Low Emission Zone (LEZ)

Vehicle Travel Restriction to Improve Air Quality in Inner Cities

Regulations restricting ownership and the utilisation of private vehicles are on the rise to improve the efficiency and quality of transport systems worldwide. Rising levels of congestion, local air pollution and greenhouse gas (GHG) emissions drive decision makers to adopt strategic policies to restrict traffic. License plate lotteries, driving bans, and peak-hour driving restrictions are gaining momentum in bigger cities. Low Emission Zones (LEZs), also called environmental zones, are a widespread measure to influence urban vehicle fleet compositions and improve air quality. The concept focuses on drawing a boundary around an urban area to deter highly polluting traffic.

LEZs at a glance

- LEZs are geographically defined areas or roads banning or restricting access for polluting vehicles.
- The overall aim of LEZs is to reduce air pollution in problem areas.
- Vehicles need to meet certain emissions standards to drive within the LEZ.
- LEZs could potentially apply to all vehicles but generally apply to heavy diesel vehicles due to their relatively large contribution to air pollution.
- Non-compliant vehicles that enter a LEZ are subject to large fines.
- Some LEZs allow non-compliant vehicles to enter the zone by charging a fee.
- LEZs are usually in operation 24 hours a day, 365 days of the year.
- LEZs sometimes apply only to specific groups of vehicles such as heavy duty vehicles or diesel passenger cars.
- Zones that completely ban all vehicles running on an internal combustion engine and only allow electric-powered vehicles to enter are called Zero Emission Zones (ZEZ).

By banning the most polluting vehicles LEZs biggest impact is on the decision to retrofit or buy a new vehicle. The distance people travel and the number of trips undertaken are not directly affected. Hence, LEZ usually change the urban fleet composition but do not reduce congestion. Therefore, many cities introduce congestion charging or parking pricing measures in addition to a LEZ.

This factsheet provides information on the concept of LEZs and their impact analysing two European examples in Berlin (Germany) and London (UK). Furthermore, the case for Beijing is presented and suggestions for the further development of Beijing's LEZ are given.

Air Quality Legislation in Europe

The latest EU *Directive on Ambient Air Quality and Cleaner Air for Europe* (2008/50/EC) adopted in 2008 defines legally binding limit values for the most hazardous pollutants, including NO_2 and PM_{10} (see table below). Member States transposed this directive into national legislation and annually report air pollution levels to the EU. In case of elevated pollution levels an action plan needs to be prepared to ensure reduction of pollution levels and compliance.

Pollutant	Concentration	Averaging period	Limit value entered into force	Permitted exceedances each year
NO2	200 µg/m3	1 hour	1.1.2010	18
	40 µg/m3	1 year	1.1.2010*	
PM10	50 µg/m3	24 hours	1.1.2005*	35
	40 µg/m3	1 year	1.1.2005*	

*application for extension possible

As of today (April 2014), 12 European countries operate LEZs in various cities with the primary aim to meet the health-based air quality limit values implemented by the EU.

1 Environmental Impacts and Co-benefits

The ultimate objective of LEZs is to improve human health by reducing exposure to harmful air pollutants such as fine particulate matters (PM_{10} and $PM_{2.5}$) and nitrogen dioxide (NO_2). According to the European Environment Agency, the single main source of these pollutants in many urban areas is road traffic. LEZs are usually established to reduce the number of older, more polluting vehicles within problem areas and to accelerate the share and use of cleaner vehicles. This includes:

- newer vehicles that comply with more stringent vehicle emission standards and/or
- older vehicles that have been retrofitted with emission reduction technology such as a particulate filter.

Both help to significantly reduce tailpipe emissions and, thus, lower direct exposure to hazardous air pollutants in inner cities. However, in some cases drivers may reorganise their trip by circuiting the LEZ instead of replacing their vehicles or shifting transport modes which ultimately puts the strain on other areas. This largely depends on the LEZ scheme design and size.

Depending on the scheme design, the impact of LEZs on GHG (mainly CO_2) emissions is usually not significant. LEZs do not significantly impact traffic volumes but rather drive changes in the overall fleet composition. More critically, although newer vehicles are often more efficient, they use more auxiliary equipment such as air conditioning and include pollution control devices which tend to increase fuel consumption. Therefore, some debate remains on changes in fuel consumption by replacing or retrofitting vehicles and the ultimate effect on GHG emissions.

LEZs also affect noise pollution levels since newer vehicles are usually quieter. The overall noise reduction highly depends on the share of existing older, noisier vehicles to be replaced. In any case, residents will notice a reduction in maximum noise levels of passing-by vehicles. Finally, LEZs and the increase in more modern vehicles also constitute some safety benefits for vehicle occupants.

European Emission Standards

The European Union (EU) implemented minimum emission standards required for all new vehicles sold in the EU market. The so called "Euro" emission standards cover a number of pollutants including PM_{10} and NO_x and are classified into different vehicle categories such as passenger cars, light commercial vehicles (LCV), trucks and buses, and large goods vehicles. The standards for light duty vehicles are typically referred to as Euro 1, Euro 2, Euro 3, Euro 4 and Euro 5. The corresponding denomination for heavy duty vehicles uses Roman numerals such as Euro I, Euro II, etc.

The European emission standards have been adopted by China. Standards were introduced for cars and light trucks (China 1 – 5), heavy-duty trucks and buses (China I – V), and off-road diesel engines (Stage I & II).

2 The London Low Emission Zone

Air quality in London was considered to be amongst the worst in Europe. PM_{10} and NO_x regularly failed to meet the EU air quality standards. Within this context the London LEZ was launched on 4 February 2008, with the aim to improve air quality for all who visit, live and work within Greater London. This LEZ focuses on diesel-powered lorries, buses, coaches and other specialist heavy duty vehicles (HDVs). Cars and motorcycles are not affected but are subject to the London Congestion Charge, which levies a daily charge for driving into the inner city centre. Vehicles that are ineligible to drive within the zone can still do so by paying a daily charge.

The London LEZ	
Introduction year	2008 (Euro III for PM for HDVs)
Latest update	2012 (more stringent standard for HDVs and inclusion of LDVs)
Coverage	All roads within Greater London, those at Heathrow and parts of the M1 and M4 motorways within the Greater London Authority (GLA) boundary are included.
Vehicle group affected	Diesel lorries, buses, coaches, motor caravans, motorised horseboxes, larger vans, and minibuses.
Emission standard (Diesel)	Euro III Standard for PM, except for lorries (> 3.5 tonnes), buses and coaches (> 5 tonnes) which need to meet Euro IV Standard for PM.
Operating hours	Permanent, 365 days a year.
Registration	Vehicles registered in Great Britain only need to register if the vehicle is classified as not meeting the emissions standards, but documentary evidence can be provided that it does (e.g. vehicle is fitted with an approved filter). Vehicles from outside Great Britain need to register by filling in a download form and sending it in.
Daily charge	£100 per day for large vans and £200 for heavy vehicles.
Enforcement	Automatic Number Plate Recognition (ANPR) cameras read number plates and check it against the register.
Penalty	£500 for large vans & £1000 for heavy vehicles; 50% discount if payment is received within 14 days.
Exemptions	Specialist vehicles built for off-road use (e.g. agricultural and forestry tractors, mobile cranes and construction machinery), historic vehicles, showman's vehicles and vehicles operated by the Ministry of Defence.

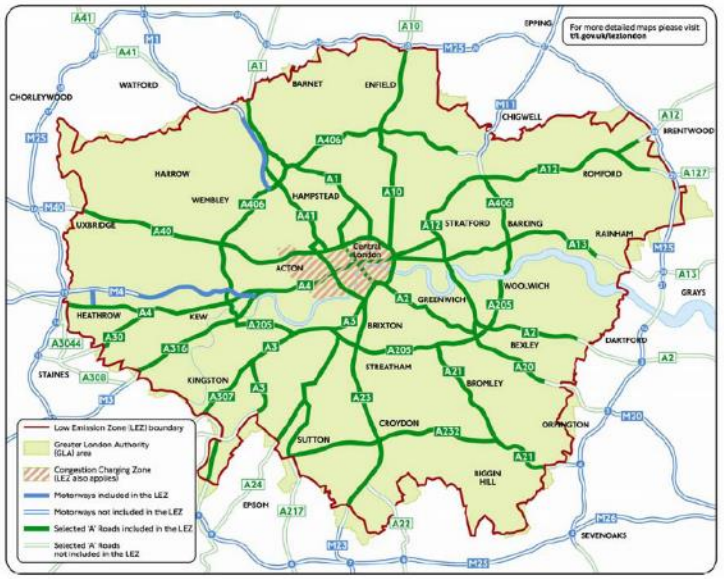


Image 1: Low Emission Zone London (TfL, 2012)

Impact - What did the London LEZ achieve?

Fleet turnover and vehicle use

- Within the first year of introduction pre-Euro III rigid vehicles registered in London dropped from 47.4% to 31.9% indicating an extra 20% of pre-Euro III vehicles being replaced compared to the natural replacement rate. The share of pre-Euro III articulated vehicles also dropped but to a less significant extent since higher purchase costs make the replacement decisions more difficult.
- The inclusion of light duty vehicles (LDVs) into the LEZ scheme brought forward a similar replacement rate for LDV compared to the approximately 20% of replaced pre-Euro III rigid vehicles mentioned above. This is a significant change since 60% of all freight-carrying vehicles entering the LEZ are heavy LDVs.
- In terms of vehicle usage within the LEZ, the proportion of non-compliant articulated vehicles dropped from 24% to 14% when the scheme was first introduced. The proportion of respective rigid vehicles reduced from 42% to 28% within the same time period. However, rigid vehicles only became part of the scheme during the 2nd phase of the LEZ roll-out. Consequently, the introduction of the LEZ generally encouraged the use of cleaner vehicles within London independent of the exact LEZ rules.

Air Quality

- Air quality measurements for PM_{10} show that annual mean concentrations reduced between 2.46% and 3.07% within the LEZ compared to just over 1% for locations outside the LEZ. For NO_x, no significant changes were monitored.
- Air quality improvements have been greater in areas with a larger share of heavy duty vehicle traffic. PM_{10} readings above the EU air quality limits were substantially reduced and hourly mean concentrations were decreased by an average of 13% within the LEZ.

3 The Berlin "Umweltzone"

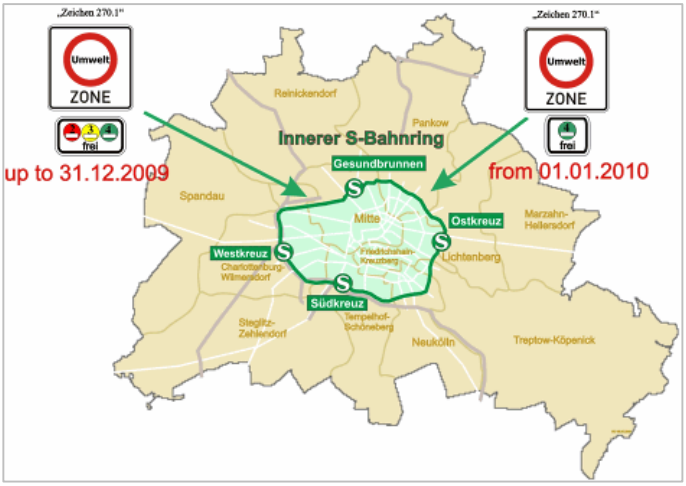


Image 2: Umweltzone Berlin (Senate Department for Urban Development and the Environment Berlin, 2013)

Due to regularly exceeding thresholds of PM_{10} and NO_x in the inner city Berlin developed a clean air action plan to tackle emission reduction. Within this context the so called "*Umweltzone*" (environmental zone) was established in 2008 to reduce diesel soot emissions. The scheme is based on coloured stickers place in the car window screen categorising vehicles according to their emission group. Only vehicles with a green sticker, which indicates the Euro 4 standard, are allowed to drive within the city's LEZ.

In 1999, Berlin already launched a retrofitting programme for Berlin's fleet of 1400 diesel buses. Retrofitting approximately 1000 buses with filters resulted in > 90% reduction of diesel soot emissions. All buses were retrofitted by 2008.

Umweltzone Berlin	
Introduction year	2008 (LEZ giving access to red, yellow and green stickered vehicles, Euro 3 or better)
Latest update	2010 (LEZ only gives access to vehicles with a green sticker, Euro 4 or better)
Coverage	The LEZ covers the city centre within the S-Bahn ring rail (approximately 88km^2). A number of (big) roads within the S-Bahn ring rail are not part of the LEZ and remain freely accessible, allowing vehicles without a green sticker to pass the LEZ without detouring.
Vehicle group affected	All diesel vehicles and petrol vehicles without a closed loop catalytic converter (Euro 1 or equivalent).
Emission standard	Euro 4 or Euro 3 with particulate filter. All petrol engines with catalytic converter and all LPG or natural gas vehicles.
Operating hours	Permanent, 365 days a year.
Registration	A sticker must be bought and displayed in the windscreen which is valid for all LEZs in Germany. Proof of emissions standard (given on German vehicle papers) is needed to purchase the sticker. Stickers can be purchased from the vehicle registration, authorities, authorised local garages, and vehicle test organisations like TÜV, DEKRA, or some websites.
Daily charge	Not applicable.
Enforcement	Manual enforcement by traffic police and public order officers.
Penalty	40€ fine and one point in the national traffic penalty register.
Exemptions	Diesel vehicles that cannot be retrofitted but comply with the Euro 3 standard (yellow sticker), general exemptions apply for people with dual amelia or phocomelia, for test vehicles, and for vehicles with special registration numbers.

Impact - What did the Berlin Umweltzone achieve?

Fleet turnover

- The first stage of the scheme affected 7% of the vehicle fleet. The number of vehicles carrying no sticker was reduced by 70-90% (depending on the vehicle category).
- The second stage affected a total of 124,000 vehicles (10% of the vehicle fleet). The number of vehicles with a red sticker decreased by 50-80%. By mid 2010, 25% of all diesel passenger cars and 18% of light and heavy duty vehicles were retrofitted.

Air Quality

- Since the LEZ implementation ambient PM_{10} pollution was reduced by 3% which equals 8% of anthropogenic PM_{10} pollution. The number of days exceeding the PM_{10} threshold was cut by four. Instead, of 28 forecasted exceedances in 2008 only 24 exceeding days were monitored.
- At *Frankfurter Allee*, a major road in the inner city, particle tailpipe emissions decreased by 25% in 2008 and 58% in 2010 compared to pollution scenarios without a LEZ (baseline scenario).

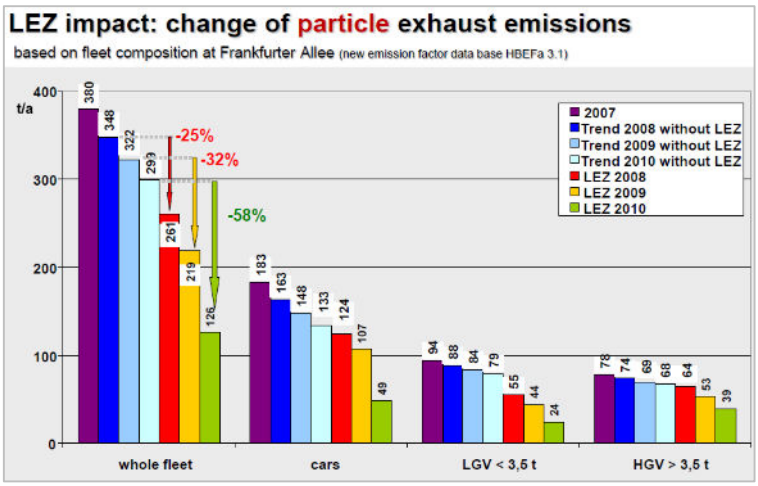
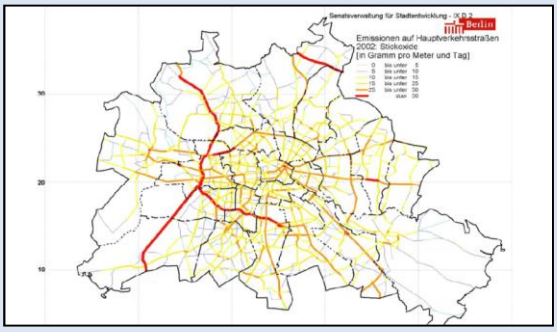
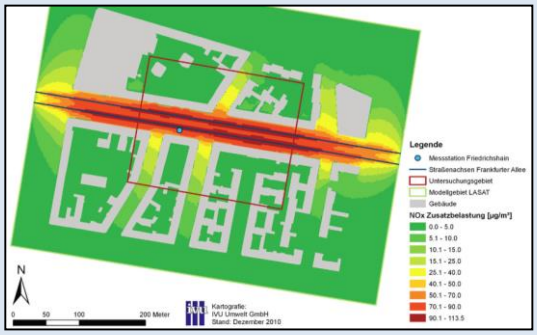


Image 3: Impact of Umweltzone Berlin on Vehicle Emissions (Senate Department for Urban Development and the Environment Berlin, 2013)

The Handbook Emission Factors for Road Transport (HBEFA)

To evaluate pollution reduction strategies detailed information is needed on how emissions vary according to traffic conditions, engine design and vehicle age. The HBEFA provides emission factors - the specific emission in g/km - for all current vehicle categories (passenger cars, LDVs, HDVs, buses, coaches and motor cycles), each divided into different categories, for a wide variety of traffic situations. Emission factors for all regulated and some non-regulated pollutants as well as fuel consumption and CO_2 are also included. The output is used to measure changes in pollution concentration and to better evaluate the effectiveness of reduction strategies. Emission calculations based on the HBEFA include examples from national, regional, and local level such as NO_x emissions in Berlin:





➢ More information on **www.sustainabletransport.org**

The latest version of the tool provides data from five European countries and is mostly applied in Europe. GIZ, its partners at the Beijing Transportation Research Center (BTRC), and the Swiss INFRAS Institute adapted the HBEFA to China (HBEFA-China). The localised database enables decision makers to quantify GHG emissions from road transport in Chinese cities and evaluate reduction measures accordingly.

4 Lessons learned from London and Berlin

The success of the implemented LEZ in London and Berlin is based on different best practise criteria, which are similar in both cities:

Success factor	London	Berlin
Phased approach to more stringent requirements	✓ 2008: Euro III for HGVs 2012: Euro III for LDVs, Euro IV for HGVs	✓ 2008: Euro 3 or better 2010: Euro 4 or better
Covering a larger area	✓ Covers all Greater London (= main freight routes in and out of the city)	✓ Covers main problem area (= inner city streets)
Linked to local circumstances	✓ Focus on freight vehicles as most polluting vehicles	✓ Focus on passenger cars to reduce kerbside air pollution
Based on ambitious reduction targets	✓ Only covers standard for PM → NO_x still subject to regulation	✓ Mainly strict standards for PM (gasoline vehicles at least Euro 1)
Exemptions are limited	✓ Off-road vehicles are exempted → responsible for 12% of NO_x em.	✓ Very few exemptions exist and only apply for minorities
No extensive discounts are given	✗ Daily charge for non-compliant vehicles → smaller incentive to replace or retrofit	✓ No discounts and no daily charge.
Strong enforcement	✓ Constant electronic enforcement	✓ Regular manual enforcement by police and public order officers
Complementary incentive policy	✓ E.g. UK vehicle scrappage scheme 2009/2010; retrofitting of buses	✓ E.g. National vehicle scrapping bonus 2009/2010; retrofitting of public buses
Complementary measures to reduce traffic volume	✓ Congestion charging and parking zoning	✓ Parking zoning and pricing

Both LEZs have been successful in overcoming air pollution problems. However, the primary focus of both is on diesel-vehicles and particulate emissions. To realise all benefits and guarantee continuous success each LEZ needs to be further developed.

In case of Berlin, the scheme can be taken to the third stage focusing on Euro 5 and/or Euro 6. Euro 5 targets the further decrease of diesel-related PM emissions by reducing emissions by 80% compared to the Euro 4 standard. Within this context, NO_x emissions are reduced by 20%. Euro 6 focuses on NO_x and requires and additional reduction of more than 50% compared to Euro 5.

London is preparing the 5th phase of its LEZ focusing on the introduction of the Euro IV standard for NO_x for lorries, buses, and coaches. Furthermore, a zero emission zone, matching the boundary of the congestion charging zone, is discussed for 2020. Nevertheless, by allowing non-compliant vehicles to enter the LEZ operators are not required to replace older vehicles and induced cost may be passed on to the customers. Improving the framework of the current scheme can help to levy additional air quality benefits.

5 Analysing the LEZ in Beijing

In 2009, Beijing implemented a LEZ within the 5th ring road focusing on vehicles that cannot meet the Euro I emission standard (so called *yellow-label vehicles*). At the end of 2008, 350.000 vehicles did not meet this standard (most of them were heavy-duty trucks). Although these vehicles only made up 10% of the total vehicle fleet they were responsible for more than half of total vehicle emissions (GreenLaw China, 2009). Later in 2009, the zone was expanded to the 6th ring road. Vehicles violating the rules are fined 100 RMB and asked to immediately leave the restricted area.

Success factor	Beijing
Phased approach to more stringent requirements	✗ Only extension in area boundary, no change in emission standard requirements
Covering a larger area	✓ Expanded to the 6th ring road in 2009
Linked to local circumstances	✓ Focus on all vehicles types
Based on ambitious reduction targets	✗ Only affects vehicles that cannot meet any emission standard (< China 1)
Exemptions are limited	n.a.
No extensive discounts are given	n.a.
Strong enforcement is ensured	✓ Manual enforcement by police officers as well as license plate recording
Complementary incentive policy	✓ Financial incentive for trading in a yellow-label vehicle given (between 500 to 25,000 RMB)
Complementary measures to reduce traffic volume	✓ Odd- and even driving ban; heavy trucks ban from entering the 5th ring road during daytime; vehicles which are not registered in Beijing from entering the 5th ring road during peak hours

Type	Buses		Coaches		Light-duty trucks		Heavy-duty trucks	
Share of total vehicle population	0.4%		3%		3%		2%	
Fuel type	diesel	CNG, LNG, hybrid	gasoline	diesel	gasoline	diesel	gasoline	diesel
Fuel split	80%	20%	75%	25%	55%	45%	10%	90%

Source: Beijing Statistical Yearbook 2012, Tsinghua University

The analysis above indicates that the LEZ in Beijing can be developed to exploit its full potentials. The current vehicle fleet composition and the respective fuel split in Beijing indicates potential LEZ policy target areas. On the one hand, buses represent a minor share within the group of non-passenger vehicles and are already subject to the progress of popularisation of energy-saving and new energy vehicles. Nevertheless, the majority of buses are still diesel powered. On the other hand, large trucks, which deliver goods from outside Beijing, are generally diesel-powered. Furthermore, some of these trucks do not meet the emission requirements or have fake emission certificates.

So far mainly private passenger cars, which account for 75% of Beijing's vehicle fleet, are targeted by traffic restricting policies. Beijing influences the vehicle fleet composition and the amount of vehicles on its roads by increasing the cost of driving a car, limiting ownership, purchase and scrapping incentives (see box below).

Considering this and the table above, indicates that the LEZ in Beijing can be enhanced to complement existing traffic restricting policies in different ways:

- Better incorporate and target heavy-duty vehicles. Shift the focus of the LEZ on freight vehicles. In general, 20% of all non-passenger vehicles are estimated to be responsible for 80% of total transport-related PM emissions (Tsinghua University, 2014). A LEZ focusing on heavy diesel vehicles helps to effectively reduce transport-related PM pollution.
- Introduce stricter emission standard requirements than the current China I standard to lever benefits of new vehicle technology and retrofitting. Depending on the type of filter up to 90% of PM generated by a diesel engine can be filtered.

Both approaches can be combined and effectively promote vehicle fleet renewal as well as retrofitting of older vehicles. They complement the existing policies in Beijing and path the way for more sustainable mobility.

Transport policies in Beijing

In 2013, Beijing municipal government released a set of policies to cut vehicle emissions and industrial pollution within its five-year *Clean Air Action Plan* (2013-2017). The transport sector is one of the key target areas within the plan which introduces new measures and complements existing ones.

- In 2003, Beijing banned diesel-powered passenger cars in the city. → Minor amount of diesel passenger cars on the roads.
- The local license plate lottery for 2014-2017 limits the amount of newly registered passenger cars. → In 2017, the total amount will be reduced from 240,000 to 150,000 new licenses per year.
- A local scrapping incentive for yellow-label vehicles ranging from 500 to 25.000 RMB is in place. → Phase-out of all yellow-label vehicles by 2015.
- In 2013, Beijing implemented China V emission standard for all new vehicles (similar to Euro V). → In 2013, the share of China IV and China V in Beijing was 65%.
- A national subsidy for new energy vehicle (NEV) is granted ranging from up to 35,000 to 60,000 RMB for passenger vehicles. New-energy buses and coaches are subsidised with up to 500,000 RMB per vehicle. → This matches Beijing's aim to have 200.000 green vehicles on the roads by 2017.
- Beijing's bus fleet is being modernised and ambitious targets for integrating new and clean energy vehicles into the public service fleet exist. → In 2012, 20% of Beijing's bus fleet were energy-saving vehicles (e.g. CNG, hybrid).

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Sources: Airqualitynews.com, Beijing Review, Beijing Statistical Yearbook, Dieselnet.com, Europa.eu, GreenLaw China, HBEFA.net, Lowemissionzones.eu, Senatverwaltung für Stadtentwicklung und Umwelt Berlin, Transport for London, Transportation Research Part D, Tsinghua University.

As of: June 2014

Imprint

Published by:
Deutsche Gesellschaft für
Internationale Zusammnarbeit (GIZ) GmbH

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