BACKGROUND // JANUARY 2017

Air Quality 2016
Preliminary Evaluation

German Environment Agency

Umwelt Bundesamt

Imprint

Publisher:
Umweltbundesamt [German Environment Agency]
Postfach 14 06
06813 Dessau-Roßlau
Tel: +49 340-2103-0
info@umweltbundesamt.de
Internet: www.umweltbundesamt.de

/umweltbundesamt.de
/umweltbundesamt

Authors:
Andrea Minkos
Ute Dauert
Stefan Feigenspan
Susan Kessinger

Direct contact to the authors:
II4.2@uba.de

Editorial:
Section II 4.2 “Air Quality Assessment”

Publications as pdf files:
www.umweltbundesamt.de/en/publications

Image sources:
Cover photo: ARTENS | Fotolia.de
Photo of Zingst air monitoring station, p. 4: Dr. Axel Eggert, UBA
Photo of Zingst passive collector, p. 9: Thorsten Zang, State Office for Environment and Consumer Affairs of North-Rhine Westphalia

As at January 2017

The information presented in this brochure reflects the level of research at the time of publication. The definitive data is presented on the UBA website from the middle of the year onwards:

for PM_{10} and $PM_{2,5}$:
www.umweltbundesamt.de/themen/luft/luftschadstoffe/feinstaub

for NO_2:
www.umweltbundesamt.de/themen/luft/luftschadstoffe/stickstoffoxide

BACKGROUND // JANUARY 2017

Air Quality 2016

Preliminary Evaluation

List of Figures

Table of Contents

In July 2015, at the UBA air monitoring station on the Baltic coast in Zingst, a new air monitoring station building entered operation. It complies with the passive house standards.

I Air Quality in 2016: Data basis and evaluation methodology

1 Air quality and air pollutants

Air quality, or expressed otherwise, the condition of the air, is monitored throughout Germany by the individual federal states and the UBA (German Environment Agency / Umweltbundesamt – UBA). In this respect, air quality is determined on the basis of the amount of air pollutants it contains, which means substances which have a harmful impact on human health and/or the environment. These include, primarily, particulate matter, nitrogen dioxide and ozone, as well as a range of heavy metals.

The pollutant concentrations in the air are measured several times a day at over 650 air monitoring stations throughout Germany.

For the Germany-wide assessment of the air quality, the data gathered by the federal states is collated and evaluated at the UBA.

The evaluation and assessment of the air quality takes place in terms of the limit and target values as defined by the Directive on Ambient Air Quality and Cleaner Air for Europe[1]. The results are also compared with the considerably stricter recommendations of the World Health Organisation (WHO).

2 Provisional nature of the information

This evaluation of air quality in Germany in the year 2016 is based on preliminary data which has not yet been conclusively audited from the air monitoring networks of the federal states and the UBA, valid on 23rd January 2017. Due to the comprehensive quality

Particulate matter (PM_{10}, $PM_{2,5}$)
is defined as particles which pass through the size-selective air inlet of a monitoring device, which demonstrates a 50 % efficiency cut-off for an aerodynamic diameter of 10 (PM_{10}) and 2.5 ($PM_{2.5}$) micrometres (μm) respectively. Above all, particulate matter is propagated by combustion processes in motor vehicles, power stations and small-scale furnaces and during the production of metals and steel. It is also propagated by soil erosion and precursors such as sulphur dioxide, nitrogen oxide and ammonia. Particulate matter has been proven to have a negative impact on human health.

Nitrogen dioxide (NO_2)
is a reactive nitrogen compound which occurs in the form of a by-product during combustion processes, particularly in motor vehicles, and can have several negative effects on the environment and health.

Ozone (O_3)
is a colourless and toxic gas which forms a natural layer in the upper atmosphere (stratosphere) and protects the earth from the harmful ultraviolet radiation from the sun (the ozone layer). During intense sunlight, however, it also arises at ground-level due to complex photochemical processes between ozone precursors – primarily nitrogen oxides and volatile organic compounds. High concentrations of ozone can cause people to suffer coughs, headaches and respiratory tract irritations.

1 EU Directive 2008/50/EC, which became German law with the 39th Ordinance of the German Emissions Control Act.

assurance within the monitoring networks, the final data will only be available in mid-2017. The currently available data allows for a general assessment of the past year. The following pollutants were subject to consideration: particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2) and ozone (O_3), since, the limit and target values for the protection of human health are still exceeded for such substances.

3 Causes of air pollution

The primary sources of the air pollutants are road traffic and combustion processes in industry, the energy sector and households. Agriculture also contributes to particulate matter emissions due to the development of what are known as "secondary particles", which are particles that arise from complex chemical reactions between gaseous substances. The degree of the pollution level is also influenced by the weather conditions. In cold weather, emissions usually increase because heating systems go into increased use. High-pressure weather during the winter, which is often characterised by low wind speeds and a limited vertical exchange of air, means that air pollutants become concentrated in the lower atmospheric strata. High-pressure weather in the summer, with intense sunlight and high temperatures, acts to boost the formation of ground-level ozone. At high wind speeds and under positive mixing conditions, the levels of pollution fall, however. Inter-year variations in the levels of air pollution are primarily caused by different weather conditions of this kind. They therefore affect the influence of the more long-term development of the emissions.

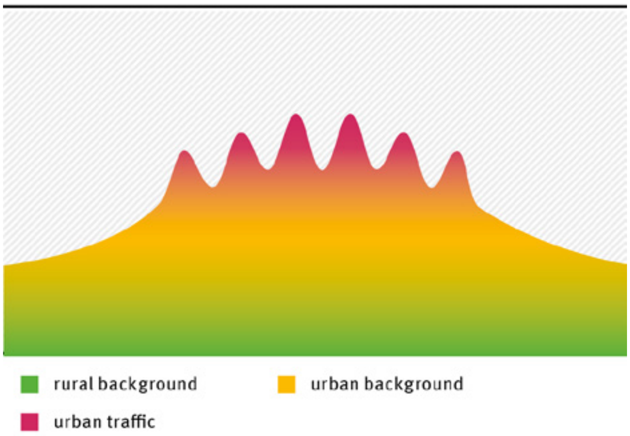
4 Influence of environmental conditions

In the following sections, the concentration values recorded at the individual air monitoring stations are summarised in the form of what are referred to as "pollution regimes". Pollution regimes group air monitoring stations together with similar environmental conditions. The "rural background" regime relates to areas in which the air quality is largely uninfluenced by local emissions. The air monitoring stations in this regime therefore represent the regional pollution level, which is also referred to as the "regional background". The "urban background" regime is characterised by areas in which the measured pollutant concentrations can be seen as being typical for the air quality in the city. In this respect, the pollution results from emissions in the city itself (road traffic, heating systems, industry, etc.) and that in the regional background. The air monitoring stations in the "urban traffic" regime are typically located on busy roads. As a result of this, the urban background pollution is joined by a contribution which arises due to the direct road traffic emissions. Figure 1 provides a diagrammatic representation of the contributions by the individual pollution regimes, although it only provides the approximate proportions.

Figure 1

Diagrammatic presentation of the pollution regime for particulate matter and nitrogen dioxide

Modified according to Lenschow*



* Lenschow et. al., Some ideas about the sources of PM_{10}, Atmospheric Environment 35 (2001) p. 23 – p. 33

II Particulate matter: A slight alleviation – but no all-clear for health

1 PM_{10} – Average daily values

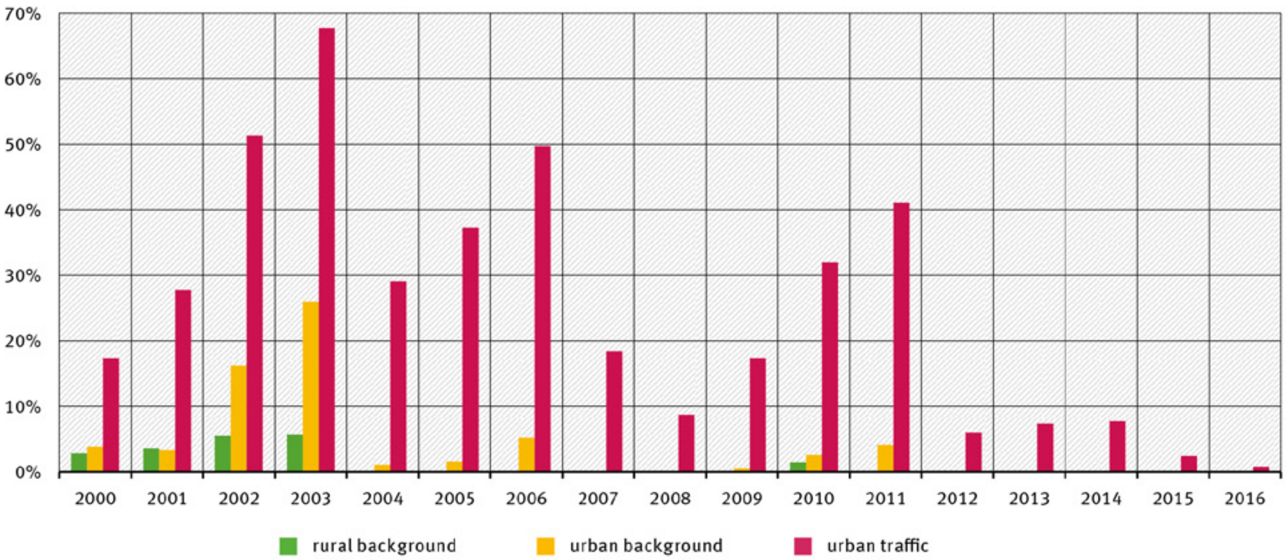
In 2016, the level of particulate matter pollution was lower in comparison with 2005–2015. In 2016, one of the lowest levels of pollution was recorded. The legal limit was only exceeded at the Am Neckartor air monitoring station in Stuttgart, with 63 average daily values of over 50 µg/m³ – only 35 such days are permitted. In the previous years, the exceeding of the limits occurred almost exclusively at urban traffic air monitoring stations, as shown in figure 2 (red bars). The recommendations of the World Health Organisation (WHO)[2] were not complied with at 46 percent of all air monitoring stations.

EU limit
The average daily PM_{10} value should not exceed 50 µg/m³ more than 35 times per year.

WHO recommendation
The average daily PM_{10} value should not exceed 50 µg/m³ more than 3 times per year.

Figure 2

Percentage share of air monitoring stations recording an exceeding of the limit for the average daily PM_{10} values in the corresponding pollution regime, time frame 2000–2016



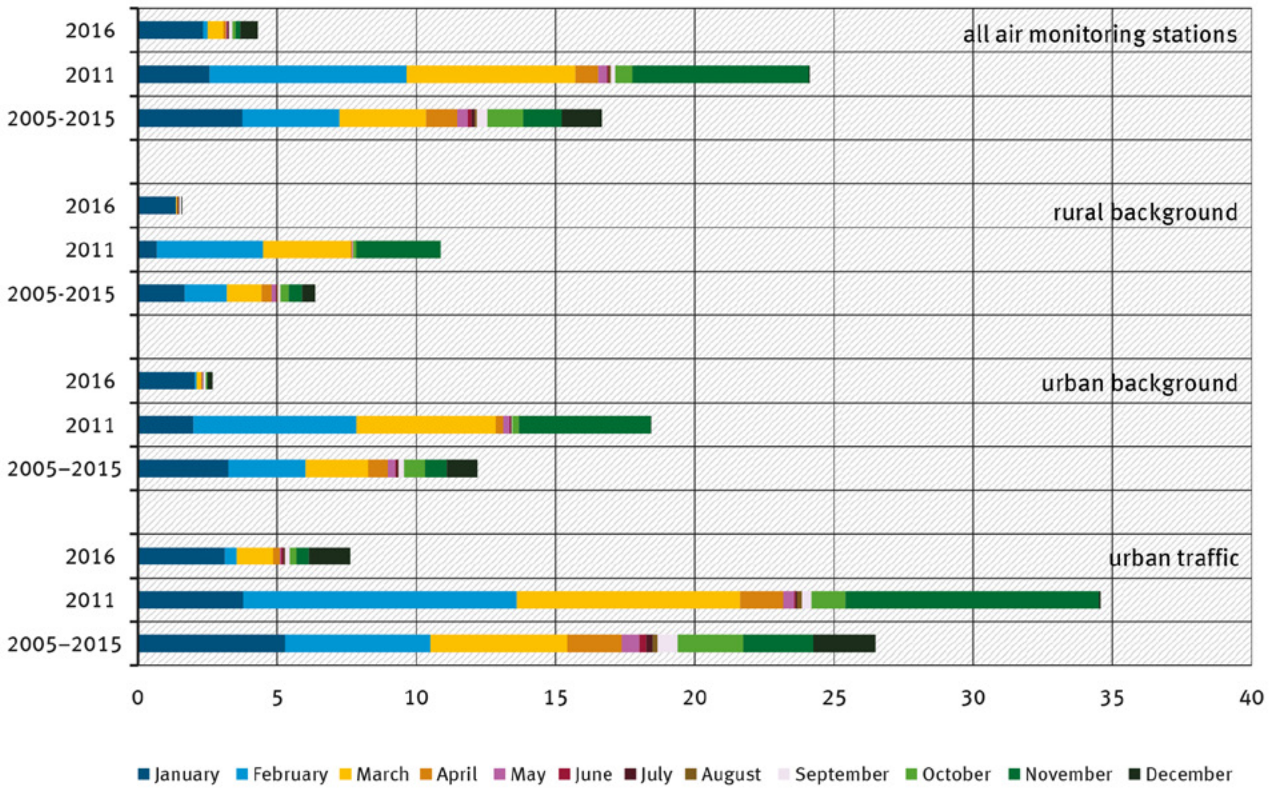
Source: UBA, 2017

Figure 3 shows how many days were recorded on which the limits were exceeded, on average, per month. In this case, 2016 is compared with 2011, in which the levels of pollution were high due to the frequent occurrence of cold, stable high-pressure weather conditions, and an extended reference period (2005–2015). It can be seen that in February 2011 there were more than twice as many days on which the limits were exceeded than there were in the whole of 2016. The long-term comparison also shows that 2016 was a year in which the levels of particulate matter pollution were low, and in which the days on which the limits were exceeded primarily occurred in January.

2 WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulphur dioxide, Global update 2005 http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/air-quality/publications/pre2009/air-quality-guidelines.-global-update-2005.-particulate-matter,-ozone,-nitrogen-dioxide-and-sulfur-dioxide

Figure 3

Average number of days on which PM_{10} limit was exceeded (average daily values > 50 µg/m³) per month in the corresponding pollution regime. Shown for the years 2016, 2011 and the period 2005–2015



Source: UBA, 2017

2 PM_{10} – Average annual values

In 2016, the PM_{10} limit of 40 µg/m³ as the average annual value was complied with throughout Germany. 24 percent of the air monitoring stations recorded values that infringed the air quality guidelines proposed by WHO, however. The vast majority of these air monitoring stations were in urban traffic locations.

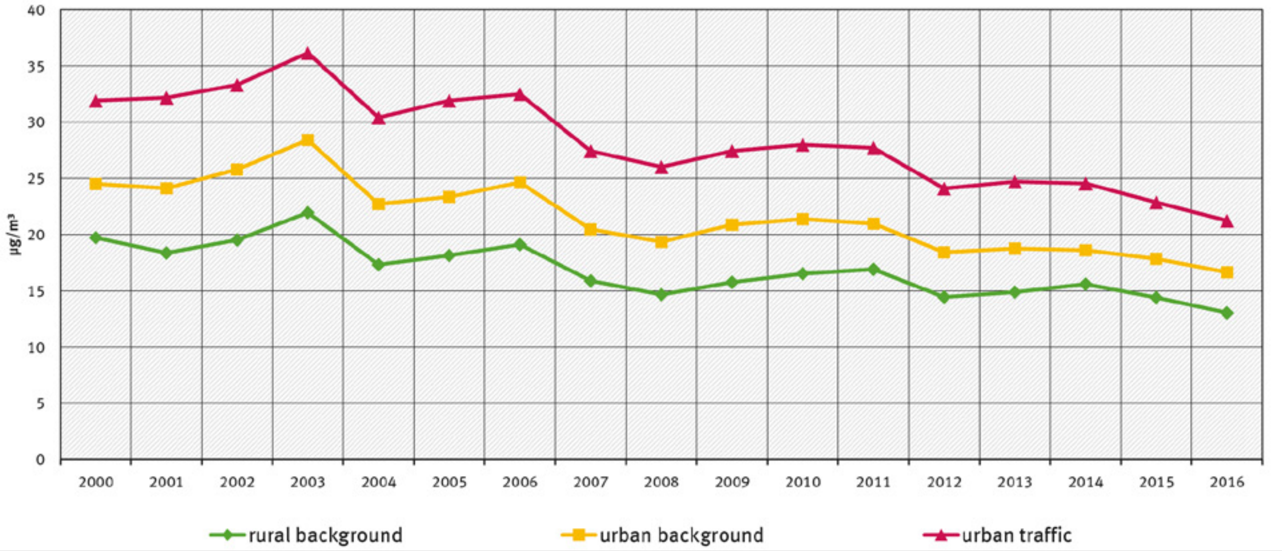
EU limit
The average annual PM_{10} value must not exceed 40 µg/m³

WHO recommendation
The average annual PM_{10} value must not exceed 20 µg/m³.

In 2016, as in the previous year, there was a lack of extreme weather conditions to foster particulate matter pollution, such as those observed in the spring and autumn of 2011, for example. From the long-term perspective, in 2016, the levels of pollution were therefore at their lowest (figure 4). Accompanied by the regional falls in the PM_{10} emissions, the average annual PM_{10} values also show a clear fall in all pollution regimes throughout the entire period of observation from 2000 to 2016. The progression is also characterised by strong inter-year variations, however, particularly due to the different weather conditions.

Figure 4

Development of the average annual PM_{10} values via selected* air monitoring stations in the corresponding pollution regime, time frame 2000–2016



* The air monitoring stations selected were those that conducted measurements over an extended period. For example: in the area of urban traffic, an air monitoring station has to have measured PM_{10} in at least 11 years for the data to be included in the calculation.

Source: UBA, 2017

3 $PM_{2.5}$ pollution

From 1st January 2015, for the smaller fraction of particulate matter which only contains particles with a maximum diameter of 2.5 micrometres (µm), an average annual limit of 25 µg/m³ applies throughout Europe. In Germany, in 2016, as in the previous year, this value was not exceeded at any air monitoring station.

The EU Air Quality Directive also requires the average exposure of the population to $PM_{2.5}$ to be reduced until the year 2020. For this purpose, the Average Exposure Indicator (AEI) was developed. As the initial value for Germany for 2010, an AEI of 16.4 µg/m³ was calculated as the average value of the years 2008 to 2010. According to the requirements of the EU Directive, this results in a national reduction goal of 15 percent until 2020. Accordingly, the AEI calculated for 2020 (average value of the years 2018, 2019 and 2020) may not exceed the value of 13.9 µg/m³. In 2016 (average value of the years 2014, 2015, 2016), the AEI totalled 13.4 µg/m³. The scenarios that were modelled for the UBA "Air Quality 2020/2030"[3] project revealed that in the 2005 to 2020 time frame, it is possible to achieve a reduction in the AEI of between 3.4 and 3.9 µg/m³. Due to uncertainties in the modelling and based on the fact that the increasing impact of wood-burning equipment may have been underestimated in the original project, it is not possible to say with any certainty that the reduction-related goals will be reached by 2020. In addition, from 1.1.2015 onwards, the AEI is not permitted to exceed a value of 20 µg/m³. This value has not been exceeded in Germany since the start of the measurements in 2008.

Exposure
The contact of an organism with chemical, biological or physical influences is known as "exposure". A person is "exposed" to particulate matter, for example.

How is the Average Exposure Indicator (AEI) calculated?
The average exposure indicator is determined as an average value over a period of 3 years from the individual average annual $PM_{2.5}$ values of selected air monitoring stations with an urban background. This results in a value which is expressed in µg/m³ for each 3-year period.

3 UBA texts 35/2014

III Nitrogen dioxide: Little improvement compared with last year

1 NO_2 – Average annual values

Since the year 2000, the levels of nitrogen dioxide pollution have only shown a limited fall. In 2016, the average NO_2 concentration at urban traffic air monitoring stations fell below an average annual value of 40 µg/m³ for the first time since the year 2000. The levels of pollution are primarily determined by local emissions sources – particularly the traffic in urban conurbations – and only show limited inter-year variations.

In rural areas, which are a long way from the major sources of NO_2, from 2000–2016, the average annual concentration for all the air monitoring stations only amounted to 10 µg/m³ (figure 5, green curve). At the air monitoring stations with an urban background, the values were well below the limit of 40 µg/m³ (figure 5, yellow curve). With values of 45 µg/m³ the average annual NO_2 value at urban traffic locations between 2000–2011 (figure 5, red curve) exceeded the limit with which compliance has been required since 2010 by approx. 5 µg/m³. This reflects the fact that average annual values of over 40 µg/m³ were measured at many air monitoring stations and cases in which the limits were exceeded were therefore recorded.

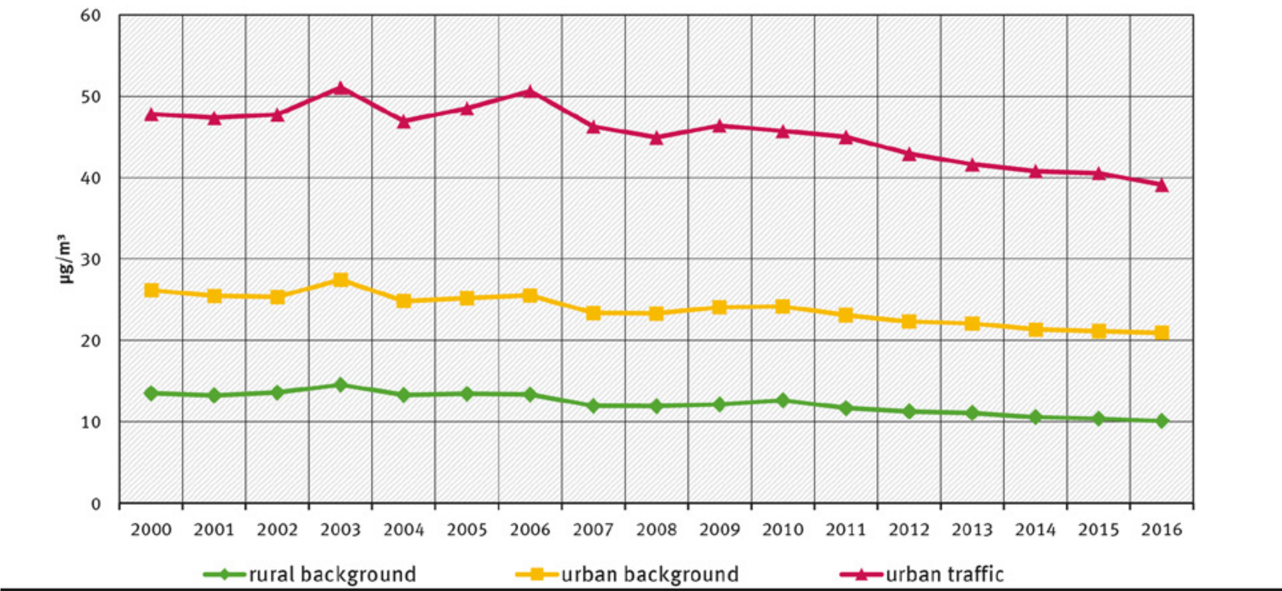
EU limit
The average annual PM_{10} value must not exceed 40 µg/m³

WHO recommendation
The WHO recommendation is equivalent to the EU limit

Passive collector: A passive collector is a small monitoring device which operates without electrical power and in which several detection tubes absorb the pollutants from the air. The detection tubes are regularly removed and their contents evaluated in the laboratory.

Figure 5

Development of the average annual NO_2 values via selected* air monitoring stations in the corresponding pollution regime, time frame 2000–2016



* The air monitoring stations selected were those that conducted measurements over the full period.

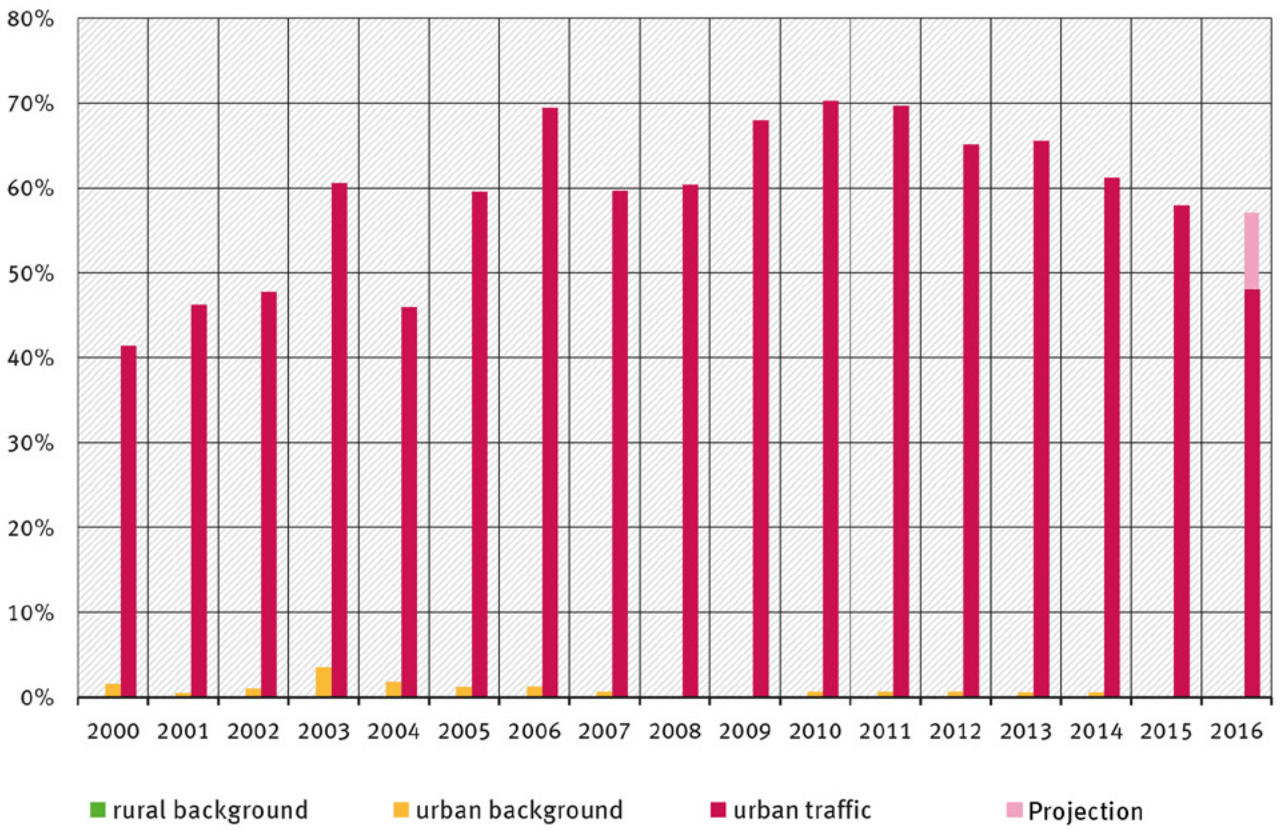
Source: UBA, 2017

The NO_2 concentrations measured by passive collectors, primarily at highly polluted urban traffic locations, are not yet available for this preliminary evaluation.

According to the current data, 48 percent of air monitoring stations in urban traffic locations exceeded the statutory limit and/or the WHO air quality guidelines (figure 6, red bars). On the basis of a projection derived from the previous year's data, we estimate the proportion of air monitoring stations in urban traffic locations that exceeded the limit in 2016 to be approx. 57 percent.

Figure 6

Percentage share of air monitoring stations exceeding the limit for the average annual NO_2 value in the corresponding pollution regime, time frame 2000–2016



Source: UBA, 2017

2 NO_2 – Average hourly values

Since 2010, average hourly NO_2 values exceeding 200 µg/m³ are only permitted a maximum of 18 times per year. In 2016, this value was exceeded at approx. 1 percent of all air monitoring stations in urban traffic locations. The situation was similar in the previous years. In 2016, 6 percent of all air monitoring stations failed to comply with the WHO recommendation.

EU limit
The average hourly NO_2 values should not exceed 200 µg/m³ more than 18 times per year.

WHO recommendation
The average annual NO_2 values must never exceed 200 µg/m³.

IV Ground-level ozone: The clean air policy is taking effect – but no all-clear

The weather during the summer of 2016 in Germany was changeable, with frequent thunderstorms and a lack of sustained periods of high pressure. This led to an absence of periods with high concentrations of ozone. Only at the end of August and in the first half of September did a period of hot weather and sunshine lead to an increased build-up of ozone.

In relation to the threshold and target values, however, in comparison with the last 20 years, the values were quite low.

The highest 1-hour average value amounted to 246 µg/m³, which was measured on 27th August at the Niederzier air monitoring station in North-Rhine Westphalia. The alert threshold of 240 µg/m³ as an average hourly value was only exceeded during the course of one hour at this particular air monitoring station; the information threshold of 180 µg/m³ was exceeded on 12 days. This means that the summer of 2016 was one of those with the lowest of levels of ozone pollution (also see figure 7).

By the year 2014, in comparison with 1990, the emissions of ozone precursors such as nitrogen oxides from road traffic and furnaces, and volatile organic compounds from paints, varnishes and cleaning agents, fell by 58 percent and 69 percent respectively in Germany.

The efforts made by Germany to further reduce the emissions of ozone precursors must nevertheless be continued, because the average target value for the protection of human health (120 µg/m³ as 8-hour average value) is not complied with throughout Germany. In 2016, 8-hour average values of over 120 µg/m³ were measured at all 258 air monitoring stations. Accordingly, the recommendation of WHO that the 8-hour average values should not exceed the value of 100 µg/m³ was missed. As an average for all air monitoring stations, in 2016, the highest daily 8-hour average values exceeded 120 µg/m³ on 16 days, which was slightly below the level of the last 20 years. A strong fall in comparison with the 1990s, as can be seen with the high concentration values of over 180 µg/m³, cannot be determined for compliance with the long-term target value.

Information threshold
With ozone values of over 180 µg/m³ (1-hour average value), the general public is notified by the media of the presence of a health risk for particularly sensitive sections of the population.

Alarm threshold
With ozone values of over 240 µg/m³ (1-hour average value), the general public is warned by the media of the presence of a general risk to human health.

Target values for the protection of human health
Ozone values of over 120 µg/m³ (highest daily 8-hour average value) are only permitted to occur on a maximum of 25 days per calendar year, averaged over 3 years. Over the long term, the 8-hour average values must never exceed 120 µg/m³.

WHO recommendation
The 8-hour average values must never exceed 100 µg/m³.

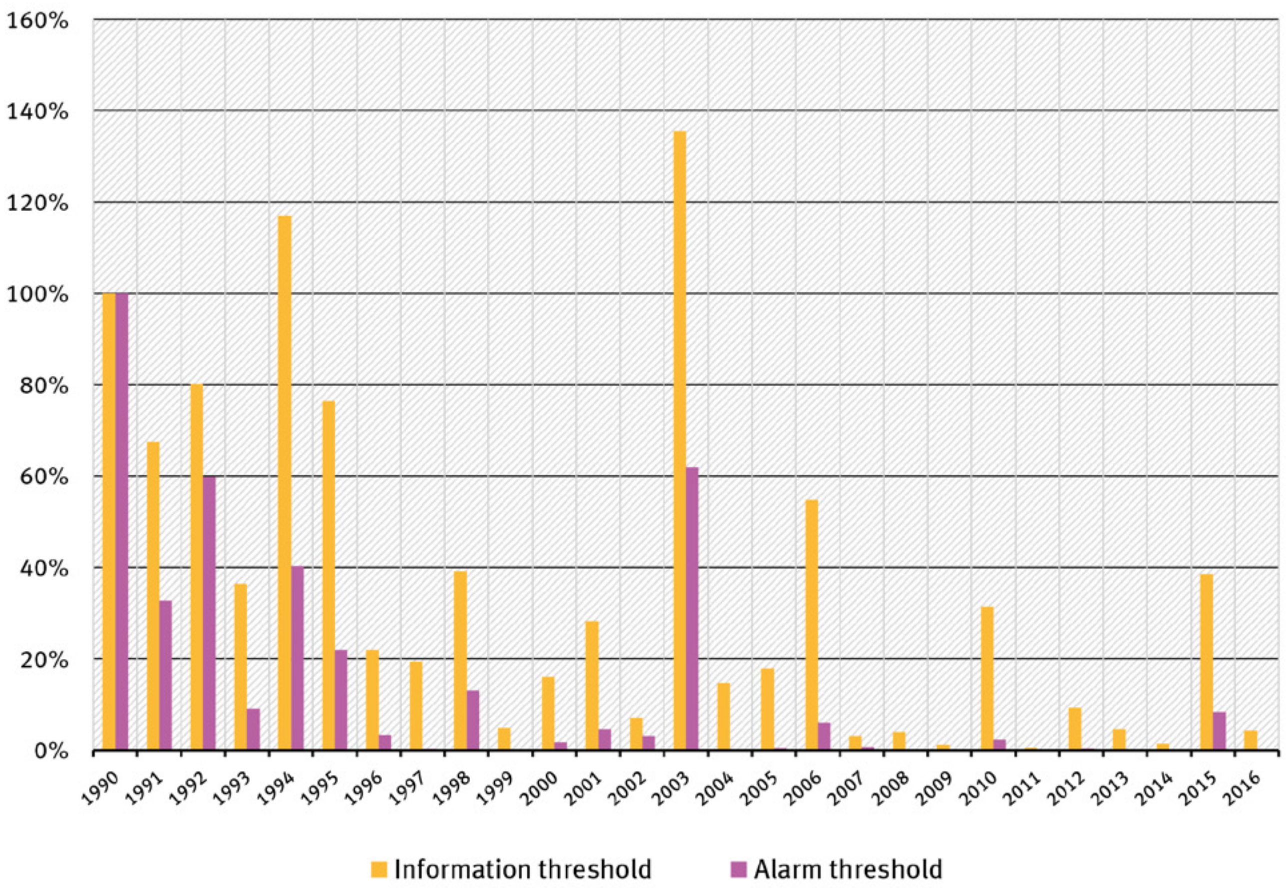
Target values for the protection of vegetation (AOT40)
The term AOT40 (Accumulated Ozone exposure over a Threshold of 40 parts per billion) designates the sum total of the difference between the 1-hour average values exceeding 80 µg/m³ (=40 ppb) and the value 80 µg/m³ between 8am and 8pm in the months of May to July. Since 2010, as 5-year average, the AOT40 target value should not exceed a value of 18,000 µg/m³ – i.e. 9,000 ppb h and/or 9 ppm h. Over the long term, the value should not exceed a maximum value of 6,000 µg/m³ in one year – i.e. 3,000 ppb h and/or 3 ppm h.

A 3-year period is monitored for the target value for the protection of human health: on average, an 8-hour average value of 120 µg/m³ may only be exceeded on 25 days. In the most recent averaging period of 2014 to 2016, however, 21 percent of the air monitoring stations exceeded this value. Figure 8 shows that most cases in which the limits were exceeded occurred in rural areas – in contrast to pollutants such as particulate matter and nitrogen dioxide, which have the highest concentrations in the vicinity of roads, the ozone values in the vicinity of roads are a lot lower. Therefore, ozone is rarely measured at air monitoring stations in urban traffic locations.

According to the EU Air Quality Directive, to determine the target values for the protection of the vegetation (AOT40), only the data from the around 160 air monitoring stations in non-urban locations is considered. For the target value (which has been mandatory since 2010), an averaging over a five-year period is required. The target value (18,000 µg/m³ h obtained from May to July) for the most recent averaging period of 2012 to 2016 was exceeded at 12 air monitoring stations (= 7 %, previous year: 15 air monitoring stations = 10 %). Over the last ten years, the target value has been exceeded comparatively few times, as shown in figure 9. This improvement does not mean that risks to vegetation no longer occur, however.

Figure 7

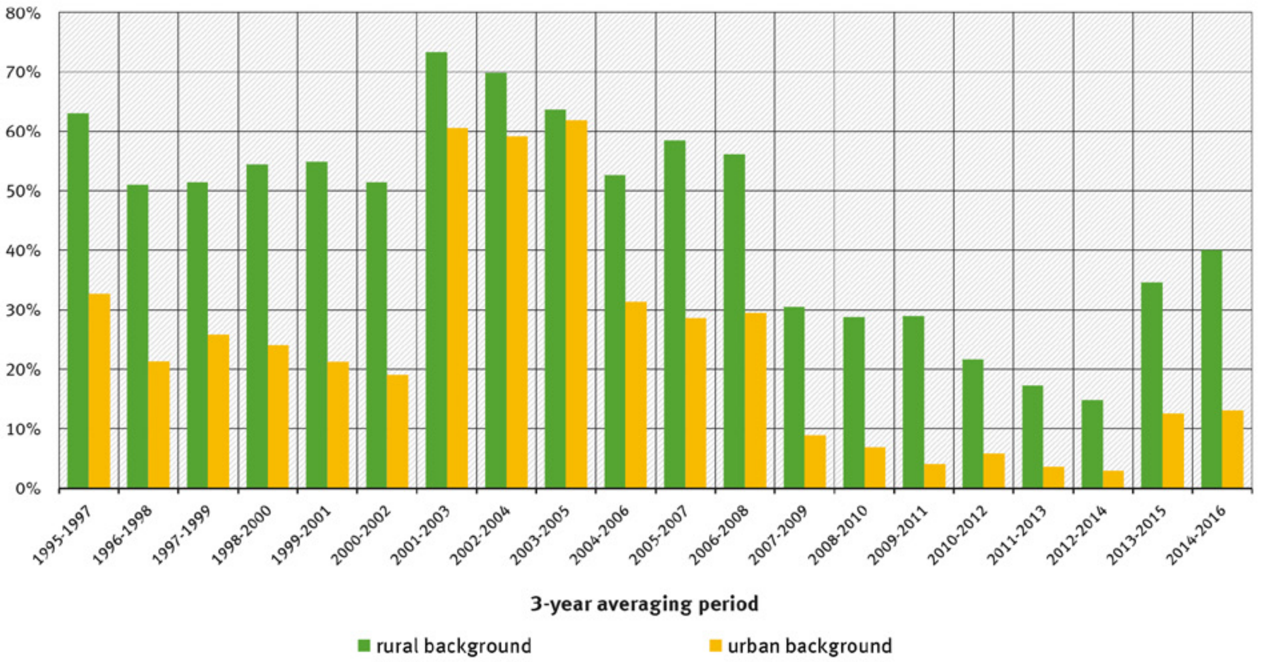
Hours during which the information threshold (180 µg/m³) and the alert threshold (240 µg/m³) for ground-level ozone were exceeded
(relative to the year of 1990 and the number of air monitoring stations in operation)



Source: UBA, 2017

Figure 8

Percentage share of air monitoring stations recording an exceeding of the target value for the protection of human health, time frame 1995 to 2016
(in each case, 1-year moving average over 3 years)

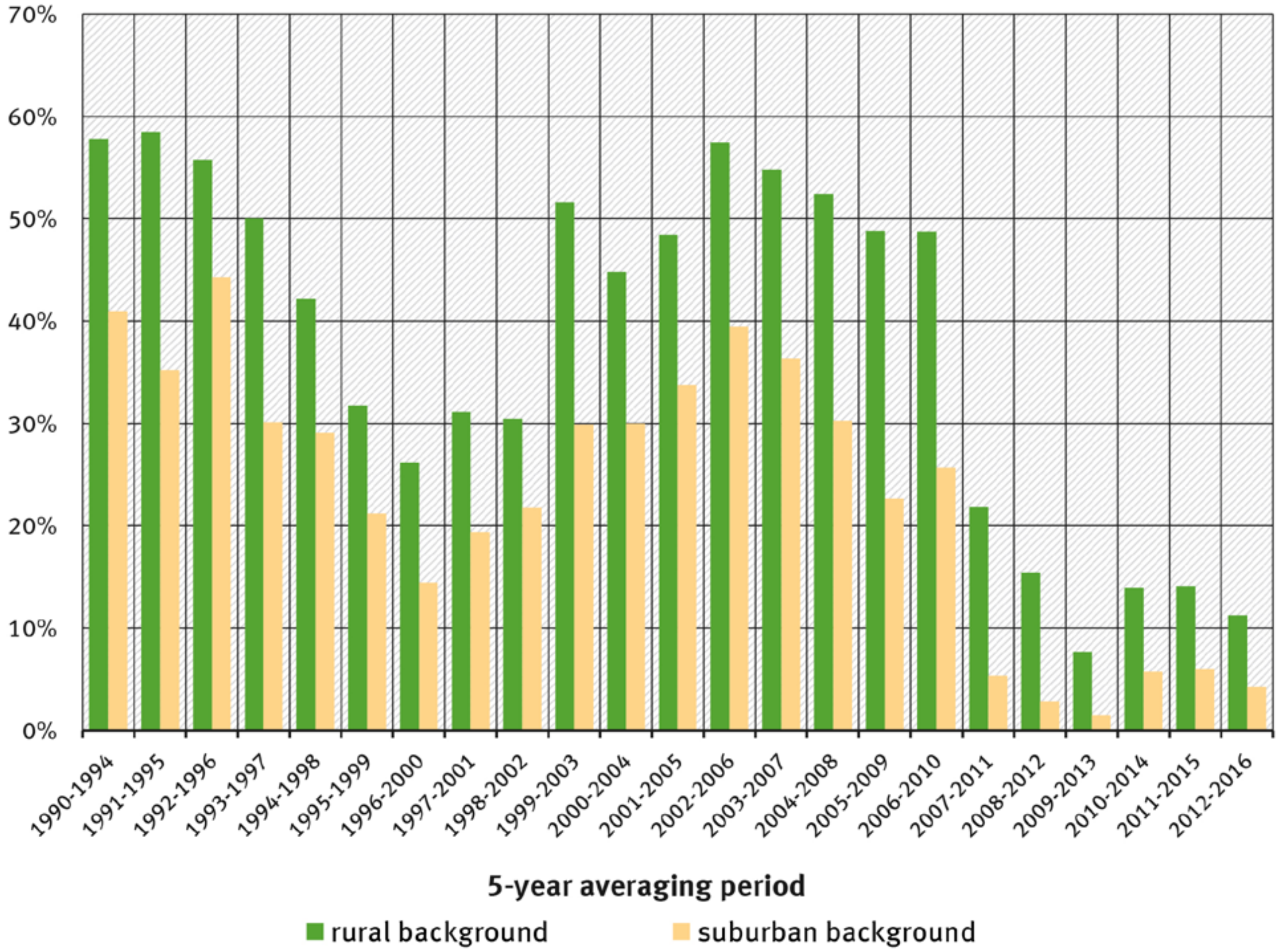


Source: UBA, 2017

According to the currently valid methodology, the critical threshold for adverse effects on vegetation amounts to the sum of the average target value (6,000 µg/m³ h, obtained from May to July), which was exceeded at 157 of the 161 air monitoring stations in 2016 (= 98 %; previous year: 99 %). The methods of the impact evaluation of ozone are currently undergoing development in Europe. In this respect, it isn't just the concentration of ozone, but the meteorological conditions, the opening characteristics of the stomata of the plants and therefore the ozone flux into the plants, which are taken into account.

Figure 9

Percentage share of air monitoring stations recording an exceeding of the target value for the protection of vegetation, time frame 1995 to 2016
(in each case, 1-year moving average over 5 years)



Source: UBA, 2017

V How is climate change influencing the quality of our air?

The effects of climate change will have a variety of consequences on the future quality of our air. If the emissions of precursors are not reduced any further, increasing temperatures, for example, will also increase the risk of higher concentrations of ozone. The extreme heat in the summer of 2015 is an example of the kind of temperatures that can be expected to occur more often in the future.

In July and August 2015, the weather in Germany was so hot that in Kitzingen, Lower Franconia, at 40.3°C, a new all-time record temperature for Germany was recorded. August 2015 was the second hottest August since 1881, and with ten months that were warmer than average, 2015 was the second hottest year in Germany[4] since records began[5].

During these exceptionally hot and dry periods of weather, ozone concentrations were recorded at the air monitoring stations which exceeded the alert threshold of 240 µg/m³ that had barely been seen in the previous 10 years. The highest average hourly value in Germany totalled 283 µg/m³ and was measured on 3rd July 2015 at the Wiesbaden-Süd air monitoring station. This was the highest value to be measured since the hot summer of 2003.

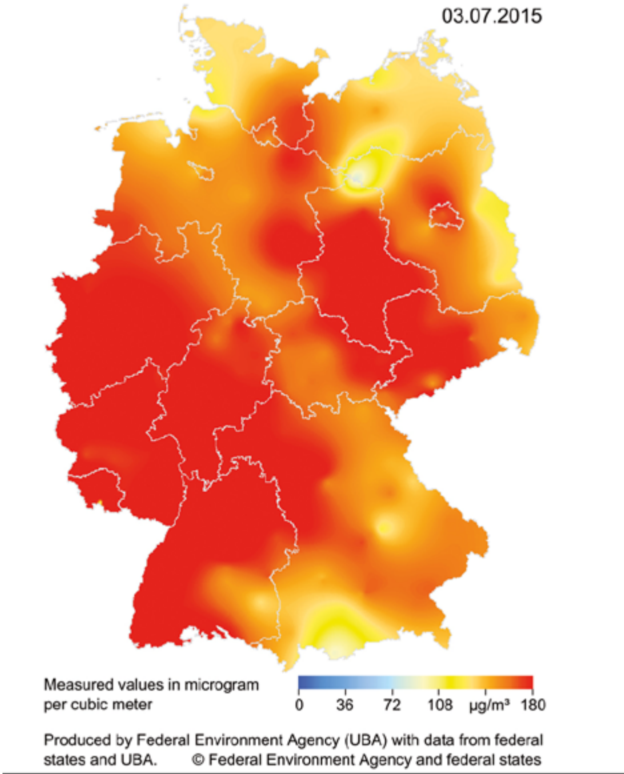
The map dating from 3rd July 2015 (figure 10) shows that at this time, the whole of Germany was affected by high concentrations of ozone. On this day, average hourly values exceeding the information threshold of 180 µg/m³ were recorded at 111 air monitoring stations (approx. 43 percent of all air monitoring stations). That is the critical concentration above which the general population must be instructed about determined or forecast cases in which the values are exceeded and the associated behavioural recommendations.

1 Climate change and air quality

If, during the course of climate change, the meteorological variables which have a decisive influence on the propagation, distribution and removal of air pollutants from the atmosphere should change, this will also influence the average air quality and air quality during periods in which the levels of particulate matter and ozone are high.

Figure 10

Map of Germany showing the maximum 1-hour average values of ozone on 3rd July 2015



For Central Europe, a clear increase in the average annual temperatures is expected to last until the end of the 21st century, which depending on the monitored emissions scenario and the region, is between 1 and 5 degrees Celsius. Due to this future increase in temperature, a variety of studies show an increase in the ozone concentration in the mid-latitudes.

While the forecast changes in temperature presented clearly in a variety of different climate projections, the projected changes in precipitation for Central Europe show considerable differences. This reflects the uncertainties in the modelling of climate models, which are associated with the high degree of temporal and spatial variability. These uncertainties have a considerable influence on the projections of the expected concentrations of particulate matter, as precipitation is a key factor in reducing particulate matter.

4 together with 2000 and 2007
5 weather in Germany in 2015, archive of press releases, www.dwd.de

The quantities of pollutants to occur, for example, the emissions of nitrogen oxides and particulate matter, also have a considerable impact on air quality and compliance with the appropriate limits.

The impact of climate change and changed volumes of emissions on the development of the concentrations of pollutants in the air can only be analysed using climate change and emissions scenarios. In this context, the meteorological conditions and emissions volumes to be expected in the future are simulated in models.

2 KLENOS research project

In the KLENOS (Klima ENergie Ozon Staub – climate energy ozone dust) research project, research was conducted into how air quality might change under a variety of assumptions on climate change and the development of emissions by combining a regional climate simulation and a chemical-transport modelling. For this purpose, a regional climate model[6] was configured and applied as a meteorological driver for a chemical-transport model[7] for the whole of Europe and for Germany. The concentration arrays for ozone (O_3), particulate matter (PM_{10}) and nitrogen dioxide (NO_2) have a spatial resolution of 7 x 8 square kilometres.

3 Evaluation of the climate model

To evaluate the quality and performance capability of the regional climate model, model results from the reference period of 1976 to 2005 were compared with the actual observation data from weather stations.

Due to the high spatial and temporal variability, the modelling of precipitation is associated with several difficulties. The model overestimates the observed level of precipitation for extensive areas of Europe, which must be taken into account with the interpretation of the results. The overestimation of the precipitation results in a high degree of cloud coverage, leading to reduced net solar radiation and warming. Due to the low oxidant potential which results, the determined climate effect for ozone is to be assessed as low. The evaluation of all of the meteorological variables also revealed that the modelled temperatures are, on average, too low, and the wind speeds, too high.

6 COSMO-Climate Local Model, Consortium for Small-scale Modelling, http://www.cosmo-model.org/

7 Chemical Transport Model REM-CALGRID, www.geo.fu-berlin.de/met/ag/trumf/Ausbreitungsmodelle/RCG-Beschreibung.pdf

The variations that were determined are at an acceptable level, however, for being able to draw conclusions regarding the future air quality.

4 Climate signal: Change to meteorological conditions in the future

As the driver for the climate simulations in the 2021 to 2050 projection period, the most pessimistic of all four RCP[8] scenarios was used. This assumes a high rate of population growth, a limited increase in energy efficiency, no new climate change regulations and the continued heavy use of fossil fuels. The results determined using this scenario can therefore be seen as a worst-case scenario which could occur as a result of climate change.

The climate changes in the 2021–2050 projection period are determined from the comparison with the previous reference period (1976–2005). The biggest change is in the temperature, the long-term average value of which increases by 0.8 degrees Celsius for Germany. In contrast to the temperature, the long-term average changes to the precipitation[9] are very low, and in view of the considerable uncertainties with the modelling of precipitation, cannot be classified as significant climate change.

The changes to the meteorological variables of the wind speed, degree of cloud coverage and height of the atmospheric boundary layer which are used directly as input variables for the chemical-transport model, are very low and merely show trends.

The meteorological fields for the reference and projection period created with the regional climate model serve as input variables for the chemical-transport model, with which the future concentrations of ozone and particulate matter are simulated.

5 More ozone due to climate change

To be able to determine the impact of climate change on the air quality, the emissions of pollutants incorporated in the model are initially held constant in the reference and projection period (in this case APS[10] 2005). This means that the calculated change in future concentrations of pollutants is solely attributable to the impact of climate change.

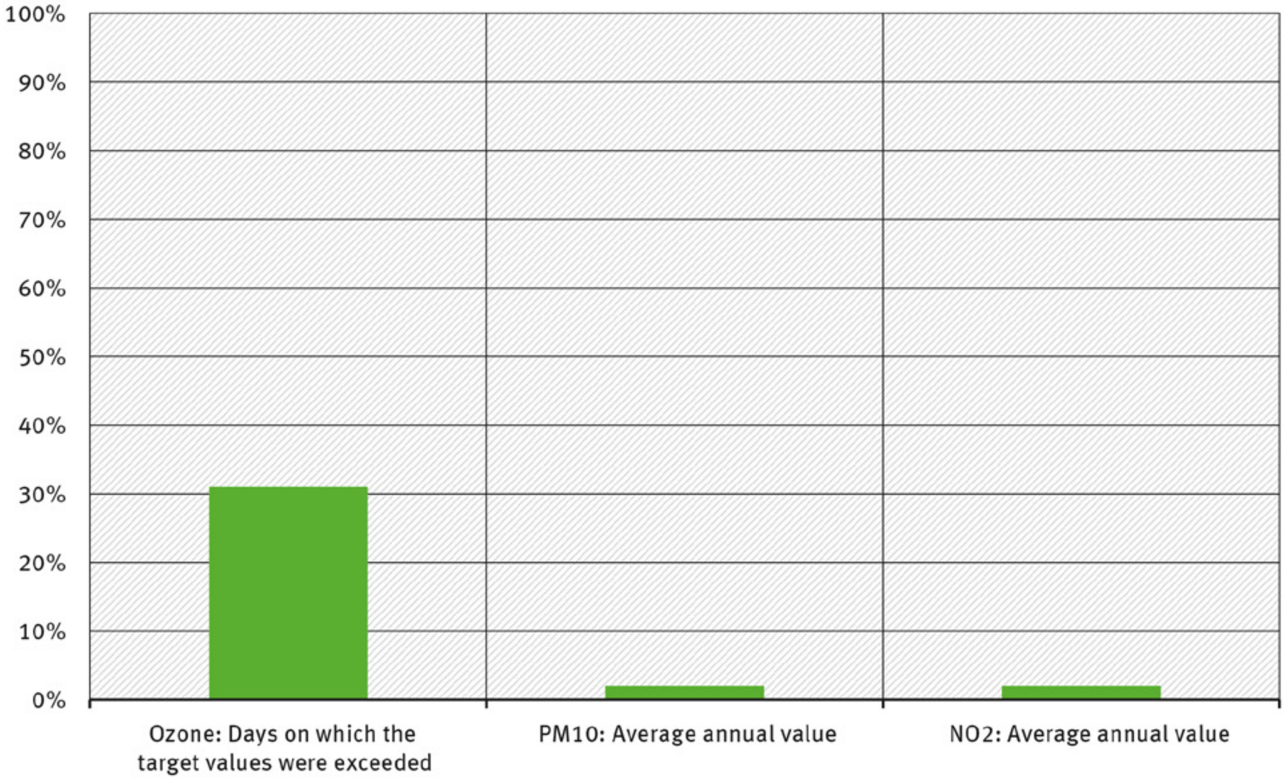
8 RCP: Representative Concentration Pathways, anthropogenic radiative forcing of 8.5 W/m2 in the year 2100 due to continuously increasing greenhouse gas emissions (RCP 8.5)

9 Increase in precipitation of 1.3 %

10 APS: Current policy scenario of the year 2005/2030

Figure 11

Relative changes in the long-term area average between the reference- and projection period due to climate change



Source: KLENOS summary report

Figure 11 shows the changes in concentrations of pollutants averaged on a comprehensive and long-term basis in the 2021–2050 projection period in comparison with the 1976–2005 reference period.

On the days on which the ozone was exceeded (days with a maximum 8-hour average value above the threshold value of 120 µg/m³), the climate impact can be clearly seen. Accordingly, the number of days on which the target value were exceeded increases by more than 30 percent.

At the local level, in southern Germany in particular, increases of 100 to 200 percent could occur. The changes to other variables for the evaluation of ozone (e.g. AOT40[11]) are, in terms of the German average, very low, although increases of up to ten percent can occur at a local level.

With a negligible increase of approx. two percent, the average concentrations of PM_{10} and NO_2 are barely influenced by climate change at all[12].

6 Despite climate change: less ozone due to future emissions reductions

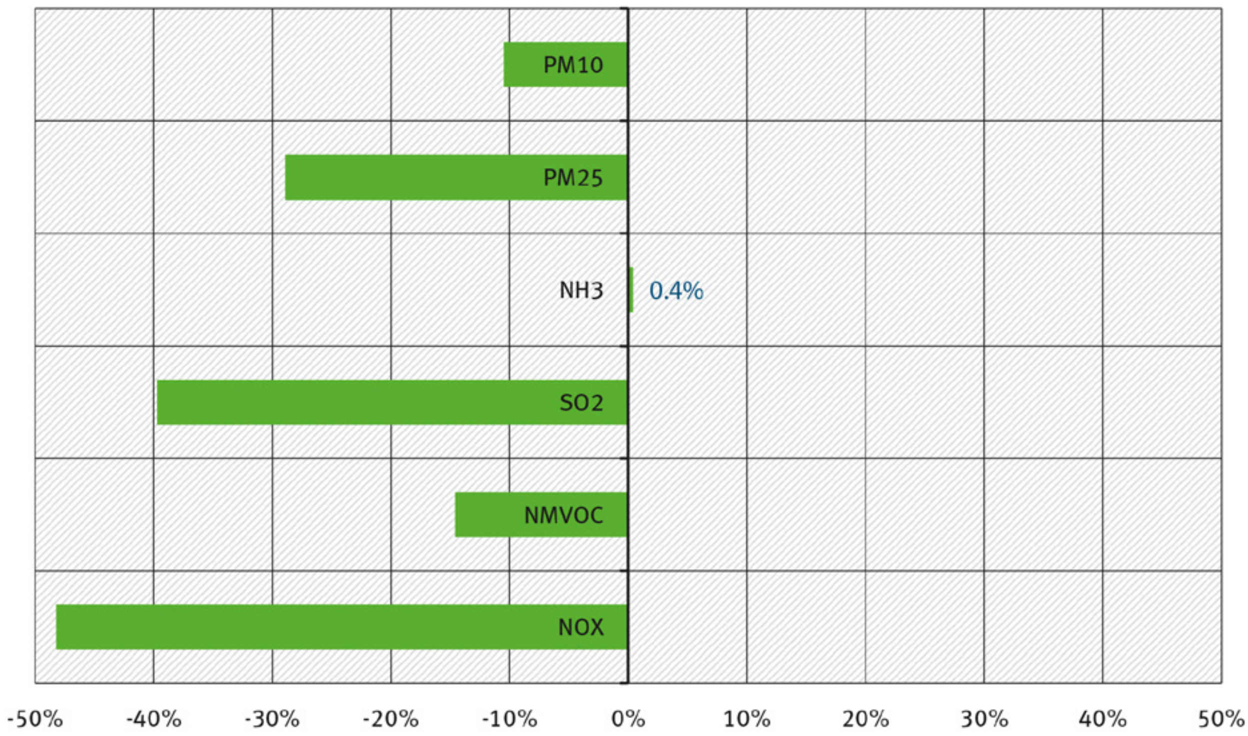
In a further model run, the concentrations of particulate matter, NO_2 and ozone are modelled, which are now affected by falling emissions of pollutants as well (APS11 2030). According to this emissions scenario, the ozone precursors nitrogen oxides (NOx) and reactive hydrocarbons (NMVOC) fall by almost 50 percent and 15 percent respectively in Germany by 2030. The fall in PM_{10} emissions is lower, at almost eleven percent (figure 12).

11 AOT40: Accumulated ozone exposure over a threshold of 40 parts per billion

12 This also applies to a regionally differentiated evaluation

Figure 12

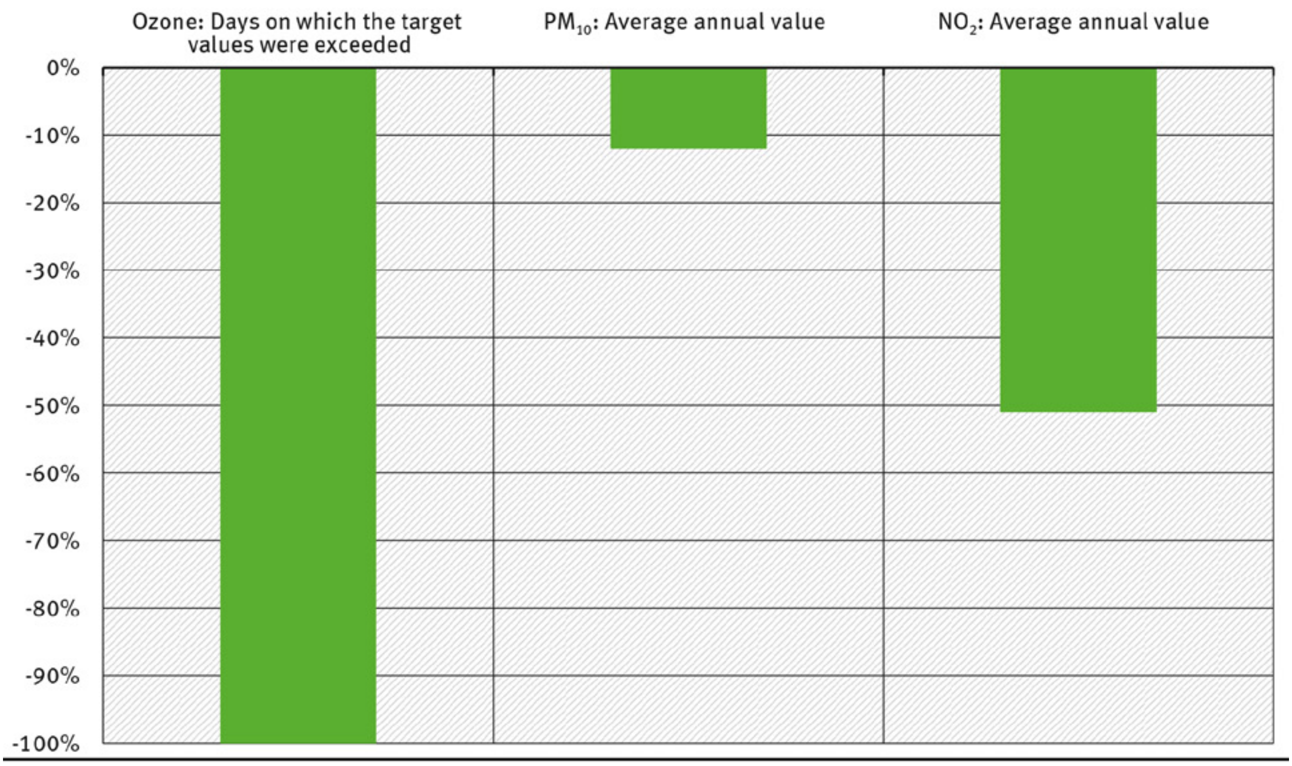
Relative changes in overall German emissions from 2005–2030, APS 2030



Source: KLENOS summary report

Figure 13

Relative changes in the long-term area average between the reference- and projection period due to climate change and changes in emissions



Source: KLENOS summary report

On the same basis as figure 11, figure 13 shows the relative changes to the future average concentrations of pollutants which are affected by climate change and falling emissions.

Accordingly, for ozone, with a fall of almost 100 percent despite climate change, there are almost no days on which the target values are exceeded. The average levels of pollution due to particulate matter and NO_2 are also falling clearly. The falling emissions, especially those of ozone precursors, therefore overcompensate for the ozone-fostering impact of climate change. Other variables for the evaluation of ozone (e.g. AOT40) diminish on a differentiated basis in terms of the area average and the region.

The comparison of the climate signal and the combined climate and emissions signal using the box whisker plots in figure 14 also highlights the dominant impact of emissions-reducing measures in terms of the future rates of air pollution by all three pollutants. In addition to the relative changes which are to be expected that are shown in figures 11 and 13, the box whisker plots provide data on the absolute concentration values of both scenarios in comparison with the reference period.

7 Conclusions from the project

In the KLENOS project it was possible to demonstrate that emissions-reducing measures require further advancement, as only in this way will it be possible for the negative consequences of climate change on future air quality to be counteracted.

At the same time, there has been a tendency to underestimate the projected ozone values in the project because the background concentrations of ozone which are required for the chemical-transport modelling were assumed to be constant. Observations at hemispheric background air monitoring stations show that these concentrations are tending to increase, however.

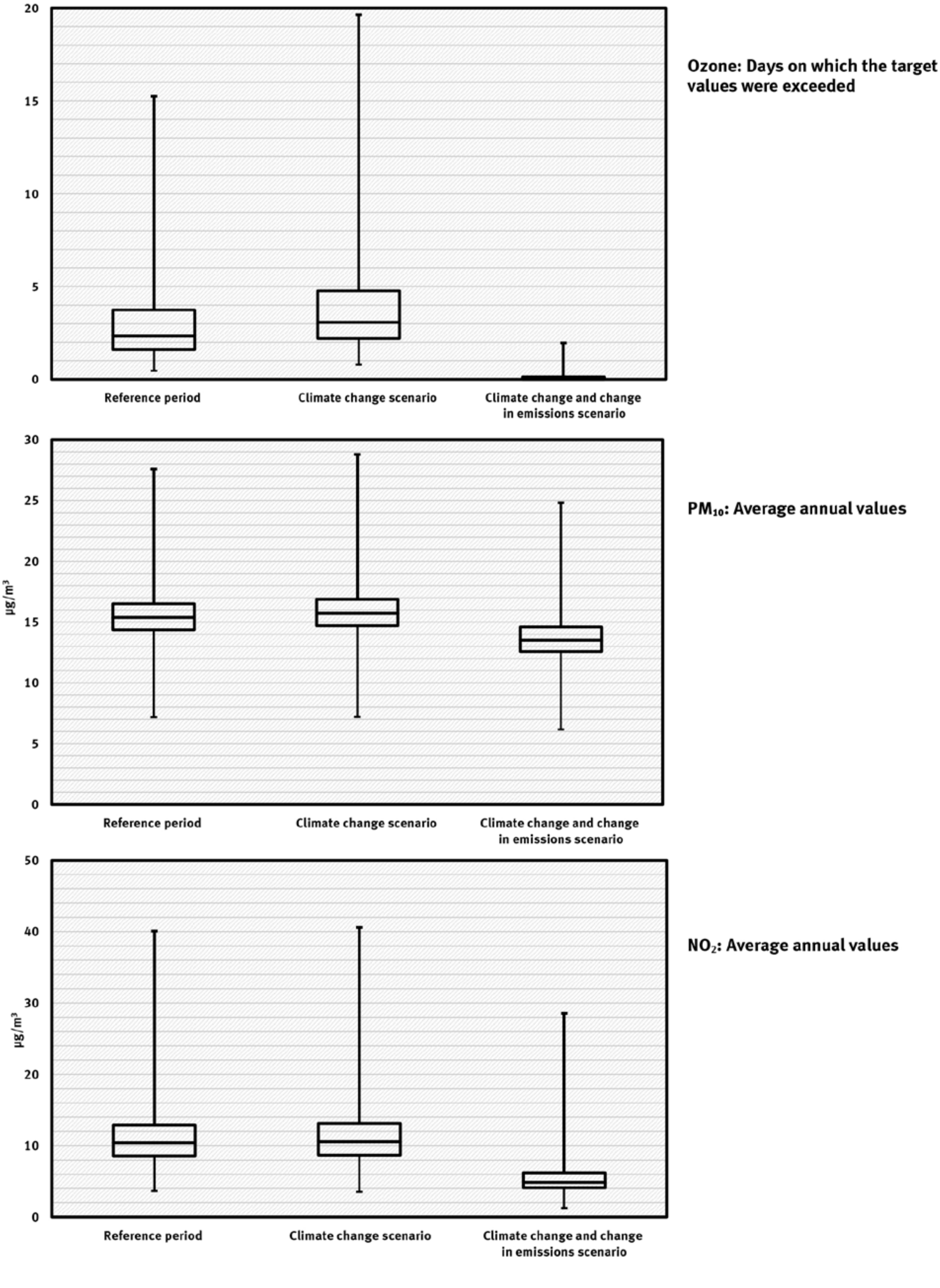
The evaluation of the climate model results also showed that the model results are, on average, too cold and too wet. The underestimation of the temperatures and the overestimation of the degree of cloud coverage and humidity led to an excessively low potential for the formation of ozone. It is therefore possible to invalidate part of the fall in ozone expected due to reductions in emissions.

It is also necessary to consider the fact that the projection period ends in 2050, as the required emissions scenario was only available until 2030. The changes in the climate parameters which are of relevance to air quality are likely to become considerably more pronounced in the second half of the century.

The full report (in German) is available to download here: https://www.umweltbundesamt.de/publikationen/klenos-einfluss-einer-aenderung-der-energiepolitik

Figure 14

Box whisker plots of the long-term average values, shown as the minimum, 25 % percentile, median, 75 % percentile and maximum of the 30-year average values



Source: KLENOS summary report

VI Further information on the topic

Current air quality data: https://www.umweltbundesamt.de/en/data/current-concentrations-of-air-pollutants-in-germany#/start?s=q64FAA==&_k=wb1qna

Air and air pollution control website: https://www.umweltbundesamt.de/en/topics/air

UBA map service on air pollutants: http://gis.uba.de/Website/luft/index.html

Development of air quality in Germany: http://www.umweltbundesamt.de/luft/entwicklung.htm

Information on the air pollutant PM_{10}: https://www.umweltbundesamt.de/en/topics/air/particulate-matter-pm10

Information on the air pollutant NO_2: https://www.umweltbundesamt.de/en/topics/air/nitrogen-dioxide

Information on the air pollutant ozone: https://www.umweltbundesamt.de/en/topics/air/ozone

▸ **This publication can be downloaded**
bit.ly/2dowYYI

www.facebook.com/umweltbundesamt.de
www.twitter.com/umweltbundesamt