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Modelling the effect on air quality of Euro 6 emission factor scenarios

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Abstract

To reduce traffic emissions effectively, from September 2017, newly registered cars will have to prove compliance with emission standards on public roads. RDE (real driving emissions) limits will be introduced in two steps. Conformity factors (CF) are introduced to link RDE with laboratory limits. In this study, the effect of several emission factor scenarios on air quality was modelled. Conformity factors were varied between CF=1.6 and CF=3.3 in step 1 and between 1.2 and 1.8 in step 2. Road traffic emissions and NO_2 concentrations were modelled for three urban main roads in Germany ("Am Neckartor" (Stuttgart, severe limit exceedance of annual mean NO_2 in 2015), "Corneliusstraße" (Düsseldorf, average limit exceedance 2015), "Dachauer Straße" (Munich, compliance with the limit 2015)) for the years 2015, 2020, 2025, and 2030 for each scenario. The results were extrapolated to all German traffic-influenced air quality measurement stations. Depending on scenario, the fraction of traffic-influenced stations exceeding the air quality limit for annual mean NO_2 is expected to be reduced from about 50 % in 2015 to 23 % up to 28 % in 2020, 7 % up to 10 % in 2025, and 1 % up to 4 % in 2030.

Keywords: NO_X emission factors, Euro 6, real driving emissions, air quality.

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1 Introduction

The EU air quality limit for the annual mean value of NO_2 was exceeded at many air quality measurement stations all over Europe in recent years. In Germany, about 50 % of all traffic-influenced air quality stations did not comply with the limit in 2015. Source apportionment analyses show that road traffic emissions are the main contributor to NO_2 concentrations at these stations; see e.g. the air quality plan for Stuttgart [1]. In spite of increasingly stringent emission standards for NO_X, road traffic emissions were not reduced accordingly. Until now, compliance with emission limits is tested in laboratories on roller dynamometer test benches. Motor emissions are measured while vehicles perform a given driving cycle under well defined conditions. For passenger cars (PC), the New European Driving Cycle (NEDC), last updated in 1997, is used. Measurements of real world emissions e.g. by Ligterink et al. [2] showed that, especially for Euro 5 diesel PC, real world NO_X emissions are much higher than emissions on NEDC. As a consequence, according to ERMES (European Research Group on Mobile Emission Sources), NO_X emission factors for Euro 5 diesel PC in the current versions of models such as COPERT (Computer Programme to calculate Emissions from Road Transport), HBEFA (Handbook of Emission Factors), or VERSIT+ (Traffic Situation model), which are used for air quality modelling, are about 4-5 times higher than the emission limit values [3]. Measurements e.g. by Franco et al. [4] or by Kadijk et al. [5] showed that real world NO_X emissions are much higher than emissions on NEDC also for Euro 6 diesel PC.
To ensure that emission reductions are achieved in real world, from September 2017 on, newly registered cars will have to prove compliance with emission standards on public roads (RDE, real driving emissions).
RDE limits will be introduced in two steps, step 1 starting from September 2017, and step 2 starting from January 2020. Conformity factors (CF) are introduced to link RDE with laboratory limits. At the meeting of the Technical Committee on Motor Vehicles (TCMV) of the EU on 28/10/2015 in Brussels, the following values were given a positive vote [6]:

- Step 1: $CF(NO_X)=2.1$ from September 2017/2019 (new type approvals/all firstly registered vehicles)
- Step 2: $CF(NO_X)=1.0$ from January 2020/2021 (new type approvals/all firstly registered vehicles)
- A measurement tolerance for NO_X of 0.5 for step 2 is allowed but subject to an annual review.

In the following paper, the effect of several emissions factor scenarios on air quality was examined; the proceeding for each scenario was the following:

1. Scenario definition: A scenario consists of values for conformity factors, the dates of their coming into effect, and, depending on scenario, the

definition of a transfer function.
2. Calculation of emission factors
3. Emission modelling: Calculation of road traffic emissions for three urban main roads (“Am Neckartor” in Stuttgart, “Corneliusstraße” in Düsseldorf, and “Dachauer Straße” in Munich) in Germany for the years 2015, 2020, 2025, and 2030
4. Air quality modelling: Calculation of annual average NO_2 for the three roads and the four years
5. Extrapolation of the results to all traffic-influenced air quality stations in Germany

By this, for each scenario, we determined the number of traffic-influenced air quality stations in Germany which, from today’s point of view, are expected to exceed the limit value for annual average NO_2 in the years 2020, 2025, and 2030.

2 Methods

2.1 Scenarios

Altogether, ten scenarios were investigated. From these scenarios, six scenarios, as defined in Table 1, are presented in this paper.
In scenario A, the base case, emission factor were taken from HBEFA3.2 [7]. When HBEFA3.2 was released in 2014, it was known that the type approval procedure for EU 6 PC would be changed in 2017, although details were not fixed yet at the time. So, in HBEFA3.2, there are emission factors for EU 6 (type approval/first registration before 2017/2018) and EU 6c (type approval/first registration after 2017/2018). From today’s point of view, emission factors for EU 6 diesel PC are too low in HBEFA3.2 [3], so in scenario B, these emission factors are increased by 90 %.

Table 1: Scenario definition

scen.	base	description	step 1		step 2		transfer function
			CF	date	CF	date	
A	HBEFA3.2	base case					
B	HBEFA3.2	EU 6 diesel PC +90% EU 6c unchanged					
E	B	EU 6 RDE	3.0	Sep 2017	1.5	Sep 2019	no
F	B	EU 6 RDE	3.3	Sep 2017	1.8	Sep 2019	yes
H	B	EU 6 RDE	1.6	Sep 2017	1.2	Sep 2019	no
I	B	EU 6 RDE, TCMV voted	2.1	Sep 2017	1.5	Jan 2020	no

Scenarios E, F, H, and I are RDE scenarios based on scenario B with varying CF.

Resulting emission factors for Euro 6 RDE were used instead of HBEFA3.2 emission factors EU 6c. In these scenarios, EU 6 RDE step 1 comes into effect in September 2017 and step 2 in September 2019 (type approval). An exception is scenario I, where step 2 comes into effect in January 2020 (type approval). Thus, scenario I is conform to the values voted for by TCMV [6].
The resulting phase-in into the fleet is shown in Table 2. The second column shows the phase-in of EU 6c PC according to the current average fleet in Germany according to TREMOD, prepared by ifeu (Institut für Energie- und Umweltforschung Heidelberg GmbH). In line with HBEFA3.2, EU 6c is introduced in one step. The third and fourth column show the phase-in of EU 6 RDE PC, step 1, and step 2, into the fleet as used for scenario E, F, and H. As stated above, in scenario I, step 2 comes into effect four months later.

Table 2: Phase-in of PC: EU 6c according to TREMOD, prepared by ifeu (Institut für Energie- und Umweltforschung Heidelberg GmbH), and two-step introduction as used in scenario E, F, and H

	EU 6c, TREMOD (ifeu)	EU 6 RDE, step 1	EU 6 RDE, step 2
2016	0 %	0 %	0 %
2017	10 %	10 %	0 %
2018	25 %	25 %	0 %
2019	100 %	90 %	10 %
2020	100 %	75 %	25 %
2021	100 %	0 %	100 %
2022	100 %	0 %	100 %

2.2 Emission Factors

Emission factors for all chemical compounds needed for air quality modelling NO_X, NO_2, SO_2, CO, VOC, NH_3, N_2O and CO_2) were taken from HBEFA3.2. Modifications for the emission factors for EU 6 and EU 6 RDE diesel PC were done for scenario B to I.
In all scenarios only the NO_X emission factors were changed compared to scenario A. In reality the exhaust gas recirculation (EGR) for NO_X control is expected to be extended with the RDE demands. This would tend to increase CO and HC emissions. These effects are expected to be quite small on absolute emission levels and were thus not considered to keep the simulation system simple.
While all emission factors for the scenarios A and B have been simulated with the model PHEM for the HBEFA [8], the emission factors for urban driving for the vehicles to be type approved under the future RDE legislation were calculated with a different method. Main assumption was that the low real drive emission limit values to be met will need sophisticated control algorithms for engine and after treatment systems. Consequently the controllers were assumed to be tuned to meet the RDE limits (= emission limit x CF) in all driving situations covered by the future legislation with the same safety margin. The safety margin for new

vehicles was 0.90 mainly to take aging effects of catalysts into consideration. For the fleet average emission values aged catalysts were assumed, so that the fleet average margin is 0.95.
Without transfer function (TF) the emission factors per vehicle emission class are thus similar for all driving conditions:

Equation 1:
NO_X Emission Factor [mg/km] = CF*Limit*0.95 = CF*76 mg/km (for PC)

The TF is discussed to be introduced in the RDE legislation to allow somewhat higher emissions under severe driving conditions. The TF shall be overall "environmentally neutral". This means that higher emissions at severe conditions have to be compensated by lower emissions under mild driving conditions. Since the details of the TF are still under discussion, a worst case scenario for the TF was assumed to show maximum effects under urban driving conditions. The worst case approach assumed that additional emissions are allowed under severe urban driving conditions but the compensation would not be relevant for those driving situations used in the scenarios. Consequently emission factors are in the scenarios F to I for all urban traffic situations 0.95 times the maximum allowed value (Figure 1).
For the scenario with TF the allowance for higher NO_X emissions under increasing dynamic driving behaviour ("aggressive driving") and under increasing cumulative altitude gain was assumed as shown in Figure 2.

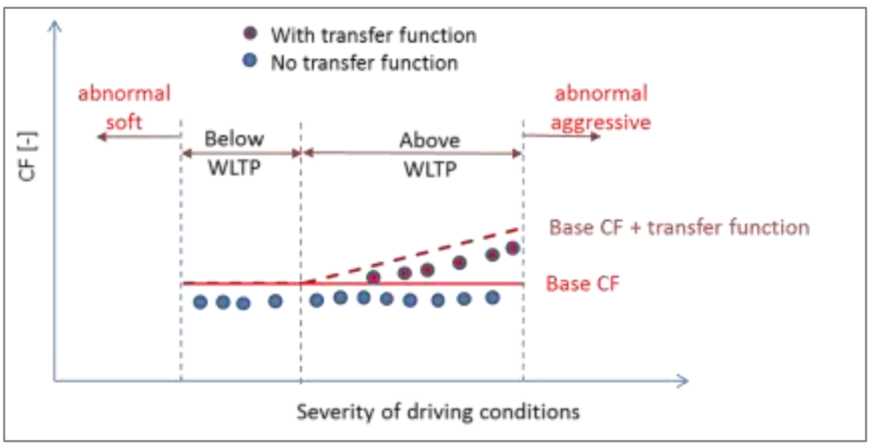

Figure 1: Schematic picture of the emission factor definition with and without transfer function for vehicles type approved under the future RDE legislation

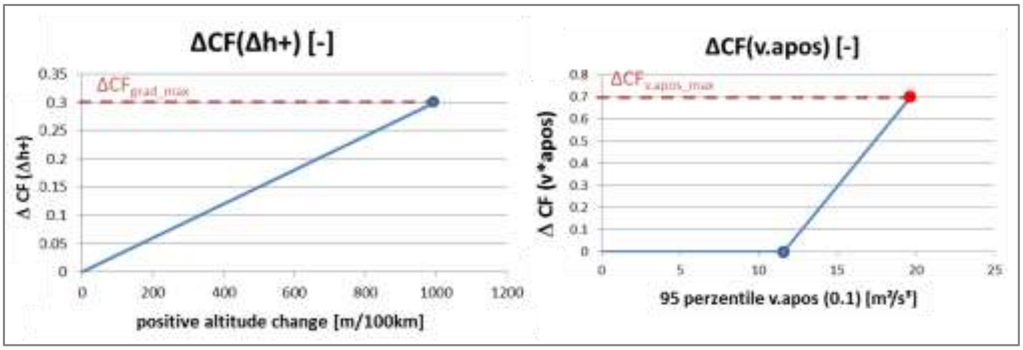

Figure 2: Schematic picture of the transfer functions assumed for positive altitude gains and for driving dynamics for vehicles type approved under the future RDE legislation

The allowance for higher NO_X emissions was introduced in the emission factor calculation by adding a ΔCF as function of the dynamic parameter of the driving cycle (95 Percentile of velocity x positive acceleration) and as function of the positive altitude gain. For a combination of very aggressive driving under hilly conditions the maximum CF increase due to the TF was assumed to be limited with +1.0. This gives e.g. in scenario F for stage 2 vehicles CFs between 1.8 (low dynamics, flat road) and 2.8 (aggressive driving, very hilly). For each driving cycle representing urban traffic situations in the HBEFA the corresponding adjustment of the CF by the TF was computed. After adjustment of the CFs for each traffic situation the emission factors were calculated using Equation 1. The emission factors were produced for all passenger car categories from HBEFA depending on vehicle type, motor concept, and traffic situation for all traffic situations. Emission values from HDV were not changed against scenario A.

2.3 Road Traffic Emissions

Specific traffic emissions (pollutant per distance and time unit) for the three urban main roads were calculated as the product of emission factors (pollutant per vehicle and distance, depending on vehicle type, motor concept, and traffic situation) and the traffic volume (vehicles per time unit), weighted by fleet composition. The traffic volume, the fraction of light duty vehicles (LDV, commercial vehicles of permissible maximum weight ≤ 3.5 t), and the fraction of heavy duty vehicles (vehicles of permissible maximum weight > 3.5 t) for the three streets is shown in Table 3. The rest of the vehicles are assumed to be PC.

Table 3: Traffic volume, fraction of light duty vehicles (LDV, commercial vehicles of permissible maximum weight ≤ 3.5 t), and fraction of heavy duty vehicles (vehicles of permissible maximum weight > 3.5 t) at the considered streets

Street	Traffic Volume [veh./24h]	Fraction LDV	Fraction HDV
Corneliusstraße (Düsseldorf)	43,700	3.8 %	1.3 %
Am Neckartor (Stuttgart)	73,500	3.2 %	2.9 %
Dachauerstraße (Munich)	21,600	3.0 %	4.2 %

The traffic situation is derived from street type, speed limit, and hourly values of traffic volume.

The fleet composition, differentiated by energy type and Euronorm concept per vehicle group, is based on the current average fleet in Germany according to TREMOD, prepared by ifeu (Institut für Energie- und Umweltforschung Heidelberg GmbH). For passenger cars, local fleet compositions were considered, taking into account the deviations of local car registration data per Euronorm from German average car registration data. Also, existing low emission zones in Stuttgart and Düsseldorf were taken into account. The resulting PC fleet composition for scenario E, F, and H are shown in Figure **3**.

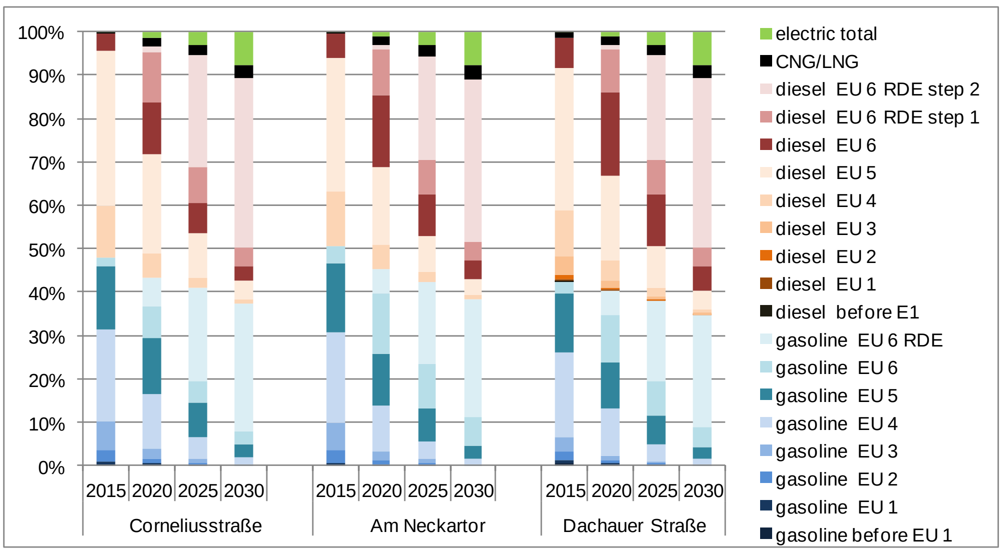

Figure 3: Local composition of the PC fleet in Düsseldorf, Stuttgart, and Munich for scenario E, F, and H

2.4 Air Quality

Corneliusstraße, "Am Neckartor", and Dachauer Straße are all street canyons with high building density on both sides of the road. Thus, air quality modelling can be done with a box model: Gas-phase concentrations of pollutants are calculated for the street canyon, which is modelled as a box of infinite length, the width of the

street, and the height of roadside buildings, and assumed to be homogenously mixed. Concentrations in the box correspond to the concentrations typically measured by an air quality station at the kerbside.
The chemistry box model comprises gas-phase chemistry and one-dimensional transport (perpendicular to street). The RADM2 gas-phase chemistry mechanism with 56 species, 140 thermochemical reactions, and 21 photochemical reactions [9] in combination with the solver of the EURAD-model [10] is used. Not considered are turbulent diffusion, deposition, a variable mixing height, and heterogeneous reactions. As input parameters, urban background concentrations of NO_2, NO and ozone, roadside concentrations of NO and NO_2 (for calibration), wind speed and direction and global radiation, and traffic emissions in the street are needed in an hourly resolution. Background concentrations were taken from air quality measurement stations of the urban background nearby, the trend of the background was taken from the German Environmental Protection Agency (UBA) [11].
This box model was already used in the past to simulate NO_2 [12, 13] and particle number [14, 15] in street canyons.
As in [12] and [13], the box model was calibrated for the year 2006. For this project, it was refitted to the year 2014.

3 Results

3.1 Emission Factors

Weighted emission factors for the three considered urban main roads resulting from the scenario definitions in Table 1 are shown in Figure **4**. The upper four groups show weighted emission factors according to HBEFA3.2 for EU 5, EU 6 and EU 6c PC (diesel and gasoline). Scenario A is based on these factors. They were derived by weighting the factors for the appropriate traffic situation from HBEFA3.2 with the mileage shares per level of service for the three streets.
According to HBEFA3.2, emission factors for diesel PC cars are reduced by about 2/3 from EU 5 to EU 6, and again by nearly 1/2 from EU 6 to EU 6c. For gasoline PC, according to HBEFA3.2, emission factors for EU 5, EU 6 and EU 6c are the same. They are about a factor of 20 lower than for EU 5 diesel PC.

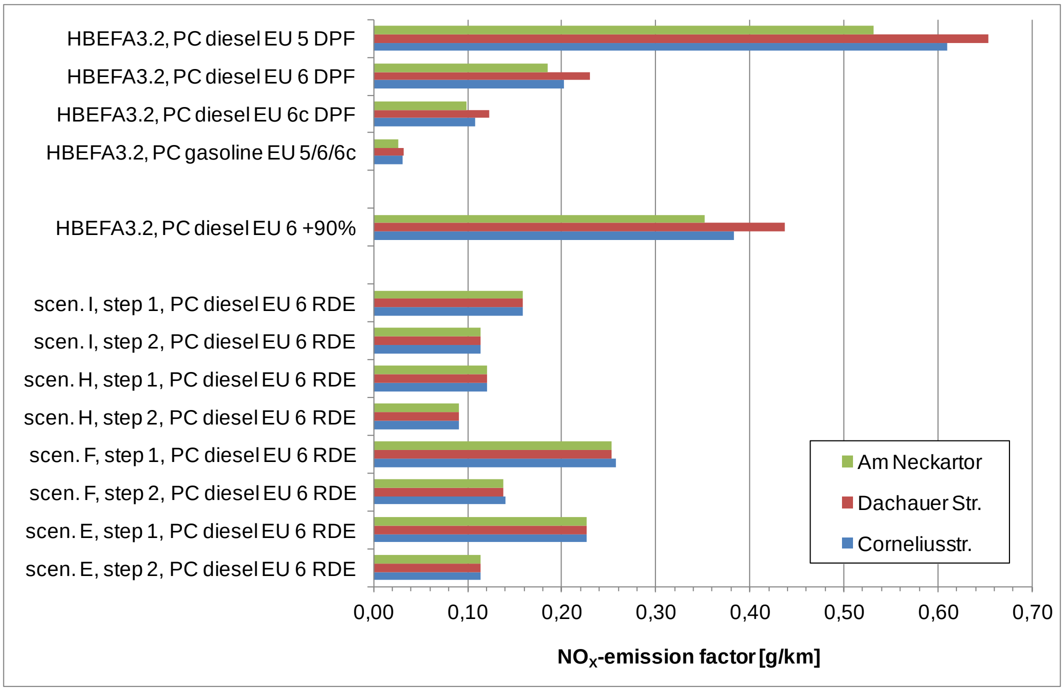

Figure 4: PC emission factors weighted with mileage per level of service for three urban main roads (“Am Neckartor” in Stuttgart, Dachauer Straße in Munich and Corneliusstraße in Düsseldorf)

Below the upper four groups of emission factors based on HBEFA3.2, in Figure 4, one group shows HBEFA3.2 weighted emission factors for EU 6 diesel PC increased by 90 % (scenario B). As stated above, from today’s point of view, this is more realistic than scenario A.
The lowest eight groups of weighted emission factors in Figure 4 were derived from the RDE scenarios. Due to the limitations considered, they are the same for the three streets. An exception is scenario F, where a transfer function was applied. However, the differences between the streets are small. As expected (see CF in Table 1), PC diesel EU 6 RDE emission factors are highest in scenario F and lowest in scenario H.

3.2 Emissions

For each hour of the year, emissions were calculated as the product of emission factors, depending on traffic situation and fleet composition, and traffic volume. In Figure **5**, NO_X-emissions for the three streets are shown for scenario B and the years 2010, 2015, 2020, 2025 and 2030.

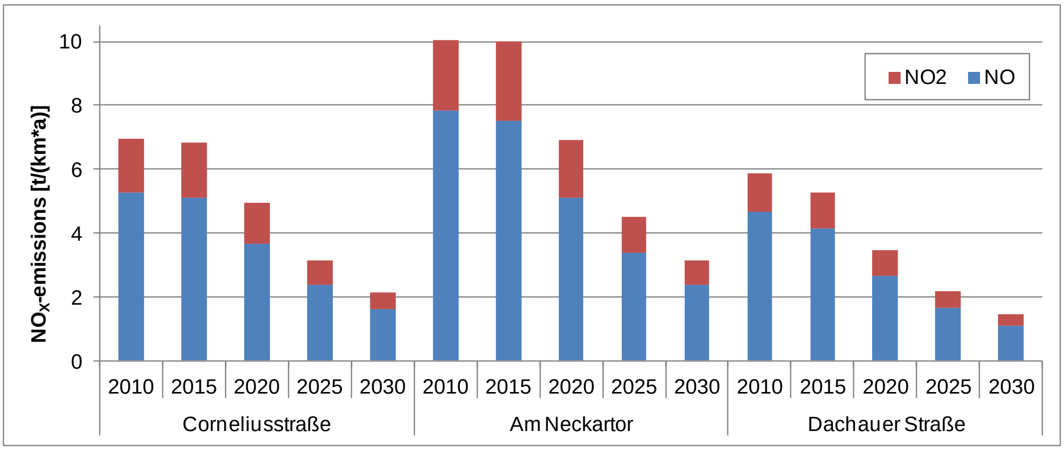

Figure 5: NO_X-emissions (total column, shown as sum of NO (blue column, NO as NO_2) and NO_2 (red column)) for scenario B

At “Am Neckartor”, where traffic volume is highest (see Table 3), also NO_X-emissions are highest, and at Dachauer Straße, NO_X-emissions are lowest. However, due to the higher fraction of heavy duty vehicles, at Dachauer Straße, NO_X-emissions are only slightly lower than at Corneliusstraße. Also, unlike at Corneliusstraße and “Am Neckartor”, there is no low emission zone at Dachauer Straße.

Due to the increasing fraction of vehicles with higher emission standards in the fleet, emissions are expected to reduce considerably until 2030. However, only little emission reduction can be seen between 2010 and 2015, especially for “Am Neckartor” and “Corneliusstraße”. This is a consequence of the fact that, despite lower emission limits, EU 5 diesel NO_X-emissions in real life are not reduced compared to EU 4 NO_X-emissions. The fraction of directly emitted NO_2 (red column) even slightly increases between 2010 and 2015.

In Figure 6, for Corneliusstraße, NO_X-emissions are shown for all scenarios and the years 2010, 2015, 2020, 2025 and 2030. The colours show the contributions of the different vehicle types, for PC, also the contributions of the different motor concepts are shown.

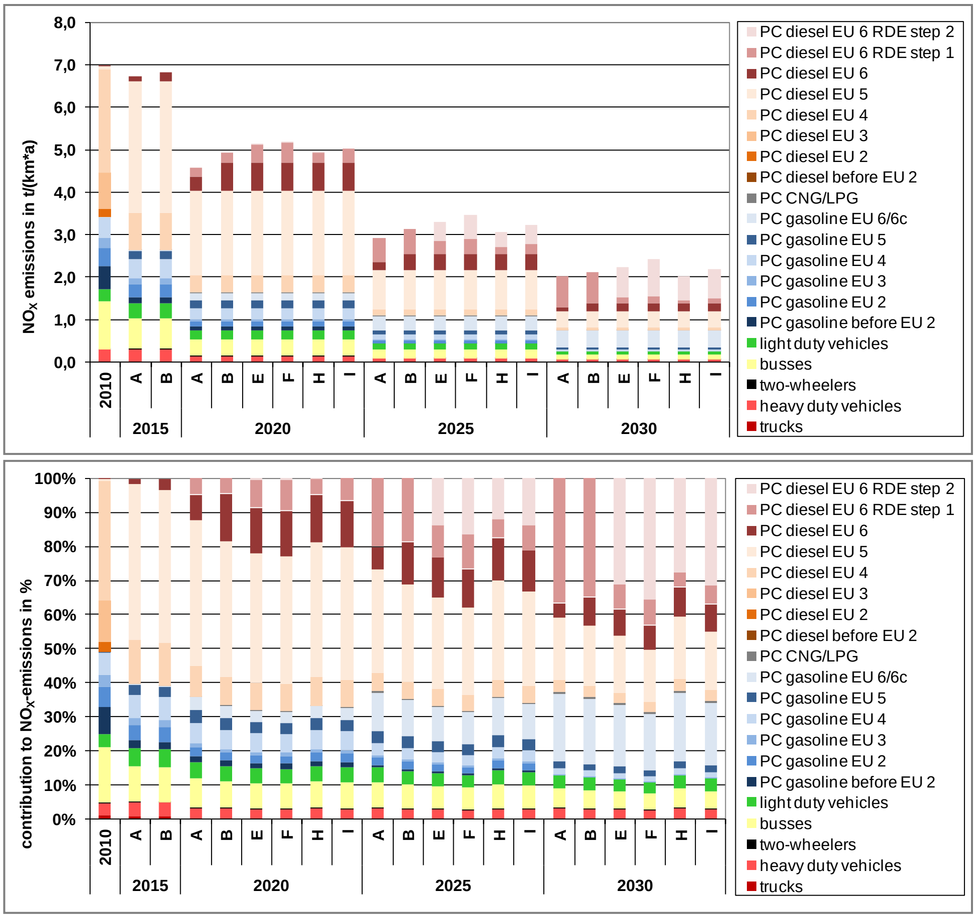

Figure 6: Corneliusstraße: NO_X-emissions for each scenario by vehicle type and motor concept

In Figure 7, the changes in NO_X-emissions are shown with respect to scenario A (2015) and scenario A (same year, respectively).

In all years, NO_X-emissions are expected to be higher than in scenario A in most scenarios (between 4 % and 19 %). Due to the stringent conformity factor in scenario H in step 2 (CF=1.2, see Table 1), in 2030, NO_X-emissions in scenario H are expected to be slightly lower than in scenario A.

Compared to 2015, NO_X-emission reductions are expected between 23 % and 32 % in 2020, between 49 % and 56 % in 2025, and between 64 % and 70 % in 2030, depending on scenario.

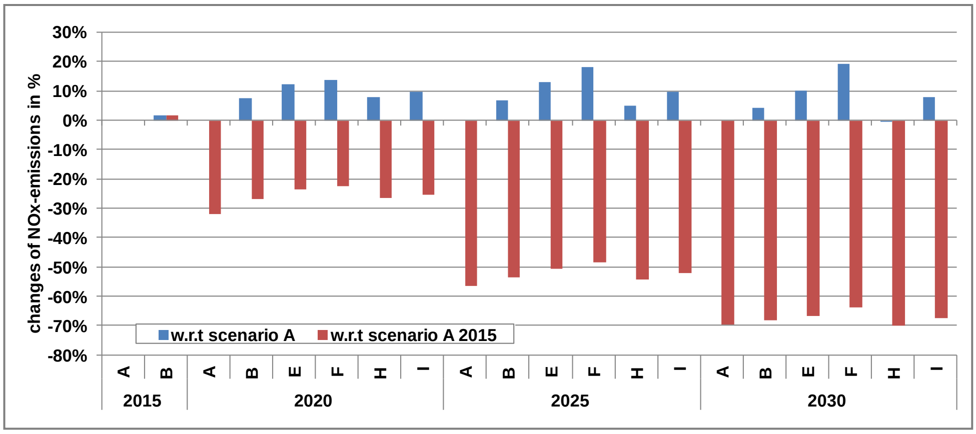

Figure 7: Corneliusstraße: Changes of NO_X-emissions for each scenario w.r.t. scenario A

3.3 Air Quality

Based on the emissions calculated above, air quality simulations were done for the three streets for all years and scenarios. The resulting annual mean NO_2 concentrations in the three streets are shown in Table 4.

Table 4: Annual mean NO_2 concentration in µg/m^3 for the three considered streets and each scenario

	2015	2020	2025	2030	2015	2020	2025	2030
	scenario A				scenario B			
Am Neckartor	89	66	50	42	90	71	53	43
Corneliusstraße	60	47	36	30	61	49	37	30
Dachauer Straße	31	25	22	20	32	26	22	20
	scenario E				scenario F			
Am Neckartor	90	73	56	45	90	74	57	47
Corneliusstraße	61	50	38	31	61	50	39	32
Dachauer Straße	32	26	22	20	32	26	22	20
	scenario H				scenario I			
Am Neckartor	90	71	53	43	90	72	55	45
Corneliusstraße	61	49	37	30	61	49	38	31
Dachauer Straße	32	26	22	20	32	26	22	20

For all scenarios and all streets, considerable reductions of air pollution are expected until 2030. For “Am Neckartor”, an air quality station at a severely polluted site, the annual mean NO_2 concentration is expected to be reduced from 90 µg/m^3 in 2015 to between 42 and 47 µg/m^3 in 2030, depending on scenario. However, the air quality limit for the annual mean NO_2 concentration of 40 µg/m^3 will still be exceeded in 2030 in all scenarios.

For Corneliusstraße, the annual mean NO_2 concentration is expected to be reduced from 61 µg/m^3 in 2015 to between 30 and 32 µg/m^3 in 2030, depending on scenario. In all scenarios, compliance with the air quality limit is expected in 2025. For Dachauer Straße, reductions from 32 µg/m³ in 2015 to 20 µg/m³ in 2030 are expected.

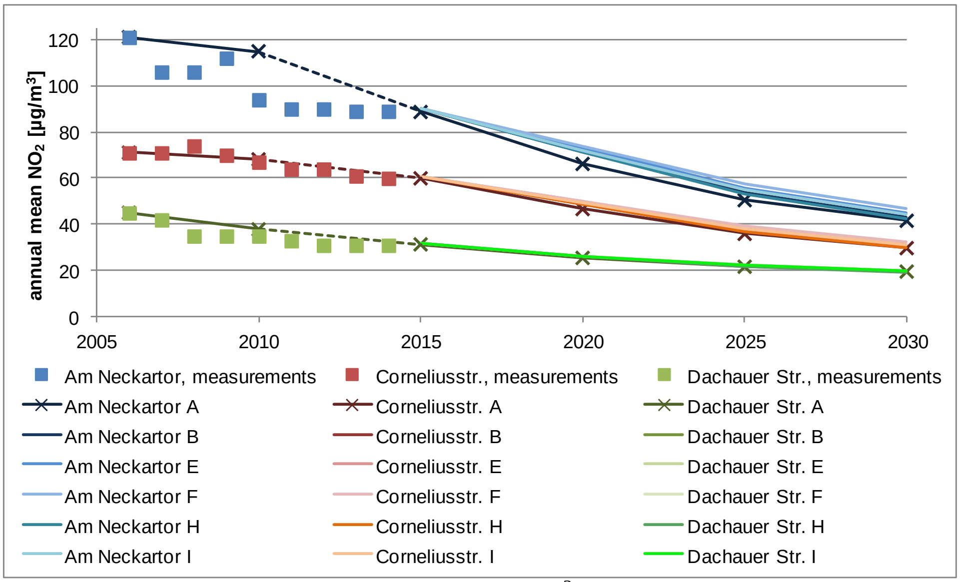

Figure 8: Annual mean NO_2 concentration in µg/m³ for the three considered streets and each scenario; model calculations (2006 and 2010 by Kessler et al.[13]) and measurements from air quality stations of the federal states of Baden-Württemberg[5], Northrhine-Westphalia[6] and Bavaria[7]

In Figure 8, the results are shown graphically. Also shown are calculations with the same model by Kessler et al. [13] for the years 2006 and 2010 (model calibration 2006) in comparison with measurements. For "Am Neckartor", the model calculation for 2010 overestimates the measurements. One reason can be that additional actions were taken to reduce emissions at this severely polluted site that were not considered in the model. For Corneliusstraße and Dachauer Straße, model calculations for 2010 agree well with the measurements. For air quality modelling of the scenarios in this study, the model results were refitted to the measurements 2014.

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[5]http://www.lubw.baden-wuerttemberg.de/servlet/is/21954/?shop=true, Reports on annual mean values of the most relevant air pollutants for the air quality stations in Baden-Württemberg between 2005 and 2013

[6]http://www.lanuv.nrw.de/luft/immissionen/ber_trend/kenn.htm, Annual mean values of the most relevant air pollutants for the air quality stations in Northrhine-Westphalia between 2000 and 2013

[7]http://www.muenchen.de/rathaus/Stadtverwaltung/Referat-fuer-Gesundheit-und-Umwelt/Luft_und_Strahlung/Luftreinhalteplan.html, Fifth follow up of the clean air plan for the city of Munich, Bavarian Ministry of Environment and Consumer Protection

3.4 Extrapolation to all German Traffic Stations

The results for the three streets were extrapolated to all traffic-influenced air quality measurement stations in Germany as follows. In Figure 9, the annual mean NO_2 values of all German traffic-influenced air quality measurement stations in the EEA (European Environmental Agency) AirBase[8] 2014 are shown as blue diamonds, sorted by annual mean NO_2. Altogether, there are 144 stations. The model results for the three streets for scenario A 2015 (fitted to the 2014 measurements) are shown as blue circles. To extrapolate the model results, a logarithmic curve was fitted through the three model calculations, shown as blue line. As you can see in Figure **9**, this line fairly well captures the behaviour of the other measurement stations as well, between station 20 and station 100, the extrapolation slightly underestimates the measurements, between station 1 and station 20, the extrapolation slightly overestimates the measurements. Such a logarithmic extrapolation curve was fitted to the modelled annual mean NO_2 values of all scenarios and years (in Figure **9** shown for scenario A only). Also shown in Figure **9** is the air quality limit for the annual mean NO_2 value (black dotted line). The intersections of the extrapolation curves with the limit line, scaled by a factor to correct for the deviations between measurements and model in 2015, give the number of air quality measurement stations with limit exceedances for all years and scenarios.

In Table 5, the number of traffic-influenced air quality stations in Germany expected to exceed the NO_2 air quality limit estimated by this extrapolation is shown for the considered years and scenarios. Also given is the percentage of stations expected to exceed the limit, referring to the total number of 144 traffic-influenced air quality stations in Germany in EEA AirBase. While in 2015 about 50 % of all German traffic-influenced air quality stations in EEA AirBase exceeded the limit, this number is expected to be reduced until 2020 to between 23 % and 28 % (depending on scenario), until 2025 to between 7 % and 10 % and until 2030 to between 1 % and 4 % (1 % for scenario I, which was TCMV voted).

[8] http://www.eea.europa.eu/data-and-maps/data/airbase-the-european-air-quality-database-8

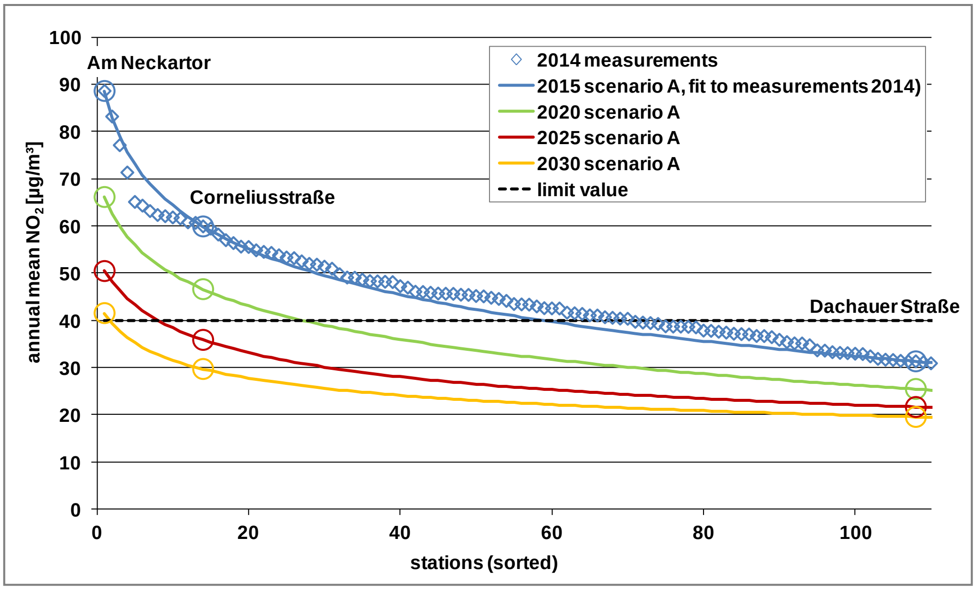

Figure 9: Extrapolation of scenario A to all German Traffic Stations

Table 5: Estimated number and fraction of traffic-influenced air quality stations in Germany which are expected to exceed the NO_2 air quality limit in the considered years and scenarios

		Sc. A	Sc. B	Sc. E	Sc. F	Sc. H	Sc. I
2015	number of stations	70	72	72	72	72	72
	fraction (of 144 stations)	49 %	50 %	50 %	50 %	50 %	50 %
2020	number of stations	33	37	40	41	37	39
	fraction (of 144 stations)	23 %	26 %	28 %	28 %	26 %	27 %
2025	number of stations	10	11	13	14	11	12
	fraction (of 144 stations)	6,9 %	7,6 %	9,0 %	9,7 %	7,6 %	8,3 %
2030	number of stations	1	2	4	5	2	2
	fraction (of 144 stations)	0,7 %	1,4 %	2,8 %	3,5 %	1,4 %	1,4 %

As done by IIASA [16], an uncertainty range was defined by setting an interval of 5 µg/m^3 around the NO_2 air quality limit: When the extrapolation of the model results shows an annual mean NO_2 value

- below 35 µg/m^3: stations are expected to comply with the limit,
- above 45 µg/m^3: stations are expected to exceed the limit,
- between 35 and 45 µg/m3: stations lie within the uncertainty range.

In Figure 10, the estimated number and fraction of traffic-influenced air quality stations in Germany which are expected to exceed the NO_2 air quality limit in the considered years and scenarios is shown, also shown is the derived uncertainty range.

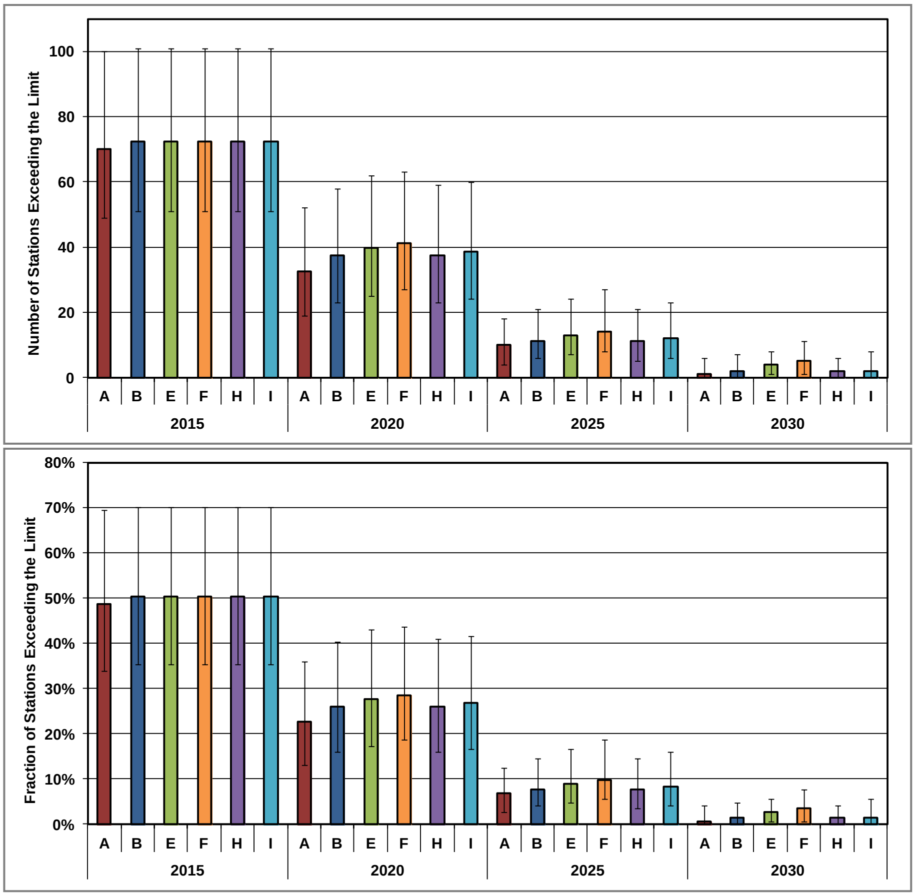

Figure 10: Estimated number of traffic-influenced air quality stations in Germany which are expected to exceed the NO_2 air quality limit in the considered years and scenarios; top: absolute numbers, bottom: fraction of all traffic stations (total: 144)

4 Summary and Conclusions

The effect of several emission factor scenarios on NO_2 air quality was modelled for three urban main roads in Germany, one with severe NO_2 limit exceedances ("Am Neckartor" in Stuttgart), one with average limit exceedances (Corneliusstraße in Düsseldorf) and one compliant with the limit (Dachauer Straße, Munich). Model calculations were done for the years 2015, 2020, 2025, and 2030 for each scenario. The scenarios were defined by conformity factors to limit the emissions of EU 6 diesel PC according to the future RDE regulation. They were varied between CF=1.6 and CF=3.3 in step 1, and between 1.2 and 1.8 in step 2. Step 1 was assumed to be introduced in September 2017, step 2 in September 2019. In scenario I, additionally, the introduction date of step two was changed from September 2019 to January 2020, thus making scenario I conform to what was voted for by TCMV. The results were extrapolated to all German traffic-influenced air quality measurement stations. For all scenarios, PC diesel EU 6 RDE emission factors are expected to be considerably lower than PC diesel EU 5 emission factors. Due to fleet renewal, this leads to lower road traffic emissions, lower NO_2 concentrations and fewer stations exceeding the NO_2 air quality limit. Depending on scenario, the fraction of traffic-influenced stations exceeding the air quality limit for annual mean NO_2 is expected to be reduced from about 50 % (72 stations) in 2015 to 23 % up to 28 % (33 up to 41 stations) in 2020, 7 % up to 10 % (10 up to 14 stations) in 2025, and 1 % up to 4 % (1 up to 5 stations) in 2030. For scenario I (TCMV voted), in 2030, two stations are expected to exceed the NO_2 air quality limit. The differences in modelled NO_2 reduction for the different scenarios and a single year are smaller than the NO_2 reductions modelled for a single scenario between the five-year intervals.

From the model calculations, you can draw the following conclusions:

For all scenarios, air quality is expected to improve considerably until 2030.

In 2020, still 23 % to 28 % of the traffic-influenced air quality stations are expected to exceed the air quality limit of annual NO_2.

In 2030, most traffic-influenced air quality stations are expected to comply with the NO_2 air quality limit. Only a few stations, where air pollution is especially high, are still expected to show limit exceedances in 2030.

Within the next five to ten years, at many traffic-influenced air quality stations, natural fleet renewal is not fast enough to achieve compliance with the NO_2 air quality limit. Here, additional actions to reduce NO_X-emissions might be considered.

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