Atmospheric nitrogen deposition and exceedance of critical loads in the Netherlands and Germany

Legislation, monitoring and assessment

RIVM & UBA report 2026-0002
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Synopsis

Atmospheric nitrogen deposition and exceedance of critical loads in the Netherlands and Germany

Legislation, monitoring and assessment

On a number of sites in the border area between the Netherlands and Germany the emission and deposition of nitrogen oxides and ammonia on a number of locations is much higher than the average emission and deposition in both countries. The situation on both sides of the border is not one-on-one comparable for different reasons. Both countries have implemented their own policies to abate nitrogen emission and deposition. There are also different national measures and instruments to comply with European jurisdiction aimed at improving the quality of water, air and nature.

In early 2024, German and Dutch experts met in The Hague (the Netherlands) to discuss the way the European Habitats Directive is implemented with reference to the causes of eutrophication an acidification in their countries. The attending experts emphasised that in order to be able to compare the implementations, getting a more complete picture of emission, concentration and deposition of nitrogen at both sides of the border is important.

As a follow up to this expert meeting, the Dutch ministry of Agriculture, Fishery, Food Security and Nature (LVVN) and the German ministry for the Environment, Climate Action, Nature Protection and Nuclear Safety (BMUKN) requested a comparison of the way both countries implement the European Habitats Directive. More specifically, this comparison is – amongst other things – related to the manner in which both countries determine the exceedance of critical nitrogen loads. The National Institute of Public Health and Environment (RIVM) in the Netherlands and the German Environment Agency (UBA) have performed the comparison.

The focus of this report is on the documentation of legislation, monitoring and assessment practices, and does not contain any conclusions or policy recommendations.

Keywords: nitrogen, nitrogen oxides, ammonia, deposition, emission, critical loads, Habitat Directive

Publiekssamenvatting

Atmosferische stikstofdepositie en overschrijding van kritische depositiewaarden in Nederland en Duitsland

Wetgeving, monitoring en evaluatie

In het grensgebied van Nederland en Duitsland is de uitstoot (emissie) en neerslag (depositie) van de stikstofverbindingen stikstofoxiden en ammoniak op een aantal plekken veel hoger dan de gemiddelde uitstoot en neerslag in beide landen. Toch is de situatie aan beide kanten van de grens om verschillende redenen niet een-op-een vergelijkbaar. Zo hebben beide landen hun eigen beleid ingevoerd om de stikstofuitstoot en -neerslag aan te pakken. Ook de nationale maatregelen en instrumenten verschillen waarmee wordt voldaan aan Europese wetgeving voor het verbeteren van de water-, lucht- en natuurkwaliteit.

Duitse en Nederlandse experts spraken begin 2024 in Den Haag (Nederland) over hoe de Europese Habitatrichtlijn in hun land is ingevoerd, met nadruk op de oorzaken van vermesting en verzuring via de lucht in de beide landen. De aanwezige experts benadrukten dat het voor de vergelijking belangrijk is om voor zowel Nederland als Duitsland een completer beeld te krijgen van de emissie, concentratie en depositie van stikstof in het gebied aan beide kanten van de landsgrenzen.

Naar aanleiding van deze bijeenkomst gaven het Nederlandse ministerie van Landbouw, Visserij, Voedselzekerheid en Natuur (LVVN) en het Duitse ministerie voor Milieu, Klimaat, Natuurbescherming en Nucleaire Veiligheid (BMUKN) de opdracht om te vergelijken hoe beide landen de Europese Habitatrichtlijn hebben ingevoerd. Meer specifiek gaat het daarbij onder meer om hoe overschrijding van de kritische stikstof depositiewaarde in beide landen wordt bepaald. Het Rijksinstituut voor Volksgezondheid en Milieu (RIVM) en het Duitse Milieu-agentschap (UBA) voerden het onderzoek uit.

Dit rapport is gericht op het beschrijven van de praktijk rond wetgeving, monitoring en evaluatie, en bevat geen conclusies of aanbevelingen voor beleid.

Kernwoorden: stikstof, stikstofoxiden, ammoniak, depositie, emissie, KDW, Habitatrichtlijn

Kurzfassung

Atmosphärische Stickstoffdeposition und Überschreitung von Critical Loads in den Niederlanden und Deutschland

Gesetzlicher Rahmen, Monitoring und Bewertung

Im Grenzgebiet zwischen den Niederlanden und Deutschland liegen die Emission und Deposition von Stickstoffoxiden und Ammoniak an einer Reihe von Standorten weit über den durchschnittlichen Emissionen und Einträgen in beiden Ländern. Dennoch ist die Situation beiderseits der Grenze aus verschiedenen Gründen unterschiedlich. Beide Länder haben eigene politische Ansätze zur Verringerung der Stickstoffemission und -deposition umgesetzt. Aus diesem Grund unterscheiden sich auch die nationalen Maßnahmen und Instrumente zur Einhaltung der europäischen Rechtsvorschriften zur Verbesserung der Wasser- und Luftqualität sowie des Zustands der Natur.

Anfang 2024 diskutierten deutsche und niederländische Experten in Den Haag (Niederlande) über die Umsetzung der europäischen Flora-Fauna-Habitat-Richtlinie in Bezug auf die Gefährdungsursachen Eutrophierung und Stickstoffdeposition in ihren Ländern. Die anwesenden Experten bekräftigten, dass es für den Vergleich der Umsetzung wichtig ist, ein vollständigeres Bild der Emissionen, Konzentration und Deposition von atmosphärischen Stickstoffverbindungen auf beiden Seiten der Landesgrenzen zu erhalten.

Als Folge der Expertentagung haben das niederländische Ministerium für Landwirtschaft, Fischerei, Ernährungssicherheit und Natur (LVVN) und das deutsche Bundesministerium für Umwelt, Klimaschutz, Naturschutz und nukleare Sicherheit (BMUKN) gemeinsam eine Gegenüberstellung der Umsetzung der FFH-Richtlinie in Deutschland und den Niederlanden angeregt. Konkret bezieht sich dieser Vergleich u.a. auf die Art und Weise, wie die Überschreitung kritischer Belastungen in beiden Ländern ermittelt wird. Das Niederländische Reichsinstitut für Volksgesundheit und Umwelt (RIVM) und das Umweltbundesamt (UBA) haben diesen Vergleich durchgeführt.

Der Bericht fokussiert auf die Darstellung des gesetzlichen Rahmens, sowie der Methoden für Monitoring und Bewertungsansätze und enthält keine Schlussfolgerungen oder Empfehlungen für weitergehende politische Ansätze.

Stichworte: Stickstoff, Stickstoffoxide, Ammoniak, Deposition, Emission, kritische Belastungsgrenzen, Critical Loads, FFH-Richtlinie

Contents

Summary

On a number of locations in the border area between the Netherlands and Germany the emission and deposition of nitrogen oxides and ammonia is much higher than the average emission and deposition in both countries. For various reasons the situation on both sides of the border cannot be compared one-on-one. Both countries have implemented their own policies to abate nitrogen emission and deposition. Therefore, the national measures and instruments to comply with European jurisdiction aimed at improving the quality of water, air and nature differ.

In early 2024, German and Dutch experts met in the Hague (the Netherlands). The most important topic of their meeting was the way the European Habitats Directive is implemented with respect to the pressure of eutrophication and nitrogen deposition in their countries. The Habitats Directive, brought into force by the European Union in 1992, is an important pillar of the European nature policy, as is the Birds Directive. For the implementation of the Habitats Directive in their respective countries both Germany and the Netherlands, look at the deposition of nitrogen and the possible exceedance of critical loads. During the meeting the experts emphasised that in order to be able to compare the implementation, getting a more complete picture of emission, concentration and deposition of nitrogen on both sides of the national borders is important.

Partly as a follow up to this expert meeting, the Dutch ministry of Agriculture, Fishery, Food Security and Nature (LVVN) and the German ministry for the Environment, Climate Action, Nature Protection and Nuclear Safety (BMUKN) requested a comparison of the way both countries implement the European Habitats Directive. More specifically, this comparison is related to the manner in which both countries determine the exceedance of critical loads. The National Institute of Public Health and Environment (RIVM) in the Netherlands and the German Environment Agency (UBA) have performed this comparison.

Regarding the implementation of the Habitats Directive, there can be a difference in the legal basis for the procedure and in the methods for using the ‘building blocks’ (e.g. emissions, models, critical loads) in the calculation of the exceedance. This report summarises these differences. It does not contain any conclusions or policy recommendations. It also does not contain an investigation or comments on how juridical and political systems in the Netherlands and Germany have lead to the different systems in both countries, given the same European regulations. The juridical and policy related texts in this report are compiled from existing literature or based on consultation with relevant experts.

Legal aspects

For the Netherlands the Nitrogen Law is in place, as a part of the Environment and Planning Act (Omgevingswet). The objective of this act

is to expose 74 percent of the nitrogen sensitive habitats within Natura 2000 areas to deposition below the respective nitrogen critical loads in 2035. The aim for 2030 is 50 percent.

Germany has almost similar goals for 2030. They are part of Germany's Sustainable Development Strategy. Although the percentages are almost similar, they apply to different nature areas: the Netherlands looks at the nitrogen sensitive habitats within Natura 2000 areas, and Germany at a percentage of the total ecosystem area.

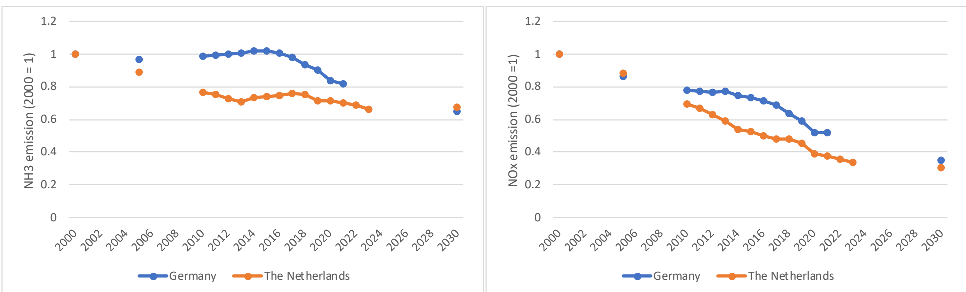
To assess the contribution of individual projects in the context of the permitting process, the Netherlands has a 'zero' cut-off criterium, combined with a 25-kilometre maximum calculation distance. The 'zero' cut-off is technically implemented through a calculation limit that rounds to at least 0.01 mol per hectare per year, below which depositions are considered to be zero. For Germany a main cut-off value of 0.3 kilogram nitrogen per hectare per year for habitat types in Natura 2000 areas is used, which is about 21 mol per hectare per year. For other ecosystems, not protected under Natura 2000, a cut-off value of 5 kilogram nitrogen per hectare per year is used under the TA-Luft (*Technische Anleitung zur Reinhaltung der Luft*). This is approximately 360 mol per hectare per year.

Emissions

Both countries signed the Convention on Long-Range Transboundary Air Pollution (CLRTAP). Part of this Convention is the obligation for countries to report their emissions annually to the Convention by means of Informative Inventory Report, following the "Guidelines for Estimating and Reporting Emission Data" under the Convention.

In both countries the emission of nitrogen oxides (NO_x) shows the same continuous decrease for the period 2000-2023 (Figure 1). This is mainly caused by the European NEC Directive. The ammonia (NH_3) emissions for both countries show a different trend. For the Netherlands, the overall decrease – that already started in 1990 – occurred mainly between 2000 and 2010. After 2010 the emission was more or less constant. For Germany the main decrease in the emission of ammonia started in 2015. Between 2000 and 2015 the emission was rather constant.

Figure 1 Emission change since 2000 for NH3 (left) and NO_x (right) for the two countries.



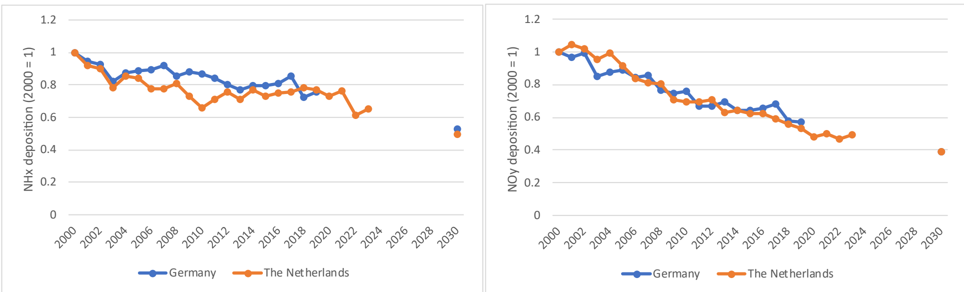
Deposition

The Netherlands and Germany use different manners to calculate the deposition. In the Netherlands wet and dry deposition are calculated by means of a dispersion and deposition model, using gridded emissions data. The outcome of the model is then calibrated using measured concentration and deposition data.

Dry deposition in Germany is also calculated by means of a dispersion and deposition model using emissions, but this dry deposition is not calibrated using measurements. Wet deposition, however, is determined by measurements. Combination of interpolated precipitation concentrations and precipitation amounts results in a high-resolution wet deposition map for Germany.

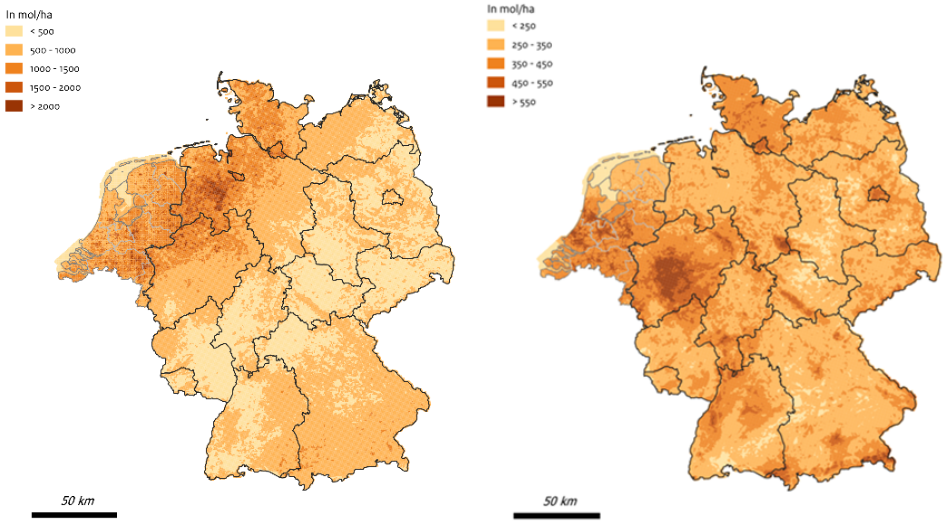
For oxidised nitrogen (NO_y) the decrease of deposition between 2000 and 2021 follows the same trend as the decrease in emissions. This holds for both Germany and the Netherlands. For the deposition of reduced nitrogen (NH_x) the trend in the decrease is different. However, the total decrease between 2000 and 2021 is reasonably comparable for both countries (Figure 2)

Figure 2 Deposition change since 2000 for NH_x (left) and NO_y (right) for the two countries.



Areas with intensive agricultural activities, industry, cities and traffic are clearly visible in deposition maps (Figure 3). This shows the spatial distribution in both countries. Here some differences between the two countries become apparent in the border regions. These border effects are most likely related to the use of different models and input data.

Figure 3 Spatial distribution of the deposition (in mol $N.ha^{-1}.yr^{-1}$) in 2021 of NH_x (left) and NO_y (right) for both countries.



Exceedance of critical loads

In the Netherlands the exceedance of critical loads is only calculated for the nitrogen sensitive nature within Natura 2000 areas. In Germany a wider range of areas is used for calculating the exceedance.

Germany calculates national exceedances using calculated critical loads. The Netherlands uses a combination of modelled and measured (empirical) critical loads for this.

1 Introduction

The excessive release of reactive nitrogen compounds to the environment constitutes a common problem in both Germany and the Netherlands. In accordance with European legislation related to air and nature quality, both countries have implemented national policies and measures to abate the problem. These national measures consequently influence the concentration of reactive nitrogen in the air and the deposition of nitrogen in vulnerable nature areas along the German-Dutch border.

In order to explore the differences between the two countries, German and Dutch policy and technical experts gathered in The Hague (Netherlands) in early 2024. Before the meeting it was already clear that a complete factual picture of the emission, concentration and deposition of reactive nitrogen, in which the available data is also linked to monitoring techniques and the policy framework in both countries, would be of mutual benefit when comparing and interpreting the available information.

This wish was reiterated during the meeting in The Hague. As a result the National Institute of Public Health and Environment (RIVM, the Netherlands) and the Umweltbundesamt (UBA, Germany) were asked to work on a bilateral study, with the aim to:

1) Predict the effects of national policy measures on atmospheric reactive nitrogen emissions, concentrations and deposition in the German-Dutch border area;
2) Compare the German-Dutch monitoring methodology:
    a. Measurements and monitoring of nitrogen emissions, concentrations and deposition
    b. The role of nitrogen monitoring in nature conservation strategies and their implementation.
3) Compare the German and Dutch implementations of laws and regulations on nitrogen sensitivity of habitats/nature types within Natura 2000 sites. This includes reporting to the EU regarding the Habitat Directive.

This report will give an insight in the last two topics above: it will provide a comparison of methodologies. To achieve this, the report looks at the following three main items:

1) Monitoring methodology: how are the nitrogen emissions, concentrations and deposition in Germany and the Netherlands monitored?
2) Figures: what do the available data show with respect to nitrogen emissions, concentrations and deposition (entire country and – where possible, the German-Dutch border area)
3) (Implementation of) nitrogen policies: how do Germany and the Netherlands assess the nitrogen sensitivity of habitats/nature types within Natura 2000 sites and how do they report to the European Commission within the context of the Habitats Directive? What is the legal basis for the nitrogen policies in both countries?

2 Legal background on European and national level Habitats Directive and exceedance of critical loads

This chapter describes the general European legal background pertaining to nature protection and long-range air pollution and national legislation related to Critical Load (CL) exceedance.

2.1 Habitats Directive

The legal framework is the same for both countries: the European Habitats Directive. The Birds[1] and Habitats[2] Directives set out the overall legal framework for protecting and managing Natura 2000 sites. Each EU member state decides how best to implement them. Every site is unique. It is important that landowners and site managers work together to find local solutions to manage the sites in the best way. Member states must first set site-specific conservation objectives. These should reflect the ecological needs of the habitats and the species present. This will determine the type of management that is required. Conservation measures can then be implemented to meet these objectives, using a variety of tools and agreements with landowners and users. EU funds[3] are also available to support the management of Natura 2000 sites.

Article 6 of the Habitats Directives defines how EU countries must protect and manage their Natura 2000 sites. They should take several factors into account: economic, social and cultural requirements, and regional and local characteristics. There are three main sets of provisions:

- **Article 6.1**: positive conservation measures. These involve management plans, and statutory, administrative or contractual measures, which correspond to the ecological requirements of the natural habitat types in Annex I and the species in Annex II present on the site.
- **Article 6.2**: preventative measures. These require EU countries to avoid the deterioration of natural habitats and the habitats of species, as well as significant disturbance of the species for which the areas have been designated.
- **Article 6.3 and .4** set out a series of procedural and substantive safeguards governing plans and projects[4] likely to have a significant effect on a Natura 2000 site.

Implementing Article 6.1 requires EU member states to set site-specific conservation objectives and measures. This ensures that the Natura 2000 site is managed effectively and contributes to reaching the overall objectives of the Nature Directives; achieving a favourable conservation status for the species and habitats protected under the directive across their natural range within the EU.

[1] https://environment.ec.europa.eu/topics/nature-and-biodiversity/birds-directive_en
[2] https://environment.ec.europa.eu/topics/nature-and-biodiversity/habitats-directive_en
[3] https://environment.ec.europa.eu/topics/nature-and-biodiversity/natura-2000/financing-natura-2000_en
[4] https://environment.ec.europa.eu/topics/nature-and-biodiversity/natura-2000/permitting-procedure_en

Site-specific conservation objectives and measures should correspond to the ecological requirements of the habitats and species present on the sites. They should be comprehensive, realistic, quantifiable and measurable. Natura 2000 management plans are a way to set objectives and measures in an open and transparent manner.

Furthermore, according to Article 17 of the habitats directive countries have to report to the EU Commission on the progress of implementation and information provision regarding the current conservation status of habitats and species. The monitoring and reporting of the conservation status of national habitats serve to take stock of successes, highlight areas where action is needed, inform about the main pressures on nature and provide information on the efficiency of the Natura 2000 network.

2.2 NEC-Directive

The EU directive on National Emission reduction Commitments (NEC) sets national reduction commitments for five main air pollutants that have a significant negative impact on human health and the environment. These pollutants are sulphur dioxide, nitrogen oxides, non-methane volatile organic compounds, ammonia and fine particulate matter.

Member states are required to monitor and report the emissions of these five pollutants. Furthermore, they have to draw up, adopt and implement national air pollution control programmes. These should show how they will meet their emission reduction commitments for 2020-2029, and how they will reach the more ambitious commitments by 2030 and beyond. The reduction commitments for 2020-2029 are the same as those made by member states under the Gothenburg Protocol to the UNECE Air Convention.

2.3 National Laws and Strategies

2.3.1 Nitrogen law in the Netherlands

In the Netherlands, the Environment and Planning Act (formerly the Nature Conservation Act) incorporates all obligations under the European Birds Directive and the Habitats Directive. Based on this Act, activities that may have a significant impact on the conservation objectives of Natura 2000 sites require a permit, including the adverse effects of nitrogen deposition.

In 2015, the Nitrogen Approach Programme (PAS) was introduced. The aim of this programme was to reduce the amount of nitrogen in Natura 2000 areas, while enabling economic development. In 2019, the Council of State ruled that the PAS could no longer serve as a basis for granting permits.

Subsequently, the Nitrogen Reduction and Nature Improvement Act (Wsn) was adopted in 2021. As a result, the Environment and Planning Act includes the obligation find a solution for the overload caused by nitrogen deposition in Natura 2000 sites (environmental values), in which the critical load (CL) is an important criterium. The law also commissions the Nitrogen Reduction and Nature Restoration Program with measures to achieve those goals and restore nature.

In order to achieve the objectives, various measures are being taken to limit nitrogen deposition in the Natura 2000 sites. In 2022 and 2023, the then government set provisional emission targets for areas and sectors as part of the (Draft) National Programme for Rural Areas (NPLG). In 2024 the subsequent government halted further development of the NPLG, and replaced it by a new approach called 'Room for Agriculture and Nature' (in Dutch 'Ruimte voor Landbouw en Natuur')[5]

There currently is political support for a proposal to remove the CL from the law and replace it with an alternative[6], that has to be sound from a juridical point of view and in which the actual measured state of nature is more leading. An alternative for the CL is currently under discussion.

Environmental values for nitrogen
The nitrogen reduction target is laid down in the environmental values for nitrogen. These environmental values describe the target percentage of surface area of nitrogen-sensitive nature where nitrogen deposition must be below the CL in a given year. The environmental values apply to all Dutch Natura 2000 sites combined. There are no targets for individual sites.

The legally established goals are:
- for 2025: at least 40 percent;
- for 2030: at least 50 percent;
- for 2035: at least 74 percent.

2.3.2 *Germany's Sustainable Development Strategy*
The German Federal Ministry for the Environment has been implementing a National Strategy for the Reduction of Reactive Nitrogen since a couple of years[7]. A first report – in German – on that strategy was published by the Federal Government in 2017[8].
Currently the focus lies on the development of a national total emissions target for nitrogen.
Germany has not only been developing a National Nitrogen Strategy, the country also has fixed nitrogen related targets in its Sustainable Development Strategy. The strategy is coordinated by the Chancellor's Office, under the chairmanship of the Head of the Chancellery[9].
Regarding nitrogen there are a few indicators for which binding targets are defined:
- Emissions of air pollutants
- Nitrate in groundwater
- Nitrogen input in the North Sea and Baltic Sea via rivers
- Greenhouse gas emissions, including nitrous oxide
- Eutrophication of ecosystems through nitrogen deposition

[5] https://www.rijksoverheid.nl/documenten/kamerstukken/2024/11/29/kamerbrief-ruimte-voor-landbouw-en-natuur
[6] https://www.internetconsultatie.nl/spoedwetvervangenomgevingswaardestikstof/document/14355
[7] https://www.bundesumweltministerium.de/en/topics/sustainability/overview-sustainability/nitrogen-reduction
[8] https://www.bmuv.de/download/stickstoffeintrag-in-die-biosphaere
[9] https://www.bundesregierung.de/breg-en/federal-government/germany-s-sustainable-development-strategy-354566

The German Environment agency provides data and updates for all indicators on a regular basis.
For the indicator "Eutrophication of ecosystems through nitrogen deposition" critical loads and nitrogen deposition are being modelled (see chapter 3). The objective is to reduce the area of ecosystems being subject to eutrophication (i.e. critical loads exceedance) to 50% of the total ecosystem area by 2030.

2.3.3 *Technical Instructions on Air Quality Control (TA Luft)*

According to the Federal Immission Control Act and the associated technical administrative regulation on air pollution control (TA Luft)[10], in Germany all installations requiring approval must show prior to licensing that they do not have a negative impact on nearby ecosystems through emissions of air pollutants, such as ammonia and nitrogen oxides. For example, this applies to livestock facilities with an indicative livestock number or to combustion plants with an indicative emission rate according to the Industrial Emissions Directive (IED). The key points of the procedure are regulated in the TA Luft itself (Annex 9 of TA Luft), while the details are regulated in a separate, more detailed guideline for determining and evaluating nitrogen deposition[11]. The procedure consists of three consecutive conditions:

1. A key point of Annex 9 is the application of a cut-off criterion of 5 $kg.ha^{-1}.y^{-1}$. (357 mol $N.ha^{-1}.y^{-1}$) This means that the project is eligible for approval if the additional load onto the assessed ecosystem by the facility (in case of an extension it is the additional load from the project, plus the already existing load from the facility) does not exceed 5 $kg.ha^{-1}.y^{-1}$.
2. In case condition 1) is not fulfilled (i.e. additional load by the facility > 5 $kg.ha^{-1}.y^{-1}$), the total load, which is the sum of the load from the facility (see above) and the background deposition, needs to be smaller than the ecosystem-specific assessment value for the project to be eligible for approval.
3. In case condition 2) is not fulfilled either, the project is still eligible for approval if the load of the facility does not exceed 30% of the assessment value relevant for the ecosystem concerned.

In Germany, the assessment value is based on the empirical critical loads according to the Geneva Convention on Long-Range Transboundary Air Pollution (CLRTAP). Depending on the assigned risk level (high, medium, low), additional factors between 1.0 (high risk) and 3.0 (low risk) are applied, so that an assessment value for low risk can correspond to three times the empirical critical load.

Important notes:

1. The assessment according to Annex 9 is only relevant in cases where no ecosystems protected under the Habitats Directive (Nature 2000 sites) are affected. If a Natura 2000 site is affected, Annex 8 of TA Luft needs to be considered, which contains a more stringent cut-off criterion of 0.3 kg $N.ha^{-1}.y^{-1}$ (21

[10] https://www.verwaltungsvorschriften-im-internet.de/bsvwvbund_18082021_IGI25025005.htm
[11] https://pd.lubw.de/50662

mol $N.ha^{-1}.y^{-1}$) and a triviality threshold of 3% for the additional load of the project (see chapter 3.5.1 for details)

2. Furthermore, ecosystems in Germany include numerous sensitive types of ecosystems which are not Natura 2000 sites but are protected under a different national Nature Conservation Law. Several court rulings have stated that the conditions in Annex 9 are not stringent enough for those protected ecosystems. In some cases, it was decided that the 0.3 kg $N.ha^{-1}.y^{-1}$ threshold criterion has to be applied to them as well. Since those protected ecosystems are abundant in Germany, this means many licensing procedures would be affected. For that reason, the national guideline[11] is under review at the moment, in order to provide an assessment procedure for those protected ecosystems. In the meantime, federal states need to provide their own procedure. The state of Brandenburg, for example, issued a decree that the 0.3 kg N-criterion must also be applied for those protected ecosystems.
3. While TA Luft is only applicable to larger installations requiring approval according to the Federal Imission Control Act, it may also be applied to smaller installations regulated under building law, if there is evidence that they harmfully impact the environment. In these cases, the assessment procedure described above is also partially applied to them, while the degree of implementation may vary largely.

3 Methodology and procedures to implement the legal framework

This section describes the way in which the two countries monitor the 'state of affairs' with regards to the legal framework described in Chapter 2 at a national level. How do they get from emissions to deposition (via concentrations) and do they then make the comparison with critical loads to determine the exceedance. How is the Habitats Directive implemented?

3.1 Natura 2000 reporting

This section describes the way in which the two countries deal with Natura 2000 reporting (every six years), in the context of Article 17 of the Habitats Directive.

3.1.1 Germany

To prepare the reports, the German federal states first collect their respective required data on habitat types and species (distribution data, monitoring, other report data). In addition to the monitoring data, biotope mapping and species registers are of particular importance. Based on this information, the Federal Agency for Nature Conservation then prepares a draft of the national report. This draft report is coordinated with the federal states under the leadership of the Federal Ministry for the Environment (BMUKN) in several evaluation conferences (along the lines of biogeographical regions), and then with the federal ministries.

3.1.2 The Netherlands

The Netherlands has submitted two reports to the EU Commission for the period 2013-2018: one based on Article 17 of the Habitats Directive, and one based on Article 12 of the Birds Directive. These Dutch reports were commissioned by the Ministry of Agriculture, Fishery, Food Security and Nature (LVVN) and carried out by Wageningen University & Research (WUR) and several species organisations. The overall process was supervised by representatives of the Ministry, provinces and the Central Bureau of Statistics. The reports are based on data and information from a broad suite of monitoring networks.

3.2 Emission reporting

This section describes the way in which the two countries set up the emission reporting under the NEC Directive and the CLRTAP for past, present and future.

3.2.1 Germany

Germany is a party to the Convention on Long-Range Transboundary Air Pollution (CLRTAP). Under the CLRTAP all parties are obliged to regularly report emission data. This data is reported annually to the executive body of the Convention, in order to fulfil obligations of the protocols under the convention. Germany publishes its reported emissions and related information in an Informative Inventory Report (IIR)[12]. Like all parties, Germany is required to submit not only annual national emissions of NO_x and NH_3, but also of SO_2, NMVOC, CO, particulate matter, various heavy metals and persistent organic pollutants (POPs), using the "Guidelines for Estimating and Reporting Emission Data" under the Convention[13]. All of Germany's reported emissions for the different air pollutants are given as national totals for a large number of source categories. In disaggregated and gridded form, they are the basis for modelling concentration and deposition with the atmospheric transport model LOTOS-EUROS used within PINETI (see section 4.1.1.3)

3.2.2 *The Netherlands*

Like Germany, the Netherlands is a party to the CLTRAP. The most recent version of the Dutch IIR is available on the site of the Pollutant Release and Transfer Register (Emissieregistratie - IIR report 2025[14]), using the same guidance documents as described for Germany. The report is commissioned by the Ministry of Infrastructure and Water and produced by RIVM in cooperation with various partner institutes. All emissions for more than 350 compounds (including the above-mentioned, see 3.2.1) are available on the website of the Emission Registration[15]. In a gridded form, these emissions are used for modelling the concentration and deposition of reduced and oxidised nitrogen with the atmospheric transport and deposition model OPS (see e.g. section 4.1.2.3).

3.3 Deposition modelling

This section describes the way in which the two countries set up their respective methodology to model nitrogen deposition for the use in national legislation.

3.3.1 *Germany*

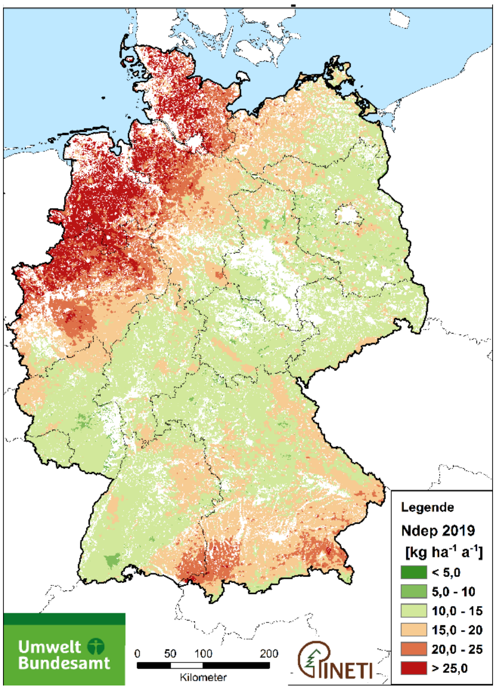
Deposition scenarios for different years in the past were calculated, based on the reported and gridded national emissions. Resulting national high-resolution maps on atmospheric deposition in Germany were created in a series of PINETI (Pollutant INput and EcosysTem Impact) projects for the UBA. The last available year for which PINETI-4 provided information was 2019. This project also provides a series of maps of nitrogen and sulphur deposition in Germany over time, for the period from 2000-2019 (until 2015 every five years, then yearly). They are based on an improved mapping procedure, and provide quantitative information on the contributions of federal state and local emissions to nitrogen deposition. The model approach of the PINETI-4 project is based on the LOTOS-EUROS model and wet deposition measurements and is described in detail in the final project documentation[16].

For a general understanding, it is important to acknowledge that the deposition of atmospheric compounds into ecosystems occurs via three pathways: dry, wet, and occult (due to fog in high altitude regions)

[12] https://iir.umweltbundesamt.de/
[13] https://www.eea.europa.eu/publications/emep-eea-guidebook-2019
[14] https://www.emissieregistratie.nl/sites/default/files/2025-04/2025-0007%20(RIVM)%20Informative%20Inventory%20Report%20(IIR)%20ER%201990-2023.pdf
[15] https://www.emissieregistratie.nl
[16] https://www.umweltbundesamt.de/publikationen/pineti-4-modelling-assessment-of-acidifying

deposition. To determine the total deposition of nitrogen, the dry, wet and occult deposition of reduced nitrogen (NH_x) and oxidized nitrogen (NO_y) are calculated and summed. Figure 4 shows the result of these calculations.
The data, with a resolution of 1x1 km², can be accessed via an UBA map-server[17] and is to be used as so-called background deposition in the permitting process.

Figure 4 Spatial distribution of the total nitrogen deposition in Germany (in kg N.ha^{-1}.y^{-1}).



3.3.2 *The Netherlands*

The nitrogen deposition map for the Netherlands is created by combining model calculations and measurement data. Calculation of both dry and wet deposition is done by means of the OPS model (Sauter et al., 2023), a langrangian dispersion and deposition model using emission data, meteorological data and information on land use as its most important inputs.

The model output is calibrated using measurement data. This is rather straightforward for wet deposition, where measured wet deposition from the national monitoring network is available for the calibration. However, dry deposition measurements are not available with sufficient coverage of the country. Therefore, concentration measurements for ammonia are used to calibrate the modelled dry deposition of ammonia. Concentrations for 300 measurement locations are interpolated by means of regression kriging (using calculated concentrations as explanatory variable). By dividing the numbers in interpolated map by those in the modelled map, a factor is obtained that is used to calibrate the modelled dry deposition map. National maps for the total nitrogen

[17] https://datahub.uba.de/server/rest/services/Lu/Hintergrund%C2%ADbelastungs%C2%ADdaten_Stickstoff/MapServer/2

deposition with a spatial resolution of 1x1 km^2 are created by combining calibrated dry and wet deposition of NH_x and NO_y.
To monitor the nitrogen deposition on the Dutch Natura-2000 sites, specific calculations are made. Instead of calculating the deposition for the entire land and water surface of the Netherlands, these specific calculations only look at the nitrogen sensitive nature/habitats within the Natura 2000 sites (see Figure 5).

Figure 5 Spatial distribution of the total nitrogen deposition on nitrogen sensitive habitats in the Netherlands (in mol N.ha^{-1}.y^{-1}) in 2022.

3.4 Mapping critical loads (and critical load exceedance)

This section describes the way in which the two countries model or derive critical loads (CLs) for use in national legislation.

3.4.1 Germany

In Germany different official sets of CL data exist.
First, there is a dataset for assessing CL exceedance on a national level. This is a nationwide dataset, based on simple-mass-balance modelling. The UBA is responsible for this dataset. Extensive documentation about the methodology can be found in the final project documentation[18].

The empirical critical loads of the CLRTAP form the second set of CLs. Their ecosystem specific validity is transferred to a biotope classification system of the federal states. These CLs are defined in LAI-Stickstoff Leitfaden and applied for project licensing only, when there is no Natura 2000 site in the proximity of the project. The responsibility lies with the environment agencies of the federal states[19].

[18] https://www.umweltbundesamt.de/publikationen/critical-load-daten-fuer-die-berichterstattung-2015
[19] https://pudi.lubw.de/detailseite/-/publication/50662

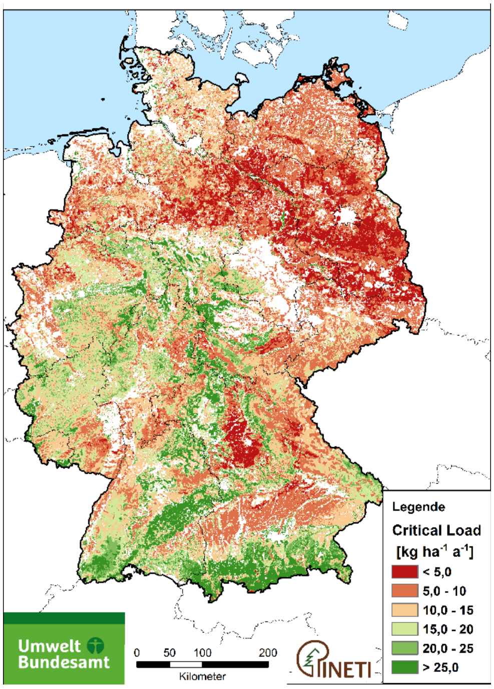
The third dataset was developed specifically for application in Nature 2000 habitats and the Natura 2000 impact assessment. The dataset comprises of nearly 2,000 predefined values of critical nitrogen deposition and different combinations of habitat-type and abiotic conditions. It was modelled in 2013 and published by the Federal Ministry for Transport[20]

For general understanding it is important to acknowledge the different approaches to assess critical thresholds for nitrogen deposition:

a) Empirical critical loads: based on studies and experiments (e.g. gradient studies, and N-addition experiments). The proposed values are published in comprehensive literature studies (the most recent were published in 2022[21]).
b) Modelled critical loads: based on presuming an ideal steady state condition of the matter fluxes in a natural or semi-natural ecosystem. For terrestrial ecosystems the most frequently used model is the so-called Simple-Mass-Balance (SMB) Model. This model approach is extensively described in the Mapping Manual of the ICP Modelling and Mapping[22].

The national CL dataset for Germany is based on the modelled CLs (SMB), which include data for land use, soil information and climate conditions. This dataset is also used for international application within the framework of the CLRTAP (Figure 6).

Figure 6 Spatial distribution of the critical loads for nitrogen for Germany (in kg N.ha^{-1}.y^{-1}).



[20] https://www.bast.de/DE/Publikationen/BerichteBASt/Fachveroeffentlichungen/Verkehrstechnik/Unterseiten/V-naehrstoffeintrag-bericht.html
[21] https://www.umweltbundesamt.de/en/publikationen/review-revision-of-empirical-critical-loads-of
[22] https://www.umweltbundesamt.de/manual-on-methodologies-criteria-for-modelling-2024

3.4.2 *The Netherlands*

The nature data used for mapping the CLs in the Netherlands are based on:

- The boundaries of the Natura 2000 sites;
- The targets per habitat type and species;
- Maps of habitats; these maps contain the present (mapped) habitat types and optionally the additional nitrogen sensitive living space of species;
- The relationship between species and living space; this describes which living space species depend on.

Mapping the different habitats is the responsibility of the provincial authorities in the Netherlands. Not all habitats are included in the CL exceedance calculations. Only nitrogen sensitive habitats of interest for the Birds and Habitats directive are included. Habitats are nitrogen sensitive when their CL is below 2,400 mol $N.ha^{-1}.y^{-1}$.

In the Netherlands, a unique CL value is available for the different Natura 2000 habitat types and the (nitrogen sensitive) other habitats of species that are protected in Natura 2000 sites. In general, the method for setting this CL value is (Wamelink et al., 2023)[23]:

- Determining per habitat whether an international empirical CL, as adopted by the UNECE in 2022, is available and whether a modelled value is available from an Alterra study[24] in 2004;
- If both empirical and modelled values are available, specifying the empirical range to a unique value by comparing it with the modelled value. This unique value is equal to the modelled value if it is within the empirical range, and equal to its lower or upper limit if the modelled value is below or above the empirical range, respectively;
- If no empirical CL is available, setting the CL as equal to the modelled value (in some cases modified using expert opinion);
- If no modelled CL is available, setting the CL as equal to the midpoint of the empirical range (in some cases modified using expert opinion);
- If both empirical and modelled CLs are unavailable, basing a critical load on expert opinion;
- If neither empirical, simulated or expert-based CLs are available, assigning no critical load. This means a type is considered insensitive to nitrogen deposition.

The resulting distribution of the critical loads in the Netherlands is shown in Figure 7.

[23] https://research.wur.nl/en/publications/overzicht-van-kritische-depositiewaarden-voor-stikstof-toegepast-/
[24] https://research.wur.nl/en/publications/simulation-of-critical-loads-for-nitrogen-for-terrestrial-plant-c/

Figure 7 Spatial distribution of the critical loads in the Netherlands (in mol $N.ha^{-1}.y^{-1}$) for the Dutch Natura 2000 sites.

3.5 Natura 2000 Permits

This section describes the way in which the two countries deal with permits related to individual sites/nature areas in the context of the Habitats Directive.

3.5.1 Germany

There is a consensus that long-term anthropogenic nitrogen inputs, even at low doses, can lead to eutrophication and acidification of sensitive habitats. This can have a negative impact on the biodiversity of habitats in Natura 2000 sites (in German also referred to as 'Flora-Fauna-Habitat', FFH, sites). Therefore, as part of the planned projects for Natura 2000 impact assessment, it must be examined whether nitrogen emissions could have significant negative impact on Natura 2000 sites. The application of the best scientific knowledge is a legal requirement for the Habitats Directive assessment. This also applies to possible adverse effects caused by nitrogen inputs. In Germany, CLs for eutrophying and acidifying nitrogen inputs, and subordinately Critical Levels (CLes) for critical air concentrations of ammonia, are used as suitable benchmarks for describing the nitrogen sensitivity of ecosystems.

According to the Federal Nature Conservation Act (FNCA[25]), projects must be assessed for their compatibility with the conservation objectives of a Natura 2000 site before they are authorised or implemented. According to Article 34 of the FNCA a project is inadmissible when this compatibility assessment reveals that the project – either individually or in combined with other projects or plans – could have a significant

[25] Bundesnaturschutzgesetz

negative impact on the site, in terms of its conservation objectives or the conservation purpose.

To determine whether a project could have a significant negative impact on a Natura 2000 site a case-by-case nature conservation assessment which considers the specific local conditions and conservation objectives is required. As with other impact factors, the possible effects of nitrogen inputs and their respective significance must be assessed separately for each individual protected site or conservation objective. The assessment is therefore carried out separately for each individual habitat type and for each identified Annex II plant species considered to be relevant for the assessment. Joint processing is possible, if it has been clearly justified that the summarised species or habitat types behave in the same way with regard to the impact factors relevant to the assessment.

The scale of CLs is of particular importance for the assessment of eutrophying or acidifying nitrogen inputs in the Habitats Directive impact assessment. CLs represent scientifically based pollution limits. If the total deposition remains below the relevant CLs, significant adverse effects can be ruled out with certainty. CLs make it possible to provide a quantified basis for the Natura 2000 assessment. The CL data used in the impact assessment are habitat-specific values, defined specifically for this purpose[26]. It is important to note, that they differ from the large-scale modelled CLs for national reporting and the eutrophication indicator presented in Section 3.4, which cannot account for site-specific conditions due to the coarse resolution of the input data.

Specifically, three main approaches (a, b and c) can be conducted to determine whether a project can be authorised regarding its nitrogen input into an FFH (Natura2000) habitat type[27]. These three approaches exist side by side and do not have to be done in the given order. If one of the assessment approaches leads to the conclusion that the project is not problematic, no further assessments are required, as no significant adverse effects due to nitrogen input are to be expected.

a) If the total nitrogen deposition resulting from the background and the project specific emission do not exceed the habitat specific CL. This approach is based on the consideration that the CL defines nitrogen inputs below which long-term negative changes to the respective habitat types can be ruled out.
b) If the nitrogen deposition related to the project into the habitat falls below the absolute cut-off criterion (amounting to 0.3 kg $N.ha^{-1}.y^{-1}$), the project is not problematic and can be authorised. This approach is based on the consideration that very small additional quantities of nitrogen input cannot be regarded as the cause of a negative change in the context of the total input of nitrogen in Germany. The cut-off criterion was technically validated[28] and recognised by the Federal Administrative Court.
c) For reasons of proportionality a project can still be approved, if the total deposition together with other cumulative plans and

[26] Publikationen - Untersuchung und Bewertung von straßenverkehrsbedingten Nährstoffeinträgen in empfindliche Biotope - BASt
[27] https://www.lai-immissionsschutz.de/documents/stickstoffleitfaden_2019_02_19_1558083308.pdf
[28] https://www.afsv.de/images/download/literatur/waldoekologie-online/waldoekologie-online_heft-14-3.pdf

projects to be taken into account does not exceed the relevant CL by more than 3 %. To ensure that this instrument does not lead to significant impairment of the habitat type due to a large number of individually small nitrogen inputs that lead to significant deposition when added up, not only must further future pressure resulting from ongoing project plans be included in the cumulation at this point, but also all previous pressure from additional projects since the Natura 2000 site was listed. The so-called *de minimis* threshold may only be used after the Natura 2000 site was placed under protection.

In addition, for installations emitting ammonia compliance with the ammonia critical levels (CLes), as defined in the Mapping Manual of the ICP Modelling & Mapping, must also be checked. However, this is limited to cases in which lichens or mosses are affected as characteristic species of the habitat under consideration (assuming a CLe of 1 $\mu g.m^{-3}$) or in which the CLs of the affected biotopes exceed 12 kg $N.ha^{-1}.y^{-1}$ in open land and 16 kg $N.ha^{-1}.y^{-1}$ in forests (assuming that the CLe of 3 $\mu g.m^{-3}$ is more sensitive criterion in comparison to the relevant CL[29]).

These specifications were developed in federal state working groups under the leadership of the Federal Highway Research Institute and the federal state working groups on air quality control and nature conservation. The main features of the specifications are also set out in the administrative regulation TA Luft Annex 8, while the details are documented in guidelines[30]. The project applicant is responsible for the implementation of the assessment and provides the documents to the authorising authority in the federal states.

3.5.2 *The Netherlands*

Similar to Germany, there is also a consensus in the Netherlands that nitrogen can have a negative impact on ecosystems. New plans or projects have to be assessed with respect to their potential significant effects on N2000 areas in both countries. The Dutch interpretation of the Habitats Directive article 6 is rather similar to the German one, but the actual application is different. There are a few key points related to the Dutch legal interpretation and application of art. 6 of the Habitats Directive:

- if the actual deposition at the locations of interest is larger than the critical nitrogen load: additional nitrogen deposition has to be assessed together with existing exceedance;
- this also holds for locations where the background deposition is 70 $mol.ha^{-1}.y^{-1}$ below the critical nitrogen load;
- (significant) negative effects cannot be excluded only because the additional deposition is (very) small;
- even an additional 0.01 mol (= 0.14 g) can cause deterioration -> appropriate assessment needed;

[29] The critical level for higher plants of 3 $\mu g\ m^{-3}$ was converted into comparable nitrogen deposition values using the deposition rates specified in VDI Guideline 3782, Sheet 5 for grass (1.5 cm s^{-1}) and forest (2 cm s^{-1}).
[30] FGSV - Forschungsgesellschaft für Straße- und Verkehrswesen (2019). Hinweise zur Prüfung von Stickstoffeinträgen in der FFH-Verträglichkeitsprufung für straßen; LAI-LANA (2019) Hinweise zur Prüfung von Stickstoffeinträgen in der FFH-Verträglichkeitsprüfung für Vorhaben nach dem Bundes-Immissionsschutzgesetz - https://www.lai-immissionsschutz.de/documents/stickstoffleitfaden_2019_02_19_1558083308.pdf

- currently there is no deposition threshold (only a technical lower limit of 0.005 $mol.ha^{-1}.y^{-1}$ - rounded to 0.01 $mol.ha^{-1}.y^{-1}$);
- for individual projects, deposition is calculated up to 25 km from the source.

Some consequences of these points are that:
- in general, permitting and accepting plans which cause nitrogen emissions are only possible if netted out by reductions elsewhere (after deduction of 30%) (sald(i)eren);
- this netting out can be internal (within the project) or external (with other existing activities)
- following a court ruling of 18 December 2024[31], this system of netting out is only allowed if it has been proven that reductions are not required as conservation measures (art. 6.1) or preventive measures (art 6.2) -> ‘principle of additionality’.

Current state in the Netherlands:
- Since the court ruling of 18 December 2024, requirements for external and internal netting out are now equal. This means that a new permit is also required for internal netting. This was already the case for external netting.
- Currently the technical lower limit is investigated / under political debate[32]: a proposal aims to raise this limit from the rounded value of 0.01 $mol.ha^{-1}.y^{-1}$ to 1 $mol.ha^{-1}.y^{-1}$.
- There are different buy-out schemes for farms in place. Financial (over)compensation of up to 120% of the value is offered for farmers terminating their activities on a voluntary basis.
- Also the use of the CL is subject of political debate. It is proposed to remove the CL from the law and replace it with an alternative. However, this doesn’t directly influence the permitting procedures.

[31] Rechtspraak over intern salderen wijzigt - Raad van State
[32] Voortgang op de wetswijziging alternatief voor de KDW en de rekenkundige ondergrens

4 Situation in Germany and the Netherlands

The overall methodology used in both countries to monitor progress with respect to the Habitats Directive, and more in particular the exceedance of critical loads, was described in the previous chapter. Building blocks for monitoring this progress are current and future emissions, concentrations, deposition, habitats and CLs & CLes. This chapter gives an overview on a national scale of the historical and future situation with respect to the different items.

4.1 From past to present

This section offers an overview of how things evolved over time in Germany and the Netherlands; how have emissions, concentrations and depositions (either measured or modelled) changed as a result of various policies.

4.1.1 Germany

4.1.1.1 Emission

The results for the German emission reporting are also documented in detail in the German Informative Inventory Report[33]. The following texts about NO_x- and NH_3-emissions to a larger extent are copied from this report.

Nitrogen oxides (NO_x)
Within the scope of the NO_x Protocol of the CLRTAP, the Federal Republic of Germany was obliged to reduce emissions of NO_x to the 1987 level of 3,177 ktonnes by 1994. However, this value is inconsistent with the time series data after 1990 because at that moment (1994) emissions from the agricultural sector were not recorded and reported yet. Emissions were successfully reduced by close to 30% to 2,255 ktonnes in this period, exceeding the obligatory requirements of the protocol and also meeting the additional voluntary commitment that was entered into by Germany and 11 other ECE countries (reduction of NO_x emissions before 1998 by 30% compared to 1986 levels).

More recently, Germany has made commitments under the multicomponent protocol to further minimise NO_x emissions. In the first version of the protocol, the objective for Germany was to comply with a National Emission Ceiling of 1,081 ktonnes NO_x for Germany as a whole by 2010. The revised second version of the Gothenburg Protocol and the revised NEC Directive both define emission reduction targets relative to a 2005 base year, mandating 39% (by 2020; Gothenburg Protocol) and 65% (by 2030; NEC Directive) reductions respectively.

NO_x total emissions show a falling trend from 1990 onwards, with emission reductions of 66% between 1990 and 2021 and steadily falling emissions in the last years.

The main driver for NO_x emissions is fuel combustion (NFR 1.A) with over 91% of 1990 emissions and a 69% reduction from 1990 to 2021.

[33] https://iir.umweltbundesamt.de/2025/start

More than half of the 1990 emissions from fuel combustion (NFR 1.A). A similar reduction (-76%) between 1990 and 2021 in these emissions comes from road transport (NFR 1.A.3.b), mainly due to constantly improving fuels and increasingly strict regulations, resulting in technical improvements.

The rest of the 1990 emissions mainly comes from energy industries (NFR 1.A.1) with a 24% share of 1990 fuel combustion (NFR 1.A) emissions and a 62% reduction between 1990 and 2021. To a lesser extent NO_x emissions stem from manufacturing industries and construction (NFR 1.A.2) with a 12% share and 73% reduction between 1990 and 2021. The NO_x emissions of the agricultural sector (NFR 3) were reduced by 26% between 1990 and 2021. While the contribution of agriculture to the NO_x emission was 5% in 1990, it amounts to nearly 12% in 2021.

Figure 8 Spatial distribution of the NO_x emissions in 2021 in Germany (submission 2023, Greta-version 1.2.0.1).

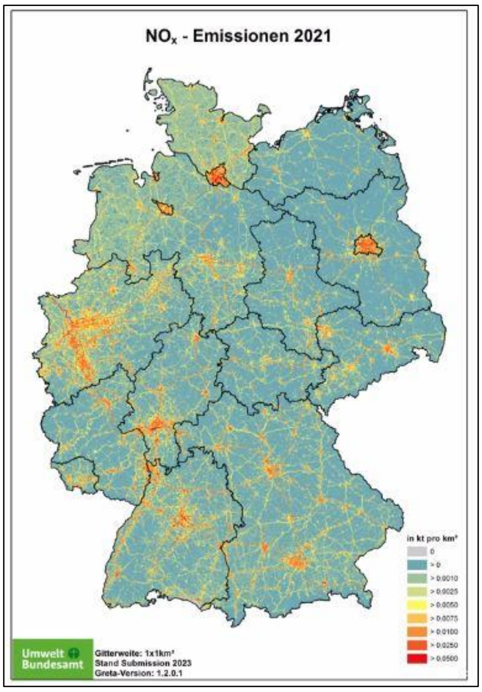
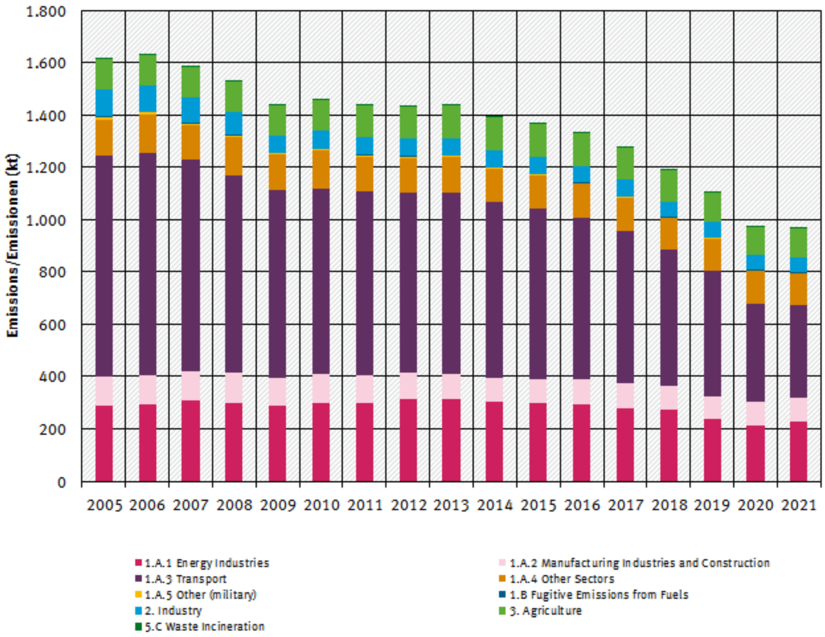


Figure 9 Contribution of different economic sectors to the total NO_x emission in Germany for the period 2005-2021.



NO_x-Target NEC-Directive: 65% compared to 2005 (560 ktonnes)

Ammonia (NH_3)

Germany has made a commitment under the Gothenburg Protocol to reduce ammonia emissions. Since 2010, it is no longer allowed to exceed a national emission ceiling of 550 ktonnes NH_3 for Germany as a whole. The revised Gothenburg Protocol and the revised NEC Directive both define emission reduction targets relative to a 2005 base year, mandating 5% (2020) and 29% (2030) reductions respectively.

The main drivers for NH_3 emissions are agricultural emissions from manure management (NFR 4.B) with 43% of total 1990 emissions and a 30% reduction between 1990-2021 and agricultural soils (NFR 4.D) with 53% of total 1990 emissions and a 31% decrease.

The overall emission trend follows the agricultural emissions closely, with a total reduction of 29% since 1990.

The decrease of the NH_3 emission in the year 1991 is due to a reduced livestock population following the German reunification, while no explicit trend is discernible for the years up to 2016. Between 2016 and 2021 the emissions are going down every year, adding up to a 15% drop. Here, emissions dropped by 9.7% between 2019 and 2020, a decrease only topped by the reduction between 1990 and 1991 (minus 11%).

Figure 10 Spatial distribution of the total ammonia emission for 2021 in Germany (submission 2023, Greta-version 1.2.0.1).

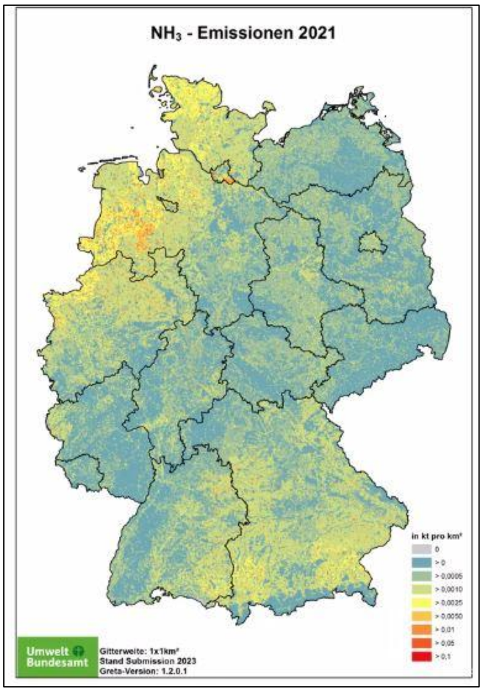
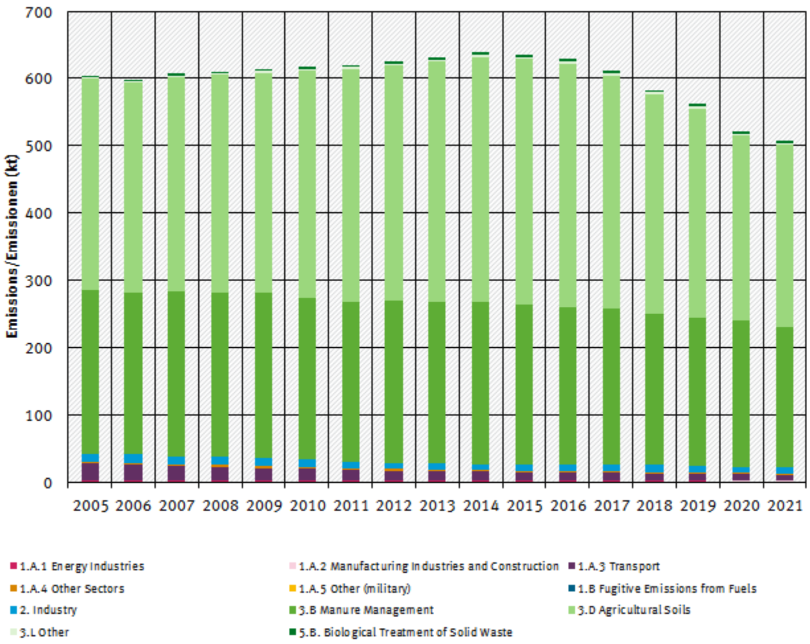


Figure 11 Contribution of different economic sectors in the total ammonia emission in Germany for the period 2005-2021.



4.1.1.2 Concentration

Nitrogen dioxide (NO_2)

Nitrogen dioxide is regulated under the EU Air Quality Directive and thus measured systematically by the German Environment Agency and all Federal States across Germany at about 600 stations. Figure 12 shows the overall decreasing trend of nitrogen dioxide at all three types of measurement stations in the rural background and at traffic stations. In 2024 at none of the stations the current limit value of 40 $\mu g.m^{-3}$ was exceeded (Figure 13)

Figure 12 Trend of yearly averaged NO_2 concentration for the period 2000-2024 in Germany. Data trend is based on the reported measurement data of the Länder networks (measurement obligation in the context of the Air Quality Directive)[34].

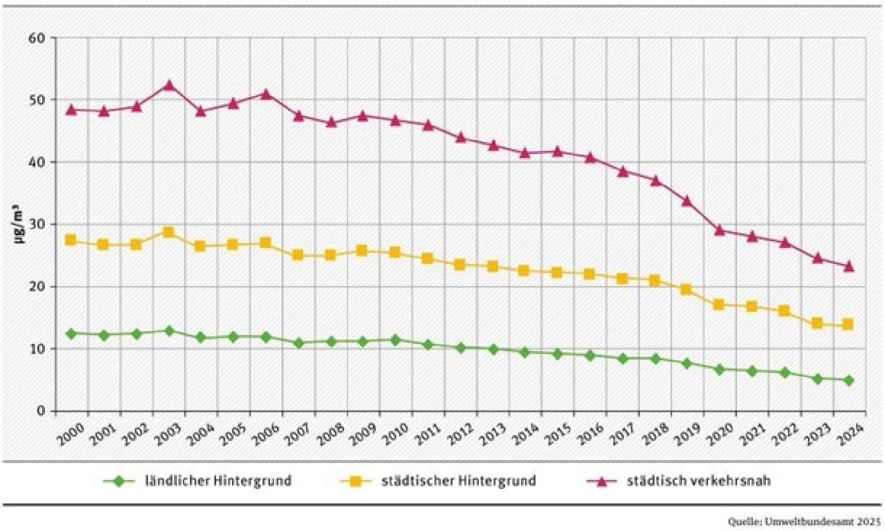
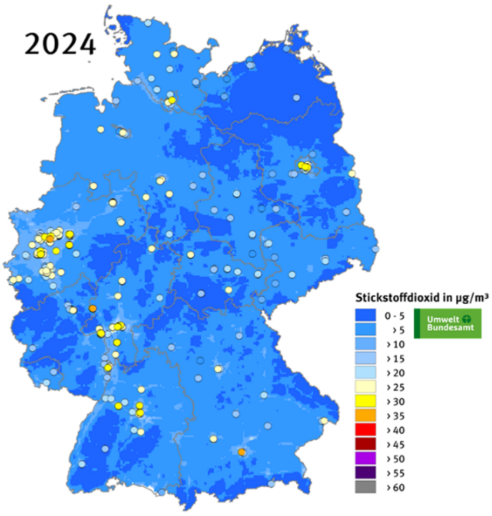


Figure 13 Spatial distribution of the 2024 average NO_2 concentrations in Germany. The map is based on RCG modelled data and assimilation of hourly measurement of background stations (optimal interpolation)[35].



34 https://www.umweltbundesamt.de/publikationen/luftqualitaet-2024
35 https://www.umweltbundesamt.de/daten/luft/stickstoffdioxid-belastung#belastung-durch-stickstoffdioxid

Ammonia (NH_3)
For ammonia there is no reporting regulation under the EU Air Quality Directive. Therefore, there is no systematic measurement network across the Federal Republic of Germany. However, some Federal States do monitor NH_3 concentrations at selected sites. Trends from such measurement sites are shown in Figure 14. The ammonia concentration between 2010 and 2019 does not show a particular trend. Besides the measurements, ammonia concentration is modelled with the LOTOS-EUROS model within the PINETI-Project framework. The map in Figure 15 shows the modelled distribution of the NH_3 concentration across Germany for the year 2019.

Figure 14 Trend of ammonia concentrations from 2010-2019, collected from all available measurement stations in Germany for rural regions (top panel) and rural remote regions (bottom panel). Green and red bars mark the UNECE NH_3 critical levels.

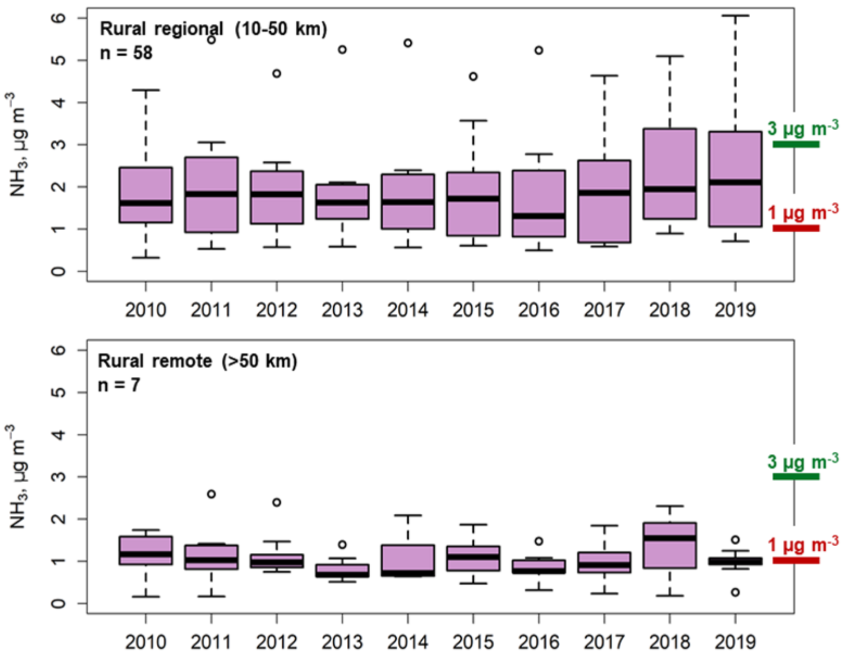
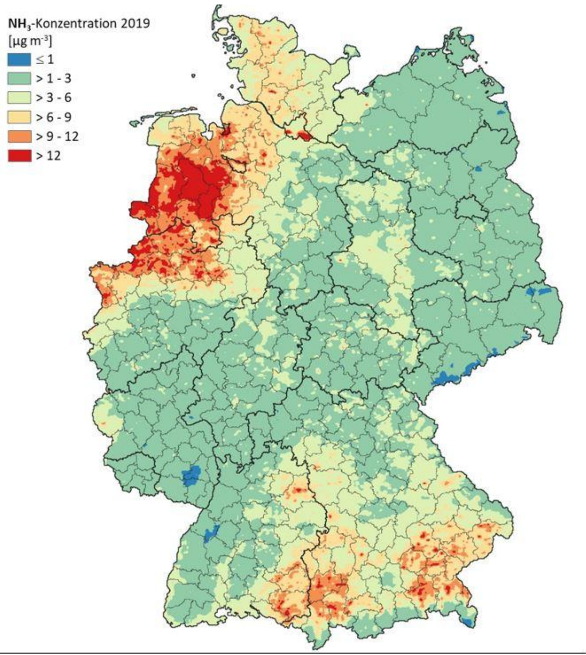


Figure 15 Spatial distribution of ammonia concentration for the year 2019 in Germany. Based on model calculations by the Lotos-Euros model, using reported national emissions and gridding with the GRETA tool; international emissions based on CAMS emission data (TNO)[36].



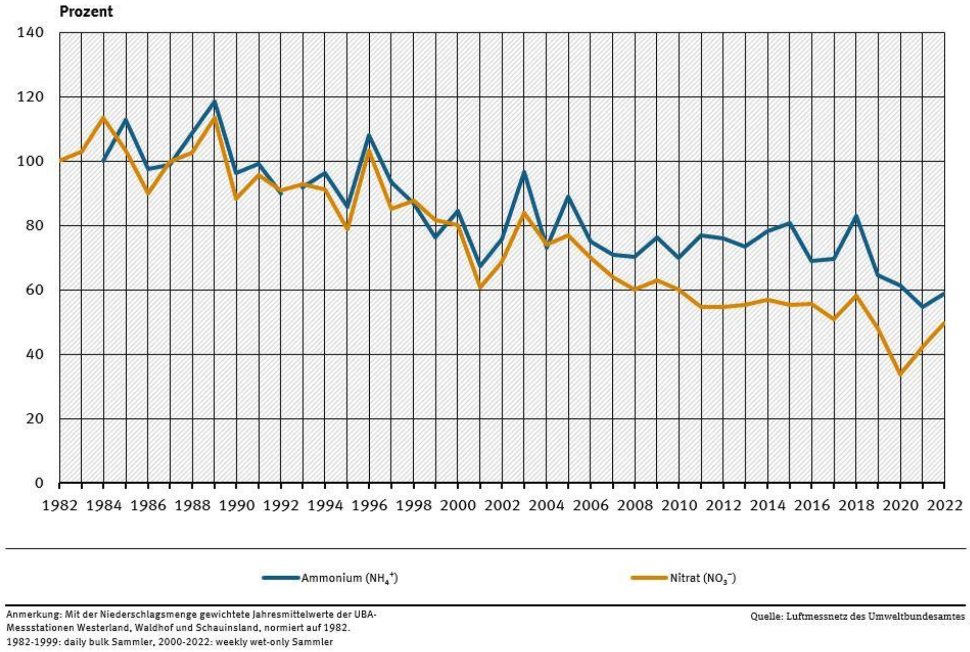
a 1 km x 1 km Rasterzellen des GeoGitterDE (BKG 2020)
Quelle: eigene Darstellung, Ingenieurbüro Dr. Eckhoff (IBE); Kartengrundlage: © Geo-BasisDE / BKG 2020.

36 https://www.umweltbundesamt.de/publikationen/entwicklung-einer-nationalen-regional-aufgelosten

NO_3^- and NH_4^+ concentration

The Air Monitoring Network of the German Environment Agency operates seven measuring stations far away from densely populated areas and cities to monitor long-range and transboundary air pollution. The trend of nitrate and ammonium concentration in precipitation is shown in Figure 16. A slow but more or less continuous downward trend of nitrogenous air pollutants in precipitation is illustrated over the past 40 years.

Figure 16 Normalized trend (1982 = 100) in ammonium and nitrate concentrations in precipitation in the period 1982-2022 in Germany[37].



4.1.1.3 Deposition

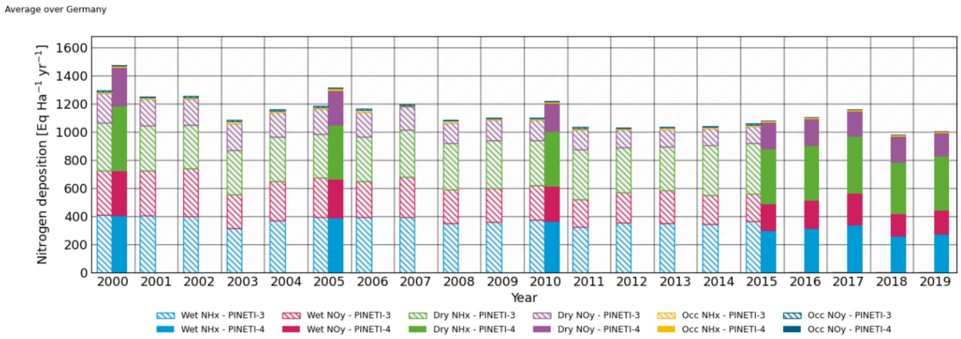
Text from the PINETI-4 report[38]: Modelling and assessment of acidifying and eutrophying atmospheric deposition to terrestrial ecosystems

Annual average depositions of nitrogen for 2015 up to and including 2019 are shown in Figure 14. Between 2015 and 2017 total deposition increases from 15.1 kg $N.ha^{-1}.yr^{-1}$ to 16.2 kg $N.ha^{-1}.yr^{-1}$ (1,080 $eq.ha^{-1}.yr^{-1}$ to 1,160 $eq.ha^{-1}.yr^{-1}$), while 2018 and 2019 show a decrease to values around 14 kg $N.ha^{-1}.yr^{-1}$ (1,000 $eq.ha^{-1}.yr^{-1}$). The time series show specified values for dry, wet and occult deposition for both NH_x and NO_y. NH_x contributes approximately 60% to the total N deposition, while NO_y contributes 40%. For NH_x, dry deposition is the most important pathway (~60%), while dry and wet depositions for NO_y have an equal share. Occult deposition has a small contribution for both NH_x and NO_y. Looking at the trend, 2018 and 2019 have a significant lower total deposition compared to the first three years. As shown in Emissionsection 4.1.1.1, in the period 2000-2019 emissions are lowest

[37] https://www.umweltbundesamt.de/daten/luft/nasse-deposition-saurer-saeurebildender#erfassung-der-nassen-deposition
[38] https://www.umweltbundesamt.de/publikationen/pineti-4-modelling-assessment-of-acidifying

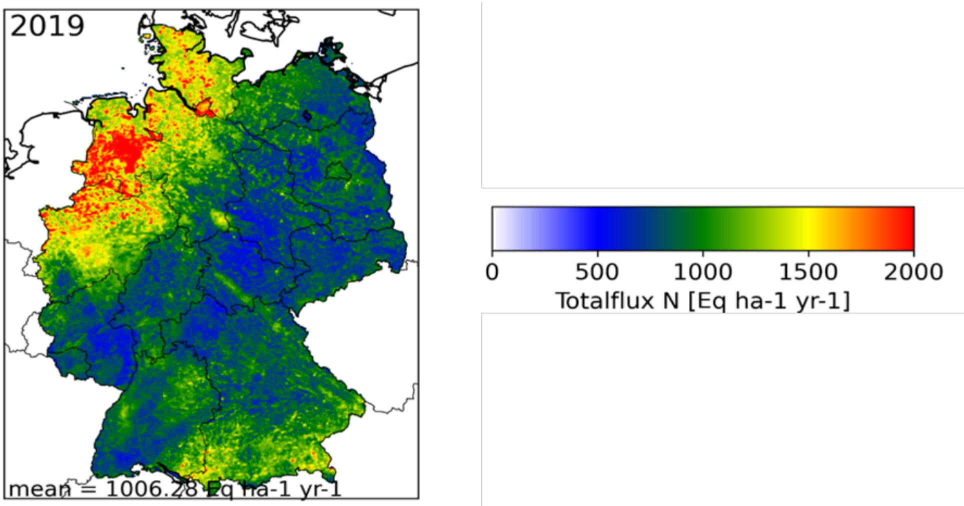
for 2018 and 2019. Meteorological circumstances with significantly less precipitation in those years also contribute to lower depositions.

Figure 17 Deposition trend between 2000 and 2019 in Germany according to PINETI-3 and update following more recent PINETI-4 calculations. PINETI-4 results in solid bars, PINETI-3 results in shaded bars.



Source: TNO

Figure 18 Spatial distribution of the nitrogen deposition in Germany for 2021.

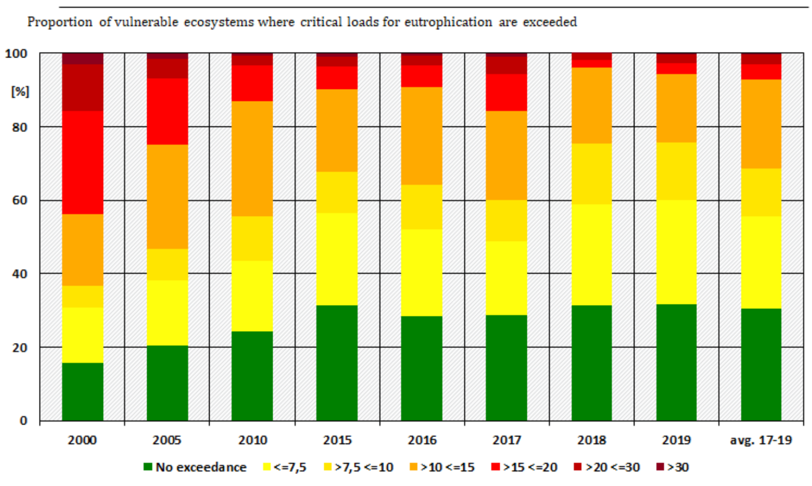


4.1.1.4 Critical Load Exceedance

Applying the national CL dataset the exceedance of CLs for several years in the past was calculated. The resulting exceedance data is used as indicator in Germany's National Sustainable Development Strategy[39]. Figure 19 shows the trend of the share of ecosystems with exceedance of the critical load for eutrophication. With the Sustainable Development Strategy, the Federal Government aims to reduce the proportion of these areas by 35% in 2030 in reference to 2005. According to the current calculation basis, this results in a target value of 52% with no exceedance by 2030.

[39] https://www.umweltbundesamt.de/en/data/environmental-indicators/indicator-nitrogen-eutrophication#assessing-the-development

Figure 19 Trend of CL exceedance in Germany based on PINETI-4 modelling results.



4.1.2 The Netherlands

4.1.2.1 Emission

The most important nitrogen emissions to the atmosphere are related to NO_x (nitrogen oxides) and NH_3 (ammonia) sources. The emission trends of these two compounds in the Netherlands are shown below.

Nitrogen Oxides (NO_x)
For the period 2020-2029 a NEC emission reduction target of 45% compared to 2005 holds. Since 2005 the emission of NO_x decreased with 56% (see Figure 20). Therefore, the reduction target for that period is met. For the period after 2030, there is a reduction target of 61%, which is not met with the current level of reduction.

During the period 1990-2021 NO_x emissions decreased from 629.0 ktonnes NO_x to 177.8 ktonnes (-72%). This is mainly the result of setting emission restrictions for passenger cars and heavy goods vehicles (Euro-standards) and a reduction in the use of coal in the energy sector. Various other measures have also led to reduced emissions, such as using selective catalytic reduction in industry, refineries and the energy sector, improving insulation in housing and other buildings, and increasing the use of high efficiency boilers. Figure 21 shows the spatial distribution of the NO_x emissions, clearly showing higher emissions in urban areas and around the roads network.

Figure 20 Trend in Dutch nitrogen oxides emissions (in ktonnes) per sector in the period 1990-2022.

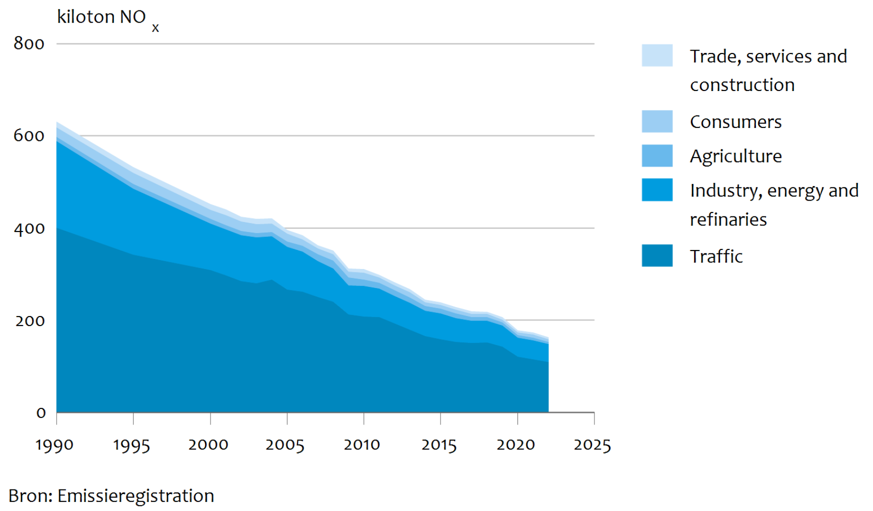
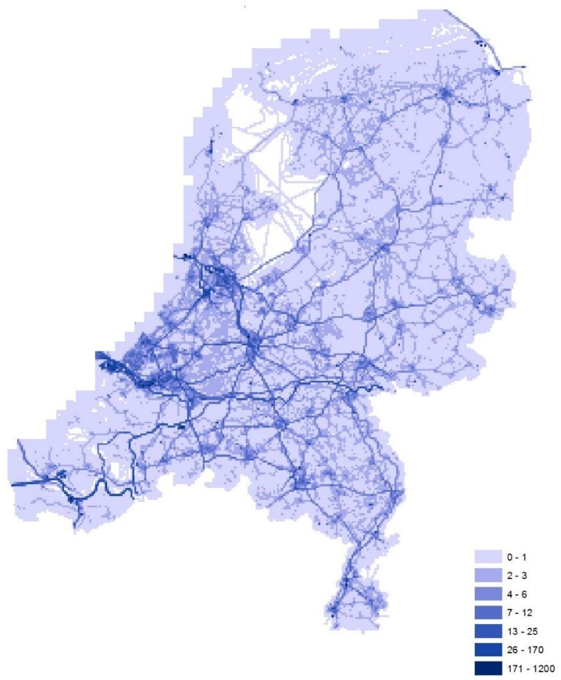


Figure 21 Spatial distribution of the NO_2 emissions (in ktonnes.km^{-2}) in the Netherlands in 2022.



Ammonia (NH_3)

For the period 2020-2029 a NEC emission reduction target for ammonia of 13% compared to 2005 was agreed on in the Netherlands. Since 2005, the emission of NH_3 decreased by 21% (see Figure: 22). Therefore, the reduction target for that period is met. For the period after 2030 there is a reduction target of 21%, which will not be met with the current reduction level.

Since 1990 NH_3 emissions decreased from 344.5 ktonnes NH_3 to 121.9 ktonnes (-65%). The decrease in the period 1990-2013 is the result of a decrease in livestock numbers, reduced protein in animal feed, covering of manure storages, low emission spreading of manure and low emission housing of animals. The largest contribution to the reduction came from the implementation of low emission spreading methods.

Between 2014 and 2017 there was an increase in the emission of ammonia, after a long period of decreasing emissions. The two main reasons for this increase were an increase in the number of dairy cattle and changing feed composition for livestock. This increase was partly balanced by cleaner housing systems for pigs and poultry.

From 2018 ammonia emissions went down again, as a consequence of a reduction in the number of dairy cattle, pigs and poultry, the increased use of mainly low emission pig housing systems and the obligatory dilution of manure for spreading on clay and peat grassland. The spatial distribution of the ammonia emissions is shown in Figure 23. The regions with intensive livestock farming are clearly visible in the map.

Figure: 22 Trend in Dutch ammonia emissions (in ktonnes) per sector in the period 1990-2022.

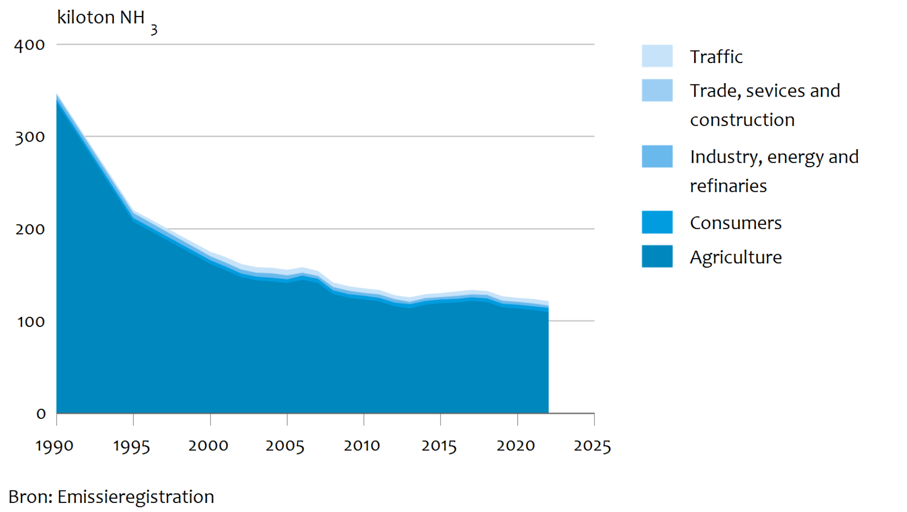
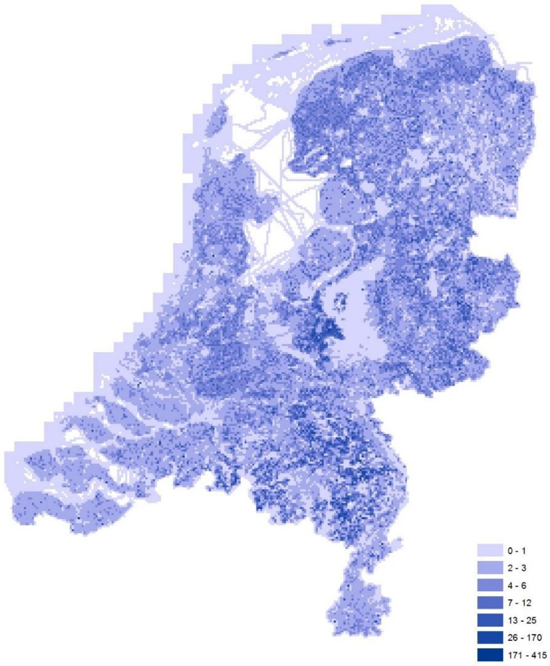


Figure 23 Spatial distribution of the ammonia emissions (in ktonnes.km^{-2}) in the Netherlands in 2022.



4.1.2.2 Concentration

Nitrogen dioxide (NO_2)

In the period 1992-2023 the NO_2 concentrations at regional/rural background measurement stations decreased from a national average of 25 µg.m^{-3} to 10 µg.m^{-3} (Figure 24). At rural background stations the concentrations decreased from 43 µg.m^{-3} to 16 µg.m^{-3}, while at measurement stations located near traffic the average concentration decreased even further (from 49 to 21 µg.m^{-3}).

The measured average concentrations of NO_2 were lower in 2020 than could have been expected, based on the long-term trend. Concentrations in 2021 and 2022 were similar to those in 2020. These lower concentrations were mainly due to COVID-19 measures taken in those years, which mainly led to a reduction in the amount of traffic.

Figure 24 Trend in annual average concentrations (in µg.m^{-3}) at regional background, urban background, and road traffic measurement locations in the Netherlands in the period 1990-2022.

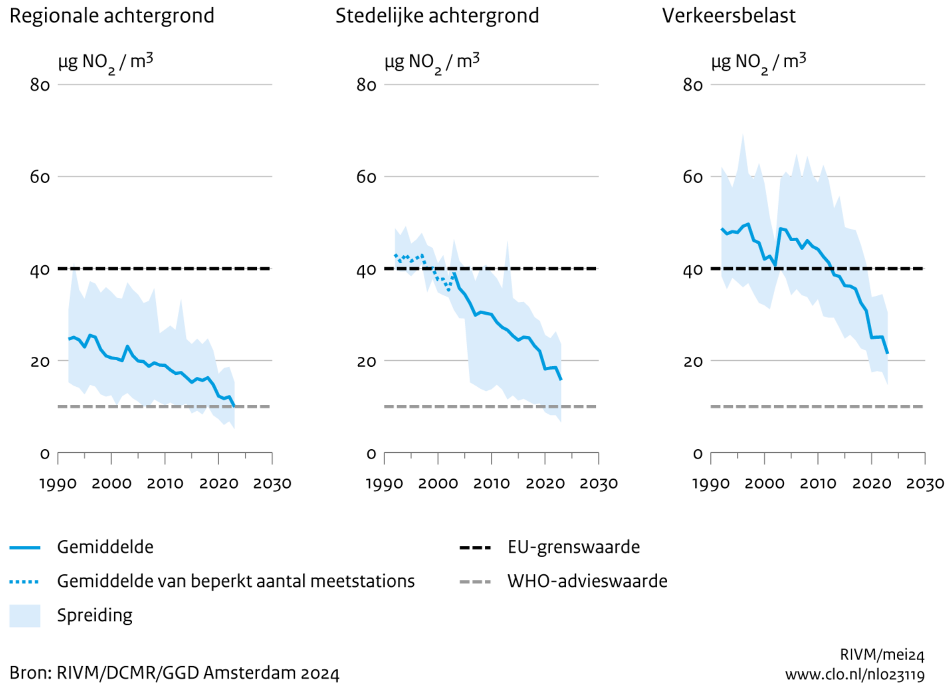
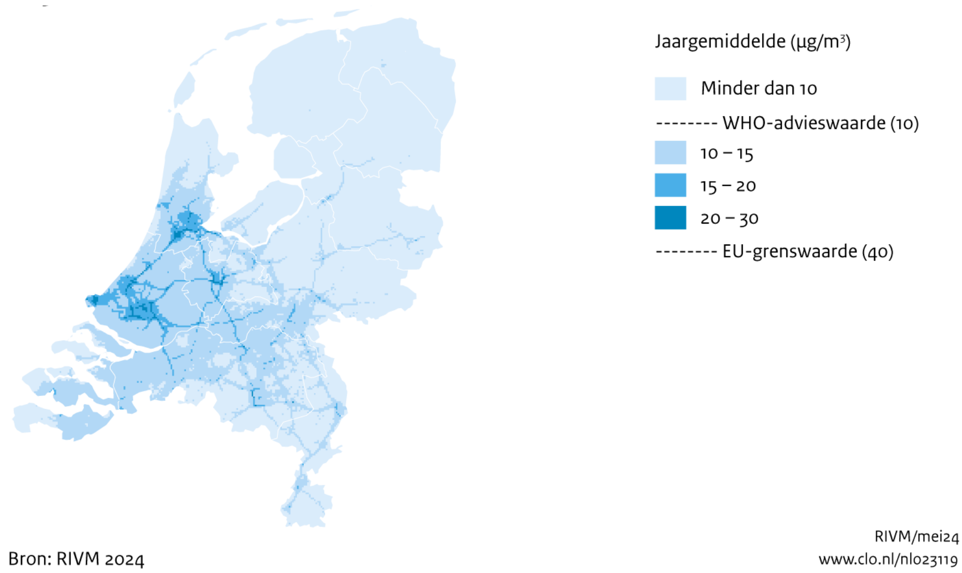


Figure 25 shows a map for 2023 with the spatial distribution of the modelled annual average NO_2 concentrations.

Figure 25 Spatial distribution of modelled annual average NO_2 concentrations (in µg.m^{-3}) in the Netherlands in 2022.



Ammonia (NH_3)

At eight measurement stations of the National Monitoring Network Air Quality RIVM measures the ammonia concentrations in the air using advanced equipment (miniDOAS). Additionally, the concentration is measured using simpler equipment (passive samplers) at more than 300 locations in more than 80 Natura 2000 areas. These samplers measure the monthly mean concentration of ammonia in the air.

To follow the concentration trend for ammonia in time, the measurement results of the 8 advanced stations are combined with the measurements at 27 passive sampler locations. These 35 stations in total have been in use for the entire period since 2005. By using only these 35 stations, a consistent picture of the concentration trend can be constructed (Figure 26). In 2022, the average concentration at these 35 locations was 6.7 $\mu g.m^{-3}$. The variation in the annual average concentrations in the previous years can be almost entirely explained by differences in meteorological conditions in these years. In 2018 and 2019, ammonia concentrations were considerably higher than the year before. This is mainly due to the warm, sunny and dry weather conditions in those years. Overall, there is a slight increase in the average concentration in the period 2005-2022. This is not necessarily the result of increasing emissions, but more likely caused by changing atmospheric chemistry conditions (see next section on aerosols for a further explanation).

The ammonia concentrations for the Netherlands model calculations are used as a basis for constructing the spatial distribution. The model results are calibrated yearly, using measured concentrations. The map shows the highest concentrations in areas with high emissions (see Figure 27). Along the coastline concentrations are low, due to relatively clean air entering the country there.

Figure 26 Trend of measured ammonia concentration in the air (in $\mu g.m^{-3}$) at 35 locations in the Netherlands in the period 2005-2022.

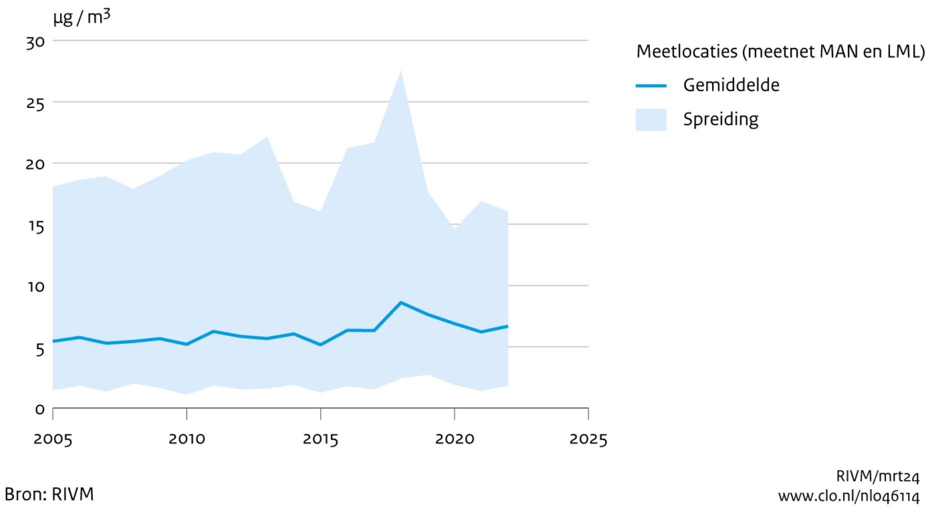
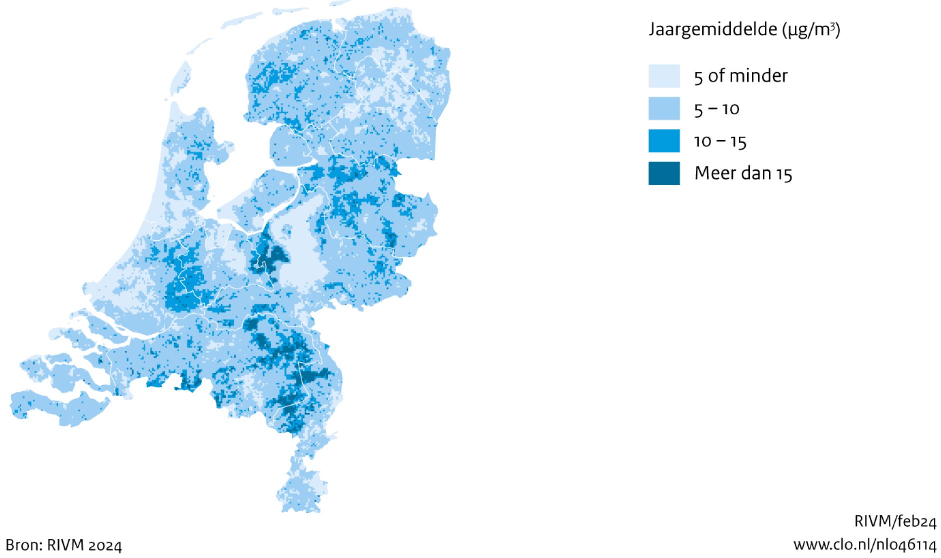


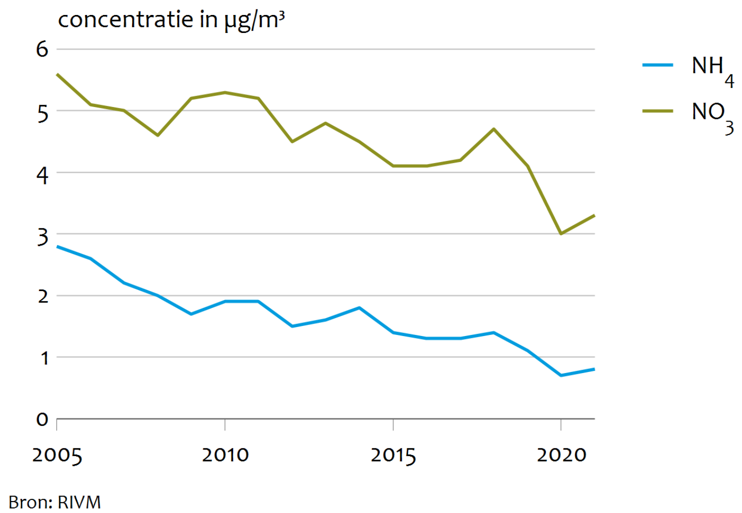
Figure 27 Spatial distribution of the calibrated modelled annual averaged ammonia concentration (in µg.m^{-3}) in the air in the Netherlands in 2022.



Nitrogen aerosols (NO_3^- and NH_4^+)

Besides NO_2 and NH_3 concentrations in the air, nitrogen aerosols (ammonium and nitrate) are also measured. This is done at five locations in the Netherlands. The trend in these concentrations for the period 2005-2022 is shown in Figure 28. Both nitrogen compounds show a clear decrease over time. The ongoing decrease in gaseous NO_2 concentrations is directly linked to the decrease of NO_3^- aerosols in the air. This then also reduces the formation of ammonium nitrate. Because the conversion of ammonia to ammonium is limited by this, overall gaseous ammonia will stay in air longer before being converted to ammonium. To a large extent, this change in the conversion rate is the reason for the increasing trend in ammonia concentration.

Figure 28 Trend of average concentration of measured nitrogen aerosols in the air (in µg.m^{-3}) in the Netherlands in the period 2005-2021.

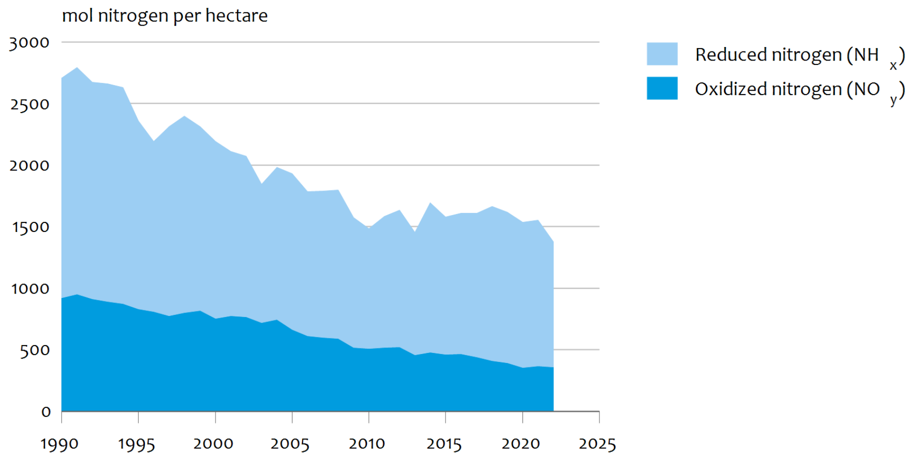


4.1.2.3 Deposition

Figure 29 shows the trend in the nitrogen deposition in the period 1990-2022. The average nitrogen deposition in the Netherlands in 1990 was more than 2,700 $mol.ha^{-1}.y^{-1}$. The deposition decreased to circa 1,500 $mol.ha^{-1}.y^{-1}$ in 2010. Since then, nitrogen deposition only decrease slightly, mainly because the deposition of reduced nitrogen has decreased since 2020, after an increase since 2010. The deposition of oxidised nitrogen did decrease in the period 2010-2022. Due to meteorological conditions, year to year variations of around 10% in the deposition can occur.

The decrease of nitrogen deposition in the period 1990-2022 was caused by lower emissions of both nitrogen oxides and ammonia (see before).

Figure 29 Trend of the average nitrogen deposition in the Netherlands (in $mol.ha^{-1}.y^{-1}$) in the period 1990-2022.

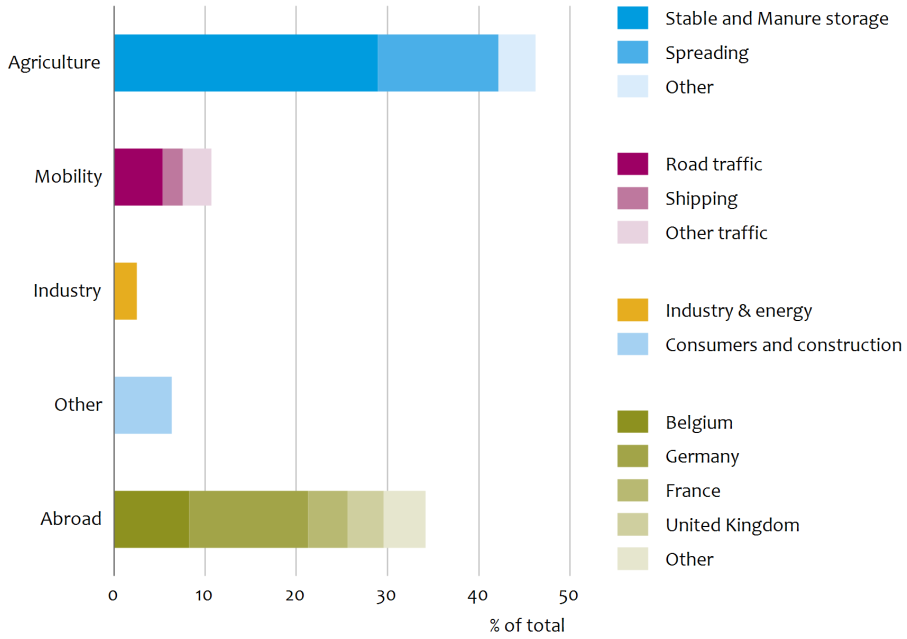


Bron: RIVM, 2023

The contribution of all Dutch sources to the average calculated nitrogen deposition on nitrogen sensitive nature in Natura 2000 areas in the Netherlands is 71% for 2022. The remaining 29% of nitrogen deposition comes from emission sources abroad (import). The nitrogen deposition is largely (46%) caused by Dutch agricultural sources. Other domestic contributors are road traffic (5%), consumers, and construction (6%). When only Dutch sources are considered, the contribution of agriculture is 71%. Agriculture is also the main emission source for the foreign contribution to nitrogen deposition in the Netherlands.

Besides the average deposition as a result of the known Dutch and foreign emission sources (1,325 $mol.ha^{-1}.y^{-1}$), a small part (50 $mol.ha^{-1}.y^{-1}$) of the total average deposition (1,375 $mol.ha^{-1}.y^{-1}$) is the result of correction based on measurements (see next chapter for further explanation). This correction (4% of the total average deposition) is not included in Figure 30.

Figure 30 Origins of nitrogen deposition (in percent) in nitrogen sensitive nature in Dutch Natura 2000 sites.



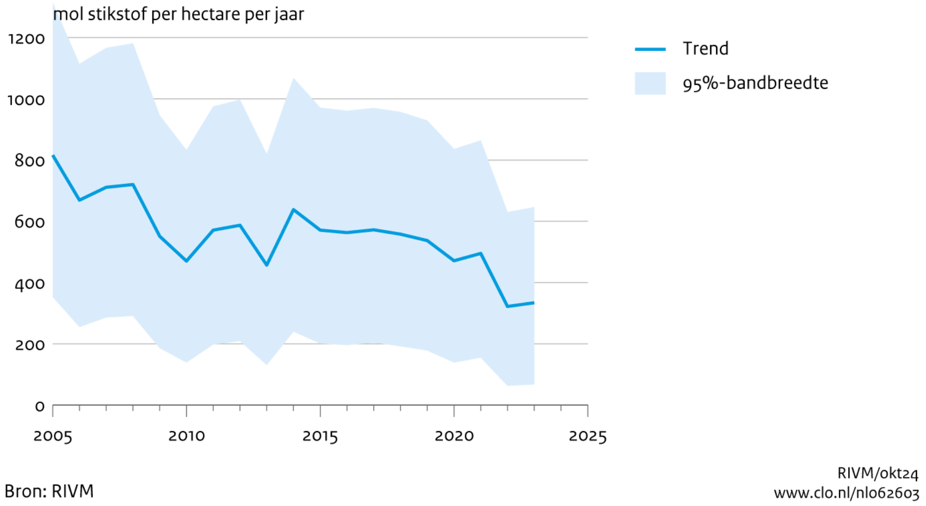
Bron: RIVM 2023

4.1.2.4 Critical Load Exceedance

The average exceedance of the CL in 2023 has halved since 2005. As a result, the total area of nitrogen sensitive nature in Natura 2000 areas with a nitrogen deposition below the CL has increased from 20% in 2005 to approximately 30% in 2023. So about 70% of the areas still have a nitrogen deposition above the CL.

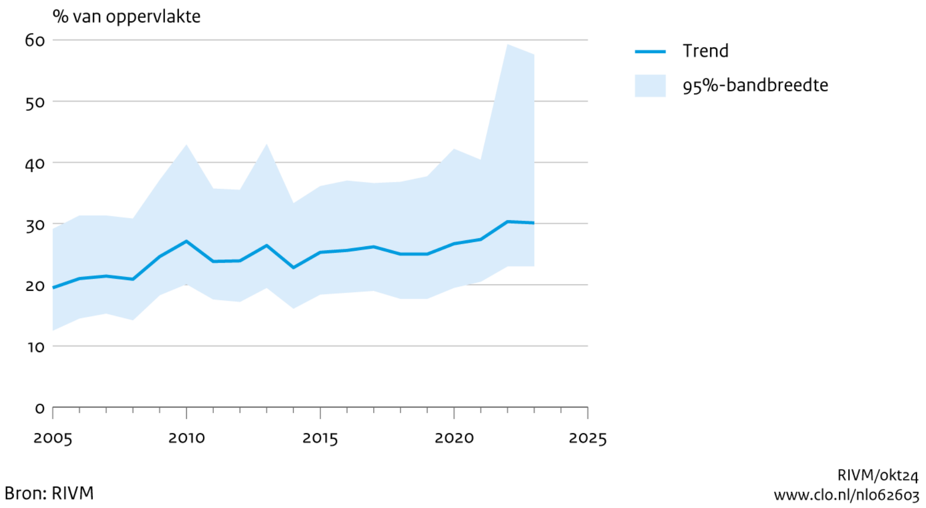
In 2023 the nitrogen deposition on average was 335 $mol.ha^{-1}.y^{-1}$ higher than the CL. In 2005 this was 815 $mol.ha^{-1}.y^{-1}$, so the average exceedance was more than halved since then. This decrease in the exceedance of the CL is caused by a decrease in the total nitrogen deposition. In nitrogen sensitive Natura 2000 areas 20% less nitrogen was deposited between 2005 and 2013. From 2014, the deposition didn't change substantially. Because of changing meteorological conditions, there is year to year variation in the deposition (see Figure 31).

Figure 31 Average exceedance of the CL (in mol.ha^{-1}.y^{-1}) in the period 2005-2023.



For many habitat types the decrease in nitrogen deposition only resulted to a small extent in a deposition below the CL. So, many of these habitats still experience a nitrogen deposition that is too high, even though the level of exceedance has come down. Given this the decrease in exceedance only has a limited effect on the increase of the nature area with a nitrogen deposition below CL.

Figure 32 Nitrogen sensitive nature in Dutch Natura 2000 sites with nitrogen deposition below CL (in percent of total area) in the period 2005-2023.

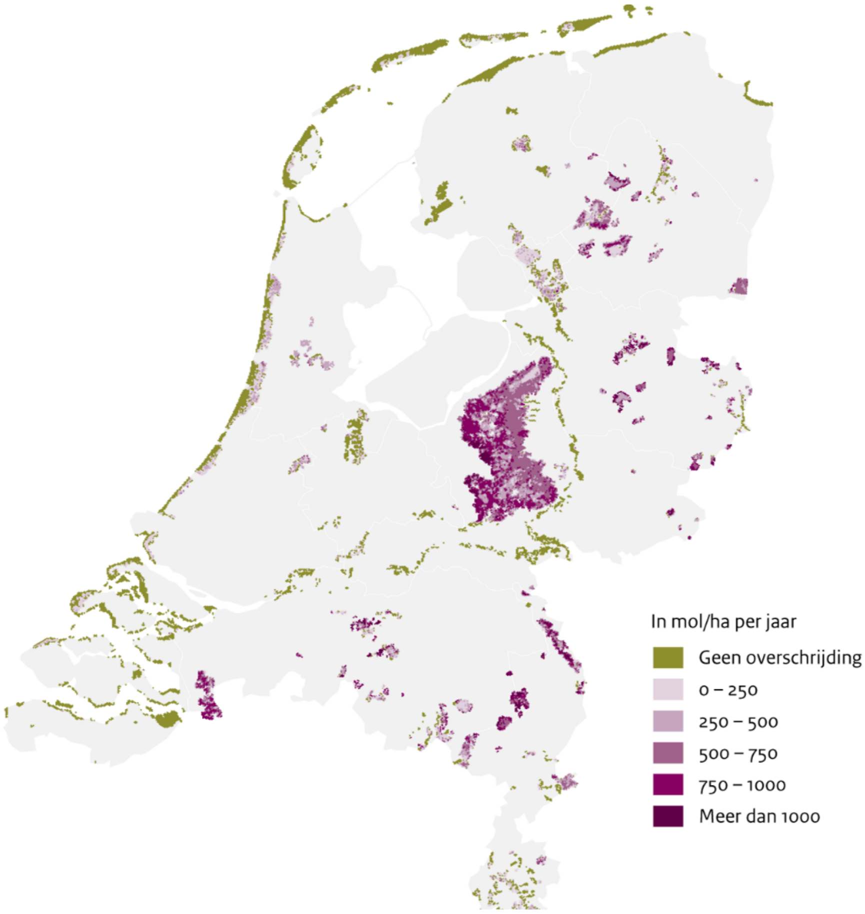


In 2005 about 20% of the nitrogen sensitive habitat types in Natura 2000 sites experienced a nitrogen deposition below the CL. This increased to 30% in 2023 (see Figure 32). The increase mainly occurred before 2010, after which the development slowed down. This is in line with the slowed down decrease in nitrogen deposition.

There are clear spatial differences in the exceedances of the CL (Figure 33). The largest exceedances occur in Natura 2000 sites consisting of nature with a low CL experiencing relatively high levels of nitrogen deposition.

Examples of these situations are areas containing peatbogs, heathlands and forests. As a result, there are big differences between the different provinces in the Netherlands. To achieve deposition levels below the CL in these areas with high exceedances, the deposition of nitrogen has to decrease further than the national averages presented before.

Figure 33 Spatial distribution of the CL exceedances (in mol.ha^{-1}.y^{-1}) in nitrogen sensitive Natura 2000 sites in the Netherlands in 2023.



4.2 Future

This section will give a description of the emission/deposition scenarios for the future, as used by the two countries.

4.2.1 Germany

In the EU NEC Directive (NECD 2016/2284/EU), Germany committed to reducing emissions of ammonia (NH_3) by 29% and nitrogen oxides (NO_x) by 65% by 2030, based on the emissions in 2005.
However, the effect of these emission reductions on critical load exceedances in Germany in 2030 might be non-linear, and influenced by the emission-to-ecosystem-distribution or atmospheric chemical processes, such as the formation of particulate matter.

Also taking the reduction targets of other EU countries – in particular those neighbouring Germany – into consideration within the UBA PINETI-4 project, the effect of the NEC-emission reduction on the critical loads exceedances for eutrophication and acidification was investigated by comparing the simulated year 2030 with the PINETI base year 2015.

Figure 34 Sector based emissions of NO_x and NH_3 for 2015 and 2030. Emissions in 2030 are according to the NEC Directive targets for Germany.

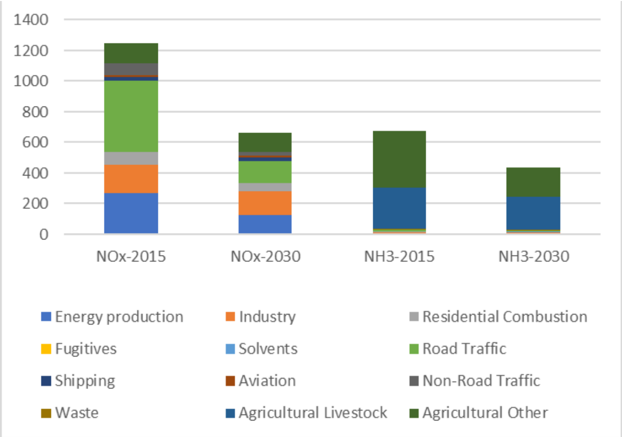


Figure 35 Total N deposition for the 2015 reference year (left) and the NEC Directive-2030 scenario (right) for oxidized and reduced N compounds and different flux pathways in Germany.

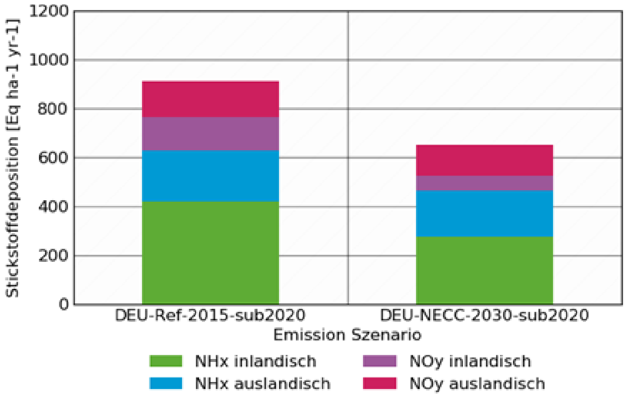
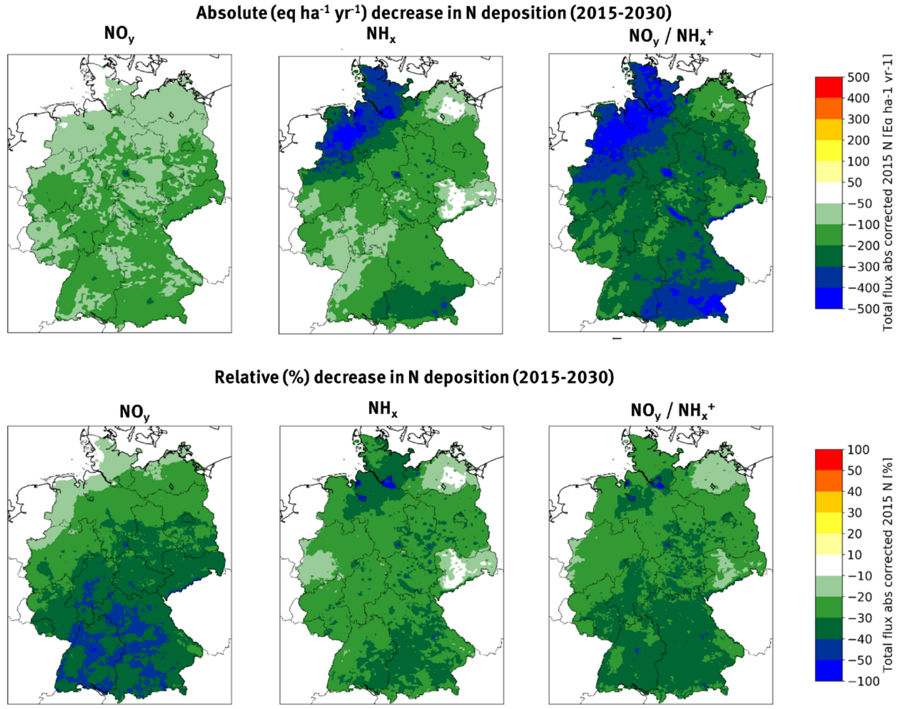


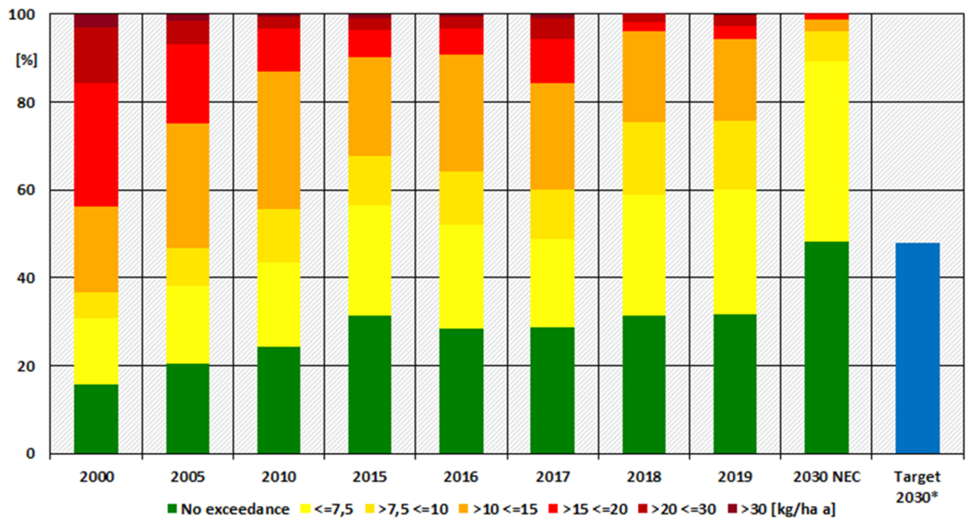
Figure 36 Impact of NEC Directive emission reductions between 2015 and 2030 on the total deposition of NO_y (left), NH_x (middle) and their ration (right).



The results show that:

- The expected reduction in total nitrogen deposition is 26%.
- The percentage reduction of oxidized (NO_y) and reduced (NH_x) nitrogen compounds is similar, despite the much lower reduction targets for NH_3 emissions. This suggests that reducing NH_3 emissions has a more immediate impact on deposition.
- The impact on emission reductions was slightly higher on dry deposition than on wet deposition.
- By 2030, the critical loads are expected to be exceeded in 50% of the ecosystems in Germany (comparison: in 2019 it was 68.5%).

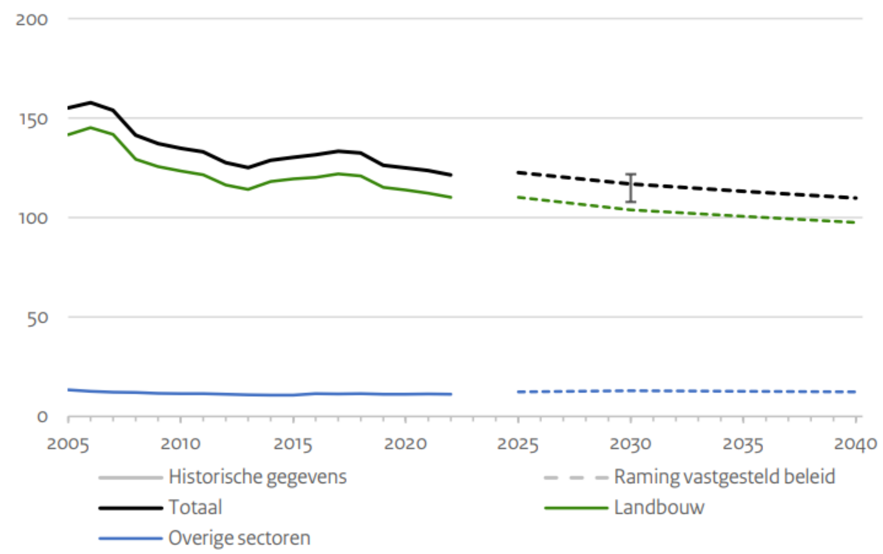
Figure 37 Proportion of vulnerable ecosystems where critical loads for eutrophication are exceeded in Germany.



4.2.2 The Netherlands

Between 2005 and 2022 total ammonia emissions decreased by 22% (see Figure 38). The largest decrease occurred before 2005. Over the entire period, agriculture was the biggest contributor to the ammonia emissions (91%). Based on a scenario with established policy from the Climate and Energy Outlook 2022[40], compared to 2021 a further reduction of 4% in 2030 is estimated (11% in 2040).

Figure 38 Development of the Dutch emission of ammonia per sector in the period 2005-2040.

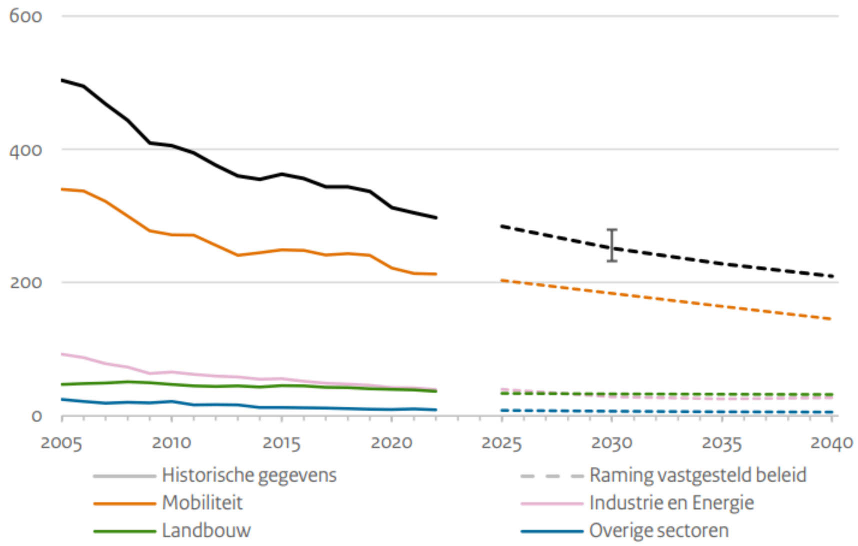


The emission of nitrogen oxides decreased by 41% between 2005 and 2022 (see Figure 39). This decreasing trend already started before 2005. Compared to 2021, the emissions for nitrogen oxides will have

[40] https://www.pbl.nl/publicaties/klimaat-en-energieverkenning-2022

further decreased by 19% in 2030 and 32% in 2040. The biggest contribution to this decrease comes from mobility.

Figure 39 Development of the Dutch emission of nitrogen oxides per sector in the period 2005-2040.



Based on information on Dutch and foreign emissions, historical deposition is calculated for the period 2005-2022 and future deposition for the period 2022-2040 – see Figure 40. Between 2005 and 2022 the national average nitrogen deposition decreased by 20%. This decrease is the result of lower Dutch and foreign emissions of ammonia and nitrogen oxides. From 2010 onwards the decrease is levelling off (see Figure 40). This can be explained by the fact that emissions for ammonia in that period are decreasing slower than before. Another reason for this levelling off lies in the fact that, due to improved air quality, more ammonia will deposit with similar emissions. Both the emission and deposition of nitrogen oxides decreased from 2010 onward.

It is expected that the deposition of nitrogen decreases by about 10% between 2020 and 2030. For 2035 and 2040 it is expected that the average nitrogen deposition decreases by 15 and 18%, respectively. This is based on the emission projection shown before.

Figure 40 Average total nitrogen deposition on nitrogen sensitive habitats in the Netherlands (in mol.ha^{-1}.y^{-1}) in the period 2005-2040.

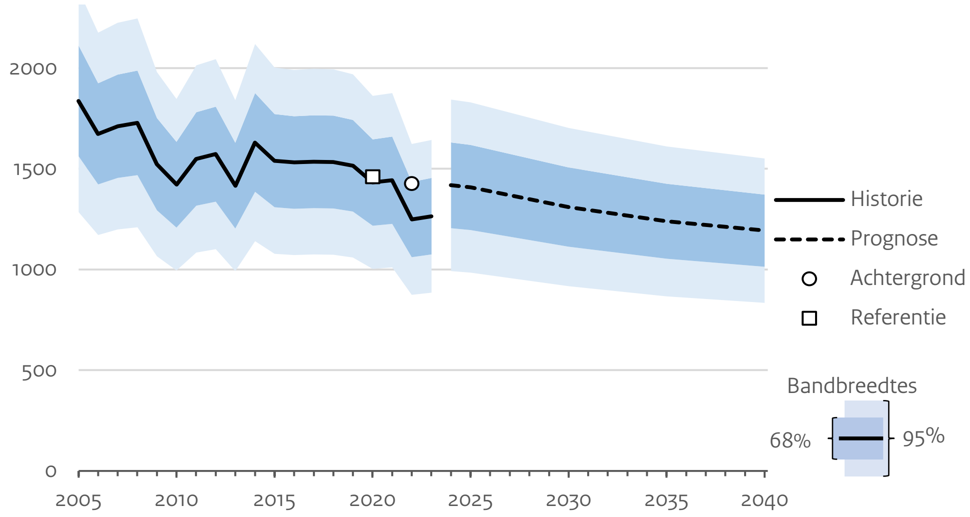
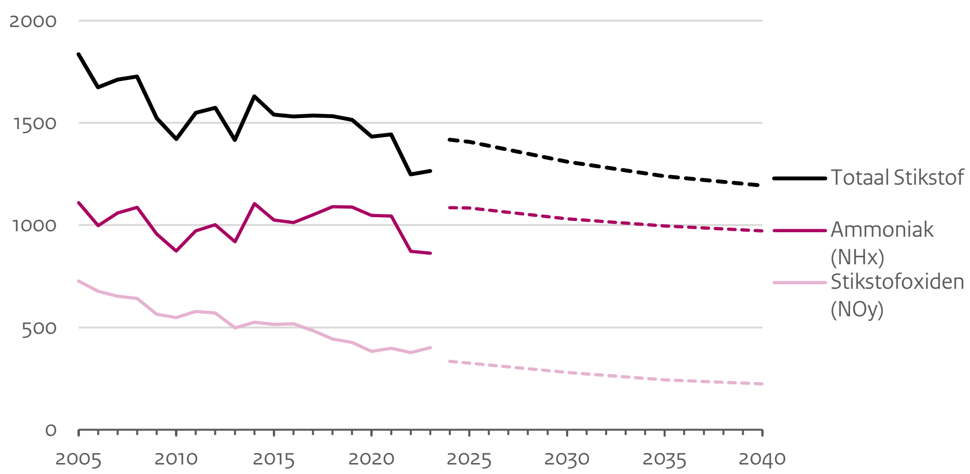


Figure 41 Average nitrogen deposition on nitrogen sensitive habitats in the Netherlands (in mol.ha^{-1}.y^{-1}) in the period 2005-2040 for the different nitrogen compounds.



As a result of the decreasing nitrogen deposition, the average exceedance of the CL decreased by about 40% between 2005 and 2022 (Figure 42). Because of this, the area of nature with a large exceedance is also decreasing. The biggest part of the area of nitrogen sensitive nature has an exceedance lower than 1,000 mol.ha^{-1}.y^{-1}. In the same period the percentage of nitrogen sensitive nature with levels below the CL increased from 20 to 28 percent. This increase mainly took place before 2010 and has levelled off since (Figure 43).

It is expected that the area of nitrogen sensitive nature with levels below the CL increases to 30 percent in 2030 and about 40 percent in 2040 (Figure 43). Despite the expected decrease of deposition, at many locations the deposition remains well above the CL. For that reason, the increase in surface with levels below CL is slower than the decrease in areas with CL-exceedance. Therefore, it is also relevant to take the development of the level of exceedance of the CL into account.

Figure 42 Expected development of the exceedance of the CL in the Netherlands for nitrogen sensitive habitats within Natura 2000 sites (in mol.ha^{-1}.y^{-1}) in the period 2005-2040.

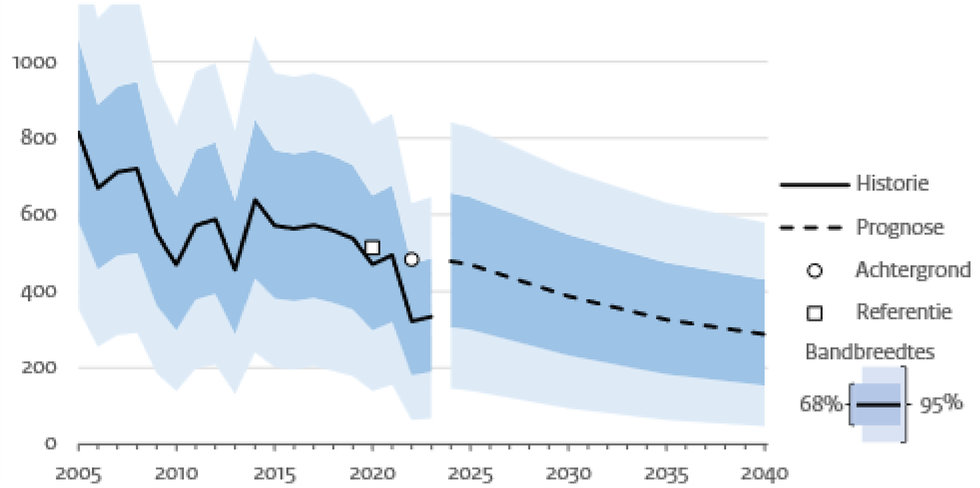
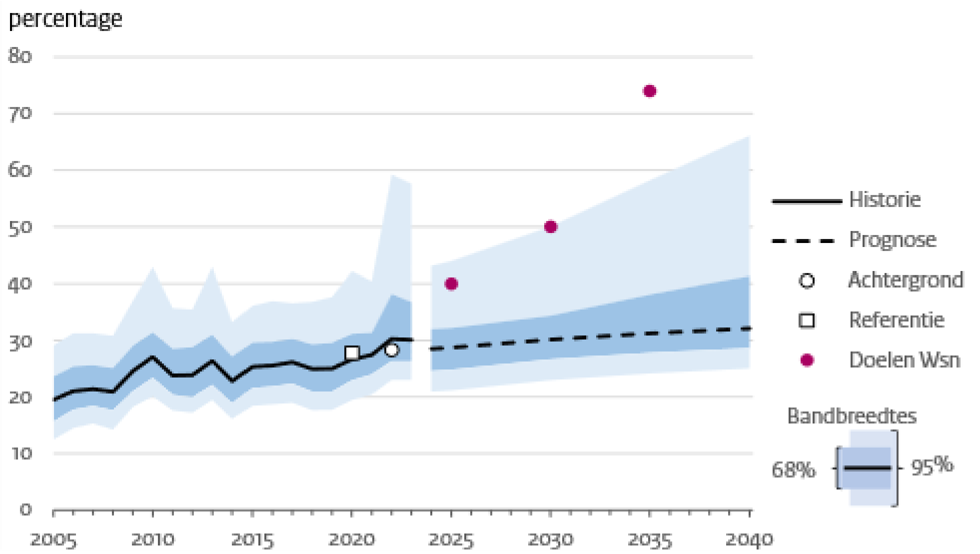


Figure 43 Percentage of nitrogen sensitive habitats under the CL in the Netherlands in the period 2005-2040.



4.3 Comparing emissions and deposition between the two countries

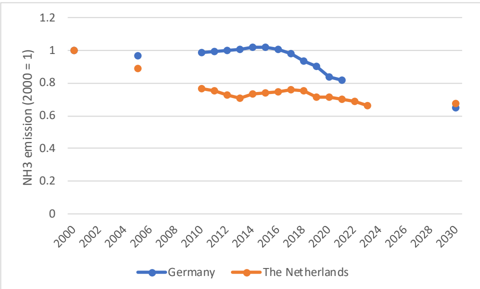
This section shows information about emission, deposition and exceedance of critical loads for both countries side by side. By doing so, similarities and differences between the countries will become visible.

4.3.1 Emissions

Sections 4.1.1.1 and 4.1.2.1 reported the emissions of NO_x and NH_3 for both countries, using their own procedures (based on the same Guidance document) and starting from 1990. Figure 44 shows the changes in emissions for these components since 2000. For the period 2000-2023, the NO_x emissions in both countries show the same continuous decrease, mainly driven by European policy (NEC-directive). Compared to the year 2000, in 2021 the total reduction in emissions was approximately 50% for Germany and 40% for the Netherlands. Compared to 1990, the reduction in NO_x emissions was approximately 65% for Germany and 75% for the Netherlands.

However, for ammonia the trends for both countries are not that similar. For the Netherlands, the largest part of the overall decrease occurred between 2000 (actually, already since 1990 – see Figure 45) and 2010. Since then, the trend is rather steady. For Germany, the main decrease in ammonia emissions only started in 2015, with a rather steady level in the period between 2000 and 2015. Compared to the situation in 2000, the reduction of ammonia emissions in 2021 was around 20% for Germany, while it was circa 30% for the Netherlands. Compared to 1990, the reduction was 30% for Germany and 65% for the Netherlands.

Figure 44 Emission change since 2000 for NH_3 (left) and NO_x (right) for the two countries.



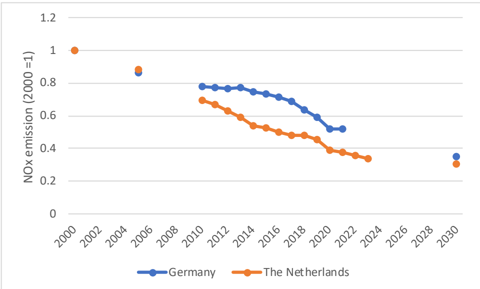
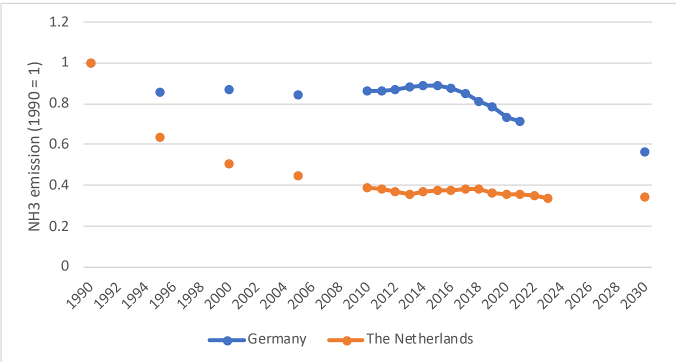


Figure 45 Emission change since 1990 for NH_3 for the two countries.



4.3.2 *Deposition*

Section 4.1.1.3 and 4.1.2.3 reported the average deposition for Germany and the Netherlands, respectively. Whereas the Dutch deposition numbers for the period 2000-2023 are based on consistent calculations for the whole period, this is not the case for Germany. The deposition data for Germany are derived from two projects: PINETI-3 and PINETI-4. The data shown in 4.1.1.3 are a combination of these two projects, where PINETI-4 shows higher deposition in some key years (2000, 2005, 2010) than PINETI-3. In order to produce a consistent trend, the difference between PINETI-3and PINETI-4 for these key years was interpolated for the other years. This was done separately for each deposition component (NO_y/NH_x; wet/dry/occult).

The resulting deposition trendlines for NO_y and NH_x for Germany are shown in Figure 46, combined with the lines for the Netherlands. For NO_y the trendline for both countries shows the same decrease in the period 2000-2021. For NH_x the trend looks slightly different, but for the entire period 2000-2021 the actual decrease is rather similar for both countries. When comparing the deposition trends with the emission trends for both countries, there are some differences. While both trends for the Netherlands show a similar pattern, with both emission and deposition trends decreasing, German emissions stayed rather constant from 2000 to 2015, while deposition decreased. A possible explanation for this is a reduction in foreign emissions in the respective period, impacting the deposition in Germany.

Figure 46 Deposition change since 2000 for NH_x (top) and NO_y (bottom) for the two countries.

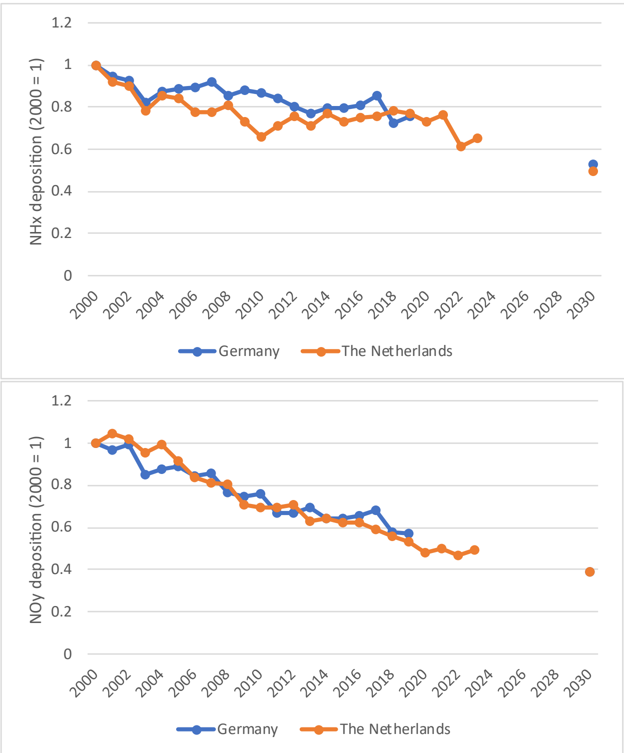


Figure 47 shows the spatial distribution of the NH_x and NO_y deposition in both countries. Areas with intensive agricultural activities (NH_x) and urban/industrial/traffic activities (NO_y) are clearly visible. Figure 48 shows the spatial distribution of the total N deposition in the Netherlands and Germany. While the primary emission areas are still visible, they are less pronounced than for the separate compounds shown in Figure 47. When zooming in on the border region, some differences between the two countries become apparent. Although not visible on the map, nitrogen deposition reaches values of 6,100 mol $N.ha^{-1}.y^{-1}$ in the Netherlands and about 5,000 mol $N.ha^{-1}.y^{-1}$ in Germany. However, this may be partly due to the difference in data resolution. While all deposition for the Netherlands is calculated with a resolution of 1x1 km^2, the maps for Germany have a resolution of approximately 7x7 km^2 for dry deposition and 1x1 km^2 for wet deposition.

Figure 47 Spatial distribution of the 2021 deposition (in mol $N.ha^{-1}.yr^{-1}$) for NH_x (top) and NO_y (bottom) for the two countries.

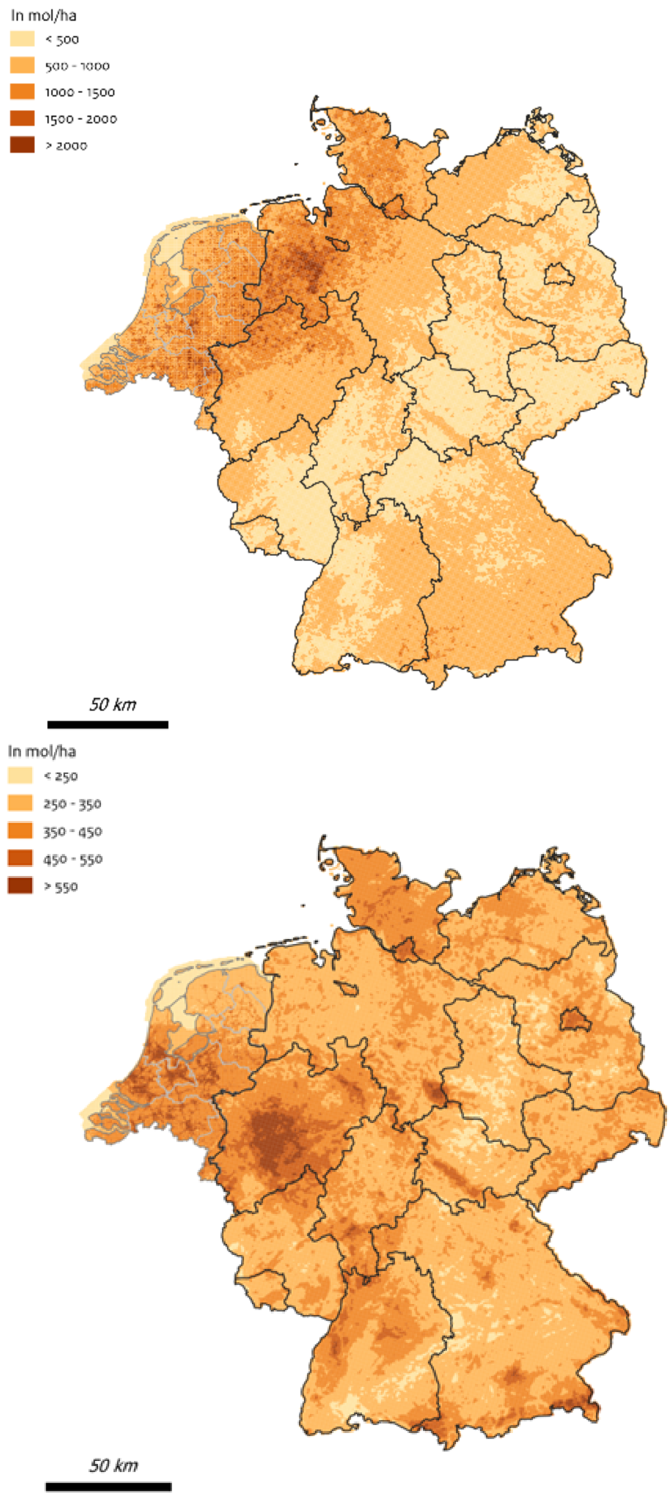
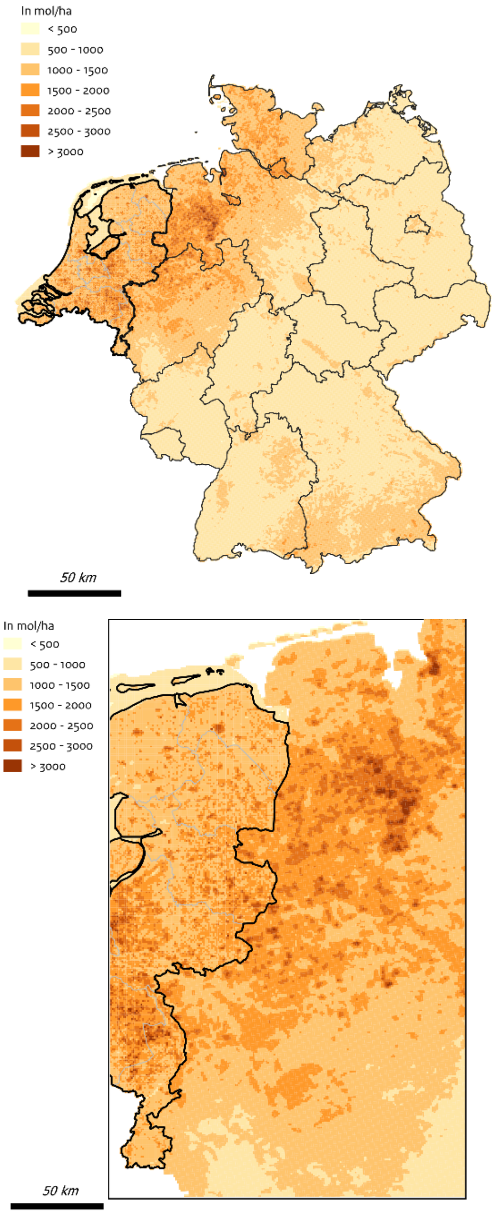


Figure 48 Spatial distribution of the 2021 deposition (in mol N.ha^{-1}.yr^{-1}) for total nitrogen for the two countries (top), and zooming in on the border area (bottom).



4.3.3 *Atmospheric nitrogen balance*

By combining available information on emissions and deposition from the previous sections/chapters, an atmospheric nitrogen balance can be produced for Germany and the Netherlands. Table 1 gives an overview of the destination of the respective emissions, as well as the origin of the deposition in both countries for 2019. Overall, the total emission of nitrogen (sum of NH_3 and NO_x) is about five times larger in Germany than in the Netherlands. For deposition this is about six times larger. However, when considering the destination of those emissions, Germany receives three times more nitrogen from the Netherlands than it exports to the Netherlands (26 vs. 9 ktonne nitrogen). This is also a result of the way both countries are positioned in relation to the prevailing wind direction.

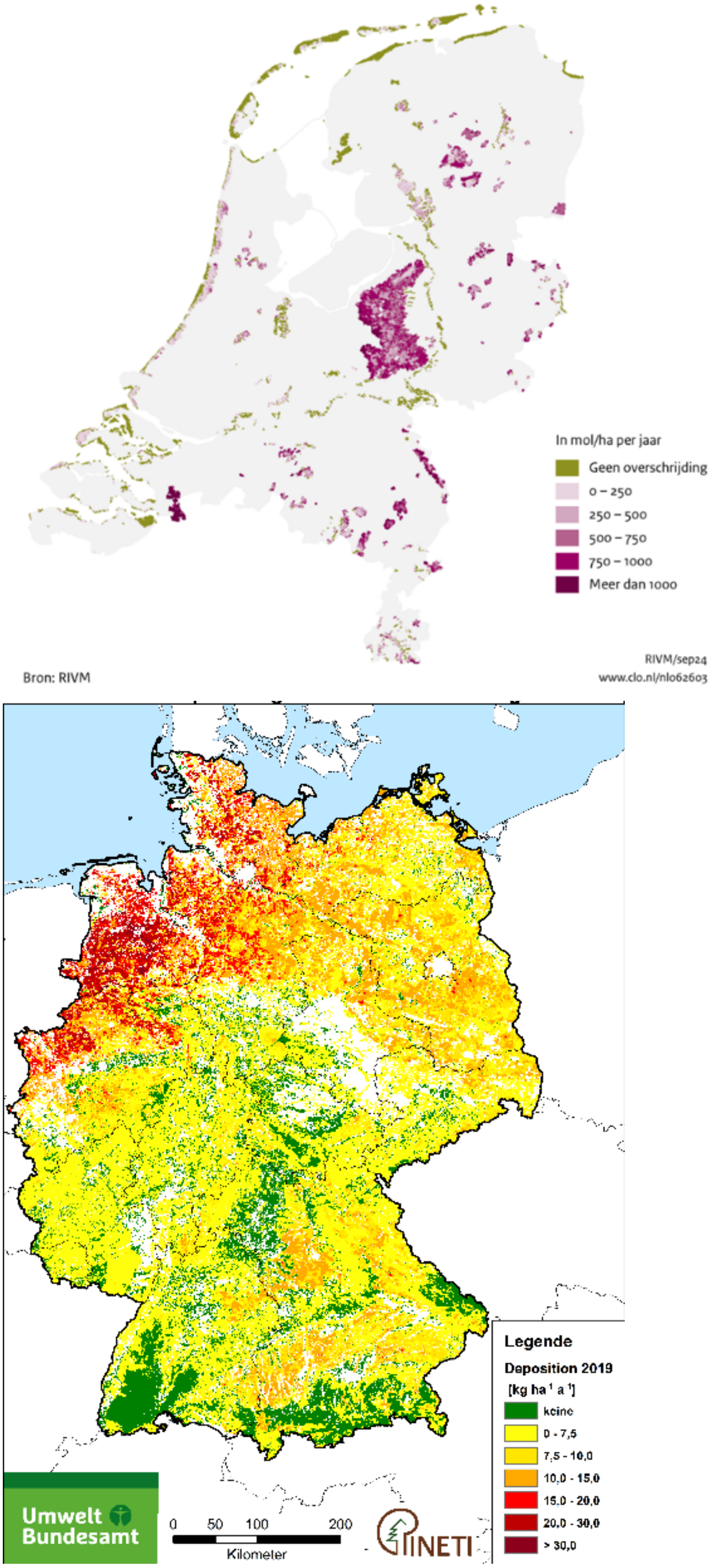
Table 1 Emission and deposition of total nitrogen (sum of NH_3 and NO_x) in ktonne N from and to Germany and the Netherlands in 2019.

	ktonne N	In % of total		ktonne N	In % of total
Germany					
Total Emission	720		Total Deposition	469	
To Germany	277	39%	From Germany	277	59%
To the Netherlands	9	1%	From the Netherlands	26	5%
To Other countries	434	60%	From Other countries	166	35%
The Netherlands					
Total Emission	142		Total Deposition	76	
To the Netherlands	52	36%	From the Netherlands	52	67%
To Germany	26	18%	From Germany	9	11%
To Other countries	65	46%	From Other countries	16	21%

4.3.4 Exceedance of critical loads

Comparing the exceedance of CLs for both countries is more complicated than comparing emissions and deposition. This is due to the fact that there are differences in the areas being considered, as well as in the CL values being used. The result of these different approaches is shown in Figure 49. For the Netherlands, the exceedance is only shown for the nitrogen sensitive nature within the Natura 2000 sites, while for Germany a wider range of areas is used to calculate the exceedance. With respect to the CLs, German exceedances are calculated using a modelled CL for eutrophication, using the SMB model (Simple Mass Balance). For the Netherlands a combination of modelled and empirical CLs is used.

Figure 49 Spatial distribution of the exceedance of the CL for nitrogen for the Netherlands (top) and Germany (bottom).



5 Overview of the main differences

In this chapter the main differences (in broad terms) between Germany and the Netherlands will be summarised. After a more general introduction, the subsequent paragraphs describe the differences for the various topics, as described in the previous chapters.

5.1 Introduction

The excessive release of reactive nitrogen compounds to the environment constitutes a common problem on both sides of the German-Dutch border. In accordance with common European legislation related to water, air and nature quality, both countries have their own national policies and measures to abate the problem. Although overall Germany and the Netherlands follow the same interpretation of the European Birds and Habitats Directives, the actual implementation of European legislation in national legislation is different.

Things like the topics being covered and the limit values being used are all subject to different (policy) processes in the two countries, as is the prioritisation of implementation of EU legislation. For example: in Germany, the NEC emission reduction targets are important as a driver for emission reduction measures. This is not the case in the Netherlands, where NEC reduction targets currently don't provide an incentive for a further reduction of emissions, since the current levels lie below the NEC reduction target. For reduction measures in the Netherlands the Habitats Directive is currently an important driver.

The main focus of this report is on how the Habitats Directive is implemented in Germany and the Netherlands. More in particular, it deals with how exceedance of nitrogen critical deposition loads is handled and how these loads are determined in both countries. Not only the legal basis for the procedure may be different, the way in which the 'building blocks', i.e. emissions/deposition/critical loads, for the exceedance are calculated may also differ. These differences will be summarised below, building on the more detailed descriptions in previous chapters.

5.2 Legal

For the Netherlands the Nitrogen Law (Wet Stikstofreductie en Natuurverbetering[41]) is in place as part of the Environment and Planning Act (Omgevingswet), in which the objective is to expose 74% of the nitrogen sensitive habitats within the Natura 2000 sites to deposition below the respective nitrogen critical loads in 2035 (50% in 2030). For Germany the percentage of almost 50 in 2030 is also the main objective. It is part of Germany's Sustainable Development Strategy. Although the percentages are the same, they cover different nature areas: the nitrogen sensitive habitats within Natura 2000 for the Netherlands, the total ecosystem area for Germany.

[41] https://zoek.officielebekendmakingen.nl/stb-2021-287.html

To assess the contribution of individual projects in the context of the permitting process, the Netherlands has a 'zero' cut-off criterium in combination with a 25 km maximum calculation distance. The 'zero' cut-off is technically implemented through a calculation limit that rounds to at least 0.01 $mol.ha^{-1}.y^{-1}$, below which depositions are considered to be zero. Another cut-off value of 1 $mol.ha^{-1}.y^{-1}$ is currently under political debate. For Germany a main cut-off value of 0.3 $kg.ha^{-1}.y^{-1}$ for habitat types in Natura 2000 areas is used, which is equivalent to 21 $mol.ha^{-1}.y^{-1}$. For other ecosystems, not protected under Natura 2000, a cut-off value of 5 $kg.ha^{-1}.y^{-1}$ (appr. 360 $mol.ha^{-1}.y^{-1}$) is used under the TA-Luft.

5.3 Emission

Both countries are party to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and report their emissions annually to the Convention by means of an Informative Inventory Report. For this they use the "Guidelines for Estimating and Reporting Emission Data" under the Convention.

In both countries the NO_x emission shows a continuous decrease in the period 2000-2023, mainly driven by European policy like the NEC Directive (Figure 44).

However, for ammonia the trends for both countries are not that similar. For the Netherlands, the largest part of the overall decrease occurred between 2000 (actually, already since 1990) and 2010. Since then, the trend is rather steady. For Germany the main decrease of the ammonia emission only started in 2015, with a rather steady emission in the period between 2000 and 2015.

5.4 Deposition

Deposition is calculated in different ways in the two countries. For the Netherlands, both wet and dry deposition are calculated by means of a dispersion and deposition model using gridded emissions data. The outcome of the model is then calibrated using measurements. The German approach is different: dry deposition is also calculated by means of a dispersion/deposition model using emissions. The calculated dry deposition is not calibrated using measurements. Wet deposition, however, is mainly determined based on measurements. Interpolated precipitation concentrations are combined with precipitation amounts (DWD) in order to derive a high-resolution wet deposition map of Germany.

The resulting deposition trendlines for NO_y and NH_x for the two countries were shown in Figure 46. For NO_y the trendlines for both countries show the same decrease in the period 2000-2021. For NH_x the trend looks slightly different, but for the entire period 2000-2021 the overall decrease is rather similar for both countries.

Figure 47 showed the spatial distribution of the NH_x and NO_y deposition in both countries. Areas with intensive agricultural activities (NH_x) and urban/industrial/traffic activities (NO_y) are clearly visible. When zooming in on the border region, some differences between the two countries become apparent. Nitrogen deposition in the Netherlands reaches values of 6,100 mol $N.ha^{-1}.y^{-1}$, while the deposition in Germany is about 5,000 mol $N.ha^{-1}.y^{-1}$. This may be partly due to the difference in data resolution. While all deposition for the Netherlands is calculated with a resolution of 1x1 km^2, the maps for Germany have a resolution of approximately 7x7 km^2 for dry deposition and 1x1 km^2 for wet deposition.

5.5 Critical loads

Comparing the exceedance of critical loads for both countries is more complicated than comparing emissions and deposition. This is due to differences in the areas being considered, as well as the critical load values being used. The Netherlands only calculates the exceedance for the nitrogen sensitive nature within the Natura 2000 areas, while Germany uses a wider range of areas to calculate the exceedance. With respect to the critical loads, German exceedances are calculated using the SMB modelled critical loads for eutrophication. For the Netherlands a combination of modelled and empirical critical loads is used.

List of abbreviations

BMUKN	Bundesministerium für Umwelt, Klimaschutz, Naturschutz und Nukleare Sicherheit (German Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear safety)
CAMS	Copernicus Atmosphere Monitoring Service
CL	Critical Load
CLe	Critical Level
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CO	Carbon monoxide
DWD	Deutsche Wetter Dienst (German Meteorological Institute)
FFH sites	Flora-Fauna-Habitat sites (equal to Natura 2000 sites)
FNCA	Federal Nature Conservation Act (German Bundesnaturschutzgesetz -BuNaSchG)
GRETA	Gridded Emission Tool for Arcgis
IED	Industrial Emissions Directive
LVVN	Ministerie voor Landbouw, Visserij, Voedselzekerheid en Natuur (Dutch Ministry for Agriculture, Fishery, Food Security and Nature)
NEC	National Emission reduction Commitments
NH_3	Ammonia
NH_4^+	Ammonium
NH_x	Reduced nitrogen
ICP	International Cooperative Programme (under the CLRTAP)
IIR	Informative Inventory Report
NFR	Nomenclature For Reporting (related to the NEC Directive)
NMVOC	Non-methane volatile organic compounds
NO_3^-	Nitrate
NO_x	Nitrogen oxides
NO_y	Oxidised nitrogen
NPLG	Nationaal Programma Landelijk Gebied (Dutch national programme for rural areas)
PAS	Programma Aanpak Stikstof (Dutch nitrogen approach programme)
PINETI	Pollutant Input and EcosysTem Impact)
POP	Persistent Organic Pollutants
KEV	Klimaat- en Energieverkenning (Dutch climate and energy outlook)
RIVM	Rijksinstituut voor Volksgezonheid en Milieu (Dutch National Institute for Public Health and Environment)
SMB	Simple-Mass-Balance
SO_2	Sulphur Dioxide
TA-Luft	Technische Anleitung Luft (German Technical Instructions on Air Quality Control)
TNO	Toegepast Natuurwetenschappelijk Onderzoek (Dutch institute on applied scientific research)
UBA	Umweltbundesamt (German Environment Agency)
UNECE	United Nations Economic Commission for Europe
Wsn	Wet Stikstofreductie en Natuurverbetering (Dutch nitrogen reduction and nature improvement act)

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