03.11.3 Clean Air Plan 2018-2025 – Scenario Calculations to Assess the Effectiveness of Selected Measures on NO_2 Levels along Streets, 2020 (Edition 2019)

Overview

Rationale

As part of the new Clean Air Plan 2018-2025, investigations were conducted into the effectiveness of additional measures on air quality. The maps on air pollution along primary roads introduced here are available online. This enables the user to view the current traffic and air pollution situation, as well as the impact of specific sets of measures on the same for each section of the primary road network.

Comprehensive documentation is available online on all major aspects of the new Clean Air Plan. The present document will therefore only outline a few fundamental concepts.

Air Quality

Air quality in Berlin (only in German) could be improved substantially in recent years. High levels of air pollution persist, however, particularly in adverse weather conditions, posing a threat to the health of Berliners.

For some years now, motor vehicle traffic has been a major cause of both noise emissions and of air pollution in key problem areas of Berlin. This is especially the case since the contribution of other groups of polluters to air pollution in Berlin has decreased considerably. As a result, Berlin is already able to comply with many of the ambitious European air quality limits reliably.

Pollutant levels recorded for nitrogen dioxide (NO_2) in the air near to the ground still remain above the limits, however. Therefore, supplementary measures need to be conducted also in the future to be able to comply with the limits permanently in accordance with the legal provisions (Article 47 Federal Immission Law (BImSchG) and Article 27 of the 39th Federal Immission Ordinance (BImSchV)).

The measurements of **nitrogen dioxide (NO_2)** show a high level of pollution along primary roads. The annual mean limit of 40 µg/m³, which has been mandatory since 2010, was exceeded every year between 2010 and 2017 (inclusive). The short-term limit, on the other hand, was met reliably. The limit of 200 µg/m³ per hour may only be exceeded a maximum of 18 times a year. Between 2011 and 2017, the 200 µg/m³ limit per hour was exceeded for between 1 and 8 hours on average. The highest values were generally measured at Hardenbergplatz.

In urban residential areas and on the outskirts, however, the NO_2 annual limit is met without fail.

For the year 2017, the NO_2 annual means in Berlin can be summarised as follows:

- measured continually at stations near roads: 41 to 49 µg/m³
- in the urban background: 20 to 28 µg/m³
- on the outskirts: 12 to 14 µg/m³
- measured by passive collectors along roads: 40 to 63 µg/m³ (highest measurement at Leipziger Straße between Friedrichstraße and Charlottenstraße).

In 2018, the NO_2 annual mean remained below the limit of 40 µg/m³ at a measurement station close to traffic for the first time, i.e. at Frankfurter Allee with an NO_2 mean of 37 µg/m³. Some of the values recorded at the remaining stations close to traffic, however, continued to far exceed the EU limit in 2018. Stricter emission limits for vehicles have not led to the decrease in nitrogen dioxide emissions expected. The only exception is the station at Hardenbergplatz. There, the NO_2 annual mean dropped from 62 µg/m³ in 2014 to 43 µg/m³ in 2018. This was achieved by retrofitting BVG (Berlin Transport Services) buses with NO_x reduction systems and modernising the bus fleet. A decrease was also achieved at Leipziger Straße, another road that is heavily travelled by buses.

Model calculations are used to supplement measurements in order to assess air quality. Whereas measurements only reflect a limited area near the measurement site, model calculations reflect pollutant levels for the entire urban area. Traffic and emission data from 2015 were used to assess the baseline air quality. It is still the most recent complete data set. In the meantime, a 30 km/h speed limit was introduced along some sections of the primary road network. Therefore, a reduction of 15 %, was taken into account in these cases, which was established during evaluations at Schildhornstraße. As regards the meteorological baseline data, the year 2015 was used to calculate the current state and forecasts for the years 2020 and 2025.

The model distribution of NO_2 levels in the urban background in 2015, shows the highest levels in urban areas. This is where the values range mostly from 22 to 25 µg/m³. Here, the high density of the primary roads leads to an increased pollution spread across the whole area. Towards the outskirts of the city, values drop to about 10 to 15 µg/m³.

NO_2 levels along primary roads, which are derived by adding the urban background pollution to the additional pollution caused by local traffic, present a more detailed picture. According to the model calculations for the base year 2015, 411 sections with a total length of about 60 km exceed the NO_2 annual mean limit, which has to be observed since 2010. Approximately 50,000 people are affected by these exceeded limits.

Statistical Base / Methodology

Immissions prognosis for 2020-2025, without additional measures (trend)

In order to develop a clean air plan, it is necessary to investigate how air quality will develop in the future without any additional measures. It is crucial in determining the required scope of further measures, which are geared towards the polluters, and at the same time are reasonable and effective. The years 2020 and 2025 were investigated, with the latter providing a long-term perspective. The Clean Air Plan includes all relevant source groups in the analysis of causes, trend prognosis and investigation of possible measures. The map contents presented here, however, focus on the **main source of near-ground air pollution, motor vehicle traffic** only.

Prognosis calculations were carried out for the years 2020 and 2025 (only in German). A complete immission prognosis comprises the following steps:

- estimating the existing pollution in the regional background, while also considering the large-scale development of emissions,
- forecasting the development of the population and other structural data regarding the urban and economic development of Berlin and the emissions to be expected for the entire city,
- forecasting traffic burden in the primary road network and the development of the vehicle fleet,
- modelling the urban background using predicted emission developments for Berlin's pollutant sources and
- calculating immission levels along roads.

The prognosis of the development of emissions related to Berlin's motor vehicle traffic is based on two types of assumptions. The first concerns the development of the driving volume for each vehicle group in Berlin and the second concerns the technical modernisation of the current vehicle fleet.

To predict driving volume development for the prognosis years of the Clean Air Plan, the overall traffic prognosis for Berlin for 2030 was adapted. This includes adjustments to the population development, employment data, school locations, retail space and changes in infrastructure, e.g. the status of parking management. The traffic model also incorporates new traffic resulting from additional land use for residential, small business and commercial purposes.

The traffic model used by the State of Berlin is an integrated model, which comprises motor vehicle traffic, public transport and bicycle traffic.

Type of vehicle	Annual driving volume [million km/a]			Relative development [%]		
	2015	2020	2025	2020 vs 2015	2025 vs 2020	2025 vs 2020
Passenger cars	8,367	8,897	8,826	6.3%	5.5%	- 1%
LCV ≤ 3.5 t	1,031	1,101	1,092	6.7%	5.9%	- 1%
HGV > 3.5 t	354	420	422	18.6%	19.2%	+ 1%
Public buses	109	109	109	-0.2%	± 0%	± 0%
Coaches	33	36	35	8.3%	6.6%	± 0%
Motorcycles	214	227	224	6.1%	4.5%	- 1%
Total motor vehicles	**10,109**	**10,790**	**10,709**	**6.7%**	**5.9%**	**- 1%**

Table 1: Development of driving volume for 2020 and 2025 vs 2015, and shares of different types of vehicles

(LCV = light commercial vehicles, HGV = heavy goods vehicles)

The local additional contribution of motor vehicle traffic was calculated with IMMIS^{luft}, based on the urban background levels. It was then added to the urban background levels to determine the immission along primary roads.

For the year 2020 (only in German), NO_2 levels above 40 µg/m³ are predicted for approx. 3.9 km of roads (400 m of which on the A 100 city motorway) if no further measures are implemented. Approximately 4,300 people are affected by exceeded limits on these roads.

Map Description

Scenario calculations on the effect of selected measures

The effect measures have on emissions and immission were modelled based on the trend prognosis for the year 2020 without the influence of measures. Measures for road traffic were selected with the goal of reducing NO_2 pollution along roads.

Measures expected to lower emission throughout the city or for the majority of road sections exceeding the limit were investigated. Additionally, appropriate models for calculating the effect had to be available. For some measures, multiple scenarios were developed. Based on these, the scope of the measures required to be able to comply with the limits was thus estimated as were strategies on how to avoid inappropriate burdens. Some of the measures were developed in detail, e.g. those for parking management, regardless of whether they are actually suitable for modelling. This serves to ascertain the possible potential for reduction, first of all.

When a measure is included in the scenarios or in the selected area of implementation, this does not mean that the measure will definitely be part of the Clean Air Plan. Deciding factors include effectiveness, proportionality, affordability and the technical, legal and administrative feasibility.

Scenario 7 “Vehicle technology”: – Retrofits on diesel vehicles

Improvements in vehicle technology are suitable for reducing pollutant emissions in the entire vehicle fleet. Lower emissions can be achieved by replacing vehicles with high pollutant emissions with low-emission vehicles. These include electric or electric hybrid vehicles, vehicles powered by natural gas or diesel vehicles with low real NO_x emissions. A further measure to lower emissions is to retrofit existing vehicles with additional exhaust gas treatment systems (hardware retrofitting).

The “Vehicle technology” scenario is based on assumptions regarding vehicle replacement and hardware retrofitting, which are summarised in Table 2. As scenarios were calculated in autumn 2018, the requirements for hardware retrofitting of passenger cars and light commercial vehicles set by the BMVI (Federal Ministry of Transport and Digital Infrastructure) could not yet be considered. The “Technical requirements for nitrogen oxide (NO_x) reduction systems with increased reduction performance for retrofits on passenger cars and similar vehicles (NO_x reduction systems for passenger cars)" published by the BMVI on December 28, 2018 could therefore not be taken into account. These requirements do not stipulate a specific degree of effectiveness, but an emission value of 270 mg/km based on the average of what is called an RDE test drive. This involves measuring exhaust emissions in real road traffic (real driving emissions). The emission model used here is based on the emission factors of the Handbook Emission Factors for Road Transport (HBEFA) recommended by the Federal Environment Agency. Such specifications cannot be used for the model directly, however, as the HBEFA differentiates emission specifications according to traffic situations.

Based on the results of retrofits on Berlin's public buses, 70 % was assumed as the level of effectiveness for retrofits on passenger cars and light commercial vehicles. For heavy goods vehicles weighing more than 7.5 t, the level of effectiveness applied was 85 %, according to the BMVI funding guidelines regarding retrofits on heavy municipal vehicles. No retrofits or replacements were assumed for buses for 2020, as the retrofitting of BVG buses was already included in the 2020 trend prognosis.

The assumed proportions of retrofitted vehicles yield correction factors for the HBEFA emission factors ranging from 0.51 to 0.93. This represents emission reductions between 7 % and 49 % for each vehicle group. Replacing Euro 4 diesel cars with Euro 6d-TEMP vehicles influences the representative proportions of the fleet regarding the emission analysis.

Exhaust emission standard	Measure	Proportion	Effectiveness of retrofitting
Diesel passenger cars			
Euro 4	replaced by Euro 6d-TEMP diesel car	20 %	
Euro 5	hardware retrofit	50 %	70 %
Euro 6	hardware retrofit	10 %	70 %
Light commercial vehicles (LCV)			
Euro 4	replaced by Euro 6 c LCV	30 %	
Euro 4	hardware retrofit	20 %	70 %
Euro 5	hardware retrofit	46 %	70 %
Heavy goods vehicles (HGV)			
Euro IV	hardware retrofit	30 %	85 %
Euro V above 3.5 to 7.5 t	hardware retrofit	70 %	70 %
Euro V above 7,5 t	hardware retrofit	30 %	85 %

Table 2: Assumptions for the 2020 "Vehicle technology" scenario

Calculation of emission

The same method used for calculating emissions for the prognosis year "2020 trend" was used here. Unlike in the trend prognosis, however, the software update was not taken into account, as it is currently impossible to estimate how software updates and hardware retrofits will be combined. This may lead to overestimations of emissions.
Emissions were calculated by sections, based on the adjusted fleet composition and the correction factors derived for the emission factors as a result of retrofitting.
Table 3 displays the emission results for motor vehicle traffic. It is based on the adjusted fleet for Berlin for the 2020 prognosis. It further presents the technology scenario for both the NO_X total emission and the NO_2 direct emission. Lastly, it presents emissions by vehicle type, also indicating the relative differences between the two calculations.

Substance	Source	2020 Trend prognosis	Vehicle technology scenario	- Difference
NO_x	**Total motor vehicles**	**4,281.5**	**3,876.2**	**-9.5%**
	diesel motor vehicles	3,785.1	3,379.9	-10.7%
	passenger cars	2,295.4	2,121.6	-7.6%
	light commercial vehicles ≤ 3.5 t	681.8	527.5	-22.6%
	heavy goods vehicles > 3.5 t	703.0	625.9	-11.0%

NO_2	**Total motor vehicles**	**1.008.5**	**872.0**	**-13.5%**
	passenger cars	616.1	548.8	-10.9%
	light commercial vehicles ≤ 3.5 t	205.8	147.9	-28.1%
	heavy goods vehicles > 3.5 t	106.6	95.3	-10.6%

Table 3: Comparison of the annual emissions of the total motor vehicle traffic [t/a] and emissions by vehicle type for the 2020 trend prognosis and the technology scenario

Based on the assumptions described above and by retrofitting and replacing older vehicles, NO_x emissions from motor vehicles can be reduced by 405 t/a or 9.5 % in total. Furthermore, NO_2 direct emissions are lowered by 137 t/a, which represents a reduction rate of 13.5 %. The highest decrease in NO_x emissions are achieved for light commercial vehicles with 22.6 %, while NO_x emissions from passenger cars decrease only by 7.6 %.

Effect on NO_2 pollution along roads

The first step to calculate the total NO_2 load of each road section is to determine the immission load in Berlin for the prognosis year 2020. For the "Vehicle technology" scenario, only the effect on local traffic emissions and thus the local additional load per section was determined. The existing load that is required to calculate the total load was adopted without change from the calculations for the prognosis year 2020. Lowered emissions caused by improved vehicle technology also affect the existing NO_2 pollution in the urban background. The chosen method therefore tends to overestimate the total NO_2 pollution.

In the "Vehicle technology" scenario, the NO_2 immission along primary roads with critical NO_2 levels, i.e. levels above 36 µg/m³, have been predicted to decrease by 1.9 µg/m³ on average for 2020 (trend prognosis), with a maximum decrease of 3.9 µg/m³ in Leipziger Straße and a minimum decrease of 1.0 µg/m³ in Turmstraße.
It is furthermore predicted for 2020, that the number of sections with an NO_2 annual mean of above 36.0 µg/m³ will decrease from 117 sections, covering a total length of 14.6 km, to 78 sections with a length of 10.1 km.
The number of road sections whose NO_2 annual mean exceeds 40 µg/m³ will drop from 31 to 17. The length of the affected sections will decrease from 3.5 to 1.7 km, representing about 1,800 people that are impacted by exceeded NO_2 limits.

Scenario 5 und 6: "Promoting ecomobility"

With a shift from cars to ecological mobile transport options (local public transport, cycling and walking), emissions caused by motor vehicle traffic can be avoided. The aim of Berlin's transport policy is to increase the share of the ecomobility. To this end, there are a variety of measures, ranging from infrastructure improvements to communication campaigns. Models, however, can only grasp the complexity of these measures to a very limited extent.
A number of selected measures were compiled, and assumptions were set regarding price incentives and effects on travel times to be able to calculate an Ecomobility scenario. Thus, the traffic model for Berlin was used to estimate the switch from cars to ecomobility and the resulting traffic volumes. These form the basis for calculating emissions and the additional NO_2 pollution along primary roads.

The following assumptions were made for the Ecomobility scenario:

- The price of a company ticket for public transport is lowered to 50 Euro.
- Cycling is promoted by measures corresponding to an increase of bicycle traffic speed by 2 km/h.
- Parking management is expanded, and fees are increased.

Two options were calculated for the Ecomobility scenario, which differ in relation to parking management. Option 1 assumes that 50 % of the area within the City Rail Circle Line is covered by parking management, without changing the parking fees ("PB 50"). Option 2 models a maximum scenario that assumes that the whole area within the City Rail Circle Line is dedicated to parking management, including parking fees of 3 Euro instead of previous fees of 1 to 3 Euro ("PB 100") per hour. The assumptions on public transport and bicycle traffic remained unchanged.

Calculation of emission

The same method used for calculating emissions for the prognosis year “2020 trend” without measures was used here (but incl. the software update). Emissions were calculated by sections, based on the altered traffic figures.
Table 4 compares the driving volume data for primary road network traffic volumes, as used in the emission calculation, with the driving volume predicted for 2020, also indicating relative differences. As ecomobility cannot include freight transport, there is no change for commercial vehicles.
According to our data, driving volume can be reduced by almost 10 % only with a complete parking management network and higher parking fees. The driving volume is lowered only by just under 2 % in the PB 50 scenario, on the other hand. This is the case despite measures promoting ecomobility.

Type of vehicle	Driving volume [million km/a]			Relative change compared with 2020 trend prognosis	
	2020 Trend prognosis	“PB 50” Ecomobility scenario	“PB 100” Ecomobility scenario	“PB 50” Ecomobility scenario	“PB 100” Ecomobility scenario
Total motor vehicles	10,790.0	10,622.3	9,751.3	-1.6%	-9.6%
Passenger cars	8,897.2	8,729.4	7,858.5	-1.9%	-11.7%

Table 4: Motor vehicle driving volume for the scenarios promoting ecomobility compared with the 2020 trend prognosis

Table 5 compares emission results for the scenarios promoting ecomobility with the emissions trend prognosis for 2020. In total, the “PB 50” option, i.e. the slight expansion of parking management, will reduce NO_x emissions by approx. 1 % or 45 t/a across all primary roads. Only the “PB 100” option will result in more substantial emission reductions of around 6.5 % or 279 t/a.

Substance	Source	Emission [t/a]			Relative change compared with 2020 trend prognosis	
		2020 Trend prognosis	“PB 50” Ecomobility scenario	“PB 100” Ecomobility scenario	“PB 50” Ecomobility scenario	“PB 100” Ecomobility scenario
NO_x	**Total motor vehicles**	**4281.5**	**4236.1**	**4002.2**	**-1.1%**	**-6.5%**
	Passenger cars	2295.4	2249.9	2016.0	-2.0%	-12.2%
NO_2	**Total motor vehicles**	**1008.5**	**996.6**	**935.4**	**-1.2%**	**-7.2%**
	Passenger cars	616.1	604.3	543.1	-1.9%	-11.9%

Table 5: Emissions for the scenarios promoting ecomobility compared with the 2020 trend prognosis

Effect on NO_2 pollution along roads

Based on the emissions of the local motor vehicle traffic, the additional local pollution was calculated for each road section. The existing pollution that is required to calculate the total pollution was adopted without change from the calculations for the prognosis year 2020.
For the “PB 50” option, the NO_2 pollution along primary roads with critical NO_2 levels, i.e. levels above 36 µg/m³ (in relation to the 2020 trend prognosis), have been predicted to decrease by 0.4 µg/m³ on average only, ranging from 0 to 1.5 µg/m³. The strongest decrease was calculated for Reinhardstraße.
Substantial improvements in air quality may be achieved with the “PB 100” option. The annual mean NO_2 values are predicted to decrease by 0.5 to 4.2 µg/m³ with an average reduction of 2.3 µg/m³. The highest decrease was calculated for Lietzenburger Straße between Pfalzburger Straße and Uhlandstraße.
The number of road sections which exceed the NO_2 annual mean of 40 µg/m³ is reduced from 36 to 34 sections for the “PB 50” option and to 32 sections for the “PB 100” option. This decreases the length of the affected sections from 3.9 to 3.8 and 2.2 kilometres respectively.

The number of sections with an NO_2 annual mean of above 36 µg/m³ decreases from 124 sections covering a total length of 15.3 km to 114 sections covering a length of 14.1 km for the “PB 50” option of the 2020 trend prognosis; and the number of sections drops to 73 with a length of 8.8 km for the “PB 100” option.

Scenario 1 to 4: “Access restrictions for diesel vehicles”

As demonstrated by the impact studies for the different measures described above, these measures are not enough to ensure that all road sections comply with the NO_2 limit swiftly.
Therefore, the effect of access restrictions for diesel vehicles on road sections was modelled for all sections with NO_2 annual means above 40 µg/m³ predicted for 2020. Extensive driving bans or driving bans for sections that go beyond the requirements of the existing environmental zone were not investigated for petrol cars. According to the ruling of the *Berliner Verwaltungsgericht* (Administrative Court) of 9 October 2018, these are not required and excessive.
The following scenarios with varying levels of intervention were investigated for diesel driving bans for road sections:

Scenario 1:

Driving ban for diesel cars with Euro 5 and older emissions standards.
This affects 16.3 % of the passenger cars expected to be driven in Berlin in 2020.

Scenario 2:

Driving ban for all diesel vehicles excluding public buses and Euro 5 / V and older motorcycles.

In terms of the 2020 fleet, this involves:

- 16.3 % of passenger cars,
- 70.4 % of light commercial vehicles (<= 3.5 t),
- 39.6 % of heavy goods vehicles (> 3.5 t) and
- 51.9 % of coaches.

Scenario 3:

Driving ban for diesel cars with Euro 6c and older emissions standards.

This applies to 35.3 % of the passenger cars expected to be driven in Berlin in 2020.
(Diesel passenger cars of the Euro standard 6d-TEMP and 6d are excluded from the driving ban).

Scenario 4:

Driving ban for heavy goods vehicles (> 3.5 t) with Euro V or lower emissions standards.
This applies to 39.6 % of the heavy goods vehicles expected to be driven in Berlin in 2020.

The vehicles expected to be driven in Berlin in 2020 were calculated based on the 2014 vehicle fleet and the German fleet development expected until 2020.
A compliance rate of 80 % was assumed for all scenarios, i.e. 20 % of the vehicles affected by the driving ban continue to drive through sections with a driving ban. This is due both to exemptions as well as to non-compliance. This rate was adopted from models of other clean air plans (Stuttgart, Hamburg).
Table 6 lists road sections below which, according to our models, will still have NO_2 levels of above 40.0 µg/m³ in 2020 and which have been investigated in regard to driving bans according to the four scenarios.

Road section	from	to	Length [m]	2020 NO_2 [µg/m³] trend
Leipziger Str.	Wilhelmstr.	Bundesrat	109.7	60.6
Leipziger Str.	Charlottenstr.	Friedrichstr.	109.5	55.9
Leipziger Str.	Friedrichstr.	Leipziger Str. 21	48.9	50.8
Brückenstr.	Köpenicker Str.	Rungestraße	99.1	50.7
Reinhardtstr.	Charitéstr.	Margarete-Steffin-Str.	104.5	47.1
Kapweg	Kurt-Schumacher-Damm	Scharnweberstr.	99.2	46.9
Reinhardtstr.	Margarete-Steffin-Str.	Kapelle-Ufer	45.6	46.5

Alt-Moabit	Gotzkowskystr.	Beusselstr.	120.0	46.2
Friedrichstr.	Mittelstr.	Dorotheenstr.	57.7	46.1
Stromstr.	Bugenhagenstr.	Kurz vor Turmstr.	96.5	44.6
Brückenstr.	Rungestr.	S-Bahnhof Jannowitzbrücke	107.3	44.1
Hermannstr.	Silbersteinstr.	S-Bahnbrücke	65.9	43.6
Leonorenstr.	Kaiser-Wilhelm-Str.	Saarburger Str	122.5	43.4
Spandauer Damm	Autobahnbrücke	Königin-Elisabeth-Str.	83.0	43.4
Joachimsthaler Str.	Kantstr.	Kurfürstendamm	131.1	42.6
Leipziger Str.	Leipziger Str. 21	Mauerstr.	95.2	42.4
Spandauer Damm	Klausenerplatz	Sophie-Charlotten-Str.	216.5	42.3
Mariendorfer Damm	Westphalweg	Königstr.	106.9	42.3
Sonnenallee	Fuldastr.	Weichselstr.	167.1	42.0
Friedrichstr.	Unter den Linden	Mittelstr.	77.7	41.6
Oranienstr.	Oranienplatz	Luckauer Str.	84.2	41.4
Dorotheenstr.	Wilhelmstr.	Friedrich-Ebert-Platz	191.1	41.2
Behrenstr.	Mauerstr.	Glinkastr.	92.2	41.1
Mariendorfer Damm	Königstr.	Eisenacher Str.	128.2	40.8
Sonnenallee	Tellstr.	Jansastr.	104.3	40.7
Hermannstr.	Mariendorfer Weg	Kranoldstraße	103.2	40.6
Potsdamer Str.	Bülowstr.	Alvenslebenstr.	184.7	40.6
Kaiserdamm	Saldernstr.	Sophie-Charlotten-Str.	183.7	40.5
Kaiser-Friedrich-Str.	Kantstr.	Pestalozzistr.	84.7	40.4
Tempelhofer Damm	Kaiserin-Augusta-Str.	Albrechtstr.	131.6	40.2

Table 6: All road sections for which the effect of driving bans has been established (including NO_2 levels for 2020 according to the trend scenario without further measures)

Effect on traffic

The effect of driving bans on traffic flows was established based on the Berlin traffic model and using traffic data from the 2020 trend prognosis. Both the shift of vehicles affected by the driving ban to alternative routes, and the shift of non-affected vehicles to freed-up slots of sections with driving bans were calculated.
Traffic flows of the entire network are divided into passenger cars and light commercial vehicles and heavy goods vehicles for each driving ban scenario. This approach considers sections in which the vehicles are still allowed to drive. For each route, the utilisation rate is indicated for low-emission vehicles that are not affected by driving bans as well as high-emission vehicles that are affected by driving bans.
In addition to changes in traffic flows on primary roads, effects on secondary roads were also investigated.

Overall, there are not only changes in traffic flows in the immediate vicinity of road sections with driving bans, but also large-scale changes in the road network due to long detours.
In all scenarios, the secondary network also sees increases in traffic volumes, which oppose efforts to calm traffic. For the majority of roads, the increase or decrease in traffic volumes lies between 25 and 250 vehicles per day. There are some roads, however, for which the changes exceed 500 vehicles per day. As regards the total volume of traffic per day, increases and decreases are generally well below 10 % per section.

Calculation of emissions

Emissions were determined for groups of vehicles that are and are not affected by the driving ban. These were investigated separately, considering the respective requirements for the fleet

compositions set by the scenarios. The emissions determined separately for the two groups were added by sections to yield the total emission. Table 7 presents the emissions predicted for the 2020 forecast baseline and the four scenarios for selected sections (cf. Table 6). A substantial reduction in NO_x emissions can be observed for the most part. Emissions decrease between 4.9 and 34.5 % on average, depending on the scenario.
For Scenario 1 (driving ban for diesel passenger cars only), NO_x emissions decreases range between 7 to a solid 31 %, i.e. emissions decrease by 14 % on average. This applies to selected sections which exceed NO_2 limits and for which the effect of driving bans has been determined. If the driving ban is extended to diesel passenger cars with Euro 6 a-c (Scenario 3), which do not have requirements regarding real emissions, the average emission reduction increases to a solid 18 % with a maximum emission reduction of 32 %. The number of vehicles affected by the driving ban in this scenario is more than double, however. Hence, there is greater capacity scope, which is taken up by permissible vehicles, including commercial vehicles. This means that for some road sections, such as Brückenstraße, there is a smaller decrease in emissions for Scenario 3 than for Scenario 1. Scenario 2, which is a driving ban for all Euro 5 diesel vehicles and older, has the greatest effect. Here, emission reductions lie between 22 % and 46 %, with an average decrease of 35 %. Scenario 4, involving driving bans only for Euro V commercial vehicles and older, results in substantially smaller decreases. In the Dorotheenstraße section, NO_x emissions even increase slightly.

Road name	**Scenario 1 Passenger car up to E 5** [1)]	**Scenario 2 Motor vehicle up to E 5/V**	**Scenario 3 Passenger car up to E6c**	**Scenario 4 Commercial vehicle up to EV**
Leipziger Str.	-15.5%	-37.0%	-23.4%	-6.1%
Leipziger Str.	-15.4%	-40.4%	-24.0%	-6.1%
Leipziger Str.	-14.4%	-39.0%	-22.2%	-6.1%
Brückenstr.	-17.5%	-46.1%	-24.0%	-5.8%
Reinhardtstr.	-7.2%	-36.5%	-8.7%	-2.8%
Kapweg	-13.2%	-29.6%	-19.2%	-4.5%
Reinhardtstr.	-10.9%	-36.7%	-15.1%	-2.2%
Alt-Moabit	-15.2%	-37.4%	-19.5%	-11.5%
Friedrichstr.	-7.0%	-25.9%	-8.3%	-3.1%
Stromstr.	-14.4%	-33.3%	-21.7%	-3.2%
Brückenstr.	-19.9%	-34.6%	-8.1%	-8.8%
Hermannstr.	-14.6%	-33.0%	-22.1%	-2.9%
Leonorenstr.	-9.0%	-22.0%	-13.2%	-5.3%
Spandauer Damm	-13.9%	-29.3%	-19.9%	-6.2%
Joachimsthaler Str.	-10.1%	-24.1%	-15.4%	-2.3%
Leipziger Str.	-14.4%	-39.0%	-22.2%	-6.1%
Spandauer Damm	-15.4%	-36.2%	-24.4%	-7.0%
Mariendorfer Damm	-15.2%	-41.0%	-22.5%	-10.6%
Sonnenallee	-14.9%	-37.8%	-22.0%	-3.7%
Friedrichstr.	-7.2%	-25.8%	-8.9%	-3.1%
Oranienstr.	-10.8%	-28.5%	-12.1%	-5.0%
Dorotheenstr.	-13.4%	-20.9%	-3.1%	1.3%
Behrenstr.	-14.6%	-36.2%	-23.8%	-5.5%
Mariendorfer Damm	-15.3%	-40.9%	-23.5%	-10.2%
Sonnenallee	-15.0%	-38.0%	-22.5%	-3.8%
Hermannstr.	-13.0%	-39.1%	-18.5%	-2.6%
Potsdamer Str.	-12.6%	-28.5%	-10.1%	-2.8%
Kaiserdamm	-20.7%	-41.3%	-32.3%	-3.6%
Kaiser-Friedrich-Str.	-21.5%	-36.1%	-20.9%	-2.8%

Tempelhofer Damm	-13.5%	-39.3%	-21.3%	-5.1%
Mean	**-13.9%**	**-34.5%**	**-18.4%**	**-4.9%**
Standard deviation	3.6%	6.3%	6.6%	2.8%

[1)] E5 = Euro 5; E5/V = Euro 5/V; E6 c = Euro 6c; EV = Euro V

Table 7: Emission reductions resulting from driving bans (scenarios 1 to 4) on routes with NO_2 annual means of above 40 µg/m³, according to the 2020 trend prognosis

Effect on NO_2 pollution along roads

The immission load along built-up roads in Berlin's primary road network for 2020 (prognosis year) forms the basis for calculating the total pollution. For all four scenarios, the effect on the local additional pollution was determined for the section. The existing pollution required to calculate the total pollution was adopted without change from the calculations for 2020 (prognosis year).
Table 8 presents a summary of the results of the four calculated scenarios below.

Road name	Starting point, 2020 trend prognosis	Scenario 1 Passenger car up to E5 [1)]	Scenario 2 Motor vehicle up to E 5/V	Scenario 3 Passenger car up to E6c	Scenario 4 Commercial vehicle up to EV
Leipziger Str.	60.6	53.1	45.5	49.4	59.0
Leipziger Str.	55.9	49.4	41.7	45.9	54.4
Leipziger Str.	50.8	45.6	38.9	42.8	49.5
Brückenstr.	50.7	44.5	36.9	42.1	49.5
Reinhardtstr.	47.1	44.9	38.9	44.2	46.6
Kapweg	46.9	43.0	39.2	41.3	46.0
Reinhardtstr.	46.5	43.4	37.8	42.0	46.1
Alt-Moabit	46.2	41.7	36.6	40.2	44.0
Friedrichstr.	46.1	44.1	40.0	43.5	45.6
Stromstr.	44.6	40.5	36.4	38.5	44.0
Brückenstr.	44.1	38.5	35.8	41.4	42.5
Hermannstr.	43.6	39.1	34.5	36.8	43.1
Leonorenstr.	43.4	40.4	37.0	38.9	42.3
Spandauer Damm	43.4	39.7	36.4	38.1	42.3
Joachimsthaler Str.	42.6	39.9	37.1	38.5	42.2
Leipziger Str.	42.4	38.6	33.6	36.6	41.4
Spandauer Damm	42.3	38.6	34.6	36.6	41.2
Mariendorfer Damm	42.3	37.4	31.1	35.1	40.1
Sonnenallee	42.0	37.9	32.9	35.9	41.4
Friedrichstr.	41.6	39.9	36.5	39.3	41.2
Oranienstr.	41.4	38.6	34.9	37.0	40.5
Dorotheenstr.	41.2	37.7	36.8	39.9	41.6
Behrenstr.	41.1	37.6	33.6	35.6	40.2
Mariendorfer Damm	40.8	36.2	30.2	33.8	38.8
Sonnenallee	40.7	36.8	32.0	34.9	40.1
Hermannstr.	40.6	37.0	33.5	35.5	40.2
Potsdamer Str.	40.6	37.3	34.4	37.7	40.1
Kaiserdamm	40.5	36.0	32.2	33.5	39.9
Kaiser-Friedrich-Str.	40.4	35.4	32.8	35.4	40.0

Tempelhofer Damm	40.2	36.4	30.9	34.3	39.4

[1)] E5 = Euro 5; E5/V = Euro 5/V; E6 c = Euro 6c; EV = Euro V

Values exceeding 40.0 µg/m³ are presented in **red**, values above 36 µg/m³ to 40.0 µg/m³ (inclusive) in **black** and values up to 36 µg/m³ in **green**.

Table 8: NO_2 annual means [µg/m³] for the 2020 trend prognosis (routes with annual mean NO_2 levels above 40 µg/m³) and driving ban scenarios 1-4

The scenario with the greatest impact bans driving for all Euro 5 / V diesel vehicles and older (Scenario 2). All tested sections of the route comply with the NO_2 limit of 40 µg/m³, except for Leipziger Straße.
On Leipziger Straße, NO_2 annual means exceeding 60 µg/m³ can be reduced to 45.5 µg/m³ between Wilhelmstraße and the building of the Bundesrat, if the driving ban for Euro 5 / V diesel vehicles and older is applied. Also on Leipziger Straße, NO_2 levels can be reduced from 55.6 µg/m³ to 41.7 µg/m³ between Charlottenstraße and Friedrichstraße. At the same time, however, diversion traffic increases the predicted NO_2 annual mean on Invalidenstraße from 39.4 µg/m³ to 41.6 µg/m³, and on Turmstraße from 39.3 µg/m³ to 41.2 µg/m³. This means that the NO_2 limit would be exceeded in those sections. From a legal perspective, the limit has been complied with if the determined annual mean lies below 40.5 µg/m³.
Driving bans of Euro 5 diesel passenger cars and older (Scenario 1) and of Euro 6c diesel passenger cars and older (Scenario 3) are not enough, however, to reliably keep NO_2 values below the 40 µg/m³ limit in the case of 11 or 10 road sections respectively. Furthermore, it is evident that these driving bans cause a traffic shift to the surrounding roads. This means that for 5 to 8 road sections, NO_2 values are predicted to exceed 40 µg/m³, which is not the case if there are no driving bans.
Compared to the other 3 driving ban scenarios, banning heavy goods vehicles above 3.5 tonnes with the Euro V standard or lower (Scenario 4) will reduce NO_2 levels the least for sections where NO_2 levels exceeding 40 µg/m³ have been predicted for 2020 (trend scenario). In addition, this driving ban would result in exceeding the NO_2 annual mean of 40 µg/m³ at Invalidenstraße, as commercial vehicles affected by the driving ban would likely choose this detour.
Besides lower NO_2 levels in roads with driving bans, diverted traffic leads to new exceedances of the annual limit of 40 µg/m³ in some roads. These sections are summarised in Table 9 below. Measures must also be taken to comply with the air quality limit for sections newly exceeding the limit.

Road name	from	to	Starting point, 2020 trend	Scenario 1 Passenger car up to E5 [1)]	Scenario 2 Motor vehicle up to E 5/V	Scenario 3 Passenger car up to E6c	Scenario 4 Commercial vehicle up to EV
Invalidenstr.	Chausseestr.	Am Nordbahnhof	40.0	39.9	39.0	39.8	**40.3**
Dominicusstr.	Ebersstr.	Feurigstr.	39.9	40.0	39.0	**40.1**	39.8
Torstr.	Prenzlauer Allee	Straßburger Str.	39.8	**40.1**	39.6	**40.2**	39.8
Torstr.	Ackerstraße	Ackerstraße 160 m east	39.8	**40.1**	39.6	**40.2**	39.8
Beusselstr.	Wiclefstr.	Siemenstr.	39.7	**40.3**	**40.2**	**40.5**	39.7
Martin-Luther-Str.	Motzstr.	Fuggerstr.	39.4	40.0	40.0	**40.2**	39.8
Invalidenstr.	Alexanderufer	Scharnhorststr.	39.4	**40.6**	**41.6**	**41.1**	**40.1**
Turmstr.	Bremer Str.	Oldenburger Str.	39.3	**41.0**	**41.2**	**41.2**	39.4
Fennstr.	Bayer-Werk	Müllerstr.	39.3	40.0	39.9	**40.2**	39.5
Erkstr.	Sonnenallee	Donaustr. 60 m east	37.5	37.9	**40.3**	37.8	39.3

[1)] E5 = Euro 5; E5/V = Euro 5/V; E6 c = Euro 6c; EV = Euro V

Values exceeding 40.0 µg/m³ are **highlighted in bold print**.

Table 9: NO_2 annual means [µg/m³] on road sections which show NO_2 values above 40 µg/m³ for the first time, due to diverted traffic in scenarios 1-4

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