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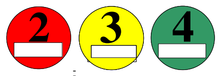
Berlin’s Low Emission Zone – top or flop ?
Results of an impact analysis after 2 years in force

Triggered by a widespread non-compliance with European air quality standards along major roads Berlin introduced a low emission zone (LEZ) in two stages covering a central city area of 85 km2 with more than 1.1 Mio residents, delimited by the local railway ring.

Based on a German national vehicle labelling scheme all diesel vehicles not meeting Euro 2 and petrol cars worse than Euro 1 were banned as from January 2008 from driving within the zone. In January 2010 the criteria were tightened in that Euro 4, or retrofit with particle filters (DPF), became mandatory for diesel vehicles, including passenger cars and commercial vehicles.

<u>Environmental criteria in Berlin’s LEZ</u>

Environmental criteria for Berlin’s low emission zone All vehicles (passenger cars, LGVs and HGVs) willing to enter the low emission zone …	
<u>in stage I</u> **as from 1.1.2008**	need a red, yellow or green label on the window screen  i.e. at least pollution class **2** of the national labelling scheme This corresponds as a minimum: • **for Diesel-vehicles to** Euro 2 or Euro 1 + particle filter • **for petrol vehicles** to Euro 1 with a catalytic converter
<u>in stage II</u> **as from 1.1.2010**	need a green label,  i.e. at least pollution class **4** of the national labelling scheme This corresponds as a minimum • **for Diesel-vehicles to** Euro 4 or Euro 3 + particle filter • **for petrol vehicles to** Euro 1 with a catalytic converter

After more than two years in force the real impact of the LEZ on
- traffic flows within and around the zone
- the emission characteristics of the registered vehicle fleet and of the vehicles on the roads
- vehicle 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.

While the LEZ has had no measurable impact on traffic flows, the turnover of the vehicle fleet towards more cleaner vehicles has speeded up considerably only because of the LEZ. Accordingly, almost three-third of all diesel passenger cars have got a green sticker (at least Euro 4 or retrofit), while in the absence of the LEZ, estimated on the basis of the long-term renewal trend of the vehicle fleet, this number would be still well below 50%. Likewise, more than 50% of commercial vehicles comply with the green category instead of only 20% in the event of no LEZ. Mostly driven by the LEZ, stage2, 40.000 (24%) diesel passenger cars and 12.000 lorries (17%) have been retrofitted with a particle filter since the end of 2009.

Taking the observed vehicle composition before and after the launch of the LEZ as a basis, it could be calculated how vehicle exhaust emissions have changed due to the LEZ. The blue bars in Figure 1 (right for particle exhaust emissions, left for NOx emissions) depict the total emissions in 2008 and 2009 in the absence of the LEZ assuming a long-term average turnover of the vehicle fleet. The red and yellow bar represents the real situation with the LEZ in place. As a result of the LEZ exhaust particle emissions dropped by 35% or by more than 100 t/a in absolute terms. NOx emissions also fell by 19% or almost 1500 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 weather conditions relevant for dispersion, dilution and resuspension of emitted pollutants from traffic and other sources 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 needed 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 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 2 depicts the percentages major sources contribute to total annual mean PM2.5 levels at this 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-emissions from traffic, both of which are the only parts of the PM2.5 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 below, should be less prone to weather changes. Hence, when using the source apportionment results of 2007 as a key to transpose the LEZ-related emission reduction into equivalent pollution reduction figures, the emerging results should be 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 PM2.5 pie would shrink by the percentage decrease of the traffic emissions mentioned above. As a result, PM2.5 concentrations would be 6.4% lower, if the LEZ was introduced in 2007, when the source apportionment study was conducted. Given a 70% share of PM2.5 in kerbside PM10, the net reduction of PM10 levels by the end of 2009 amounts to 4.5%. 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 6 of such excess days can be prevented by the LEZ assuming the boundary conditions of the

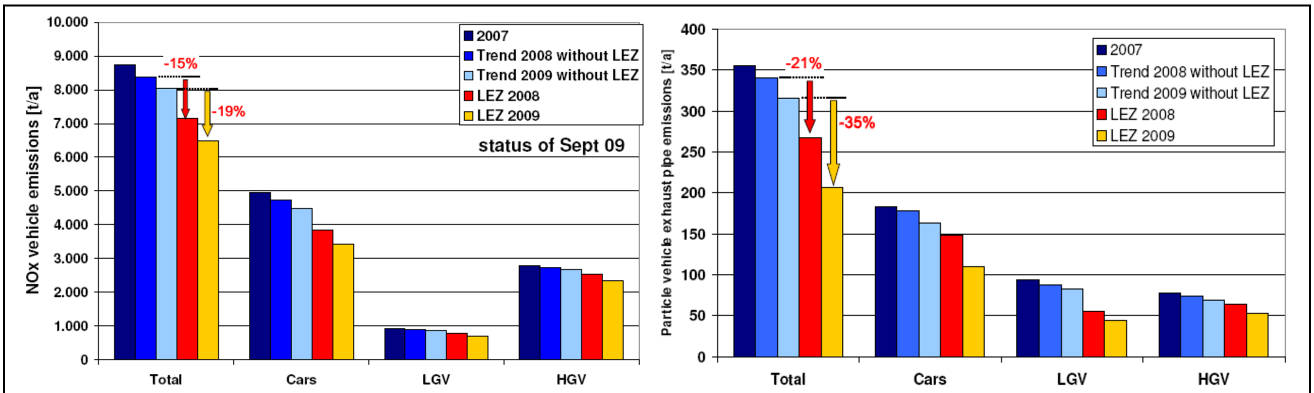


Figure 1: NOx emissions (left) and exhaust particle emissions (right) for trend assumptions and for the LEZ

year 2007.

Total 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. In order to largely exclude the impact of changes in other carbon source sectors, like house heating, the carbon levels at a downtown urban background station were subtracted from the concentrations measured at the busy traffic spot in the city centre. The resulting local traffic increment was adjusted for any traffic volume changes, so as to become largely independent of traffic flow changes not related to the LEZ. So, in comparison to 2007, total carbon levels decreased steeply in 2008 (the first year with the LEZ) by more 25% inside and 20% outside of the LEZ even though atmospheric dispersion condition worsened in 2008. Dispersion conditions were assessed by chosing low wind speed frequency and radon concentrations as a proxy for the dispersion of fine particles and NO2 in the boundary layer.

2009 saw almost no continuation of the downward trend, which may be largely due to the increase in days with stagnant dispersion conditions, i.e. with a surge in low wind speed situations by one-third associated also in 10% higher radon levels. Hence, the measured improvement in total carbon levels could be largely linked to the implementation of the LEZ. Traffic adjusted city-generated NO2-concentrations also decrease by 8%, the first decrease since several years. However, concentration levels slightly rose again in 2009. While this feature might also be explained by the unfavourable dispersion conditions in 2009, there was also growing suspicion that continuously regenerating particulate filter (CRT) systems could actually increase the share of NO2 in the exhaust gas released by retrofitted vehicles. Fortunately, a balance sheet calculation for Berlin's Diesel fleet revealed, that 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.

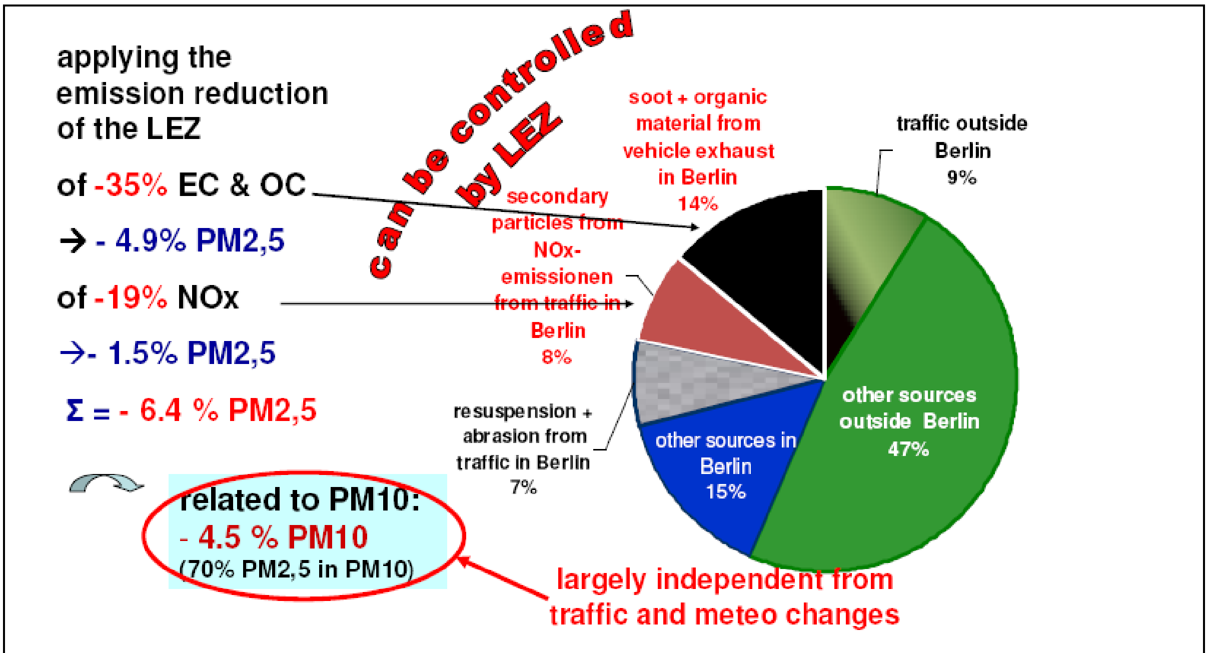


Figure 2: Estimation of the LEZ impact on PM2.5/PM10 by applying the calculated LEZ-related emission reduction on the those parts of total PM2.5 level, which can be traced back to traffic exhaust emissions

In conclusion, the LEZ is the most effective single measure in Berlin, provided that ambitious emission criteria (i.e. particle emissions of Euro 4) are required within a reasonably short time scale (i.e. by 2010), not watered down by extensive granting of exemptions for residents and business. Nevertheless, in order to be proportionate, a transition period is needed between the adoption and practical implementation of a LEZ so that business and car drivers can adapt. Furthermore, a LEZ area needs to be large enough in order to generate the expected effect on the renewal rate of the vehicle fleet and in order to avoid detrimental affects in adjacent areas by undesired traffic re-routing generated by the LEZ.

However, implementation of the LEZ and all the additional measures stipulated by Berlin's Clean Air Plan still leaves a **compliance gap**, even if we take advantage of the prolongation of the attainment period offered by the revised EU air quality legislation. So, the LEZ needs to be supplemented by further action, like traffic planning measures on the local level and stricter vehicle emission standards by the EU. Current standards like the Euro 5 emission limit for passenger cars and light duty vehicles fall short with respect to the NOx emission reduction needed to attain the NO2 limit values even within the extra 5 years period granted by the new air quality Directive. Tangible progress can only be expected with Euro 6 becoming mandatory, because it's NOx emission standard will require auto industry to install efficient NOx 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-NOx 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-word 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 EU Commission, national governments 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.

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