matter and nitrogen oxides in the whole urban area.
References


http://www.umweltbundesamt.de/produkte/beschaffung/energieversorgung/kraft-waerme-kopplung.html  
(Last retrieved on 21 August 2012)

http://www.umweltbundesamt.de/emissionen/publikationen.htm  
(Last retrieved on 21 August 2012)

Federal Pollution Control Act (BImSchG), Sec. 47, para. 4.

(Last retrieved on 21 August 2012)

http://www.die-gruene-stadt.de  
(Last retrieved on 21 August 2012)


(Last retrieved on 21 August 2012)


http://www.hbefa.net  
(Last retrieved on 21 August 2012)


http://www.ifeu.de/verkehrundumwelt/pdf/IFEU(2010)_TREMOD_%20Endbericht_FKZ%203707%20100326.pdf
(Last retrieved on 21 August 2012)


(Last retrieved on 21 August 2012)


http://www.lubw.baden-wuerttemberg.de
(Last retrieved on 21 August 2012)


http://www.ecorails.eu
(Last retrieved on 21 August 2012)

http://vision-traffic.ptvgroup.com/de/produkte/ptv-visum/
(Last retrieved on 21 August 2012)


http://www.stadtentwicklung.berlin.de/verkehr/politik_planung/strategie/de/download.shtml
(zuletzt abgerufen am 21. August 2012)

http://www.stadtentwicklung.berlin.de/umwelt/luftqualitaet/de/luftreinhalteplan/download/umweltzone_1jahr_stufe2_bericht.pdf
(Last retrieved on 21 August 2012)
Senatsverwaltung für Gesundheit, Umwelt und Verbraucherschutz: Handlungsfeld Umweltgerechtigkeit, Umweltbelastungen und -ressourcen auf der Ebene der Lebensweltlich orientierten Räume (LOR) – Grundlagen für die Entwicklung umweltpolitischer Strategien, Maßnahmen und Instrumente zur Verbesserung der Umweltqualität im Land Berlin, Basisbericht [Senate Department for Health, the Environment and Consumer Protection; Field of Action in Environmental Justice, Environmental Pollution and Resources at the Level of Environmental life-oriented Spaces (LOR) – foundations for the development of environmental policy strategies, measures and instruments for the improvement of the environmental quality in the State of Berlin, Base Report] 2011.


(Last retrieved on 21 August 2012)

http://www.iqmobility.de/
(Last retrieved on 21 August 2012)


http://www.stadtentwicklung.berlin.de/planen/basisdaten_stadtentwicklung/index.shtml
(Last retrieved on 21 August 2012)

(Last retrieved on 21 August 2012)

http://www.stadtentwicklung.berlin.de/verkehr/politik_planung/oepnv/nahverkehrsplan/index.shtml
(zuletzt abgerufen am 21. August 2012)

http://www.stadtentwicklung.berlin.de/planen/stadtentwicklungsplanung/de/gewerbe/news.shtml
(Last retrieved on 21 August 2012)
http://www.stadtentwicklung.berlin.de/verkehr/politik_planung/step_verkehr/de/download.shtml
(Last retrieved on 21 August 2012)

http://www.stadtentwicklung.berlin.de/planen/stadtentwicklungsplanung/de/zentren/index.shtml
(Last retrieved on 21 August 2012)

http://www.stadtentwicklung.berlin.de/planen/bevoelkerungsprognose/
(Last retrieved on 21 August 2012)

(Last retrieved on 21 August 2012)


http://www.stockholm.se/trangselskatt
(Last retrieved on 21 August 2012)


(Last retrieved on 21 August 2012)


(Last retrieved on 21 August 2012)

Legislation


Regulation (EG) Nr. 692/2008 of the European Parliament and of the Council on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro V and Euro VI) and on access to vehicle repair and maintenance information


Federal Pollution Control Act [Bundes-Immissionsschutzgesetz BImSchG] – German Federal law governing the harmful environmental impact of air pollution, noise, vibration and the like as amended in the announcement of 17 May 2013 (BGB I S. 1247)

Version of the announcement of 26 September 2002 (BGB I S. 3830), last amended by Article 2 of the law of 24 February 2012 (BGB I S. 212)

1st Federal Pollution Control Act [Bundes-Immissionsschutzgesetz BImSchG] – Ordinance on small and medium-sized combustion plants of 26 January 2010 (BGB I S. 38)

4th Federal Pollution Control Act [Bundes-Immissionsschutzgesetz BImSchG] – Ordinance on installations requiring a permit of 2 May 2013 (BGB I S. 973)

11th Federal Pollution Control Act [Bundes-Immissionsschutzgesetz BImSchG] – Eleventh Ordinance on the implementation of the Federal Pollution Control Act (Ordinance on emissions reporting) as amended in the announcement of 5 March 2007 (BGB I S. 289), last amended by Article 9 of the Ordinance of 2 May 2007 (BGBl. I S. 1021)


39th Federal Pollution Control Act [Bundes-Immissionsschutzgesetz BImSchG] – Thirtyninth Implementing Regulation of the implementation of the Federal Pollution Control Act (Ordinance on air quality standards and emission ceilings) of 2 August 2010 (BGBl. I S. 1065)

Road Traffic Regulation [Straßenverkehrsgesetz StVG] as amended in the announcement of March 2003 (BGBl. I S. 310, 919), last amended by Article 2 (118) of the law of 22 December 2011 (BGBl. I S. 3044)

Road Traffic Act [Straßenverkehrsordnung StVO] – Road Traffic Act of 6 March 2013 (BGBl. I S. 367)

Road Traffic Approval Order [Straßenverkehrs-Zulassungs-Ordnung StVZO] of 26 April 2012 (BGBl. I p. 679), last amended by Article 2 of the order of 19 October 2012 (BGBl. I p. 2232)

Vehicle Registration Law [Fahrzeug-Zulassungsverordnung FZV] of 3 February 2011 (BGBl. I p. 103), last amended by Article 1 by the law of 13 January 2012 (BGBl. I p.103)

Berlin Tendering and Procurement Law [Berliner Ausschreibungs- und Vergabegesetz], 08/07/2010, GVBl. p. 399

Pollution Control Act of the State of Berlin [Landes-Immissionsschutzgesetz Berlin LImSchG Bln], GVBl. p. 735, ber. GVBl. 2006 p. 42

Administrative Order on Procurement and Environment [Verwaltungsvorschrift Beschaffung und Umwelt VwVBU] – federal administrative order on the application of environmental protection requirements for the procurement of works, supplies and services (GVBl. of 2 November 2012)

GVBl = Gesetz- und Verordnungsblatt (Journal of Laws and Ordinances)
BGBl = Bundesgesetzblatt (Federal Law Gazette)
BGB = Bürgerliches Gesetzbuch (Civil Code of Germany)
Glossary: Definitions and acronyms

Air  Ambient air of the troposphere with the exception of air in interior spaces.

Air pollution  means changes in the natural composition of air particularly induced by smoke, soot, dust, gases, aerosols, steam, odorants or the like. Those changes may cause stress situations for humans as well as acute or chronic damages to health, threaten animal populations and plants and may lead to material defects. Air pollution is mainly caused by industrial and business installations, road traffic and combustion plants.

Air Pollution Register  Spatial illustration of pollution concentrations within a given area, differentiating between peak concentrations and long-term levels. Air Pollution Registers form an important basis for Air Quality Plans and other pollution control measures.

Air Quality Plan (AQP)  according to § 47 Abs. 1 BImSchG, an Air Quality Plan has to be prepared by the competent authority in cases where the pollution concentration before the expiry of the compliance date of the limit value (2005 or 2010 respectively) exceeds the sum of the limit value and the margin of tolerance. Its objective is, by means of long-term measures, not to exceed any longer those limit values and to maintain them permanently after expiry of the compliance date indicated in the 39th BImSchV.

Alert threshold  means a level beyond which there is a risk to human health from brief exposure and at which immediate steps shall be taken by the Member States as laid down in Directive 2008/50/EC.

Background level  is the concentration of air pollutants on a larger scale than the exceedance area on an air quality standard.

BaP  Benzo[a]pyrene is a polycyclic aromatic hydrocarbon (PAH) which is toxic and may have carcinogenic effects. It is considered representative for the pollution from the group of polycyclic aromatic hydrocarbons. BaP is primarily formed during the incomplete combustion of organic substances, e.g. oil, coal and wood.

BImSchG  Federal Pollution Control Act [Bundes-Immissionsschutzgesetz]. Law promoting the protection against hazardous environmental effects caused by air pollution, noise, vibration and the like.

BImSchV  Implementing Regulation to the Federal Pollution Control Act [Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes]

BLUME  Air quality monitoring network of Berlin [Berliner Luftgütemessnetz]

BSR  Berlin waste management company [Berliner Stadtreinigungsbetriebe]

BVG  Berlin public transport services [Berliner Verkehrsbetriebe]

BWB  Berlin water company [Berliner Wasserbetriebe]

CHP plants  small combined heat and power plants are installations that simultaneously generate heat for heating purposes and electricity mostly in the range of up to 50 kW (partly up to 1 MWel).

CMA  Calcium-Magnesium-Aacetat
| **CRT-Filter** | Continuous Regeneration Trap: a Diesel Particulate Filters (DPF) with continuous regeneration, i.e. continuous removal of accumulated soot particles by oxidation (combustion) on a catalytically coated filter material. |
| **DPF** | Diesel Particulate Filter for motor vehicles to reduce particle emissions from Diesel engines |
| **Ecomode** | in German Umweltverbund, comprises ecological means of transport, that is public transport, bicycles and pedestrian traffic. |
| **EEV Standard** | Enhanced Environmentally friendly Vehicle; European exhaust emission standard |
| **EMEP** | is the so called Cooperative Programme for Monitoring and Evaluation of the long-range transmissions of air pollutants in Europe under the Convention on Long-range Transboundary Air Pollution (CLRTAP). The inter-governmental agreement initialled 25 years ago under the United Nations Economic Commission for Europe concluded several agreements to control environmental problems caused by the transboundary transport of air pollutants, e.g. acidification and eutrophication of soils and waters and summer smog. EMEP is the scientific program under the convention. In its framework, continuous air pollutant measurements are carried out, air pollutant emission levels of all participating nations are recorded, emission forecasts are prepared and dispersion calculations are carried out to determine the pollution balance between the individual states (see [http://www.emep.int/](http://www.emep.int/)). |
| **Emission inventory** | is the spatial coverage of specific sources of air pollutants (installations and vehicles). The emission inventory includes data on the type, level, spatial and temporal distribution and the dispersion conditions of air pollution. It ensures that the substances significant for air pollution are registered. |
| **Emissions** | means the release into the environment of air pollutants, noise, light, rays, heat, vibrations and other similar phenomena that derive from an installation (e.g. power plant, waste incineration plant, blast furnace) or from products (e.g. fuels, fuel additives). |
| **FNP** | Land use plan [Flächenutzungsplan]: The land use plan is the preliminary urban land use plan in Berlin which is adopted by the Parliament. It comprises an overview of the most important planning objectives of the city and is constantly/continually updated by revision/amendment procedures. |
| **HBEFA** | Handbook Emission Factors for Road Transport: data base to calculate the exhaust emissions of vehicles in real-life traffic depending on the traffic situation and other parameters. |
| **HEAVEN** | „Healthier Environment through Abatement of Vehicle Emissions and Noise” was a research project co-financed by the 5th Framework Programme for research of the EU. |
| **Hot-spots** | are focal points at which people are exposed to high air pollution levels, e.g. near traffic sites. |
| **IMMIS\textsuperscript{sub}** | is a computer program to calculate [temporally and spatially resolved] air pollutant concentrations at any point in street canyons with buildings on both sides. |
| **IMMIS\textsuperscript{em}** | Sub-module of IMMIS\textsuperscript{luft} for calculating emissions from motor vehicles |
| **IMMIS\textsuperscript{luft}** | is a calculation program to determine air pollutant emissions and imissions in inner cities. The exhaust gas emissions of motor vehicles are determined on the basis of the Handbook of Emission Factors of the Federal Environmental Agency, vehicle emissions from abrasion and resuspension are determined according to Diegmann 2010. The calculation of pollutant concentrations in street canyons is based on IMMIS\textsuperscript{sub}. |
**IMMISnet** is a climatological dispersion model for calculating the spatial extent of air pollution at the urban level. Treated as a stationary process, the model describes the dilution and the transport of pollutants from point, line or area sources, assuming a Gaussian normal distribution. On the basis of the Gaussian smoke plume equation, IMMISnet calculates concentration contributions from the emissions of all point, line or area sources of the city.

**Incremental pollution** means the air pollution level occurring at a road section solely caused by the local motorised traffic in this road section. It is calculated as the difference between the concentration of pollutants measured at a roadside station and the urban background concentration measured at a site in residential areas.

**Installations** means a stationary technical unit such as a factory, warehouse and other building and object that is permanently and firmly connected to the ground. It also includes all mobile technical equipment such as machines, devices, vehicles on the same site and properties used to store substances or to carry out work that may cause emissions; public roads are excluded.

**Installations not requiring permits** this refers to installations which are particularly likely to cause harmful effects on the environment or other risks, significant disadvantages or nuisances for the neighbourhood or for the general public. The Annex of 4th BImSchV determines the installations requiring permits.

**Installations requiring permits** includes all installations not listed in 4th BImSchV or installations for which 4th BImSchV determines that no permit is required.

**iQMobility** project to establish an integrated quality and mobility management in road traffic in the region Berlin-Brandenburg. For more information see www.iqmobility.de.

**level** 'level' shall mean the concentration of a pollutant in ambient air or the deposition thereof on surfaces in a given time.

**LGV** light goods vehicle with a total weight below 3.5 tonnes for transportation of goods

**Limit value** a value, which is defined based on scientific knowledge to avoid, prevent or reduce harmful effects on human health and/or the environment as a whole and which has to be met within a specific period of time and is not be exceeded afterwards.

**LImSchG** Federal State Pollution Control Act of Berlin [Landes-Immissionsschutzgesetz Berlin]

**LOR** Environmental life-oriented space [Lebensweltlich orientierter Raum]: is an area planning category defined by Berlin’s authorities for urban planning and for statistics, representative for homogenous and comparable social living environments.

**LOS** Level of Service: a measure to describe the quality of vehicle traffic by categorizing the traffic flow in four stages “free circulation/free-flow” (LOS1), “heavy/dense traffic” (LOS2), “saturated traffic/unstable flow” (LOS3) and “stop&go” (LOS4)

**LSA** Traffic lights systems

**LVwA** State Administration Department of Berlin [Landesverwaltungsamt Berlin]

**Margin of tolerance** a surcharge to the limit value that decreases annually and reaches zero at the end of the period to comply with the limit value (2005 or 2010 respectively). When exceeding the sum of limit value and margin of tolerance, the measures to ensure compliance with the limit value have to be presented in the form of an Air Quality Plan, which has to be published and reported to the European Commission.
Mean value is the arithmetic mean of all observed or measured values and is a measure of location for statistical frequency distributions. Single/individual outliers may significantly influence this measure.

MIV Motorised individual transport [Motorisierter Individualverkehr]

Modal-split describes the distribution of traffic volume by mode of transport, e.g. pedestrians, bicycle traffic, public transport and motorized private transport.

Nitrogen oxides abbreviated as NOx, refers to the sum of nitrogen monoxide and nitrogen dioxide, added as parts per billion and expressed in µg/m³ nitrogen dioxide.

NN Mean sea level [Normalnull]

PAREST Strategy for reducing particles (project of the Federal Environment Agency: UFOPLAN project 206 43 200/01)

PLR Planning areas [Planungsräume]

PM<sub>10/2.5</sub> particulate matter with an aerodynamic diameter of less than 10 µm (PM<sub>10</sub>) and less than 2.5 µm (PM<sub>2.5</sub>) with a 50% efficiency cut-off. The share of fine particles showing a size between 0.01 and 10 µm may cause risks to human health, particulate matter can be carried deep into the lungs via the respiratory passages. It may be deposited in the alveolus from where it may enter the blood circulation.

Pollutant any substance directly or indirectly released into the atmosphere by humans that may have adverse effects on human health and/or the environment as a whole.

RCG Regional REM Calgrid Model: is a model system developed by the Federal Environmental Agency as part of a research project, which allows for the calculation of large scale regional PM<sub>10</sub> background pollution and the urban background level.

RUBIS Soot and benzene pollution sampler [Rüß- und Benzol-Immissions-Sammler] is a combined active and passive sampler for determining bi-weekly mean values of benzene, soot and nitrogen dioxide.

SCR Selective catalytic reduction (chemical conversion) of nitrogen oxides into molecular nitrogen (N₂). Most often urea is used as reductant. It serves to reduce nitrogen oxide emissions in large combustion plants and motor vehicles.

SenStadtUm Senate Department for Urban Development and the Environment of the Senate Berlin [Senatsverwaltung für Stadtentwicklung und Umwelt]

SenWiTechForsch Senate Department for Economics, Technology and Research [Senatsverwaltung für Wirtschaft, Technologie und Forschung]

Soot fine carbon particles or particles with a high carbon content, that result from the incomplete combustion.

SPNV local rail passenger transport services [Schienenpersonennahverkehr]

StEP Urban development plan (UDP), e.g. for traffic, industry and business, city centres or climate. Urban development plans are a means of informal urban planning (concepts) and are contemplated in the Berliner Ausführungsgesetz zum Baugesetzbuch (AGBauGB) (§ 4, Abs. 1). With these plans, guidelines and objectives for different areas, e.g. working, living, social infrastructure, supply and disposal, traffic, are developed. They form the basis of any
further planning, substantiate the land development plan by determining spatial and temporal priorities for land takes and locations and identify appropriate measures.

**StVG** Road Transport Law [Straßenverkehrsgegesetz]

**StVO** Road Traffic Act [Straßenverkehrsordnung]

**Suspended particulates** solid particles that are classified as coarse particles and fine particles depending on its size. While coarse dust only remain in the air for a short time before reaching the ground due to dust precipitation, fine particles may remain in the atmosphere for a long time and transported over large distances. The size of the particles is the main distinguishing feature. Suspended particulates have a size between 0.001 and 15 µm. Particles with a diameter below 10 µm are designated as PM\(_{10}\), below 2.5 µm as PM\(_{2.5}\), and below 1 µm as PM\(_{1}\). Dust derives from both, natural as well as man-made sources. Depending on its size and the substances attached to the particles, dust is hazardous to health to a greater or lesser extent.

**TA Luft** Technical Instructions on Air Quality Control [Technische Anleitung zur Reinhaltung der Luft], commonly referred to as TA LUFT, is an administrative instruction pertaining to the BImSchG (Federal Air Pollution Control Act). It consists of four parts: Part 1 regulates the scope of application, part 2 lays down general rules on air quality control clean air, part 3 substantiates the requirements for reducing and determining emissions, part 4 concerns the restoration of certain installations requiring permits (old sites).

**Tellus** a EU research project „Transport & Environment Alliance for Urban Sustainability“ of the 5th Framework Programme for Research of the EU.

**TÖB** representative of public interests [Träger öffentlicher Belange]

**Trucks/HGV** Heavy Good vehicles with a total weight of more than 3.5 tonnes for the transportation of goods

**TUT** Thousand environmental caps for Berlin [„Tausend Umwelt Taxen für Berlin“] is a project by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

**UBA** Federal Environment Agency [Umweltbundesamt]

**UEP** Environmental Relief Programme [Umwelzentlastungsprogramm]: programme for funding innovative environmental projects using money from the European Structural Funds, especially from the European Regional Development Fund (ERDF).

**VISEVA** Programme for the calculation of traffic demand. The calculations are based on a demand model developed by the Technical University of Dresden (TU Dresden) for the generation, distribution and segmentation of traffic flows.

**VLB** traffic management authority in Berlin [Verkehrslenkung Berlin]

**WHO** World Health Organization
Substances, units and parameters

BaP  Benzo[a]pyrene
NH₄  Ammonium
NO₃  Nitrate
NO₂  Nitrogen dioxide
NO  Nitrogen monoxide
NOₓ  Nitrogen oxides (sum of NO + NO₂)
SO₄  Sulphates
µg/m³  Microgram (one millionth of a gram) per cubic metre
kg/a  Kilogram per year
t/a  Tons per year
Kd/a  Kelvin days per year (heating degree total)
kW  Kilowatt
MW  Megawatt
## Appendix

### Tab. A-1: Overview of the monitoring stations of the network BLUME

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### Figure A-1: Share of vehicle types in the traffic-related incremental NO₂ pollution in selected major roads in % for the year 2015

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Figure A-2: Share of vehicle types in the traffic-related incremental PM$_{10}$ pollution in selected major roads in % for the year 2015.
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<td>44 38 15 0 2</td>
</tr>
<tr>
<td>Karl-Marx-Str.</td>
<td>47 36 8 2 7</td>
</tr>
<tr>
<td>Schlesische Str.</td>
<td>45 35 12 2 7</td>
</tr>
<tr>
<td>Budapester Str.</td>
<td>50 35 7 1 6</td>
</tr>
<tr>
<td>Tempelhofer Damm</td>
<td>50 37 13 0</td>
</tr>
</tbody>
</table>

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- **Blue**: cars
- **Light blue**: light goods vehicles
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- **Red**: bus
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