

THE LOW EMISSION ZONE IN BERLIN – RESULTS OF A FIRST IMPACT ASSESSMENT

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ABSTRACT

Introduction:

The air quality in Berlin has considerably improved during the last decade due to tangible progress in curbing emissions especially in the power plant and house heating sector. As an example, SO₂-concentrations have fallen to 5% of the levels 20 years ago.

However, current EU limit values for particulate matter (PM₁₀) were still exceeded until 2006 along one third of Berlin’s main road network of 1500 kilometres. Since 2007 PM standards have been met by a small margin and most likely due to favourable meteorology, so that a significant risk exists that in years with more stagnant weather conditions pollutants levels might exceed the standards again.

A huge non-compliance problem also exists with annual NO₂ levels. So, like hundreds of other EU cities, Berlin had to draw up a clean air plan which spells out measures to meet the air quality standards.

Two source apportionment studies revealed that road traffic is the predominant source for PM₁₀, PM_{2.5} and NO₂-pollution. Hence, current abatement measures in Berlin focus on the transport sector.

As an second pillar of the strategy to reduce traffic related pollution an urban master plan for transport (StEP) was adopted in 2004 as a blueprint for a sustainable transport policy and traffic planning, which is currently under revision. It aims to avoid traffic and to achieve a shift in the modal split from road transport to public transport and cycling, so that ultimately only 20% of journeys in the city centre and 40% in the remaining areas would be undertaken by car. Among other drivers, reduction of the CO₂-emission and the attainment of certain air quality and noise standards were set as long-term goals underpinning the transport policy within the next 15 years. The StEP is expected in the longer term to bring about tangible reductions of not only exhaust emissions but also of non-exhaust emissions of particles, generated by re-suspension of road dust and abrasion of tyres and road material. These emissions are largely mileage dependent and hardly combatable by technical measures.

Nevertheless, abatement of traffic exhaust emissions clearly remains the most urgent measure to curb primary and secondary PM and to meet the NO₂ air quality limit values by 2010. Use of alternative fuels, like compressed natural gas (CNG) has already been pursued, including setting of emission criteria for the municipal diesel vehicle fleet and buses.

The low emission zone (“Umweltzone”):

However, such action covers only a limited part of the whole vehicle fleet. Providing economic incentives to install or retrofit modern exhaust technology will not be enough by itself to accelerate the take-up rate of this equipment in the vehicle fleet. In order to achieve mitigation effects faster and on a larger scale a low emission zone (LEZ) is being introduced in two stages for motor vehicles whose emission standards do not meet certain criteria.

A low emission zone will not reduce traffic per se, but it can significantly increase the pressure to switch to environmentally friendly vehicles or to retrofit with exhaust after treatment technology, like particle traps.

Before introducing a LEZ several options were evaluated in 2005 in terms of their emission reduction potential. These scenarios were based on the assumption that technical options for retrofitting diesel vehicles with particle traps were available at acceptable costs for a large proportion of the existing vehicle fleet.

The findings of the study indicated that

- a scheme covering both diesel passenger cars and diesel HDV leads to substantially higher emission reductions than a concept limited to heavy-duty vehicles;
- the main reduction occurs in the inner city area (“S-Bahn Ring”), as the population density and hence the number of residents affected by air quality limit value exceedances is greater
- a much larger decrease can be achieved by accelerating the implementation of the LEZ (e.g. start in 2008) because, due to normal replacement rate of old vehicles, the abatement diminishes rapidly if the transitional period is chosen too long;
- in case of a longer transitional period (e.g. 2010), the exhaust emission criterion must be more ambitious (at least Euro III standard plus a retrofit diesel exhaust particle trap) to achieve any worthwhile reductions.

The national labelling scheme:

Pushed by Berlin the German government eventually adopted a national labelling scheme, which provides the basis to control emission related traffic restrictions in LEZ in Germany.

The scheme, which is in force since March 2007, introduced 4 pollution classes, according to the following emission criteria:




sticker:			
minimum criteria for Diesel vehicles	Euro 2, or Euro1 plus particle filter	Euro 3, or Euro 2 plus particle filter	Euro 4, Euro 3 plus particle filter
ban for Diesel veh. older than ...	1992	1996	2000
minimum criteria for petrol cars			Euro 1 plus catalytic converter



Figure 1: German vehicle labelling scheme

Vehicles not meeting any of these criteria belong to pollution class 1. They cannot be exempted from any traffic ban. Two-wheelers, vintage cars, off-road vehicles, police, fire brigade and emergency vehicles are exempted from the scheme.

An amendment to the national vehicle registration ordinance set out the minimum efficiency particle filter systems needs to fulfil so that any retrofitted diesel vehicle can be upgraded into a higher pollution class. The minimum filter efficiency criteria for passenger cars and LDVs needs to be at least 30%, while a particle trap for HDVs must remove between 30 and 50% of the particle load for unregulated systems and at least 90% for regulated CRT systems.

Foreign vehicles are classified according to their age, if the Euro standards cannot be clearly identified in the vehicle registration.

Environmental criteria in Berlin’s LEZ

Environmental criteria for Berlin’s low emission zone	
All vehicles (passenger cars, LDVs and HDVs) willing to enter the low emission zone need to...	
in stage I as from 1.1.2008	have a red, yellow or green label,  i.e. at least pollution class 2 of the national labelling scheme This corresponds as a minimum: <ul style="list-style-type: none"> • for Diesel-vehicles to Euro 2 or Euro 1 + particle filter • for petrol vehicles. Euro 1 with a catalytic converter
in stage II as from 1.1.2010	have a green label,  i.e. at least pollution class 2 of the national labelling scheme This corresponds as a minimum <ul style="list-style-type: none"> • for Diesel-vehicles to Euro 4 or Euro 3 + particle filter • for petrol vehicles. Euro 1 with a catalytic converter

Of a total of 1.3 Mio registered vehicles, around 80.000 vehicles, among them about 30.000 commercial vehicles, will be affected by the traffic ban in stage I. Another 120.000 will be covered by stage II in 2010, of which 85.000 can be upgraded by retrofitting a particle filter. No general exemption is granted for residents or commercial traffic, but some leeway exists in cases of proven financial hardship for businesses and for disabled people and night shift workers.

Spatial extension of the LEZ:

The LEZ covers the city centre area of 85 km² with more than 1.1 Mio residents, delimited by the local railway ring.

Projected Environmental benefits:

In preparation of the clean air plan scenario calculations were made for several options of a LEZ. For the LEZ concept eventually adopted 2005 the following impact was predicted on pollutant emissions

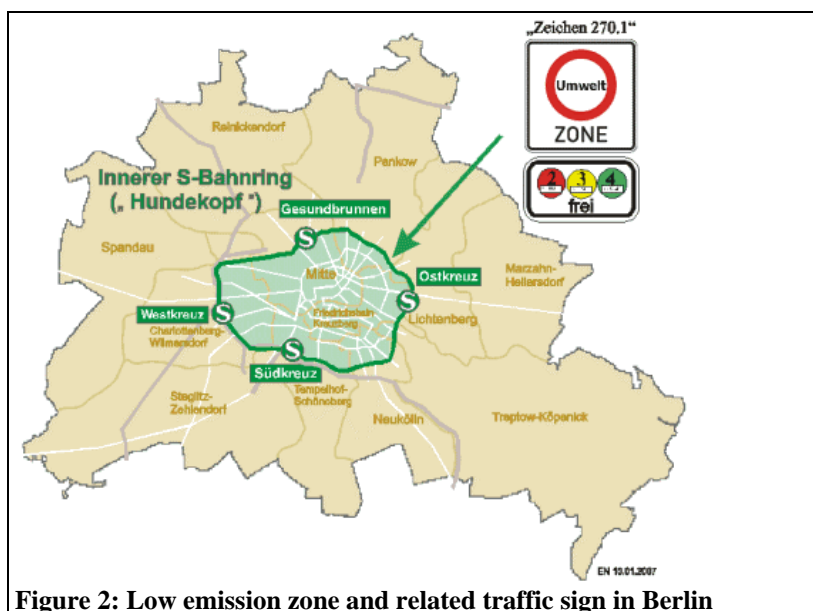


Figure 2: Low emission zone and related traffic sign in Berlin

LEZ stage 1, as from 2008:	LEZ stage 2, as from 2010:
impact on emissions	impact on emissions
<ul style="list-style-type: none"> ■ ~15% less PM-exhaust emissions <ul style="list-style-type: none"> ↘ cars/LDVs: ~10% ↘ HDVs: ~5% 	<ul style="list-style-type: none"> ■ ~50% less PM-exhaust emissions <ul style="list-style-type: none"> ↘ cars/LDVs: ~35% ↘ HDVs: ~15% ■ ~10% less PM & NOx- total traffic emissions
impact on pollution levels	impact on pollution levels
<ul style="list-style-type: none"> ■ ~3% decrease of PM₁₀ annual mean ■ ~5 decrease in days >50 µg/m³PM₁₀ 	<ul style="list-style-type: none"> ■ ~5-10% decrease of PM₁₀ annual mean ■ ~4% decrease of NO₂ annual mean ■ ~10-15 decrease in days >50 µg/m³PM₁₀ ■ ~10.000 less residents living along main roads in the LEZ in non-compliance with PM standards (20-25% reduction)

Table 1: Projected impact of the LEZ on PM10 and NO2-pollution

and concentrations of PM10 and NO2:

The effect on PM10 levels could be almost doubled if Berlin’s transport strategy (StEP) was fully implemented, because an expected 10 % reduction of the traffic volume in the city centre area due to the traffic calming effect of the strategy would curb the non-exhaust emissions of PM10 accordingly.

Real impacts after 1 year in force:

After one year in force the real impact of the LEZ on

- traffic flows within and around the zone
- the emission characteristics of registered vehicle fleet and of the vehicles on the roads
- traffic emissions
- on the air quality within and outside of the zone

was analysed using traffic data, Berlin’s vehicle registration data base, conducting extra video recordings at representative spots of the main road network and evaluating air quality monitoring data, including black and organic carbon.

A closer look at the traffic volume data recorded at 36 selected detectors in busy roads in and outside the LEZ reveals a decrease of motor traffic by 4% inside the zone and 6% in the surrounding areas in the year 2008 after introduction of the LEZ. Given the larger drop of vehicle numbers outside the zone it can be concluded that the LEZ has had **no measurable impact on traffic flows**. Initial concerns that traffic could be pushed into residential areas around the zone did not materialize. The observed decrease in traffic load, which also leads to lower emissions and air pollution from traffic, is not sparked by the LEZ, but rather a result of the peak in fuel prices in 2008 and of Berlin’s transport policy to promote cleaner modes of transport.

On the other hand the number of registered **vehicles with high emissions**, thus not eligible for any sticker, **dropped** significantly (see Figure 3 below) after the LEZ came into force. 70% of high

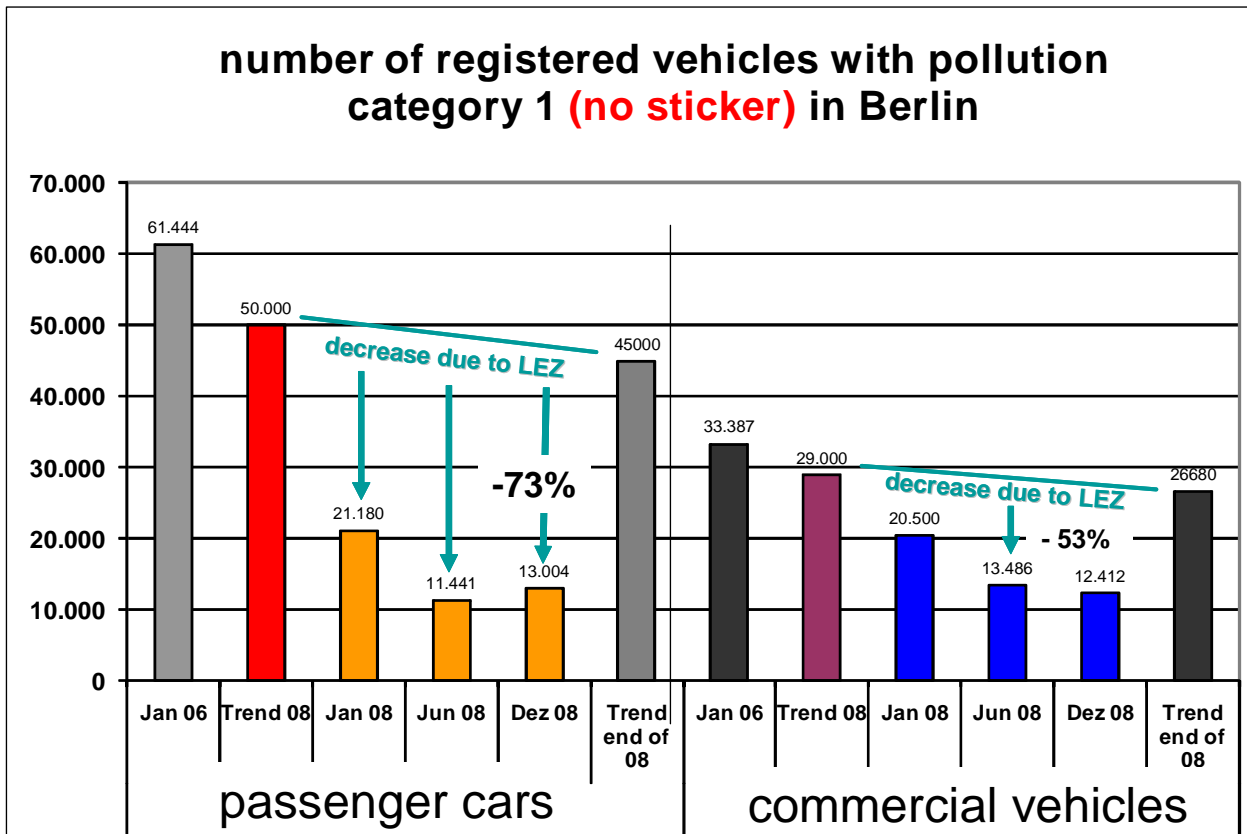


Figure 3: Change in registered vehicles in the worst pollution category (not eligible for a sticker) after introduction of the LEZ

polluting passenger cars and more than 50% of old commercial vehicles have disappeared only because stage 1 of the LEZ took effect in 2008.

Likewise, a clear net switch from such high polluting vehicle towards cleaner ones could be detected in a detailed analysis of the vehicle fleet at some representative heavily trafficked street segments. Such accelerated renewal of the vehicle stock could be observed also in city areas outside the LEZ. Only outside Berlin, for example in the nearby town of Potsdam and the more so in Cottbus, 120 km away, older vehicles with higher emissions are still more frequent in the vehicle registry and on the roads as well.

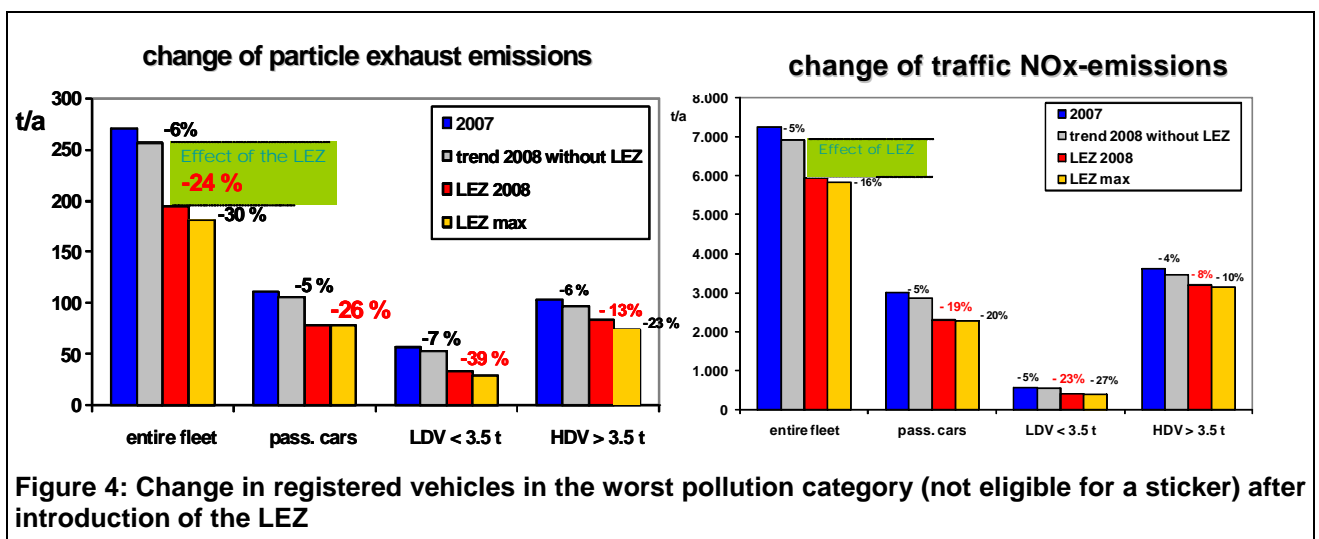


Figure 4: Change in registered vehicles in the worst pollution category (not eligible for a sticker) after introduction of the LEZ

Taking the recorded vehicle composition before and after the launch of the LEZ as a basis it could be calculated how vehicle exhaust emissions changed due to the LEZ. The grey bars in Figure 4 (left for particle exhaust emissions, right for NOx emissions) depict the total emissions in 2008 in the absence of the LEZ assuming a long-term average turnover of the vehicle fleet. The red bar represents the real situation with the LEZ in place, calculated from the recorded vehicle fleet data inside the LEZ, while the yellow bars show the emissions in the event that all non-labelled vehicles would have been fully replaced by cleaner ones. As a result of the LEZ exhaust particle emissions dropped by 24% or by more than 60 t/a in absolute terms. NOx emissions also fell by 14% or almost 1000 t/a.

In order to identify any impact of the LEZ in the air quality data it is not sufficient to simply compare concentrations or excess days of certain limit values before and after the enforcement of the LEZ. Changes in the weather conditions relevant for dispersion, dilution and re-suspension of emitted pollutants from traffic also have a large impact on measured pollution levels irrespective of any changes in the emissions. While NO2-levels are largely dominated by local emission sources total PM concentrations also depend on regional and long-range pollution transport. Likewise, any shift in traffic volumes around the air quality monitoring sites used for the impact analysis need to be taken into account as such changes are barely related to the LEZ.

In order to better retrieve the net benefit of the LEZ from the air quality data, the following approach has been pursued:

- a) The results of a PM2.5 source apportionment study in 2007, one year before the launch of the LEZ was taken as a basis to translate the calculated emission reduction into a numerical decrease of the PM10 concentration measured at a traffic site in Berlin’s city centre. The pie chart in Figure 5 depicts the percentages major sources contribute to total annual mean PM2.5 levels at a traffic site. The pollution from outside sources (in green), from non-transport emissions in Berlin (in blue) and from the non-exhaust PM-emissions by vehicles (in grey) cannot be mitigated by the traffic ban enforced by the LEZ. Only 14% of PM2.5 at the kerbside stems from exhaust particle emissions of the urban traffic in Berlin and another 8% appears as secondary inorganic PM from urban NOx-

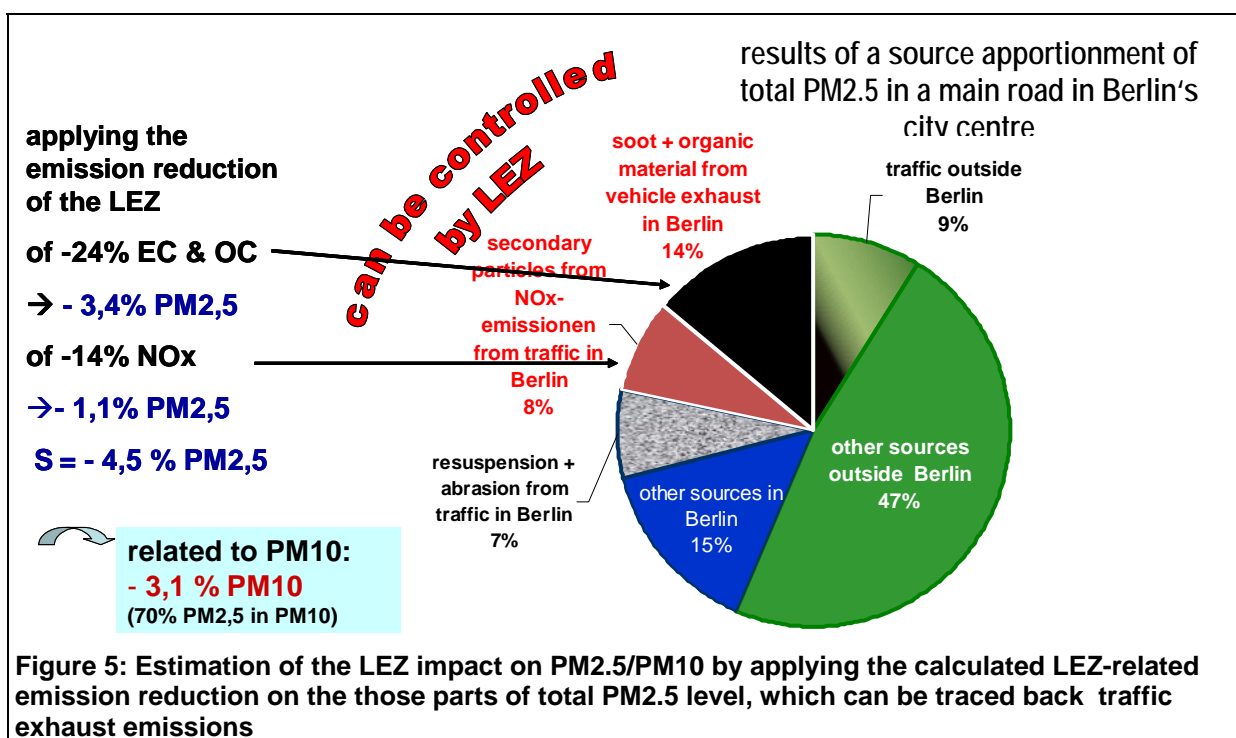


Figure 5: Estimation of the LEZ impact on PM2.5/PM10 by applying the calculated LEZ-related emission reduction on the those parts of total PM2.5 level, which can be traced back traffic exhaust emissions

emissions from traffic, both of which are the only parts of the PM_{2.5} mixture affected by the LEZ. While absolute concentrations of pollutants strongly depend on the meteorological conditions, the relative contribution of the source sectors, like those shown in the pie chart above, should be less prone to weather changes. Hence, the results obtained by using the source apportionment results of 2007 as a key to transpose the LEZ-related emission reduction into equivalent pollution reduction figures should produce a result fairly representative also for other years with a different meteorology.

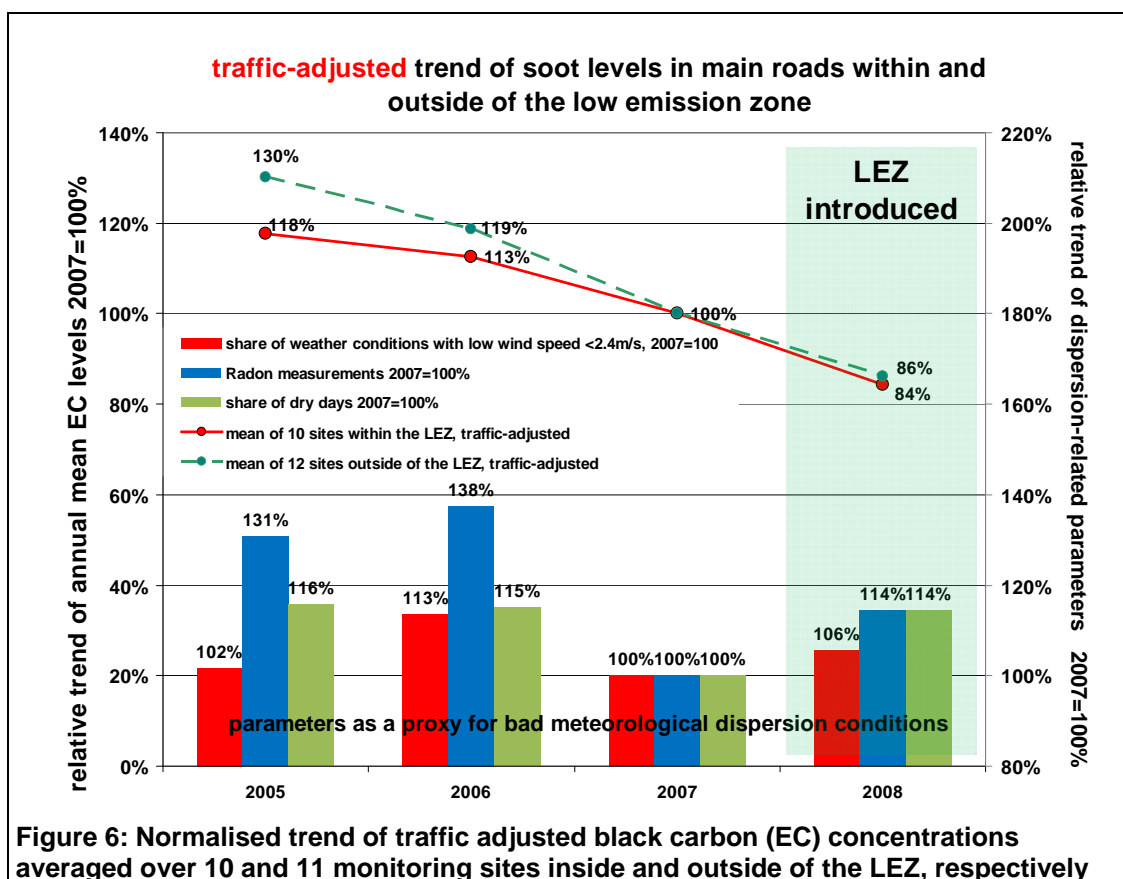
Assuming linearity between emission reduction and the resulting decrease of the pollution concentration, the two LEZ-related parts of the PM_{2.5} pie would shrink by the percentage decrease of the traffic emissions mentioned above. As a result, PM_{2.5} concentrations would be 4.5% lower, if the LEZ was introduced in 2007, when the source apportionment study was conducted. Given a 70% share of PM_{2.5} in kerbside PM₁₀, the net reduction of PM₁₀ levels due to stage 1 of the LEZ amounts to 3.1%. Based on a statistical relation between annual mean levels and the number of excess days of the 24h PM₁₀ limit value of 50 µg/m³, about 4 of such excess days can be prevented by the LEZ under the boundary conditions of the year 2007.

The attempt to derive a quantitative figure for the LEZ-effect directly from a comparison of the PM₁₀ measurements before (i.e. 2007) and after (i.e. 2008) the launch of the LEZ has yet failed, even if the LEZ-independent regional PM-background level was subtracted and the remaining urban increment was adjusted for any local changes in traffic volumes. There is still too much noise in the data resulting from varying weather conditions and other unknown factors, in order to allow to extract a statistically significant LEZ-related signal.

- b) As a consequence, black carbon data were analysed hoping that the effect of lower diesel soot emissions due to the LEZ could be easier seen in those data series. Such measurements were conducted at more than 20 spots within and outside of the LEZ. Figure 6 shows the trend of black carbon concentrations averaged among the measurements in and outside of the zone. The data, which were adjusted for any traffic volume changes, are normalised to 2007 figures, so that the net reduction in percent can be immediately obtained from the graph. So, in comparison to 2007, black carbon levels decreased by 14 or 16% in 2008, the first year with the LEZ in force.

In order to qualitatively assess the weather dependency of the result three parameters were chosen as a proxy for conditions in the boundary layer, which are thought to determine the dispersion of fine particles, like soot. Low wind speed, days without precipitation and radon concentrations were considered as most relevant. The latter is an inert, but radioactive gas with a decay time of around 4 days. As it diffuses from the ground soil at roughly constant rate higher Radon levels reflect worse dispersion conditions in the ground-near atmosphere.

Figure 6 shows that, despite dispersion conditions worsened in 2008 the rate of decline of black carbon concentrations was the same and in the low emission zone even larger than in the year before. Hence, this improvement of around 15% must be largely linked to the implementation of the LEZ. Traffic adjusted NO₂-concentrations also decrease by 8%, a much larger reduction rate than in the year before.



Conclusions

After one year since the start of the Low Emission Zone in Berlin its success can be clearly seen in terms of an accelerated shift towards cleaner vehicles, reduced pollutant emissions and better air quality.

While traffic flows have not changed due to the LEZ, the turnover of the vehicle fleet towards more cleaner vehicles has speeded up considerably. As a result, a net reduction of 24% of exhaust particle emissions and 14% lower NO_x emission from Berlin’s motor traffic can be allocated exclusively to stage 1 of the LEZ.

Its impact on annual PM₁₀ pollution is about 3%, which corresponds to 4-5 avoided excess days of the 24h PM₁₀ limit value. Similar figures were obtained from a first preliminary evaluation of air quality data in the Rhine-Ruhr Area, where LEZ have been set up in several cities in October 2008.

Black carbon concentrations on Berlin were more strongly affected with levels falling by around 15%. As the LEZ is targeted towards reducing the most hazardous PM component, i.e. black carbon released by the exhaust pipe, the benefits to public health are much more pronounced than the pure reduction figures in PM₁₀ concentrations suggest. Despite an increasing share of direct NO₂-emissions, NO₂ concentrations in Berlin have also decreased by 7-10%, after several years without a visible downward trend.

As weather conditions were even more stagnant in the first year of the LEZ, the observed improvement of the air quality can be largely allocated to the implementation of the LEZ.

These results are also consistent with projections based on model calculations. Hence, according to these calculations, it can be expected, that the impact of stage 2 of the LEZ will be two to three times stronger. That could mean in 2010 a decrease of annual PM₁₀ levels by up to 10% and 10-15 days less with PM₁₀ levels above the 24h-limit value. These benefits emerging from the LEZ are significant, given the short time span towards 2011, the ultimate deadline for compliance with the PM limit values.

However, full implementation of the LEZ and other control measures still leaves a huge **compliance gap** in Berlin and in many other EU cities **with regard to NO₂-levels**. Unfortunately, the European legislator has failed to limit direct emissions of NO₂ of modern Diesel cars, which tend to release about 40% of NO_x-emissions as NO₂ since Euro 3 became mandatory. That’s why there are nice but irrelevant downward trends in NO_x-emissions and air concentrations, while NO₂ levels have stagnated or gone up in recent years.

What adds to the calamity in Germany is, that the national legislator missed the chance to limit NO₂ emissions when retrofitting a diesel vehicle with a particulate filter. It turned out that a number of particle filter systems with passive regeneration tend to accumulate NO₂ in the exhaust gas, a fact that might jeopardize the net benefit of the forthcoming stage 2 of the LEZ on NO₂ concentrations, because most of the Diesel vehicles with a yellow sticker will need to get a particle filter. Fortunately, as revealed by a calculation for Berlin’s Diesel fleet, the net effect of stage 2 of the LEZ on NO₂ is still positive, because all vehicles already equipped with an oxidation catalyst (i.e. most cars, vans and light goods vehicles) will emit less NO₂ after being retrofitted with a particle filter. Another reason is that NO-emissions of modern vehicles since Euro 3 have fallen so drastically that NO₂ concentrations in a typical street canyon, about 60% of which are formed from former NO, will eventually decrease even though the share of NO₂ emissions has gone up.

Anyway, the forthcoming Euro 5 standard for passenger cars and light duty vehicles falls short with respect to the NO_x emission reduction needed to attain the NO₂ limit values even within the extra 5 years attainment period granted by the new air quality Directive. Tangible progress can only be expected with Euro 6 becoming mandatory, because its NO_x emission standard will require auto industry to install efficient NO_x control technology in every Diesel car and lorry, so that both NO- and NO₂ emissions will drop drastically. However, Euro 6 will only become mandatory in 2014, definitely too late to help meeting the NO₂ air quality standards by 2015 at the very latest. The brand-new Euro VI emission standard for heavy goods vehicles and buses, due for 2013, will be barely helpful too. Unfortunately, contrary to the particle filter systems, retrofit kits for NO₂-control of the existing vehicle stock will not be available for passenger cars and light goods vehicles.

So, progress on urban NO₂ levels largely depends on the ambition of national governments in subsidising the purchase or the operation of Euro 6/VI vehicles so that they would appear earlier in showrooms and on the roads.

At least for buses and heavy goods vehicles retrofit with de-NO_x SCR technology seems to be technically feasible. SCRT filter systems for retrofitting buses have been developed recently. Berlin will launch very soon a pilot project, in which different types of Diesel buses will be retrofitted with

such systems and emissions be monitored under typical real-world driving condition. Provided that functioning and efficiency of these SCRT retrofit systems can be demonstrated a retrofit program will be started aimed at reducing substantially NO- and NO2 emissions of Berlin’s fleet of about 1400 buses.

However, given the lessons learnt five years ago during the preparatory phase of the LEZ, cleaning up only a small segment of the whole vehicle fleet will not be sufficient to generate a tangible improvement of the air quality, here of NO2-pollution. Hence, the Commission, national government and industry ought to come up with a coherent concept to ensure fast development and dissemination of SCRT retrofit for larger commercial vehicles in Europe. What is still lacking with regard to particulate filters should be pursued as soon as possible: Setting a up a harmonized framework for technical certification of SCRT filter systems on EU level, combined with economic incentives, such as discounts on vehicle taxes and road tolls, for retrofitted lorries and trucks on a national scale.