Chapter 9 - Projections

In May 2019, Germany published its first National Air Pollution Control Programme (NAPCP) under the revised NEC directive (EU) 2016/2284. It covers all up-to-date information on projected air pollutant emissions and mitigation approaches in detail. In addition, Germany also published the same results under the CLRTAP using the Annex IV projected emissions templates, presenting both the “with measures” (WM) and the “with additional measures” (WAM) scenarios as defined in the NAPCP 2019 mentioned to above. According to Article 8 (6) of the EU Directive 2016/2284, these projections must be updated and reported every two years. Emission projections under the CLRTAP are therefore fully aligned with the reporting presented in the context of the NEC directive.

Based on the emissions inventory submission 2020 these results can be summarized as follows:

kt	NO_x	SO_2	NMVOC	NH_3	$PM_{2.5}$
National Total 2005	1522	477	1183	641	141
National Total 2010	1358	405	1057	641	123
National Total 2015	1084	289	816	636	97
Reduction Commitment 2020 [%]	-39	-21	-13	-5	-26
Reduction Commitment 2020 [kt]	928	377	1029	608	104
Projected Emissions 2020 WM [%]	36	39	34	11	30
Projected Emissions 2020 WAM [%]	36	39	34	11	30
Reduction Commitment 2030 [%]	-65	-58	-28	-29	-43
Reduction Commitment 2030 [kt]	533	200	852	455	80
Projected Emissions 2030 WM [%]	62	60	32	20	43
Projected Emissions 2030 WAM [%]	62	62	32	29	43
Notes: This table does neither include NO_x and NMVOC emissions from agriculture (NFR 3B and 3D) nor future adjustments. Projected emissions and historic data are based on submission 2020.					

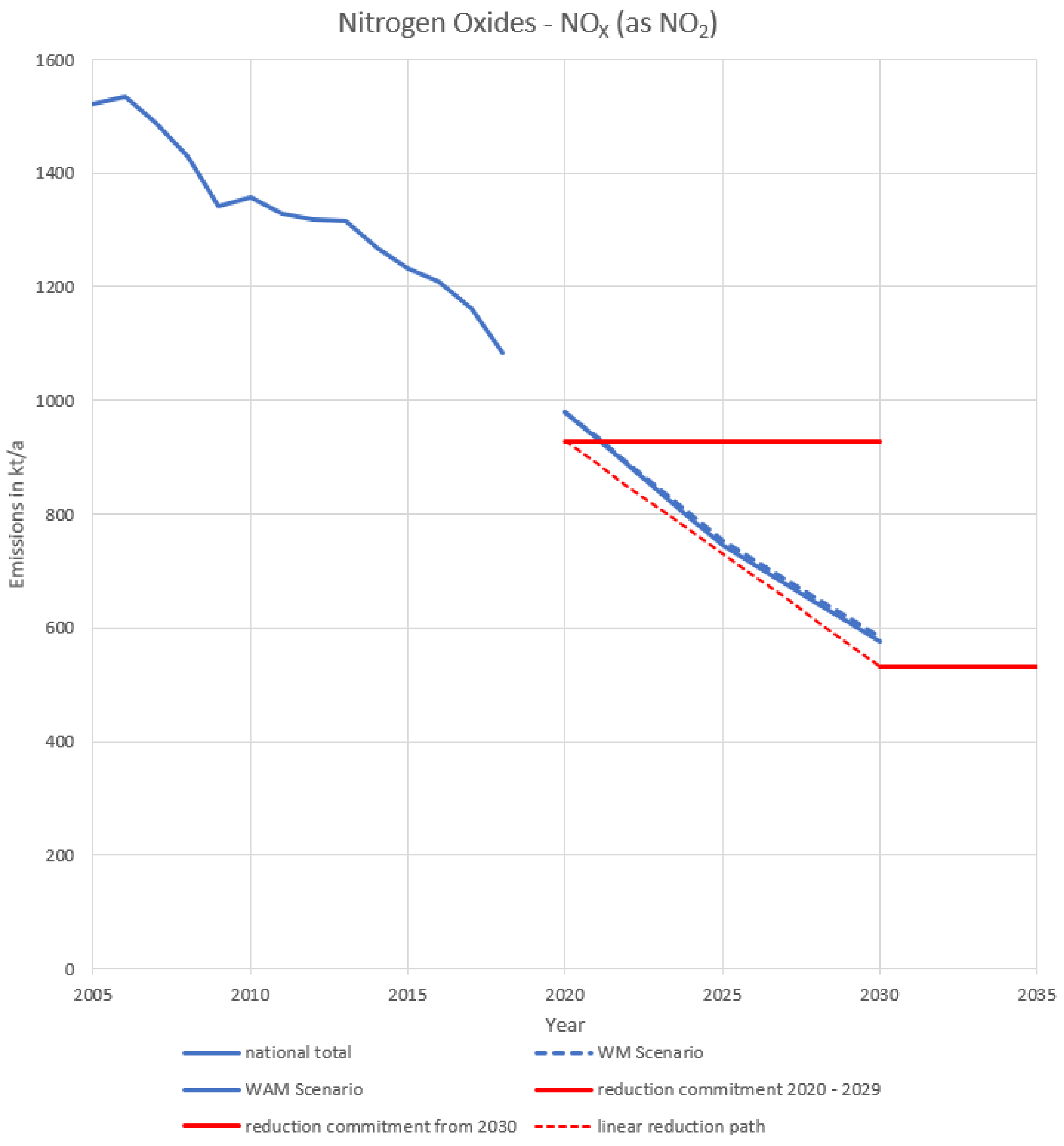
Results

Modelling different scenarios in our database, we finally calculated the following numbers for Germany's emissions in 2030:

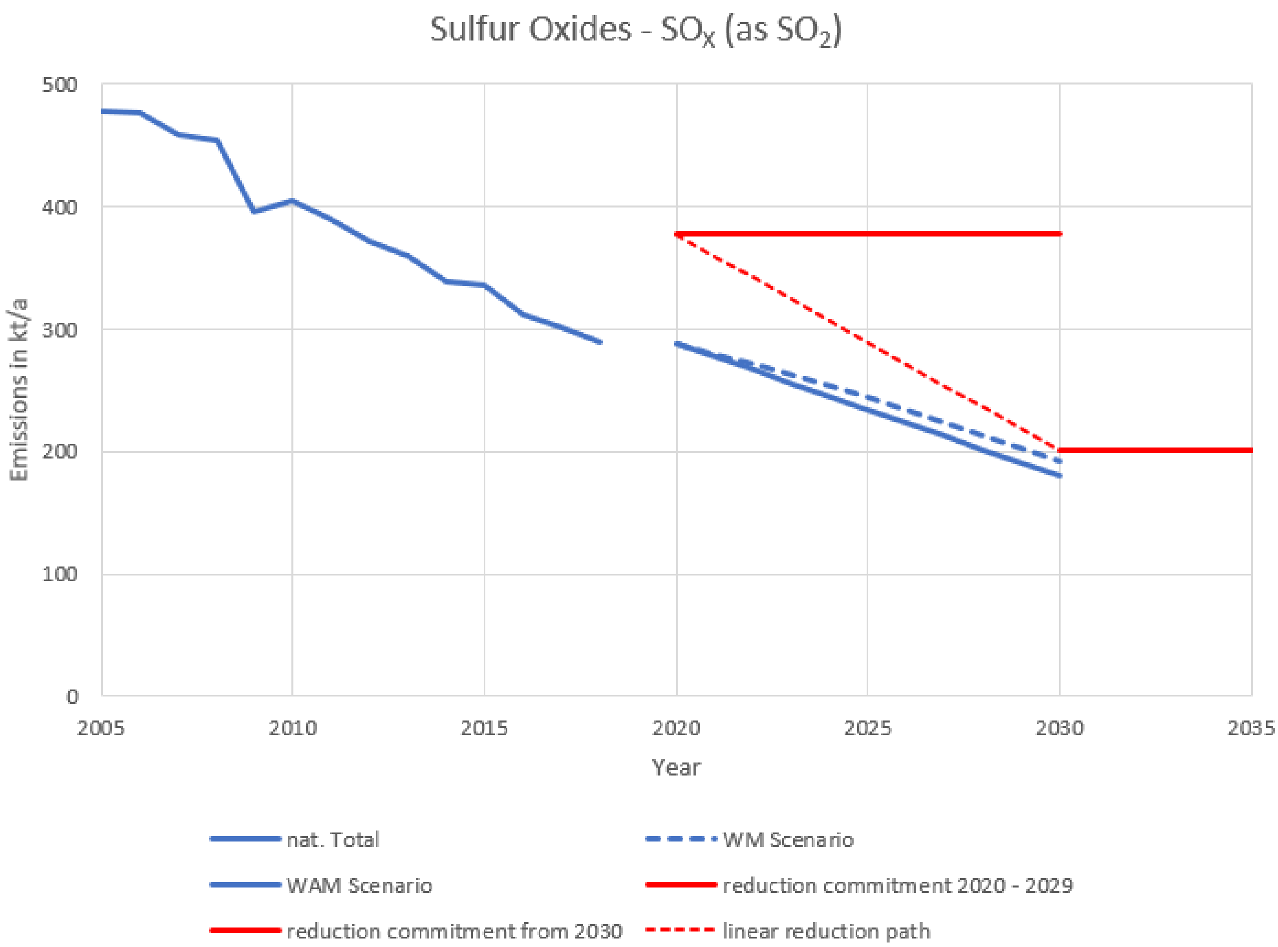
	NO_x	SO_2	NMVOC	NH_3	$PM_{2.5}$
Reduction commitment [% reduction vs. 2005]	-65	-58	-28	-29	-43
With measures [kt]	583.3	191.7	805.3	512.1	81.0
With measures [% reduction vs. 2005]	-62	-60	-32	-20	-43
With additional measures [kt]	576.9	180.3	804.1	454.0	80.8
With additional measures [% reduction vs. 2005]	-62	-62	-32	-29	-43
Amendment of 13th BImSchV	-4.86				
Agriculture package	-9.4		-3.38	-57.98	-0.24
Promotion of public transport, cycling and walking	-1.46		-1.17	-0.10	-0.01
Low-sulphur fuels in industry		-11.37			

With these numbers, Germany will meet its reduction commitments for almost all pollutants in 2030 at least in the WAM scenario. Only NO_x does not achieve the reduction commitments.

The following figures show the developments for each pollutant in the WM and WAM scenarios. In addition, the reduction commitments for 2020 to 2029 and from 2030 as well as the linear reduction path are shown. Please note that projected emissions were only calculated for the years 2020, 2025 and 2030. A linear reduction in the years between can not be assumed but is shown in the graphs just for illustrative reasons.



Please note that projected emissions were only calculated for the years 2020, 2025 and 2030. A linear reduction in the years between can not be assumed but is shown in the graphs just for illustrative reasons.



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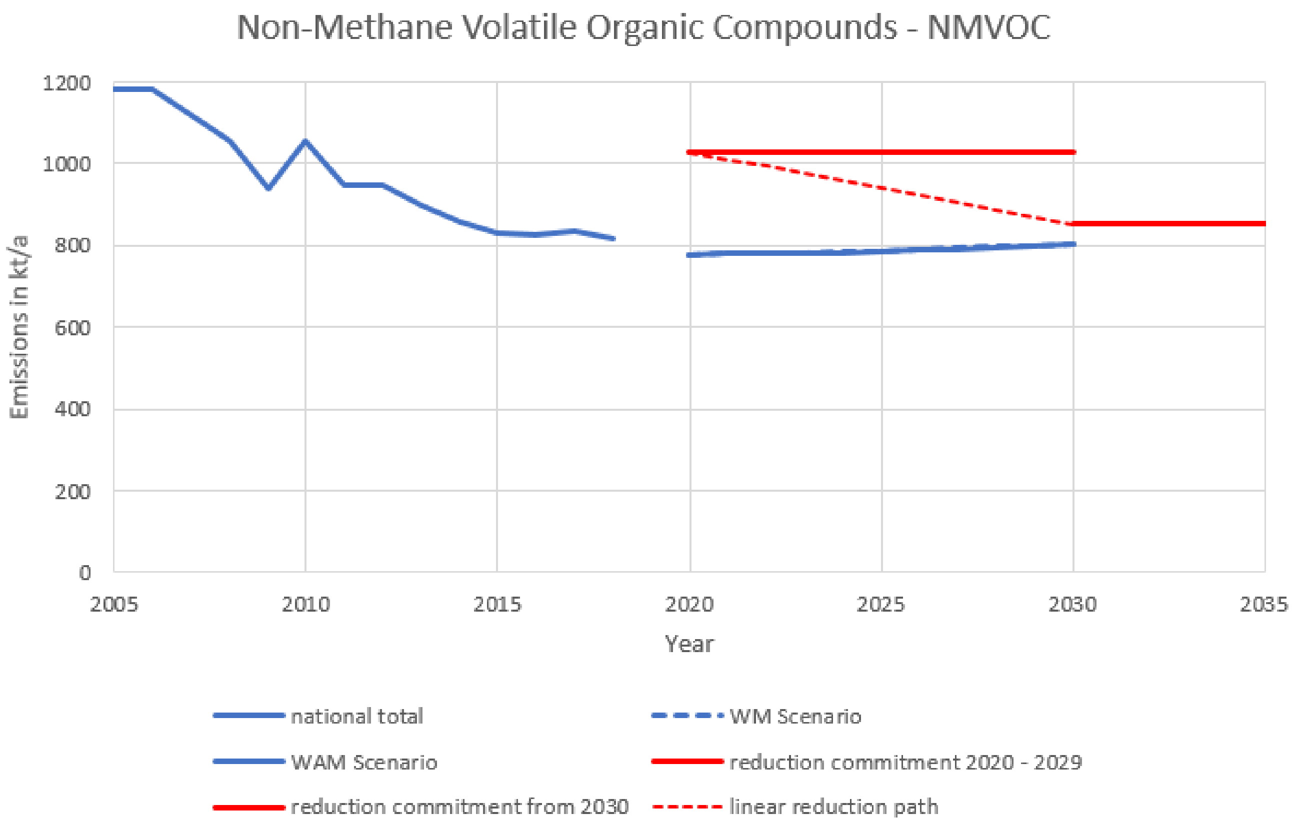
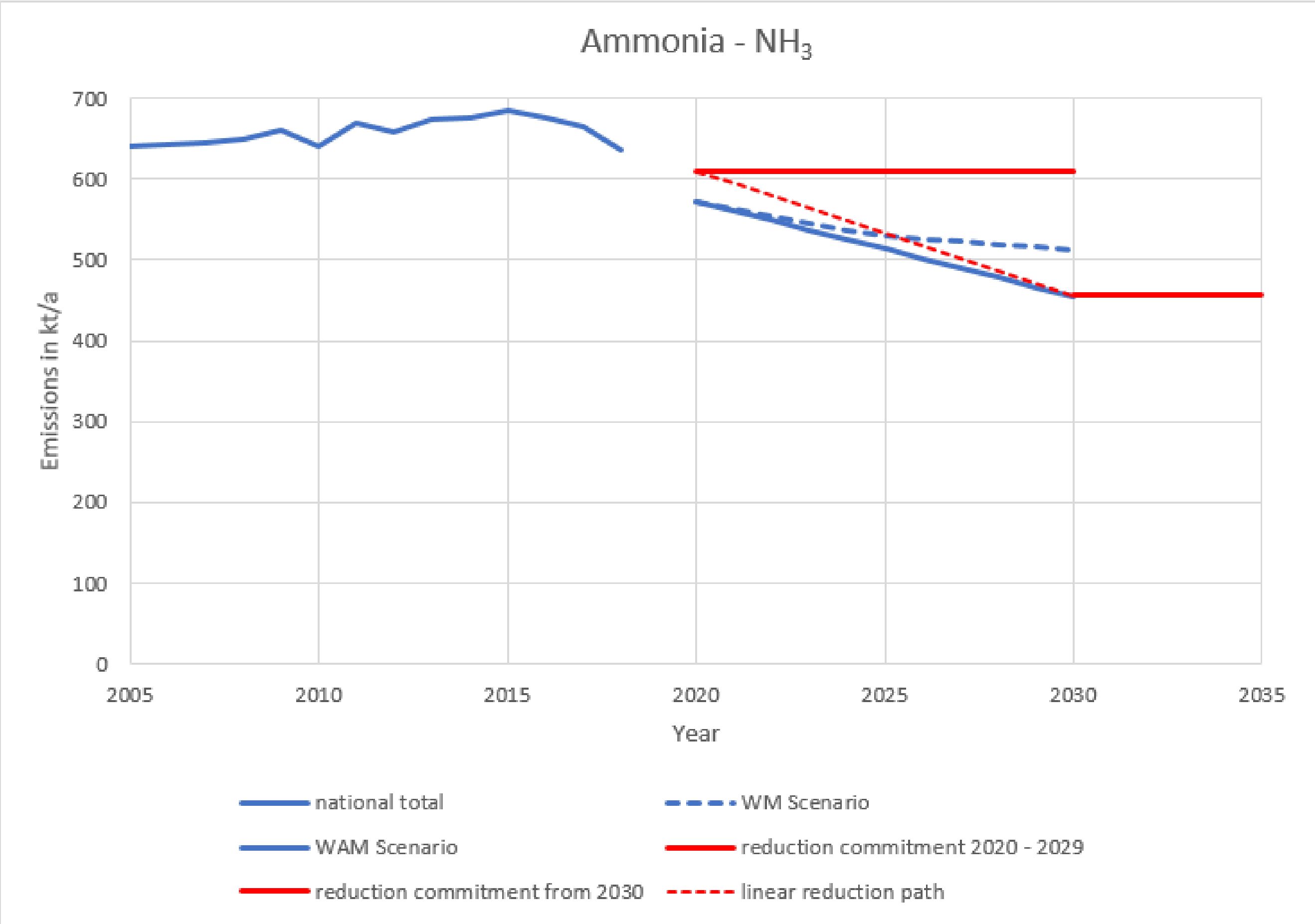
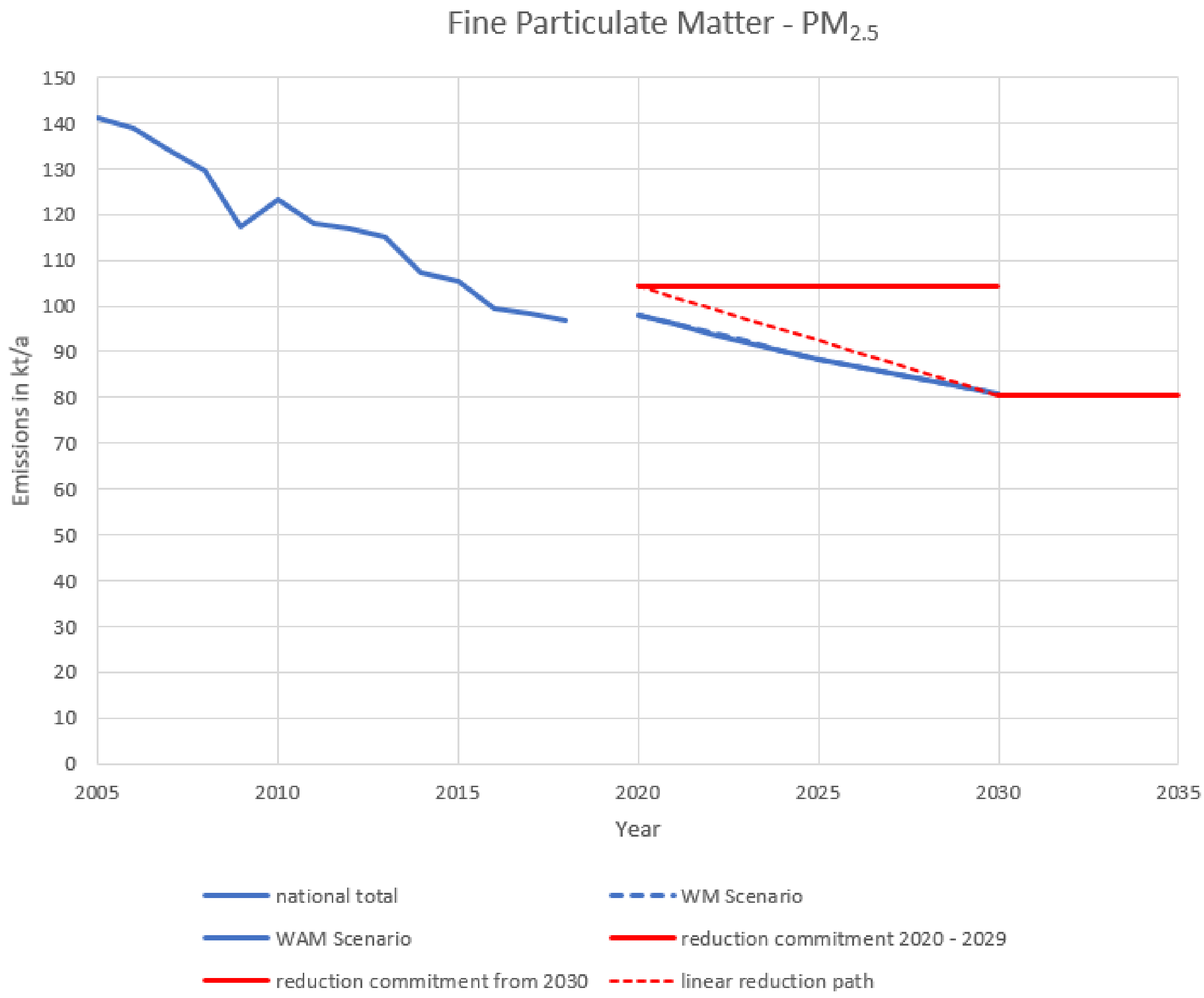


Please note that projected emissions were only calculated for the years 2020, 2025 and 2030. A linear reduction in the years between can not be assumed but is shown in the graphs just for illustrative reasons.



Please note that projected emissions were only calculated for the years 2020, 2025 and 2030. A linear reduction in the years between can not be assumed but is shown in the graphs just for illustrative reasons.



Please note that projected emissions were only calculated for the years 2020, 2025 and 2030. A linear reduction in the years between can not be assumed but is shown in the graphs just for illustrative reasons.

Context

Reliable data on historic emissions are key to the political process and to decisions on abatement technology promotion. However, future emission paths also do have the power to shed a new light on these discussions. Therefore, greenhouse gases (GHG) and air pollutants are inventoried and projected in the same database system using the same structure of detailed time series.

For the National Air Pollution Control Programme, a new database within this system was created in 2018 that is basically a copy of the German inventory database. In addition, multiple scenarios are taken into account, sketching development of activity data and emission factors up to 2030 and in many cases to 2035. The new system features integrated assessment for both greenhouse gases (GHG) and air pollutants. In particular, existing projections for GHG can be applied to air pollution contexts. The databases used also allow for the flexible combination of distinct scenarios for specific sectors and source categories to add up to a complete projection of the inventory. Furthermore, reduction potentials of mitigation measures can be modelled in detail and quantified directly in the database. The projection database is fully operational and used as the common basis for reporting on emission projections under NEC directive and CLRTAP reporting obligations.

Policies

For the past few years, climate change and greenhouse gas (GHG) emissions have been an important issue in society and politics. GHG emission inventories have seen a lot of attention as a consequence. However, there have also been a couple of air pollution related headlines, including “diesel gate” and particulate matter concentrations caused by residential wood burning. In Germany, these discussions have led to a number of legislative projects and new regulations which have the power to significantly change emission levels. Thus, projections generally show further decline in emissions, even for ammonia, where not much progress has been achieved during the last decades. The main policy drivers are listed and contextualized below:

- Energy
  - Phase-out of coal use for energy production until 2038 with significant reductions before 2030
  - Recent high Emission Tradring System (ETS) prices and low natural gas prices cause a shift in the energy market, abandoning coal even faster
  - Increased production of renewable energy
  - New regulations with stricter limit values for some installation types
- Transport
  - New vehicle regulations, including updated Euro norms
  - More electric vehicles, more public transport
- Agriculture
  - New “Düngeverordnung” (fertiliser ordinance) as well as other legislative and incentive measures to reduce fertiliser use and lower animal numbers

Projections

For its national emission projections, Germany takes into account climate projection activity data and category-specific reports on air pollution emission factor development in the future. For all sectors, emission scenarios were developed in the greatest possible consistency with the latest available energy and greenhouse gas emission scenario of Germany’s National Energy and Climate Plan (NECP), assuming all measures of the Climate Protection Programme 2030 will be fully implemented.

Deviating from this comprehensive projection of activity data, the transport emissions are calculated with the aid of the TREMOD model (“Transport Emission Model”), version 6.03 (Allekotte et al. 2020[1)]). For estimating the future development of transport-related energy consumption and emissions a TREMOD trend scenario to 2050 has been developed, which is regularly updated each year. The trend scenario builds on recent traffic performance projections and considers all relevant political regulations that came into force by mid-2018. The TREMOD trend scenario was used as the basis for the WM scenario for every time series related to transport.

The activity rates and the emission factors for the emission projections of the sector NFR 3 “Agriculture” in both scenarios are calculated and provided by the Thünen-Institute (TI). These data are transferred directly to the database and used for the projections.

The NMVOC emissions from NFR sector 2.D.3, containing emissions from solvent and solvent-containing product use and their manufacturing, are not calculated from activity rates and emission factors within the emission inventory database. For their calculation a separate model run by the Institute for Environmental Strategies (Ökopol GmbH) is used (see Zimmermann and Jepsen, 2018[2)]) and resulting emissions are imported into the inventory database. This model also contains an emission projection based on economic projections for specific branches of industry. These economic projections were updated using Prognos (2019) “Deutschland Report 2025 | 2035 | 2045“[3)]. The resulting NMVOC emission projections are taken directly into the database.

Starting from these activity data set as a basis, future emission factors for air pollutants were modelled for each of the policies and measures individually. For each measure, the relevant emissions factors were identified and the existing historic time series in the database was extended to 2020, 2025, 2030 and partially to 2035. Then, the future activity data for those years were multiplied with the modelled emission factors to derive projected emissions. This approach allows detailed calculations of mitigations attributable to each measure. The following documentation shows the calculation of emission projections in detail.

Calculation documentation of emission projections

Data basis of the emission projections calculation is the inventory of the submission 2020 with the processing of the emission data. The calculations of the emission values are based on the NEC directive EU 2016/2284 as well as the German regulations for the implementation of the Federal Immission Control Act (BImSchV), which define plant-specific limit values.

Because the limit values in the BImSchVs and in the BAT conclusions are usually given in mg / Nm^3, a conversion into kg / TJ is necessary. Table 1 shows the conversion factors (Rentz et al., 2002[4]) which are used to convert mg / Nm^3 into kg / TJ for the reduction measures under consideration. For each relevant pollutant, a fuel-specific conversion factor is given, taking into account the reference oxygen content in percent.

Table 1: Fuel-specific conversion factors for air pollutants according to Rentz et al. (2002)

Pollutant	**Fuel**	**Reference oxygen content 3 %**	**Reference oxygen content 6 %**	**Reference oxygen content 15 %**
NO_x	Hard coal		2.75	
	Lignite	2.88	2.40	
	Heavy fuel oil	3.39		
	Light heating oil	3.49		
	Natural gas	3.57		
	Natural gas (gas turbines)	3.45		1.15
	Heavy fuel oil (gas turbines)	3.53		1.18
SO_2	Hard coal		2.74	
	Lignite	2.87	2.39	
	Heavy fuel oil	3.39		
	Light heating oil	3.49		
	Natural gas	4.00		
	Natural gas (gas turbines)	3.60		1.20
	Heavy fuel oil (gas turbines)	3.53		1.18
TSP	Hard coal		2.86	
	Lignite	2.97	2.48	
	Heavy fuel oil	3.39		
	Light heating oil	3.38		
	Natural gas	3.24		
	Natural gas (gas turbines)	3.75		1.25
	Heavy fuel oil (gas turbines)	3.50		1.17

Furthermore, the calculations of the emission factors for particulate matter ($PM_{2.5}$ and PM_{10}) always result from the TSP emission factors. In most cases the same ratio between TSP and $PM_{2.5}$ or PM_{10} is assumed as in the reference year from the 2020 submission and is adopted for the years 2020 to 2030.

Measures that have already been implemented or measures whose implementation has been decided are assigned to the WM scenario.

Reductions in large combustion plants through implementation of the 13th and 17th BImSchV as well as minimum requirements of recent BAT conclusions:

Measures for large combustion plants (LCP) that have already been implemented through the 13th and 17th BImSchV or do have future reduction effects from the existing regulations as well as minimum requirements of recent BAT conclusions are considered as WM scenario. With the judgment of 27 January 2021 - T-699/17 - by the ECJ, the complete implementation of these assumptions is fraught with uncertainties. At the time the emission projections were drawn up, the jurisdiction had not yet been made. For this reason, the measures are included in WM scenario. The measures affect time series from the NFR sectors 1.A.1, 1.A.2 and 1.A.3 and lead to a reduction in the emission factors. Potential mitigation effects emerge from BAT conclusions according to Directive 2010/75/EU. If the current submission 2020 shows that the emissions in the time series are already below the upper ends of the specified emission ranges and thus the statutory maximum limit values will be fulfilled, these will be updated unchanged. In the case of time series above the upper range, the maximum permitted limit values are used as a result of the measure in the sense of a conservative estimation and the emission factors of the pollutants for each source group are recalculated.

The calculations always follow the same procedure. Important elements are the specific limit values of the 13th and 17th BImSchV as well as the distribution of the plants according to their rated thermal input (RTI) in megawatts (MW). In addition, it is assumed that all new and existing plants correspond at least to the standard of the upper range of the associated BAT conclusions. The lower emission factor out if both calculations is than compared with the reference value. If the recalculated emission factor of the source category under consideration is greater than the current reference value, the reference value from the 2020 submission will be updated unchanged. If the reference value is larger, the new value is set and projected.

According to expert estimates, the plant inventory is split as in Table 2 according to the RTI (in MW). These (cumulative) proportions are necessary for the calculation of the mean values in relation to the upper range of limit values for each source category and pollutant.

Table 2: Proportionate inventory of LCPs according to their power range

RTI in MW	Proportion
<100	4.5 %
100-300	14.5 %
300-1000	68 %
>1000	13 %

The limit values of LCP are set according to their power ranges. The table shows the estimated proportion of LCP in Germany in relation to the RTI provided.

Example 1

The concrete procedure is illustrated using the example of NO_x emissions from the use of raw lignite as fuel for heat generation in public district heating plants.

The specific limit values for lignite can be found in Commission Implementing Decision (EU) 2017/1442 BAT 20. With a reference oxygen of 6 per cent, the plants are differentiated according to size and specified with the limit value in mg / Nm^3. The limit values are converted into kg / TJ using the specific conversion factor of 2.40 (see Table 1). The calculated limit value is therefore averaged for each plant size, taking into account the number of plants, and thus, the estimated value for the necessary NO_x emission factor for compliance with the limit value is calculated in accordance with the BAT conclusions. The necessary data can be found in Table 3. This shows the plants subdivision according to their RTI with the assigned limit values in mg / Nm^3 and kg / TJ.

Table 3: Emission limit values (yearly averages) when using raw lignite in existing plants

Plant size according to RTI in MW	max limit value in mg/m^3	max limit value in kg/TJ	Proportion
<100	270	112.70	4.5 %
100-300	180	75.13	14.5 %
>300	175	73.04	81 %

The LCP emission limit values for the use of raw lignite are regulated in (EU) 2017/1442 BAT 20. There are separate limit values for each RTI of the plant. The upper range is shown here as a limit value for existing plants as yearly averages in mg / Nm^3 and kg / TJ.

The emission factor is calculated in (1).

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  (1) emission factor (lignite) = 112.70 kg/TJ * 4.5% + 75.13 kg/TJ * 14.5% + 73.04 kg/TJ *
81% = 75.13 kg/TJ
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The comparison with the current submission 2020 shows that the calculated emission factor (75.13 kg / TJ) is lower than that of the reference value from 2018 (76.8 kg / TJ). Thus from 2020 onwards the emission factor will be replaced by the new value and used for the projection.

This procedure is analogous for the evaluation of all source groups and pollutants.

Example 2

According to the Commission Implementing Decision (EU) 2017/1442 of 31 July 2017 on Conclusions on Best Available Techniques (BAT) according to Directive 2010/75/EU of the European Parliament and of the Council for large combustion plants, the maximum permissible pollutant emission for NO_x while using heavy fuel oil as fuel in plants with more than 1500 operating hours per year is 300 mg / Nm^3 as yearly average for existing plants. Thus, the maximum emission quantity is applicable law and is below the inventory emission factor for the reference year 2018 and therefore assigned to the WM scenario. Affected time series are assigned to the NFR sector 1.A.1.b in which the emission factors are reduced. Since a reduction is not expected until 2025, the emission factor of the source categories corresponds to the current value of the 2020 submission. The emission factors from 2025 onwards result from assuming the upper range of the BAT conclusion (300 mg / Nm^3) as the maximum permitted emission and thus set it as emission factor. The value is converted into kg / TJ according to the specific flue gas volume of heavy fuel oil (see Table 1).

After the conversion, a projected NO_x emission factor of 88.5 kg / TJ results as indicated in equation (2).

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  (2) emission factor (heavy fuel oil) = 300 mg/Nm^3 / 3.39 = 88.5 kg/TJ.
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Special features of the evaluation of the emission factors

When using liquid fuels in LCP, the specific conversion factor of 3.39 (see Table 1) is used for the assessment of NO_X emissions, analogous to heavy fuel oil, when using “other mineral oil products”.

When evaluating NO_X emissions from the use of refinery gas, a distinction must be made between electricity and heat generation, as the limit values differ. A maximum limit value of 100 mg / Nm^3 applies to electricity generation, whereas plant size-specific limit values (200 mg / Nm^3 for plants <300 MW and 100 mg / Nm^3 for plants >300 MW) must be taken into account for heat generation.

When calculating the SO_2 emissions from source group “Mitverbrennung in öffentlichen Fernheizwerken” and “Mitverbrennung in öffentlichen Kraftwerken”, a clear distinction is made between existing plants and new plants. The emission factor of the existing plants is estimated at 78.44 kg / TJ and adopted for 2020. It is assumed that by 2030 all plants will correspond to the latest technology and will therefore be adopted from 2030 onwards with the limit value for new plants, estimated at 61.81 kg / TJ. Furthermore, it is assumed that a linear / continuous renewal takes place, so that the mean value from 2020 and 2030 is calculated for 2025 and assumed as the emission factor (70.13 kg / TJ).

Reduction in large combustion plants burning lignite through the coal phase-out:

The German Coal Phase-Out Law (“Kohleausstiegsgesetz”) from August 2020 stipulates to gradually phase out coal power plants burning lignite until 31 December 2038. The activity rates and emission factors of public heating and thermal power plants for NO_X are therefore reassessed.

The starting point for the evaluation of the activity rates as a result of the phase-out is the current total RTI. According to the official phase-out path of the Federal Ministry for Economic Affairs and Energy[5] and assuming that from 2039 onwards (after the shutdown of the last blocks) no more RTI will be provided, the RTI per district counted back for the years 2020, 2025, 2030 and 2035 are shown in Table 4. As a result, the reduction in the observed periods from 2020 to 2035 can be calculated in absolute and relative values for each district.

Table 4: Decommissioning path of the districts according to RTI in the years 2018 to 2039

District	**RTI 2018 in MW**	**RTI 2020 in MW**		**RTI 2025 in MW**		**RTI 2030 in MW**		**RTI 2035 in MW**		**RTI 2039 in MW**
Lausitz	6292	**6000**	0	**6000**	-3000	**3000**	0	**3000**	-3000	**0**
Central Germany	2650	**2650**	0	**2650**	0	**2650**	-900	**1750**	-1750	**0**
Rhineland	8985	**8520**	-2820	**5700**	-2700	**3000**	0	**3000**	-3000	**0**
Total	17927	**17170**		**14350**		**8650**		**7750**		**0**
Current RTI of the individual districts as well as the overall RTI according to the decommissioning path in the course of the coal phase-out in Germany.										

The total emissions per district for the years 2020 to 2035 are now calculated from the relative values of the years under review and the total emissions from the 2020 submission (1123133.92 kt NO_X). The calculation of the value for the Lausitz district in 2020 is shown in (3) - (4) as an example.

According to the values in Table 4 the relative value of the Lausitz district is calculated as:

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(3) RTI proportion (Lausitz in 2020) = (6000 MW)/(17170 MW) = 0.35.
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The total emission for the area in 2020 results from the total emission from the submission and the calculated share of the Lausitz district:

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(4) total NOx emission (Lausitz in 2020) = 1123133.92 kt * 0.35 = 392475.45 kt.
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In addition, the distribution of the electricity and heat generation per district is necessary for the estimation of the activity rates. For this purpose, the share of NO_X emissions is divided into the two energy generation processes per district and the activity rates from the time series of the 2020 submission are averaged over the years 1995 to 2018. This results in a share of electricity or heat energy for the reference value from 2018.

Finally, the activity rates of the individual districts for the years 2020 to 2035 result from the product of the calculated share of the reference value from 2018 for electricity or heat generation and the total emissions of the districts for the year under consideration. The activity rates of the Helmstedt and Hesse districts will be updated with 0 for electricity and heat generation from 2020, since the phase-out has already been completed here.

When calculating the NO_X emission factors as a result of the phase-out, the areas of Central Germany, Lausitz and Rhineland are considered separately. The Helmstedt and Hesse districts are not included in the analysis as explained above. The individual districts will be subdivided into their existing power plants. For each power plant, the total activity rate and the emission factors for NO_x for the years 2004 to 2018 in TJ or kg / TJ from the 2020 submission are adopted as data basis. In order to take into account fluctuations in the activity rates and emission factors, the activity rates and emission factors are averaged over the years. In addition, the mean value for all power plants in a district is calculated for the formation of the emission factor by weighting according to their activity. Hence, each district is assigned an implied emission factor for the years 2020 to 2035 according to its phase-out path.

With the shutdown of the last block of a power plant, this plant is considered to be shut down and from this point in time it is no longer included in the calculation of the emission factor. This applies to the Schkopau power plants (Central Germany district) from 2035 onwards, Jänschwalde, Boxberg III (both: Lausitz district) and Weißweiler (Rhineland district) from 2030 onwards.

In the case of Boxberg IV in the Lausitz district, the time series will only be taken into account from 2013 onwards, as Unit R started continuous operation on 16 February 2012, initially on a test basis and finally officially as the last unit in October 2012, meaning that the Boxberg IV power plant will only have reliable data from 2013 onwards.

Reduction in small combustion installations through the 1st BImSchV

The amendment of the 1st BImSchV in 2010 by further tightening the emission limit values for NO_x in oil-fired small combustion installations in § 6 (1) to 110 mg / kWh for installations up to 120 kW, 120 mg / kWh for installations between 120 kW and 400 kW and 185 mg / kWh for installations above 400 kW results in approximately 30.1, 33.3 and 51.4 kg / TJ as emission factors. In dependence of a weighting based on the size class distribution in different sectors, that were determined in the UBA project PAREST[6], leading to averaged implied emission factors shown in Table 5, relevant for time series from the NFR sectors 1.A.4 and 1.A.5.a. The implied emission factors of the four relevant source groups are given in the project for 2020 in kg / TJ and are kept constant for the projection in 2025 and 2030. Table 5 shows the values from PAREST for 2020 and the reference value from the 2020 submission for each source category and fuel.

Table 5: Emission factors for oil-fired small combustion installations (SCI)

Source Group	**Fuel**	**NO_x EF 2018 in kg/TJ (Submission 2020)**	**NO_x EF 2020 in kg/TJ (PAREST)**
Heat generation in SCI of the households	Light heating oil	41.77	31.8
Heat generation in SCI in agriculture and horticulture	Light heating oil	43.65	39.6
Heat generation in SCI of the military services	Light heating oil	43.65	39.7
Heat generation in SCI of the other small consumers	Light heating oil	43.65	39.6

Reductions of dust emissions from small combustion installations are achieved in the NFR sectors 1.A.4 and 1.A.5 through the implementation of the 1st BImSchV. The calculation of the future emission factors is based on the projection of the “Energiewende” scenario (EWS) from Tebert et al. (2016)[7], while the current underlying projection is containing a greater use of solid biomass in 2030 than the EWS. The developments in the area of small combustion systems, in particular the development of fuel use and the existing plant inventory, are difficult to assess and are fraught with uncertainties. According to expert assessments, with an increase of solid biomass use the implied emission factor will further decrease as the share of newer and cleaner installations will go up. Therefore, the projected implied emission factors based on the EWS used here are expected to be conservative.

The report by Tebert et al. (2016) as well as the appendix show the fractions of fuel consumption in small combustion installations according to plant type and output range in absolute and relative sizes for 2030. In addition, a distinction is made between households (“Haushalte” (HH)) and commerce, trade, services (“Gewerbe, Handel, Dienstleistung” (GHD)). In Table 6, the dust emission factors for 2030 for HH and GHD are given in kg / TJ per type of installation and the relative share in TJ is shown. All types of installations are weighted with the associated emission factor and finally the weighted mean for HH and GHD in kg / TJ for 2030 can be calculated and taken over into the projection for dust.

Table 6: Share of fuel used in small combustion installations in 2030 in EWS

plant type	**HH-EF in kg/TJ**	**GHD-EF in kg/TJ**	**Proportion of HH in TJ in %**	**Proportion of GHD in TJ in %**
slow-burning stoves	86	86	0.8	0.0
tiled stoves	97	97	12.3	1.7
fireplaces with open combustion chamber	132	132	8.7	0.3
fireplaces with closed combustion chamber	32	32	35.1	2.0
pellet stoves	21	21	7.5	0.4

plant type	HH-EF in kg/TJ	GHD-EF in kg/TJ	Proportion of HH in TJ in %	Proportion of GHD in TJ in %
split log boilers (manually-stoked) (4-25 MW)	41	41	4.9	1.0
split log boilers (manually-stoked) (25-50 MW)	13	13	13.0	2.7
split log boilers (manually-stoked) (> 50 MW)	17	17	8.4	1.7
wood chip boiler (4-25 MW)		12		0.5
wood chip boiler (25-50 MW)		31		16.1
wood chip boiler (>50 MW)		20		14.4
pellet boilers (4-25 MW)	14	14	6.8	0.4
pellet boilers (25-50 MW)	13	13	1.0	0.1
pellet boilers (>50 MW)	14	14	1.1	0.1
bathroom boilers	51	51	0.0	0.0
cooking stoves	41	41	0.4	0.2
manually-stoked heating boilers (commercial, incl. residual wood)		18		19.8
injection furnaces		35		13.4
underfeeding furnaces		27		15.7
pre-boiler furnaces		21		9.5
Weighted mean EWS	**43.44**	**26.44**		

For the years 2020 and 2025, the emission factors were calculated using the reference value from the 2020 submission in such a way that a linear reduction in dust emissions takes place.

The emission factors of the source groups “Wärmeerzeugung in KFA der Landwirtschaft und Gärtnereien” and “Wärmeerzeugung in KFA der militärischen Dienststellen” result in the year 2030 from the same ratio as to “Wärmeerzeugung in KFA der Haushalte” in the reference year 2018. This is shown as an example for the case of “Wärmeerzeugung in KFA der Landwirtschaft und Gärtnereien” in (5).

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  (5) emission factor (""Wärmeerzeugung in KFA der Landwirtschaft und Gärtnereien") = (43.44
kg/TJ / 75.93 kg/TJ) * 84.24 kg/TJ = 48.19 kg/TJ
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Reduction in industrial processes through low-dust filter technology in sinter plants:

The assumed potential for reducing dust emissions from sinter plants is taken from the final report of the UBA project Luft 2030 (Jörß et al., 2014[8)]), where measure P 009 results in dust emissions of less than 10 mg / Nm^3 due to better filter technology. It is assumed that only half of the potential from the LUFT 2030 project will be reached in average. Thus, the emission factors for $PM_{2.5}$ and PM_{10} result from the mean value of the current submission 2020 and the emission factor from the LUFT 2030 project at 50 per cent each. The affected time series are assigned to the NFR sector 2.C.1. This technology also causes new split factors for the calculation of $PM_{2.5}$ and PM_{10}. Therefore, the split factor for PM_{10} is taken from the LUFT 2030 project, too.

The emission factor for dust is calculated by dividing the given sizes of the emission factor for PM_{10} by the split factor for PM_{10}. Consequently, the split factor for $PM_{2.5}$ can be calculated by dividing the emission factor for $PM_{2.5}$ by the emission factor for dust.

These calculated factors (emission factor dust and the split factors for $PM_{2.5}$ and PM_{10}) for the recorded emission sources are used for the projection and transferred to the database.

Reduction in industrial processes resulting from updated emissions factors in the nitric acid production:

The NO_x emissions from nitric acid production in Germany are preliminary reassessed by updating the emission factors. This reduction concerns the time series of the NFR sector 2.B.2. In 2020, an internal query was carried out among the relevant companies on the NO_x emission factors, in which almost all producers participated. As a result, there was a certain variability of the emission factors, both with regard to the data quality and the absolute measured values. In the overall picture, however, it became clear that all plants had an emission factor of less than 2 kg NO_x per tonne of nitric acid and thus fell well below the constant inventory emission factor of 10 kg per tonne. The industry association and industry experts assume that the non-participating systems will not exceed the stated value. As a result, the conservative assessment of the experts is taken into account in the emission projection and the emission factor is updated to 2 kg / t for the years 2020 to 2035. A comprehensive update of the inventory is planned for 2021.

Reduction in medium combustion plants through implementation of the 44th BImSchV:

The general conditions for the calculation of the pollutant emissions from medium combustion plants (MCP), gas turbines and combustion engine plants are regulated by the 44th BImSchV and are therefore part of the WM scenario. The underlying limit values of the emission calculation are taken from the 44th BImSchV (March 2020). The measure leads to a reduction in the emission factors of the affected time series from the NFR sector 1.A.1 to 1.A.5.

The data basis for the calculation is the submission 2020. The source categories are reassessed separately according to the pollutants and the relevant fuel inputs. The expected service life of the plants (in years) is taken into account (see Table 8) as well as a distinction is made between old and new plants and the RTI of the plants in MW (see Table 7). Table 7 shows the plant split for the various fuel uses taking into account the RTI.

Table 7: Proportional plant split of the MCP according to fuel consumption and RTI

Plant split according to fuel consumption	RTI in MW	Proportion
Biomass	1-5	6.5 %
	5-20	17.7 %
	20-50	75.8 %
Lignite	1-20	95.8 %
	20-50	4.2 %
Hard coal	1-20	90.2 %
	20-50	9.8 %
Heavy fuel	5-20	68.0 %
	20-50	32.0 %
The limit values of the MCP are specified in the 44th BImSchV according to their performance ranges. The table shows the estimated proportion of MCP in Germany in relation to the RTI provided and the fuel input used.		

Table 8: Expected service life of MCP according to type of plant, pollutant and fuel use

	Expected average service life
Combustion plants - solid fuels	20 years
Combustion plants – liquid and gaseous fuels	15 years
gas and steam turbines (GuD) and gas turbines (GT)	22 years
internal combustion engines - biogas	5 years
internal combustion engines – other fuels	10 years

The new emission factors are always calculated according to the same pattern. The limit values of the 44th BImSchV are weighted for each power range of the plants and calculated for old and new plants. Assuming that a constant rate of existing plants is renewed or upgraded annually, the weighting of the limit values for new plants for the projections in 2025, 2030 or 2035 is increased or, depending on the expected service life of the plant, only the limit values for new plants are taken into account.

If the current emission factor from the 2020 submission undercuts the calculated value, the current reference value is updated because it is already below the upper range according to the 44th BImSchV and thus complies with the maximum limit values. The recalculated values for the time series are adopted and the maximum permitted limit value is assigned to time series when the current emission factor is above the upper range.

Example:

The exact procedure is exemplified by the example of NO_x emission factors when using solid biomass as fuel. The procedure is in principle the same for all pollutants and fuels.

The basis for the calculation is the maximum amount of NO_x emissions permitted in the 44th BImSchV §10 (4) and (15) when using solid biomass (other solid biomass) as fuel (see Table 9). After conversion with the specific conversion factor of 2.39 (see Table 1), the limit values for old and new plants are available in kg / TJ. Table 9 shows the limit values for solid biomass according to the performance range for old and new plants in mg / Nm^3 and kg / TJ.

Table 9: Limit values for solid biomass in MCP according to the power range for old and new plants

Fuel	Plant	Limit value according to 44th BImSchV in mg/Nm^3			Limit value in kg/TJ		
		Power range in MW			Power range in MW		
		1-5	>5	>20	1-5	>5	>20
Solid biomass (other solid biomass)	existing	600		370	250.4		154.43

Fuel	Plant	Limit value according to 44th BImSchV in mg/Nm^3			Limit value in kg/TJ		
Solid biomass (other solid biomass)	new	370	300	200	154.4	125.2	83.5
Limit values for solid biomass in MCP for old and new plants according to the 44th BImSchV in mg / Nm^3 and kg / TJ.							

It is assumed that the service life of the plant is 20 years (see Table 8). In addition, it is assumed that an annual renewal of the plant will be implemented after the 44th BImSchV comes into force in 2019 and that the limit values for new plants getting greater weight each year.

According to the assumption in 2025 (6 years after the regulation came into force) there is a proportion of 6/20 which fulfil the requirements of new plants and 14/20 which adhere to the limit values of old plants. In 2030, eleven years after the 44th BImSchV was introduced, the proportion of new plants is 11/20 compared to 9/20 old plants. After 16 years, the limit value for new plants is included in the calculation with 16/20.

Taking into account the plants proportions per size measured in RTI in WM (see Table 9), a new emission factor of 153.01 kg / TJ for 2025 results, as shown in (6).

```
  (6) emission factor (solid biomass in 2025) = 14/20 * {(6.5% + 17.7%) * 250.4 kg/TJ + 75.8% * 154.4 kg/TJ} + 6/20 * {6.5% * 154.4 kg/TJ + 17.7% * 125.2 kg/TJ + 75.8% * 83.5 kg/TJ} = 153.01 kg/TJ.
```

Since the reference value from the 2020 submission (137.5 kg / TJ) is already below the calculated limit, it will be updated for the year 2025. The procedure for calculating the emission factor in 2030 is identical and is shown in (7).

```
  (7) emission factor (solid biomass in 2030) = 9/20 * {(6.5% + 17.7%) * 250.4 kg/TJ + 75.8% * 154.4 kg/TJ} + 11/20 * {6.5% * 154.4 kg/TJ + 17.7% * 125.2 kg/TJ + 75.8% * 83.5 kg/TJ} = 132.46 kg/TJ
```

In 2030 the newly calculated limit value will be below the reference value, so that this is adopted as the new NO_x emission factor.

<u>Special Feature:</u>

When calculating the NO_x emission factors when using lignite and hard coal as fuel, the plant split is only differentiated according to the RTI of less than 20 MW and greater than 20 MW. The limit values given in the 44th BImSchV are differentiated according to 1-5 MW, 5-20 MW and more than 20 MW. As a result, the assumption was made that the plant split between 1-5 MW and 5-20 MW in equal proportions would be valued with a factor of 0.5.

According to the 44th BImSchV § 16, the emission limit values for combustion engines will only apply from 1 January 2025 on, so that the assumption of the partial renewal of plants will only apply from 2025 on. As a result, the reference values from the 2020 submission will be updated as the emission factor for the source categories concerned for 2020 and 2025.

In some cases, data series have a strong deviation in the emission factors in the reference scenario compared to the remaining source groups with the fuel use of other liquid fuels. Therefore, the source groups of “Wärmeerzeugung in TA Luft-Anlagen der Landwirtschaft und Gärtnereien“ (for SO_2 and NO_x) as well as “Wärmeerzeugung in Pfanzenölmotoren der übrigen Kleinverbraucher” (for NO_x) were assessed separately.

Reduction in agriculture in the updated Thünen-Baseline-Projection:

The starting point for the WAM scenario were not the emissions from 2005, but the probable emissions that result from the updated Thünen baseline for the year 2030[9)]. For the NAPCP 2019 this was the Thünen baseline 2017-2027[10)], which was extrapolated for the year 2030. According to this old baseline, agricultural NH_3 emissions in 2030 were expected to be 542 kt NH_3.

Since the methods for calculating emissions improve or change between inventory submissions and these changes also have an impact on previous years, the NH_3 quantities to be reduced when converted to absolute figures are variable and depend on the respective underlying inventory submission.

According to the updated baseline 2020-2030, however, agricultural emissions for 2030 are only 485 kt NH_3. This large difference between the two baseline emissions (a reduction by 57 kt NH_3) is explained by the following differences between the two baselines:

1. Reduction of the amount of energy crops for fermentation to about half the amount of the old baseline (effect: -22 kt NH_3 emissions).
2. Reduction of the amount of mineral fertilizer applied (from 1772 kt N to 1655 kt N) and a lower proportion of urea in the amount applied (effect: -19 kt NH_3 emissions).
3. Due to the new Fertilizing Ordinance (DÜV 2020), liquid manure (except for leachate) and poultry manure applied to uncultivated arable land must be incorporated within 1 hour. In addition, a decline in the prevalence of the “broad-cast” technology was projected (effect: approximately -15 kt NH_3 emissions).
4. There are also slight differences in the new baseline in the forecasted number of animals and animal performance. Additionally, there were changes in the emission models (see previous IIRs). This strongly interacts with the previous point, so that it is not possible to determine a more specific reduction effect of the new Fertilizing Ordinance. (Overall, the effects of 3. and 4. add up to approx. - 16 kt NH_3 emissions.)

In total, according to the updated baseline, only 57 kt of NH_3 need to be additionally reduced by agriculture.

Additional measures that have not yet been implemented are assigned to the WAM scenario

Reduction in pulp and paper production through amendment of the 13th BImSchV

According to the existing 13th BImSchV (as of 2017), different maximum amounts of NO_X emissions are permitted according to the production process (sulphate and sulphite process) and the size of the plant (measured in RTI in MW) in pulp and paper production. A relating amendment of the 13th BImSchV results in reductions in the emission factor in the NFR sector 2.H.1.

It is assumed for the sulphite process that all four plants located in Germany are operated with RTI of 50-300 MW. In the sense of a conservative estimate of the reduction potential, a maximum current emission factor of 300 mg / Nm^3 for all plants according to the 13th BImSchV is assumed for the further calculation of the reduction potential. The emission factor for the sulphite process will be taken over from the 2020 submission in 2020, as no reduction is expected from the amendment of the 13th BImSchV in 2020. As a result, the emission factor for 2020 will be 2 kg / t. The new emission factor results from the current emission factor (2 kg / t) and the maximum emission value proposed in the amendment (85 mg / Nm^3) divided by the calculated mean value of the currently applicable law (300 mg / Nm^3). This results in an emission factor of 0.57 kg / t for 2025, 2030 and 2035 as shown in (8).

```
  (8) emission factor (sulphite process) = (2 kg/t * 85 mg/Nm^3) / (300 mg/Nm^3) = 0.57 kg/t
```

In the field of the sulphate process there are two plants with different boiler sizes in Germany. To calculate the reduction potential, the percentage distribution of the two plants per boiler size was calculated according to a combustion heat output in the range of 100-300 MW and more than 300 MW over all time series (2006 to 2018). For this purpose, the emission values of the individual years for the individual location or the individual plant are divided by the annual activity of both plants for each considered time series. The data basis for the calculation is the 2020 submission. This results in the estimates of the proportionate use of the various plant sizes for the past years up to 2018 with the plant-size-specific maximum emissions according to the daily mean value with 250 mg/Nm^3 for the plant with a thermal output of 100-300 MW and 200 mg/Nm^3 for the plant with more than 300 MW. The mean value of the current NO_X emissions from the sulphate process results from the sum of the maximum permitted emissions per boiler size multiplied by the current proportionate NO_X emissions. Equation (9) indicates the calculation.

```
  (9) mean NOx emission (sulphate process) = 0.36 t/a * 250 mg/Nm^3 + 0.64 t/a * 200 mg/Nm^3
= 217.78 mg/Nm^3
```

The emission factor for the sulfate process will be taken over from the 2020 submission in 2020, as no reduction is to be expected from the amendment to the 13th BImSchV in 2020. The new emission factor results from the emission factor according to the current status and the maximum emission value proposed in the amendment of the 13th BImSchV divided by the calculated mean value of the applicable law. This results in an emission factor of 0.68 kg / t for 2025, 2030 and 2035, as shown in equation (10).

```
  (10) emission factor (sulphate process) = (1.75 kg/t * 85 mg/Nm^3) / (217.78 mg/Nm^3) =
0.68 kg/t
```

Reduction in refineries through amendment of the 13th BImSchV:

A possible amendment of the 13th BImSchV can lead to emission reductions in the area of refineries and is assigned to the

WAM scenario. It causes a reduction in the emission factors in the affected time series of the NFR sector 1.A.1.b. A distinction must be made between refinery plants and the fuel input used by them. For plants using raw petrol (naphtha), light heating oil or other petroleum products, the proposed limit value is set 85 mg / Nm^3 and adopted as the maximum emission level. When using heavy fuel oil, there is a bell control for the plants, whereby individual parts of the plant are allowed to exceed the limit value of 85 mg / Nm^3 if other parts of the plant fall below the limit value and the plant emission in on average not above the limit value.

First reductions are not expected until 2025, which is why the emission factors of the concerned source categories for 2020 correspond to the reference value from the 2020 submission. For plants using raw petrol (naphtha), light heating oil or other petroleum products as fuel, the new maximum emission level corresponds to the limit value of 85 mg / Nm^3 NO_X. Consequently, only the conversion factor of the specific flue gas volume for heavy fuel oil or light heating oil (see Table 1) has to be used to convert to kg / TJ NO_X.

The conversion is carried out for all source groups as shown in (11) using the example of refinery underfiring in LCP with light heating oil as fuel.

```
  (11) NOx-emission (refinery underfiring with light heating oil) = 85 mg/Nm^3 / 3.49 = 24.4 kg/TJ
```

This results in emission factors of 24.4 kg / TJ for light heating oil and 25.1 kg / TJ for other petroleum products for 2025, 2030 and 2035.

For a total of twelve plants with heavy fuel oil as fuel input the bell regulation apply. First of all, the emission limit value according to the current 13th BImSchV and to its specific RTI is assigned to each plant and the mean value is calculated across all plants (274.85 mg / Nm^3). The bell regulation allows parts of plants to exceed the maximum emission level if another part of the plant emits proportionally less. The estimated percentage reduction, taking into account the bell control, is calculated as shown in (12) by setting the limit value of 85 mg / Nm^3 NO_X in relation to the mean value of the current emission limit values.

```
  (12) percentage reductio of NOx-emission (refineries) = 1 - (85 mg/Nm^3 / 274.75 mg/Nm^3) = 0.69
```

A calculated reduction of approximate 69 per cent is assumed for the bell. The projected emission factors for the concerned source categories for 2025, 2030 and 2035 are now derived from the current emission factor of the source category under consideration from the 2020 submission minus the proportional reduction.

The conversion is carried out in the same way as in (13) for all source groups as shown in the example of refinery underfiring in LCP with light heating oil as fuel.

```
  (13) NOx-emission (refinery underfiring with light heating oil) = (400 mg/Nm^3 * (1 - 0.69) / 3.39 = 36.5 kg/TJ
```

Other reductions in large combustion plants through amendment of the 13th BImSchV:

Emissions from other LCPs, which emerge from the energy balances, but cannot be clearly assigned to a specific fuel use or fuel mix and also show a reduction potential in the event of an amendment of the 13th BImSchV are assigned to the NFR sector 1.A.1.c and a reduction in the emission factor was calculated.

The emission factors for all non-gaseous materials other than coal for electricity and heat generation are considered and the maximum emission amount for NO_X is assumed to be 85 mg / Nm^3. The relevant fuels are heavy fuel oil, light heating oil and other petroleum products. According to the 13th BImSchV, only plants with more than 1500 operating hours per year are taken into account for which the new limit value of 85 mg / Nm^3 NO_X applies. Table 10 shows the estimated relative and absolute plant split of the LCP according to its annual operating time assuming an equal fuel use distribution.

Table 10: Estimated relative and absolute plant split of LCP according to operating time in the year

Operation time	RTI in MW	Proportion
<1500 h/a	46573	17.8 %
>1500 h/a	214990	82.2 %
Total	261563	100 %

Since the first reduction effects are not expected until 2025, the emission factors of the affected source groups for 2020 correspond to those of the reference value from the 2020 submission. The emission factors will be recalculated for 2025, 2030 and 2035. First, the limit value of 85 mg / Nm^3 is converted into kg / TJ using the specific conversion factor (see Table 1). The new emission factor results from the sum of the reduction for the 82.2 per cent of the fuel use with an operating time of more than 1500 h / a and the unchanged value from the 2020 submission for the 17.8 per cent of the fuel use with less than 1500 h / a operating time that is not obliged to reduce it by the amended 13th BImSchV.

The calculation is shown using the example of the source category of electricity generation in LCP of the other industrial power plants with the fuel consumption of light heating oil (reference value: 103.2 kg / TJ) in (14), whereby the procedure is analogous for all other source categories.

```
  (14) NOx emission (electicity generation in LCP of the other industiral power plants) = (85 mg/Nm^3 / 3.39) * 82.2% + 103.2 kg/TJ * 17.8% = 39.0 kg/TJ
```

Reduction in gas and steam turbines through amendment of the 13th BImSchV:

In the case of LCPs with gas and steam turbines, the assumed requirement is a stricter limit value of 20 mg / Nm^3 NO_x for plants with more than 1500 operating hours per year and assigned to the WAM scenario. The affected time series in which the emission factor is reduced are in the NFR sectors 1.A.1.a, 1.A.1.b, 1.A.2.g and 1.A.3.e. It is assumed that as a result of the regulations, SCR technology will have to be retrofitted for the first time from 2021 on. According to an expert estimate, this affects 40 per cent of the plants in the gas and steam turbine sector (GuD) and 30 per cent of the plants in the gas turbine sector. Since the first reduction effects are expected from 2021 on, the emission factors of the concerned source groups for 2020 correspond to the reference value from the 2020 submission.

For GuD, the proportional NO_x reductions are finally calculated based on the assumption that 40 per cent of the plants as a result of SCR retrofitting have a maximum emission value of 20 mg / Nm^3 NO_x and that 60 per cent of the plants retain the existing emission factor. The values converted into kg / TJ for the emission factors from 2021 on are assumed for the projections for 2025, 2030 and 2035. As an example, the calculation for electricity generation in LCP of the combined cycle plants of public power plants with the reference value 27.48 kg / TJ (31.6 mg / Nm^3) is shown in (15). The procedure is identical for all other source groups.

```
  (15) NOx emission (electricity generation in LCP of the combined cycle plants of public power plants) = (31.602 mg/(Nm^3) * 60% + 20 mg/Nm^3 * 40%) / 1.15 = 23.44 kg/TJ
```

The calculation of the reductions from 2021 on in the area of gas turbines is considered analogous to that of GuD with a reduction of 30 per cent to 20 mg / Nm^3 NO_x as a result of the SCR retrofitting and keeping the emission factors constant for 70 per cent of the plants. The exception in the area of gas turbines is the source category of gas turbines in natural gas compressor stations. According to expert estimation, an additional reduction in the existing plants without SCR retrofitting by a delta of 10 mg / Nm^3 to the reference value can be expected. The calculation is given in (16).

```
  (16) NOx emission (gas turbines in natural gas compressor stations) = ((72.45 mg/Nm^3 - 10 mg/Nm^3) * 70% + 20 mg/Nm^3 * 30%) / 1.15 = 43.23 kg/TJ
```

Reduction of motorised private transport by strengthening the environmental alliance (e. g. public transport, cycling and walking):

The WAM scenario includes one further measure in the transport sector: the promotion of public transport, cycling and walking. Therefore, the activity rates for in town road transport with passenger cars were reduced by 5 per cent compared to the WM scenario.

Reduction in agriculture through a bundle of measures quantified as an agricultural package:

Basis for modeling of NH_3 emissions was the 2020 submission of emission reporting (Thünen-Report 77[11)]). Starting point were the projections of the Thünen baseline projection 2020 - 2030. Modeled mitigation measures are according to the National Air Pollution Control Programme 2019 (NAPCP 2019) and, additionally, from the Climate Protection Programme 2030.

In the projections of NAPCP 2019, two variants had been calculated:

1. The measures are carried out in full.
2. Small and very small farms are excluded from the measures.

Small farm exclusions resulted in mitigation being smaller by approx. 3 per cent. In the updated projections, small farm exclusions, other exceptions from and implementation of measures deviating from the assumptions were not modeled explicitly. Instead, it is assumed that they result in 10 per cent lower mitigation.

The inventory model can only calculate complete scenarios. The effect of individual measures was quantified by starting with the baseline scenario and sequentially calculating scenarios with mitigation measures added until arriving at the complete WAM scenario. Because mitigation effects of measures are interdependent, the quantified effects of individual measures partly depend on the order of scenarios and cannot account for all interactions. Therefore, the reported additional reduction achieved by a measure cannot to be equated with an isolated effect of the measure. Focus of interpretation should be the complete WAM scenario that includes all mitigation measures and the effect of their interactions. In the WAM scenario, the measures listed below reduce NH_3 emissions by 57.8 kt NH_3.

- 70 per cent of the cattle and pig slurry is digested in biogas plants (Measure 3.4.5.1 of the Climate Protection Programme 2030).

  Implementation in 2030:The proportion of liquid manure going into a biogas plant was set to 70 per cent for both cattle and pigs (the proportions of solid cattle manure and poultry manure that are digested remain as in 2018).

  Calculated emission reduction in kt NH_3: - 5.06 (i. e. emission increase)

- No use of broadcast application on uncultivated arable land and incorporation of liquid manure within an hour. This measure only affects liquid manure (slurry, leachate, digestates).

  Implementation in 2030: The distribution frequencies already reduced in the baseline for broadcast application with incorporation <1h and <4h (the latter only exists for manure according to DÜV 2020) were added to the corresponding frequencies for trailing hose application and set to zero for broadcast application. In addition, the incorporation of leachate within 4 hours, which is still permitted under DÜV 2020, was reduced to incorporation within 1 hour.

  Calculated additional emission reduction in kt NH_3: 1.47
  Calculated cumulative emission reduction in kt NH_3: - 3.59

- Uncovered external storage facilities for liquid manure / digestates are at least covered with a plastic film or comparable technology. A one-to-one implementation in inventory model GAS-EM is not possible, since for digestates only “gas-tight storage” and “non-gas-tight storage” is implemented.

  Implementation in 2030: The current distribution frequencies for “external slurry storage facility without cover”, “external slurry storage facility with natural floating cover” and “external slurry storage facility with artificial floating cover” have been set to zero and added to the distribution frequency for “external slurry storage facility with foil cover”. In the case of digestate storage facilities, it was assumed that 90 per cent of the digestate storage facilities are gas-tight. In the baseline (and also currently) around 60 per cent of the digestate storage facilities are gas-tight.

  Calculated additional emission reduction in kt NH_3: 6.76
  Calculated cumulative emission reduction in kt NH_3: 3.16

- Air scrubber systems in 75 per cent of the agricultural operations regulated under IED (permitted after type of procedure G in the 4th BImSchV), 25 per cent of the agricultural IED operations reduce 40 per cent of emissions through further system-integrated measures in housing.
  Air scrubber systems for pigs reduce the NH_3 emissions in the stable by 80 per cent on average; this percentage is retained. A reduction rate of 70 per cent is assumed for air scrubber systems for poultry. It should be noted that the reductions were not calculated for turkeys, as these are excluded from the requirement in the Technical Instructions on Air Quality Control (TA-Luft).

  Implementation in 2030: For pigs and poultry, the mean reduction performance from air scrubber systems and “further system-integrated measures” was calculated (pigs: 0.75 * 80 % + 0.25 * 40 % = 70 %; poultry: 0.75 * 70 % + 0.25 * 40% = 62.5 %) and with this the emissions of the animals in agricultural IED operations are calculated as if they were air scrubber systems with a correspondingly lower output.

  Calculated additional emission reduction in kt NH_3: 13.61
  Calculated cumulative emission reduction in kt NH_3: 16.77

- 75 per cent of the agricultural operations that are permitted after type of procedure V in the 4th BImSchV (smaller than IED operations) reduce 40 per cent through system-integrated measures in housing, 25 per cent of these operations do not reduce emissions.

  Implementation in 2030: Agricultural operations (type of procedure V) reduce the emissions from housing by a total of 30 % (0.75 * 40 % + 0.25 * 0 % = 30 %). This was mathematically integrated into the measure above. This results in the following total housing reduction performances for the individual animal categories (rounded reduction percentages are shown, unrounded numbers were used for calculation):

- Sows: an effective emission reduction of 63.0 per cent was calculated for 54.2 per cent of the animals
- Weaners: an effective emission reduction of 59.4 per cent was calculated for 45.8 per cent of the animals
- Fattening pigs: an effective emission reduction of 59.4 per cent was calculated for 27.1 per cent of the animals
- Laying hens: an effective emission reduction of 53.2 per cent was calculated for 85.1 per cent of the animals
- Broilers: an effective emission reduction of 59.0 per cent was calculated for 92.8 per cent of the animals
- Pullets: an effective emission reduction of 58.9 per cent was calculated for 82.1 per cent of the animals
- Ducks: an effective emission reduction of 62.5 per cent was calculated for 20.6 per cent of the animals

  Calculated additional emission reduction in kt NH_3: 2.13
  Calculated cumulative emission reduction in kt NH_3: 18.90

- 50 per cent of slurry storage underneath slatted floors is replaced by external storage with at least a plastic film cover

  Implementation in 2030: The current distribution frequency for “storage under slatted floor” has been halved and this amount has been added to the distribution frequency for “external slurry storage with foil cover”.

  Calculated additional emission reduction in kt NH_3: 0.77
  Calculated cumulative emission reduction in kt NH_3: 19.68

- 5 per cent reduction of N excretion by protein-optimized feeding in cattle husbandry

  Implementation in 2030: The N and TAN excretions in the inventory model were reduced with a reduction factor of 0.95.

  Calculated additional emission reduction in kt NH_3: 11.44
  Calculated cumulative emission reduction in kt NH_3: 31.12

- System-integrated measures in cattle housing (> 100 cattle), 50 per cent implemented
  The introduction of a “grooved floor” was calculated as an additional measure in cattle housing, i.e. the stable is kept clean by regularly wiping the floor. For this, an emission reduction of 25 per cent compared to a normal, slurry-based loose housing is assumed. Since 50 per cent implementation is assumed for this measure, the average reduction is 12.5 per cent.
  Stable size distributions are not known for Germany. As an alternative, herd sizes for 2016 were calculated and made available by the Federal Statistical Office. According to this, 80 per cent of all dairy cows and 72 per cent of all heifers and male beef cattle are kept in herds with greater than / equal to 100 cattle.

  Implementation in 2030: For dairy cows, heifers and male beef cattle with herd sizes greater than or equal to 100 cattle, the emission factor for “slurry-based loose housing” was reduced by 12.5 per cent. Mathematically, the following emission reductions in the EF result: For dairy cows from 19.7 to 17.730; for heifers and male beef cattle from 19.7 to 17.927 kg NH_3-N per kg TAN. For the other cattle categories, “slurry-based loose housing” plays only a minor or no role and no effect of this measure was projected.

  Calculated additional emission reduction in kt NH_3: 4.34
  Calculated cumulative emission reduction in kt NH_3: 35.46

- Application of liquid manure on tilled fields and grassland only with injection / slot techniques or acidification, 50 per cent implemented
  For the sake of simplicity and due to data limitations, it was assumed for the calculation that the emissions are reduced in the same way with acidification as with the use of injection / slot techniques.

  Implementation in 2030: The current distribution frequencies for application on grassland and in the stand (except for “slurry cultivators”) have been halved and the remaining half has been added to the distribution frequency for “injection techniques”. The EFs for injection / slot techniques / acidification (based on TAN, in kg per kg N) are: for cattle slurry or digestates: 0.24; for pig slurry: 0.06 and for leachate 0.04.

  Calculated additional emission reduction in kt NH_3: 22.23
  Calculated cumulative emission reduction in kt NH_3: 57.69

- Organic farming on 20 per cent of the area (Measure 3.4.5.3 of the Climate Protection Programme 2030)
  Underlying changes were taken from parallel projections for the 2021 Projection Report. With an increased expansion of organic farming to 20 per cent of the agricultural area by the year 2030 (at the same time the goal of the German Sustainability Strategy), in comparison to a more moderate expansion to 14 per cent, there is in particular a reduction in the mineral fertilizer applied. In addition, projected increase of animal performance is slightly reduced compared to the baseline. There are further changes for the cultivated areas and yields. However, the latter have no additional impact on the level of NH_3 emissions.

  Implementation in 2030: A new input data set concerning mineral fertilizers, animal performance, cultivated areas and yields was taken from the GHG projections. Otherwise it was calculated as in measure 3.9.

  Calculated additional emission reduction in kt NH_3: 0.30 (through animal performance), 2.29 (through less mineral fertilizers)
  Calculated cumulative emission reduction in kt NH_3: 60.28

- Reduction of the N balance to 70 kg / ha (Measure 3.4.5.1 of the Climate Protection Programme 2030)
  To achieve the climate protection goal (also a goal of the German Sustainability Strategy) of the overall balance of 70 kg N / ha (three-year average) in 2030, the N input must be further reduced beyond the previous measures (see 2021 Projection Report).

  Implementation in 2030: The N supply via mineral fertilizers was reduced by 8 kg / ha.

  Calculated additional emission reduction in kt NH_3: 3.94
  Calculated cumulative emission reduction in kt NH_3: 64.22

- Subtraction of 10 per cent on the total reduction

  Implementation in 2030: In order to take into account an incomplete implementation of the measures, such as exceptions for small and very small farms, the overall reduction is reduced by 10 per cent at the end.

  Calculated cumulative emission reduction in kt NH_3: 57.80

Reduction in industrial processes through the optional measure g) of the National Air Pollution Control Programme:

For the additional emission reduction of sulfur dioxide, the optional measure g) from the National Air Pollution Control Programme according to Article 6 and Article 10 of Directive (EU) 2016/2284 is assumed to be adopted and continued for the WAM scenario. It is assumed that a future lower-sulfur fuel use or more efficient exhaust gas cleaning technology will result in a 20 per cent reduction in the emission factor for sulfur dioxide in the source groups with the highest sulfur dioxide emissions in the NFR sectors of industrial processes (NFR 2). It is further assumed that the first reduction effects will show up by 1 January 2025 at the latest and that implementation has to be completed beforehand.

Since the first reduction effects are to be expected from 2025 on, it is assumed that the emission value for 2020 corresponds to that of the reference value from the 2020 submission. Thus, the emission factors for 2025, 2030 and 2035, as shown in (17) using the example of the glass production of flat glass (reference value 1.96 kg / TJ), are recalculated.

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(17) SO2 emission (glass production of flat glas) = 1.96 kg/TJ * 80% = 1.57 kg/TJ
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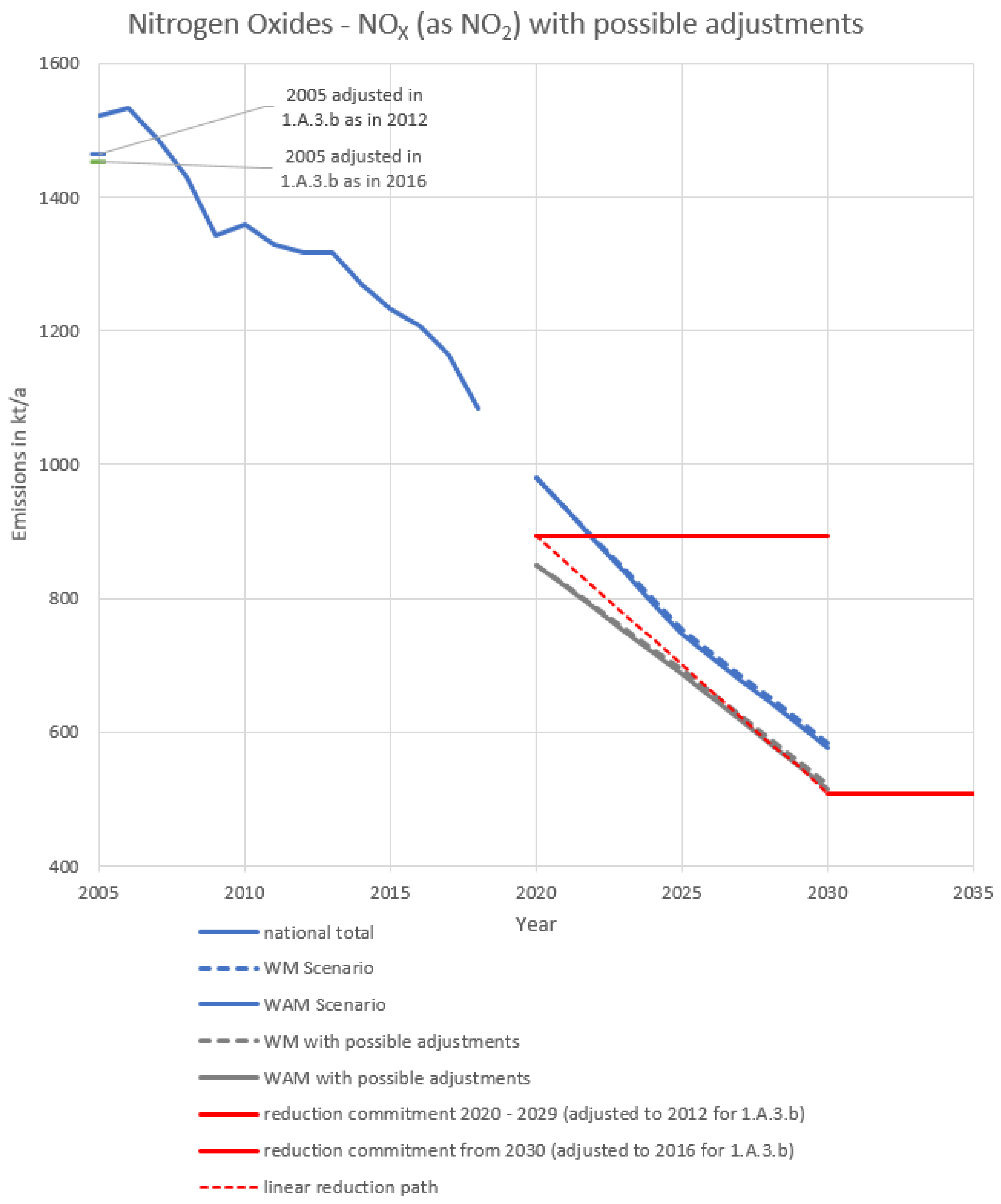
The results as presented at the top of the page have been widely circulated and discussed with sector experts from industry, science and public authorities.

Projection Adjustments

The projections of the pollutant emission development in accordance with Directive (EU) 2016/2284 shows that the reduction obligations in accordance with Annex II of this directive for NO_x cannot be met in the years 2020 to 2029 and from 2030 onwards without the flexibility provisions given in Art 5(1). Referring to The Directive´s Annex III Part 1 Nr. 1 (e) and Implementing Decision 2018/1522, No. 2.2.7 and 2.2.8, it can therefore be assumed that Germany will apply for an adjustment of its national emission inventory in order to attain compliance with reduction commitments for 2020 to 2029 and from 2030 onwards.



NO_x adjustment in 1.A.3.b road transport

According to Annex IV Part 4 Paragraph 1 of Directive (EU) 2016/2284, an adjustment can be made for the calculation of NO_x emissions for “1.A.3.b Road transport”. The admissibility of the adjustment results from the projected exceedance of the NO_x emission reduction commitment (Annex IV Part 4 Paragraph 1 a) and the fact that very different emission factors were used when determining the emission reductions and the current calculations (Annex IV Part 4 Paragraph 1 d ii).

Without the application of these adjustments, the emissions in the emissions projection submitted in 2021 for NO_x will exceed the permissible absolute maximum amount by 52 kt in 2020 and 44 kt in 2030. Taking into account the adjustment in category 1.A.3.b, the additional reduction corresponds to 130 kt NO_x in 2020 and 62 kt NO_x in 2030. With this adjustment, the reduction commitments are met.

The adjustment takes into account the application of different emission factors from the Handbook Emission Factors for Road Transport (HBEFA[12)]). According to Directive (EU) 2016/2284 Art. 5 Paragraph 1 for the purpose of determining whether the relevant conditions set out in Part 4 of Annex IV are fulfilled, the emission reduction commitments for the years 2020 to 2029 shall be considered as having been set on 4 May 2012. Therefore, the emission factors known on 4 May 2012 for the period from 2020 to 2029 in the area “1.A.3. b Road transport” - in this case the emission factors based on the HBEFA version 3.1 (published in January 2010) - must be used as a basis.

To determine the adjustment according to Annex IV Part 4 from 2030 onwards, the emission factors of the HBEFA known in 2016 must be used as a basis, in this case the emission factors of the HBEFA version 3.2 (published in July 2014).

The additional conditions for an applicability of the adjustment from the year 2025 onwards as listed in the last subparagraph of Article 5 (1) are fulfilled, since the emission factors in different versions of HBEFA do not arise from Germany’s implementation or enforcement of Union source-based air pollution control legislation but increased knowledge about realistic NO_x emissions in road transport.

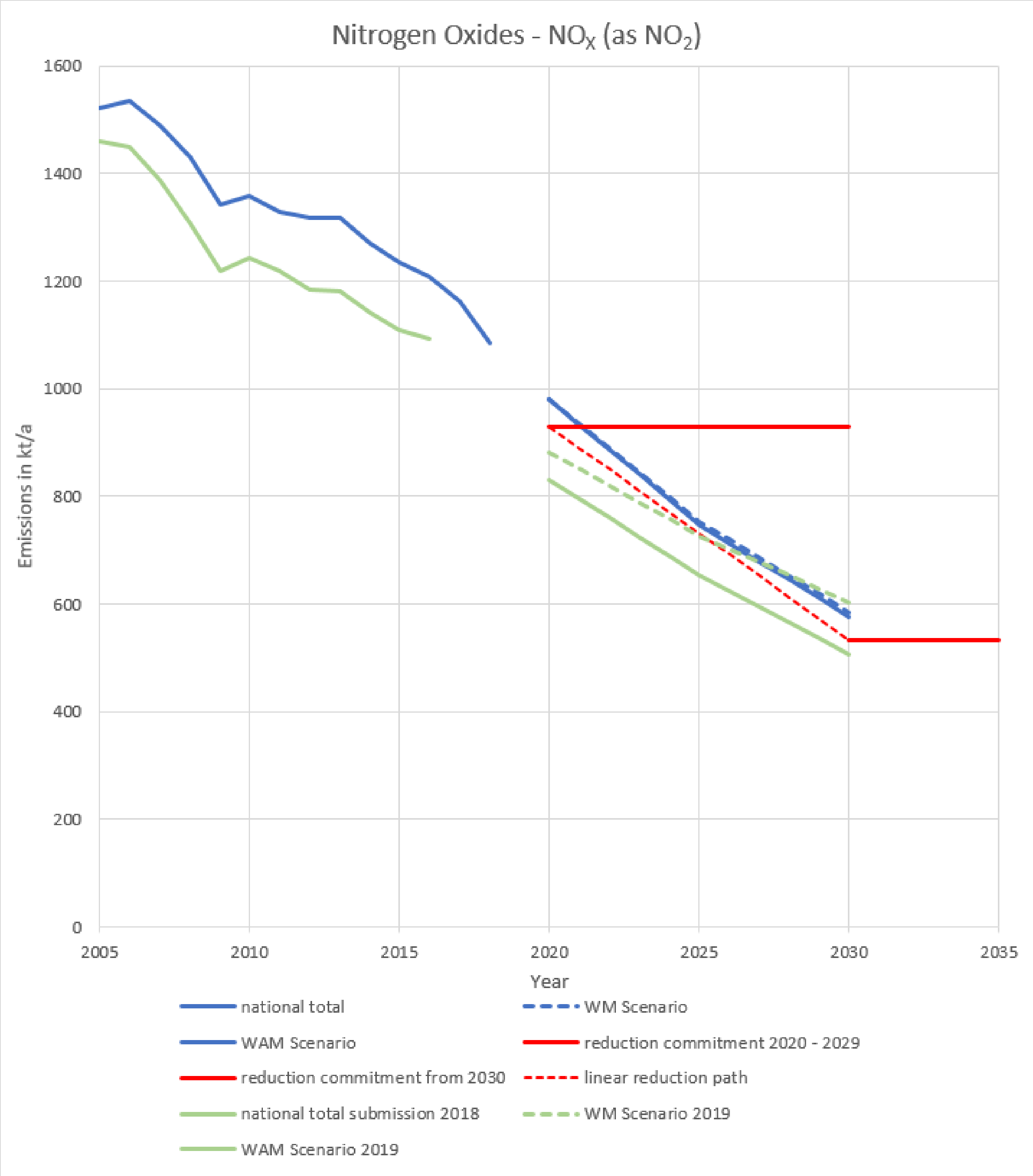
For calculating the projections submitted in 2021, new emission factors were used according to HBEFA version 4.1 (published in August 2019). In version 4.1, many parameters were updated on which the determination of the emission factors is based, whereby the emission factors for NO_x, especially for diesel cars, light- and heavy-duty vehicles, have been corrected significantly upwards. This leads to significant changes in the emission calculation in “1.A.3.b road transport” and makes the described adjustment of the NO_x emissions necessary.

Recalculations

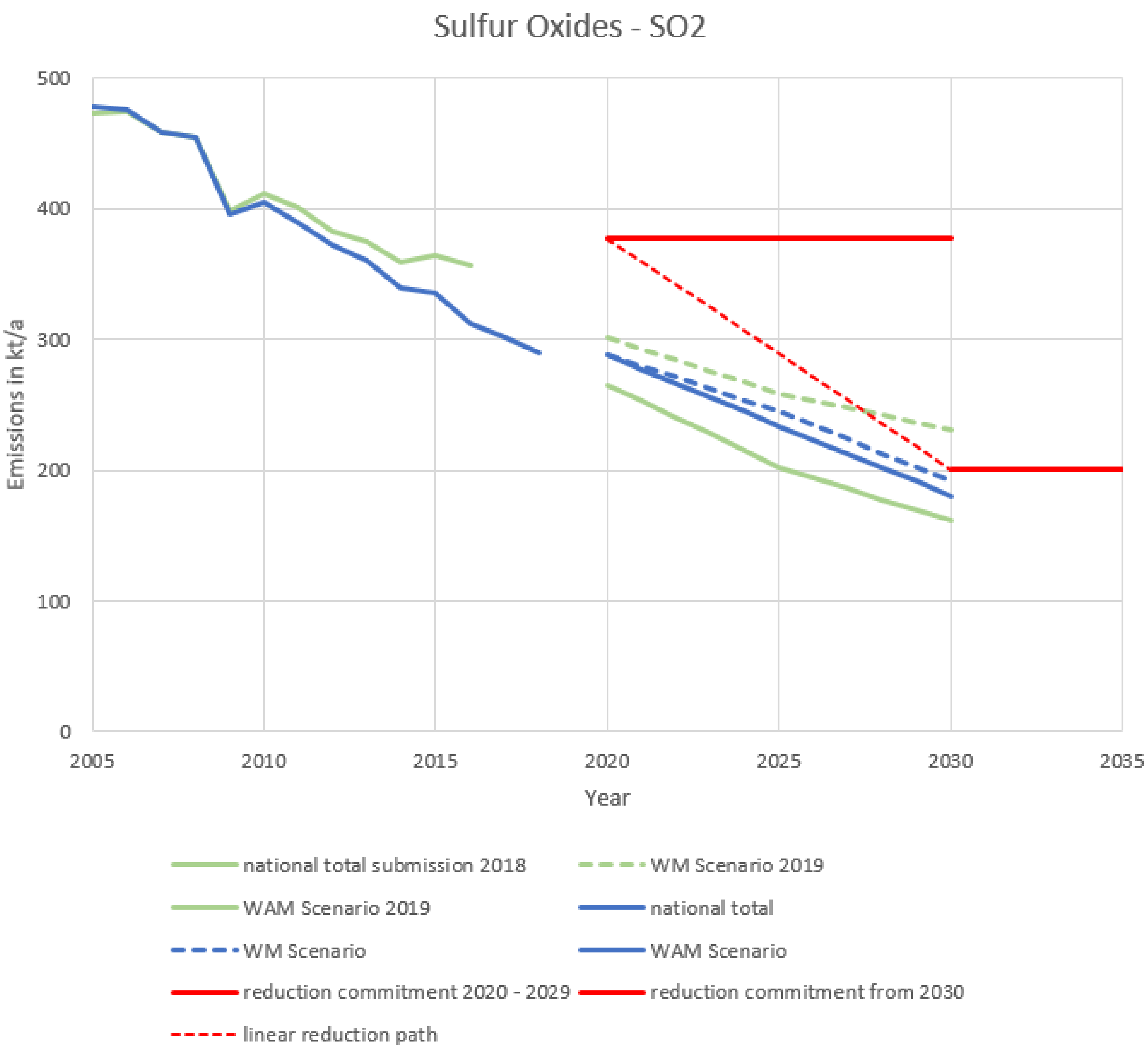
Due to recalculations for the emission inventory submission 2020, all emission reduction potentials had to be updated compared to the emission inventory submission 2018, upon which the emission projections reporting in 2019 was based. Furthermore, measures that had been included in the former WAM scenario have now been integrated in the WM scenario, as they were put into force in the meantime (e. g. 44th BImSchV). In addition, updated GHG emission projections using most recent projections of economic and other parameters result in a new projection of activity rates that needs to be considered for updating the emission projections of air pollutants.

The following figures show the differences between submission 2018 and 2020 for past emissions as well as the differences between the emission projections reported in 2019 and the current projections in the WM and the WAM scenario for each pollutant. For each pollutant a breif explanation of the most relevant reasons for the occurring differences is given.

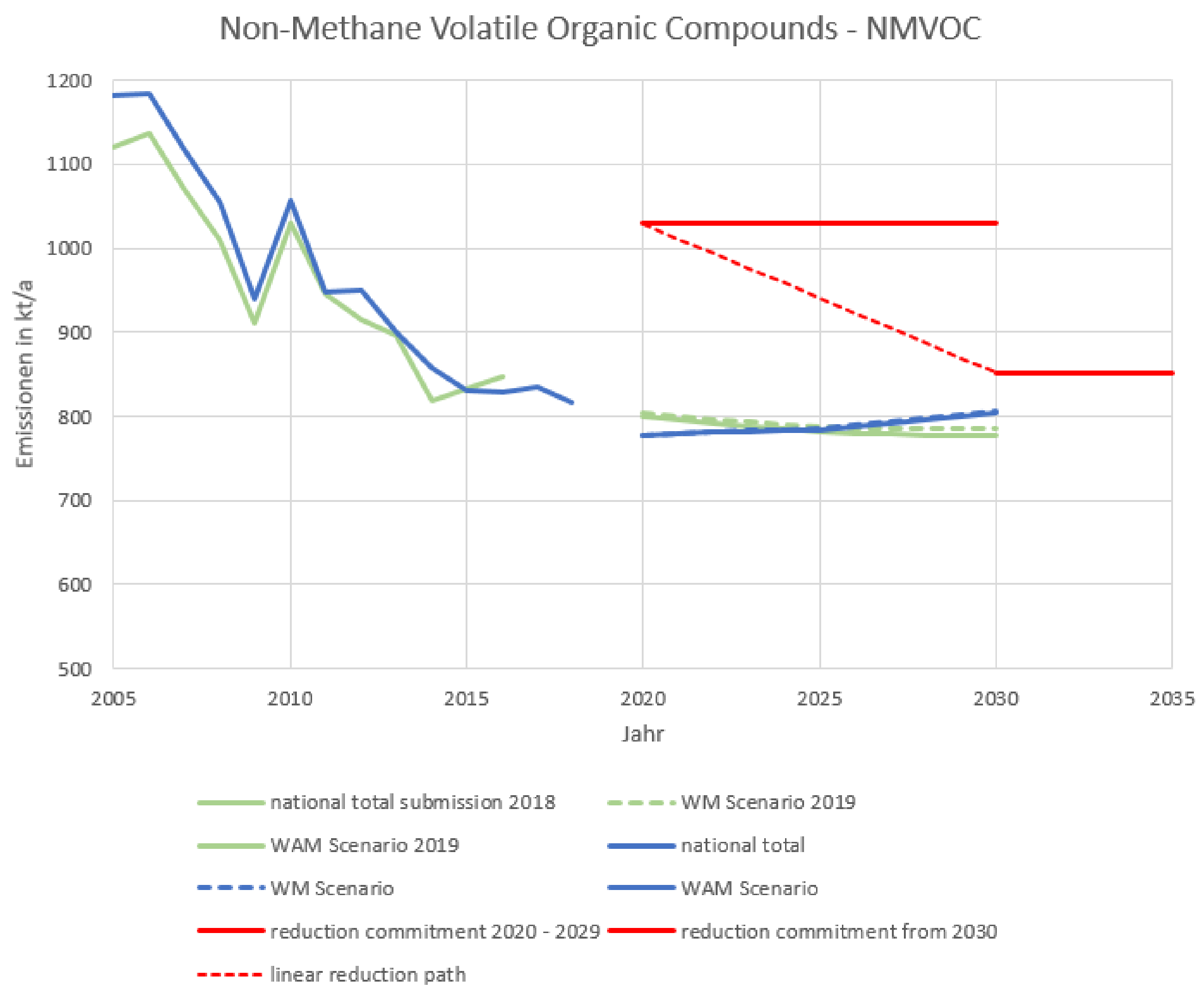
For NO_x a new version of the HBEFA (4.1) was used for calculating past emissions of road transport in the submission 2020 leading to higher historical emissions for all vehicle categories (HDV, LDV, PC). The vehicles with higher emission factors compared to former HBEFA versions stay in the fleet until 2030. This also explains the differences between the two WAM scenarios. Whereas the WM scenarios show a similar difference in 2020, caused by the same reason, this is nearly compensated until 2030, where the current WM scenario ends up with lower emissions than the WM scenario from 2019. This can be explained by the coal phase-out, that has been taken from the former WAM into the current WM scenario leading to lower projected emissions from the energy sector.



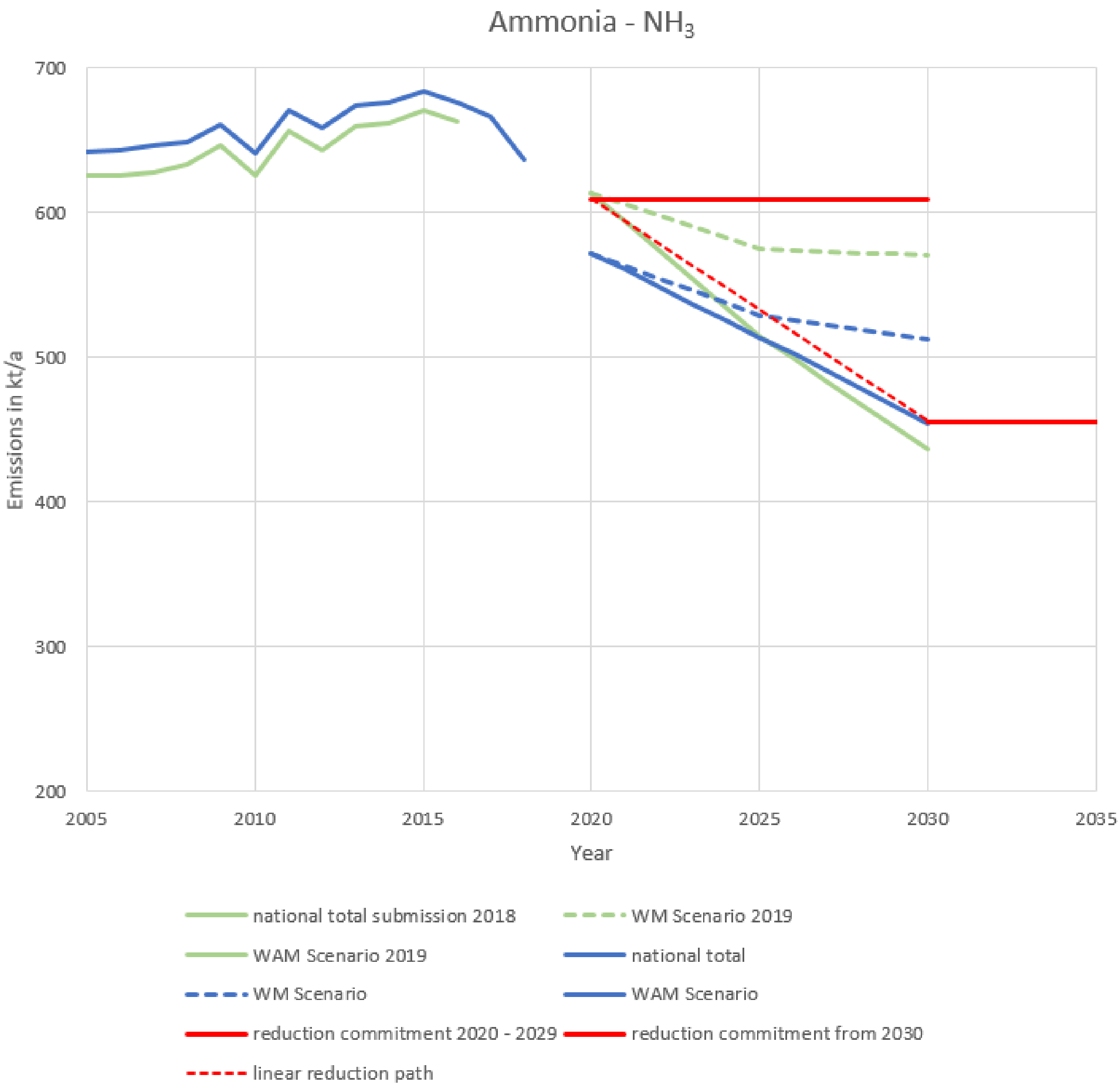
The coal phase-out is also the reason for the differences between the two WM scenarios for SO_2. Furthermore, the reduction potential had been overestimated in the WAM scenario from 2019. This can be explained by a bug in calculating sulphur dioxide emissions from refineries in the 2019 WAM scenario, that more than halved the emission factors for SO_2 in this sector unintentionally.



The current NMVOC emission projections show a different trend than the 2019 projections in both scenarios, caused by updated economic projections, which strongly influence the NMVOC emission projections from solvent production and use.

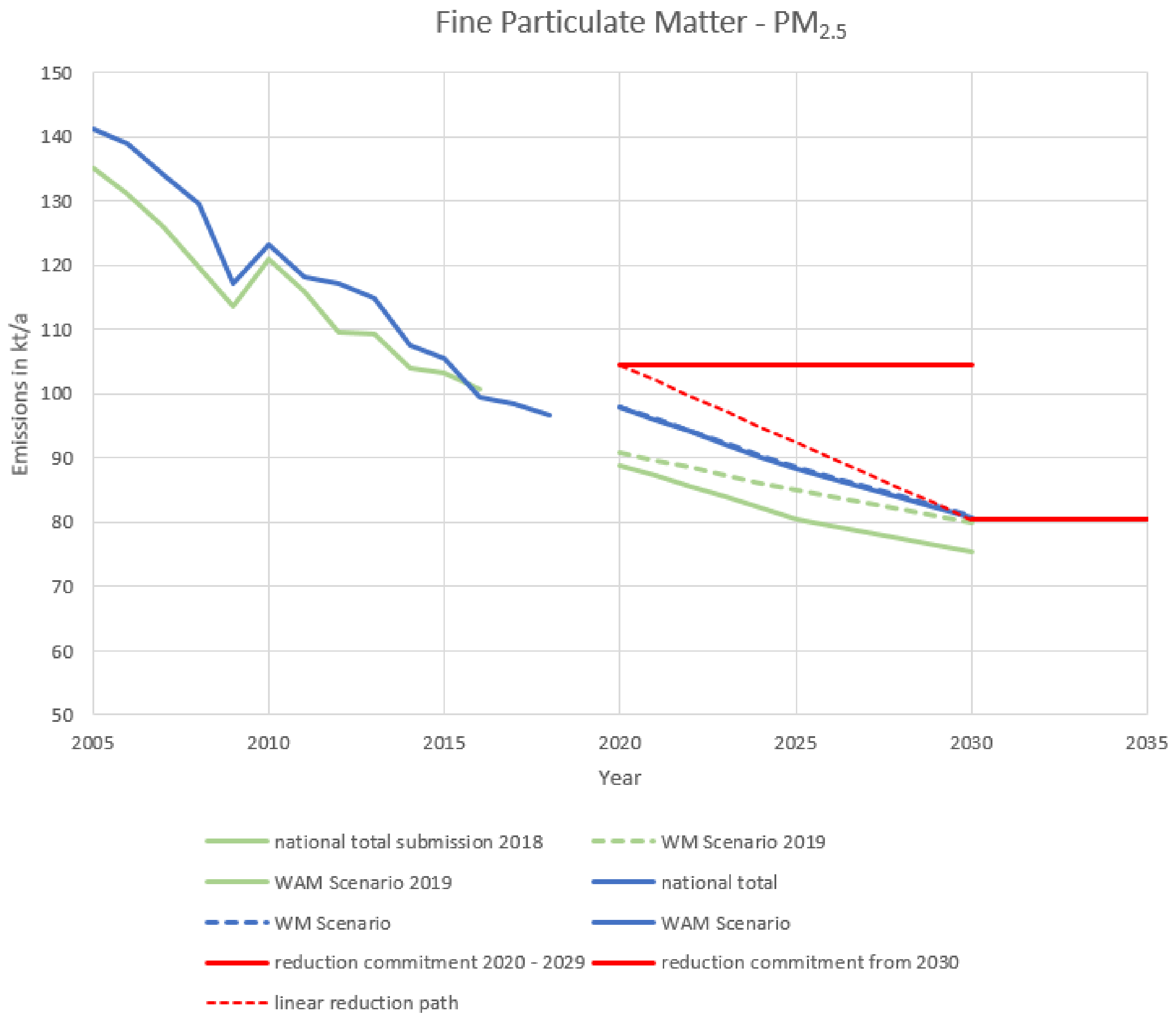


The current WM scenario for NH_3 shows a significant decrease compared to the 2019 WM scenario mainly caused by the assumed effects of the new Fertilizing Ordinance (DÜV 2020) from 2020. However, the remaining reduction potentials in the current WAM scenario result in a less steep decrease from 2020 to 2030 than in the 2019 WAM scenario. The assumptions for calculating the reduction potential of measures in the WAM scenario were carefully updated by the Thünen Institute according to current political activities and incentives for their implementation in practice as described above.



For fine PM ($PM_{2.5}$), the recalculations for past emissions are not that relevant. Nevertheless, the projected emissions are higher than those reported in 2019, at least compared to the former WAM scenario. This is mainly caused by three effects:

First, there are higher $PM_{2.5}$ emission factors in the HBEFA 4.1 also influencing the future fleet (increasing the projection in 2030 by about 1.5 kt). Second, there is a higher projected use of solid biomass in small combustion installations due to climate protection policies that are still promoting biomass as a renewable and climate friendly energy source ignoring the antagonism with other environmental goals (increasing the projection in 2030 by about 1.3 kt). And third, we applied a different methodology for the projection of activity rates in certain industrial sectors that have no GHG emissions and therefore no projection of activity rates in the underlying dataset (increasing the projection in 2030 by about 1.5 kt). While assuming the latest historical activity rate as constant for projections reported in 2019 (that means using the value of 2016 from the emission inventory submission 2018), for the current projections the average of the last 10 years (2008-2018 according to submission 2020) was set constant for the projection years. This leads for example, to significantly higher emissions in the source category handling and storage of bulk products. However, in most cases estimates can be considered conservative.



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