JNCC Report
No. 665a

Nitrogen Futures

Annex 1
Future nitrogen emission scenarios and comparison with baseline

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October 2020

ISSN 0963-8091

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This report should be cited as:

Hampshire, K., Dore, C., Raoult, J., Laxen, D., Marner, B., Williamson, T., Misselbrook, T., Tomlinson, S., Carnell, E. & Dragosits U. 2020. Nitrogen Futures - Annex 1, Emission scenarios and comparison with baseline. JNCC Report No. 665a. JNCC, Peterborough ISSN 0963-8091.

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JNCC would like to thank Alastair Burn, Clare Whitfield, Tom Pearson, David Vowles, Susan Zappala and Alexandra Cunha for their valuable review of this report.

Contents

Glossary

Acronym	Meaning
AAE	Annual Average Exceedance
ASSI	Area of Special Scientific Interest (Northern Ireland), equivalent of SSSI in Great Britain
AENEID	Atmospheric Emissions for National Environmental Impacts Determination. A model to produce high-resolution (1 km grid) maps of agricultural ammonia, methane and nitrous oxide emissions for the UK, annual maps available through the NAEI
BAU	Business As Usual - includes only those policies that have already been adopted or implemented at the time of the project projection compilation. It does not include additional measures set out in the NAPCP which are designed to meet NECD/NECR targets.
CBED	Concentration-Based Estimated Deposition, a model generating maps of deposition of sulphur, oxidised and reduced nitrogen
CCE	Coordination Centre for Effects, of the WGE
CNCBs	Country Nature Conservation Bodies (Natural England, Scottish Natural Heritage, Natural Resources Wales, Council for Nature Conservation and the Countryside)
CL	Critical Load, an amount of deposition per unit area and time. The formal definition is “a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge” (Nilsson & Grennfelt 1988)
CLe	Critical Level, a concentration in air e.g. of ammonia, below which harmful effects do not occur according to present knowledge
CL_{empN}	Empirical critical load for nutrient-nitrogen, as defined in Bobbink *et al*. (2011) and refined for the UK by Hall *et al*. (2011)
CLRTAP	Convention on Long Range Transboundary Air Pollution
DA	Devolved Administration
Daera	Department of Agriculture, Environment and Rural Affairs
Defra	Department for Environment, Food & Rural Affairs
ECA	Emission Control Area
EDZ	Emission Displacement Zone
ELM	Environmental Land Management
ERC	Emission Reduction Commitments
ERZ	Emission Reduction Zone
EU	European Union
FAPRI	Food and Agricultural Policy Research Institute
FRAME	Fine Resolution Atmospheric Multi-pollutant Exchange (atmospheric chemistry and transport model)
ha	Hectares. One hectare is 100 m x 100 m
ICP-M&M	International Cooperative Programme for Modelling and Mapping critical loads and critical levels.
IED	Industrial Emissions Directive
LEZ	Low Emission Zone (a defined area where access by some polluting vehicles is restricted with the aim of improving air quality)
MCPD	Medium Combustion Plant Directive
N	Nitrogen. Strictly, reactive N, i.e. including oxidised and reduced forms of N but not dinitrogen gas, N_2.
NAEI	UK National Atmospheric Emissions Inventory
NAMN	UK National Ammonia Monitoring Network
NARSES	UK agricultural emission model (spreadsheet based), developed by Rothamsted Research
NAPCP	National Air Pollution Control Programme
NE	Natural England
NECD	EU Directive on the Reduction of National Emissions (2016/2284)
NECR	UK National Emission Ceilings Regulations (2018 No 129) transposing NEC Directive 2016/2284/EU.
NFC	UK National Focal Centre, under ICP-M&M

NFR	Nomenclature for Reporting (Format for reporting of national emission data in accordance with the CLRTAP)
NH_3	Ammonia
NMVOC/VOC	Non-Methane Volatile Organic Compounds/Volatile Organic Compounds
NO_x	Nitrogen Oxides
NRMM	Non-Road Mobile Machinery
NRW	Natural Resources Wales
MCPD	Medium Combustion Plant Directive
PaMs	Policies and Measures
PCM	Pollution Climate Mapping (model)
PM	Particulate Matter
SAC	Special Area of Conservation, designated site protected under the Habitats Directive
SEPA	Scottish Environment Protection Agency
SNAP	Shared Nitrogen Action Plan
SNAP (sectors)	Selected Nomenclature for reporting of Air Pollutants. Pollution sources categorised into sectors for reporting. For example: S3 – Combustion in manufacturing industry, S7 – Road Transport, or S10 Agriculture.
SNCBs	Statutory Nature Conservation Bodies (Joint Nature Conservation Committee, Natural England, Scottish Natural Heritage, Natural Resources Wales, Northern Ireland Natural Environment Division)
SNH	Scottish Natural Heritage
SO_2	Sulphur Dioxide
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
UAN	Urea Ammonium Nitrate (a liquid fertiliser combining urea, nitric acid, and ammonium)
WAM	With Additional Measures. This scenario includes policies that have been adopted and implemented as well as those that are planned.
WGE	Working Group on Effects, within CLRTAP
WM	With Measures. This scenario includes policies that have been adopted and potentially implemented at the time of projection compilation.
WP	Work Package

Summary

This document forms Annex 1 to the main Nitrogen Futures project report. The main purpose of this annex is to provide more details of the development of the most realistic emission baselines for 2030, and represents work carried out under Work Package 1a. These baselines are set in the wider context of the emission reduction commitments under the EU National Emission Ceilings Directive (NECD) and UK's 2018 National Emission Ceilings Regulations (NECR) which translate the UK's NECD commitments into UK law. The European context with emission projections for the EU Member States for 2030 is important to capture transboundary air pollution for the UK scenario modelling under the Nitrogen Futures project.

Two 2030 baselines are described here:

- Business As Usual (BAU) With Measures (WM) - includes only those policies that have already been adopted or implemented at the time of the projection compilation. It does not include additional measures set out in the NAPCP which are designed to meet NECD/NECR targets. This baseline therefore represents an incomplete set of measures to meet the 2030 NECD/NECR targets and is referred to in the reporting of the high-resolution modelling as *2030 BAU (WM)*.
- The most likely scenario for achieving NECD/NECR targets - includes additional measures (WAM, With Additional Measures) to meet NECD/NECR targets that are still in development, but not yet adopted or implemented, at the time of the projection compilation. These additional measures are represented by the UK's National Air Pollution Control Programme (NAPCP), with some country-specific modifications from consultations by the Devolved Administrations of Scotland, Wales and Northern Ireland. Throughout the reporting of the high-resolution modelling, this is the main 2030 baseline for comparing all mitigation scenarios with and is referred to as *2030 NAPCP+DA (NECR NOx)*.

The insights derived from the detailed assessments of the two baselines were used to develop the specific Nitrogen Futures mitigation scenarios, which included both UK-wide and spatially targeted mitigation of atmospheric nitrogen input to sensitive UK habitats and designated sites. The development of these scenarios is described in detail in Annex 2 and summarised in the main report.

1 Introduction

The United Kingdom is a signatory of the Convention on Long Range Transboundary Air Pollution (CLRTAP) and bound by the National Emission Ceilings Regulations 2018[1] (NECR). As such it has statutory emission reduction commitments for oxides of nitrogen (NO_x), ammonia (NH_3), sulphur dioxide (SO_2), particulate matter ($PM_{2.5}$) and non-methane volatile organic compounds (NMVOC). The NECR also requires the development of a National Air Pollution Control Programme (NAPCP) which sets out the policies and measures (PaMs) aimed at attaining the emission reduction commitments.

This JNCC commissioned project on Nitrogen Futures aims to inform policy development in the UK regarding atmospheric emissions of NH_3 and NO_x. It aims to assess the effectiveness of spatially targeted mitigation actions and quantify the impact of a range of policy options on sensitive ecosystems. The evidence gathered during this study is expected to feed into the development of policies that achieve the national targets whilst also maximising benefits for ecosystems, priority habitats and designated sites.

This annex outlines the background to the data and information used for the baseline scenario. It contains the following sections:

- A review of the UK's 2030 projections as presented in the National Air Pollution Control Programme (NAPCP);
- The European context for 2030 to capture transboundary air pollution relevant for UK scenario modelling – Current and projected UK emissions are considered in the context of European emissions and UK and European legislation under which these were developed; and
- Devolved Administration information – A summary of the information and data gathered from the Devolved Administrations, to complement UK-level information under the NAPCP.

Table 1 and Figure 1 below explain some of the key terms used in this annex. A separate report (Annex 2) describes mitigation scenarios developed under the Nitrogen Futures project that build on these most realistic 2030 baselines described in this report. Annex 2 describes the full list of scenarios modelled in the project and assumptions made.

Table 1. Definitions of key terms.

Acronym	Term	Description
PaMs	Policies and Measures	Actions implemented with the aim of reducing emissions of greenhouse gases and air pollutants.
WM	With Measures	This scenario of projections to 2030 includes policies that have already been adopted or implemented at the time of the projection compilation. It does not include additional measures set out in the NAPCP which are designed to meet NECD/NECR targets.
WAM	With Additional Measures	This 2030 scenario of projections includes measures that have been adopted and/or implemented and/or planned at the time of the projection compilation, to meet NECD/NECR targets. For the UK, these additional measures are represented in the NAPCP.

[1] The National Emission Ceilings Regulations 2018: http://www.legislation.gov.uk/uksi/2018/129/contents/made

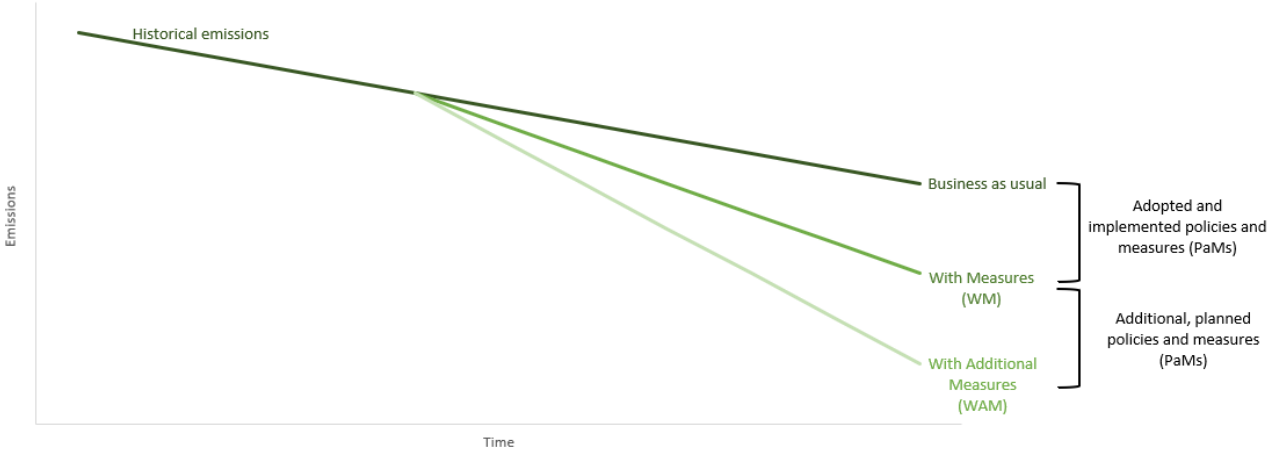

Figure 1. Illustrative graph to show how policies and measures contribute to the With Measures (WM) and With Additional Measures (WAM) 2030 baseline scenarios.

2 A review of the UK's 2030 projections as presented in the NAPCP

2.1 Current UK policies and policy intentions to meet NECD/NECR emission reduction commitments for NH_3 and NO_x

2.1.1 Introduction

Within this project, a key task was to take official UK emission projections and develop quantitative spatial datasets for emissions of NO_x and NH_3 in 2030 as baselines for spatially targeted measures. Two 2030 baselines were developed:

- With Measures (WM) i.e. includes policies that have been adopted and may have already been fully or partially implemented, at the time of projection compilation; and
- The central estimate of the National Air Pollution Control Program (NAPCP) scenarios, which represents a set of measures that meets the UK's NECR targets.

More information on the detailed implementation of the scenarios as part of the high-resolution modelling carried out under the Nitrogen Futures project is available in Section 2.3.3 of the main report and Annex 4 (scenario modelling results). The focus of this section is to provide background information on the projections to 2030 and current policies and measures planned under the NAPCP. The section is split into the following:

- **2030 projections: Overall trends** – Summary of the NO_x and NH_3 trends from 2000 to 2030;
- **2030 projections: Sector contributions and key sources** – Identification of key emissions sources in 2017 and 2030 and trends in these sectors;
- **Compliance with commitments** – a summary of the UK's forecasted compliance with the NECD emission reduction commitments (as transposed into UK law as the NECR);
- **Current policy intentions under the NAPCP** – a summary of the policies and measures (PaMs) included in the NAPCP including objectives, timeframe and estimated NO_x and NH_3 reductions; and
- **Other policy statements** – An overview of other policies in the UK and at the Devolved Administration level that could impact on future emissions of NO_x and NH_3.

2.1.2 2030 Projections: Overall Trends in NOx

Historical emissions of NO_x in the UK have steadily declined, falling by 56% between 2000 and 2017 (Figure 2a). This is largely due to emissions reductions from road transport and energy industries. Vehicle NO_x emissions have fallen as a result of the introduction of increasingly stringent Euro standards and technological improvements. Emissions from power stations have fallen due to the fitting of NO_x reduction technologies and the phasing out of coal-fired power stations.

Future emissions of NO_x are forecasted to continue to decline until 2030 but at a slower rate, falling by 33% from 2017 to 2030 (Figure 2b)[2].

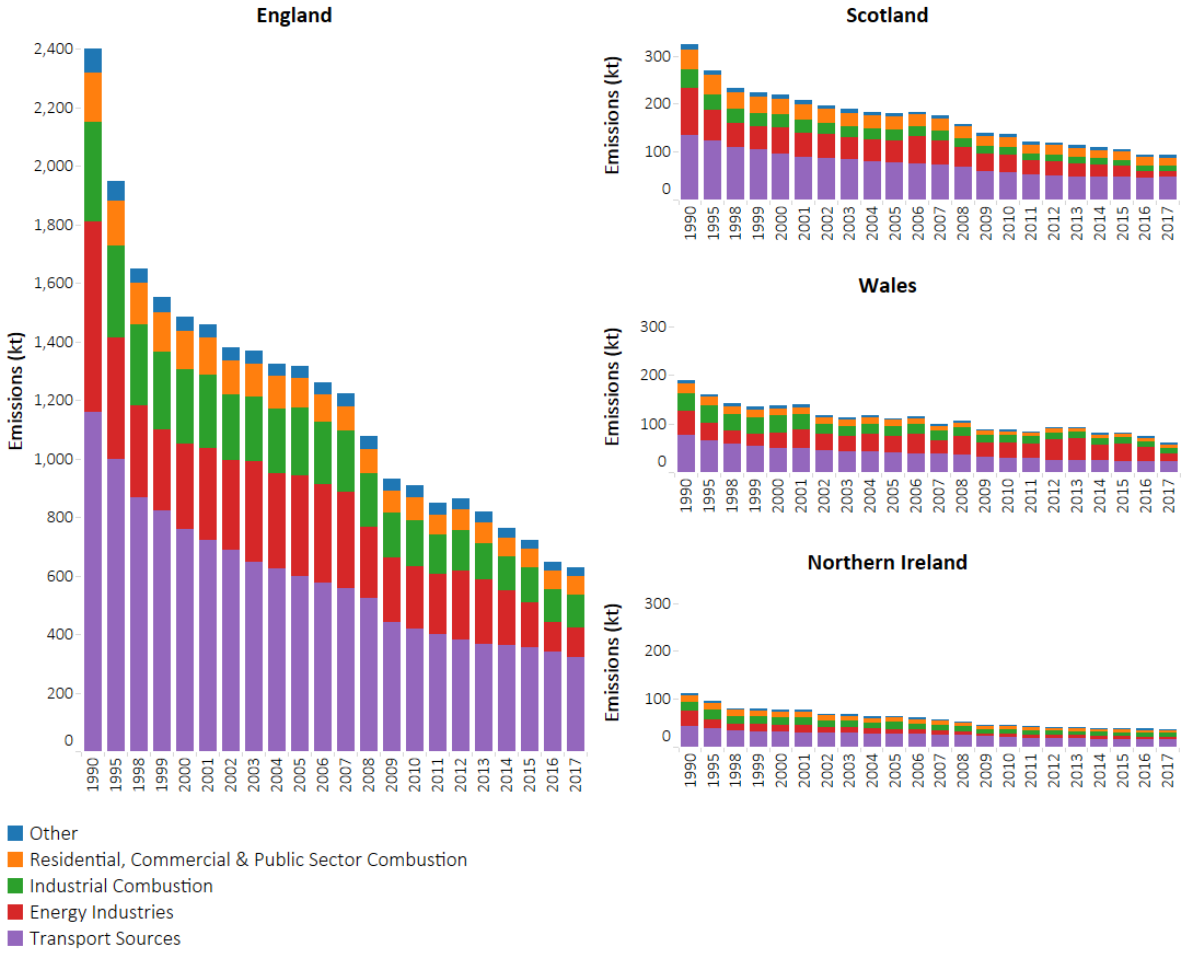

Figure 2a. NO_x emissions – breakdown by UK countries and emission sector.

[2] Further information on projections data can be found here: https://www.eea.europa.eu/themes/air/national-emission-ceilings/nec-directive-reporting-status-2019

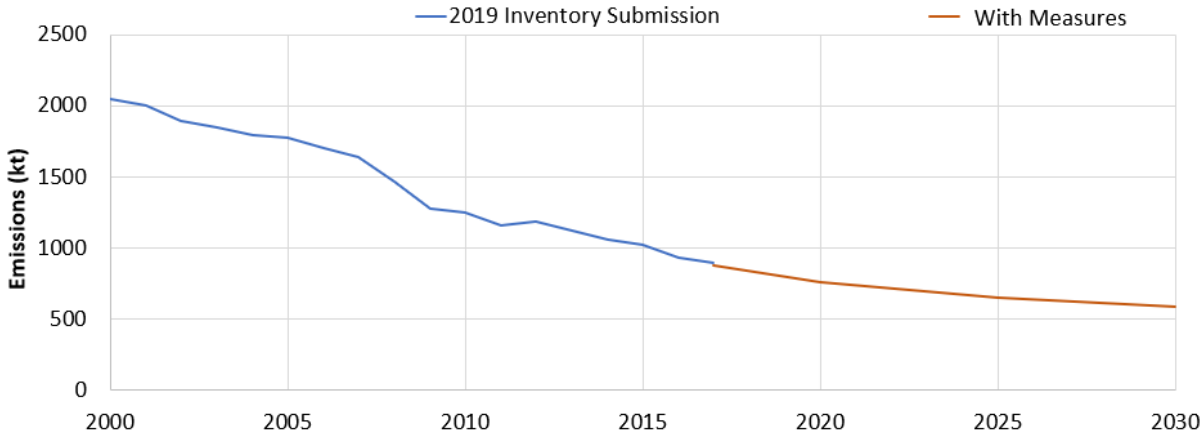

Figure 2b. NO_x emissions - National total for the entire territory with predicted reductions from 2017 to 2030 based on the With Measures (WM) scenario.

Additional policies and measures (PaMs) implemented at both the UK and country levels could provide a NO_x emissions reduction in 2030 of between 75.2 and 138.3 kt beyond the WM scenario (see Figure 3).

The range of emission savings that are predicted highlights the extent of the uncertainties associated with determining emissions projections. The levels of uncertainty associated with PaMs depends on a number of factors, for example the way in which the policy is implemented, the speed at which it is implemented and the scope of the policy.

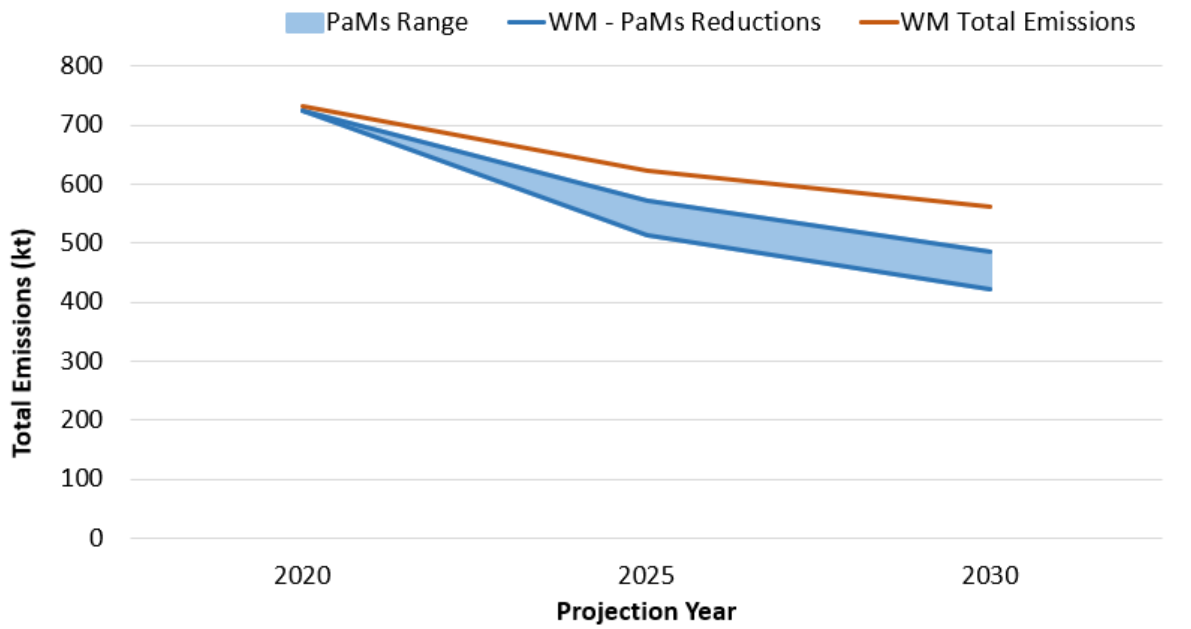

Figure 3. Total projected NO_x emissions - breakdown of projected emissions With Measures (WM) and the range of predicted emission reductions through Policies and Measures (PaMs).

2.1.3 2030 Projections: Overall Trends in NH_3

The historical time series for NH_3 is more variable than for NO_x with emissions largely declining between 2000 and 2013 but then exhibiting an increasing trend to the year 2017. The net result is a 7% decrease in emissions between 2000 and 2017 (Figures 4a and 4b).

The reduction in NH_3 emissions over the time series is largely due to a reduction in the number of cattle and pigs as well as a reduction in the use of chemical fertilisers.

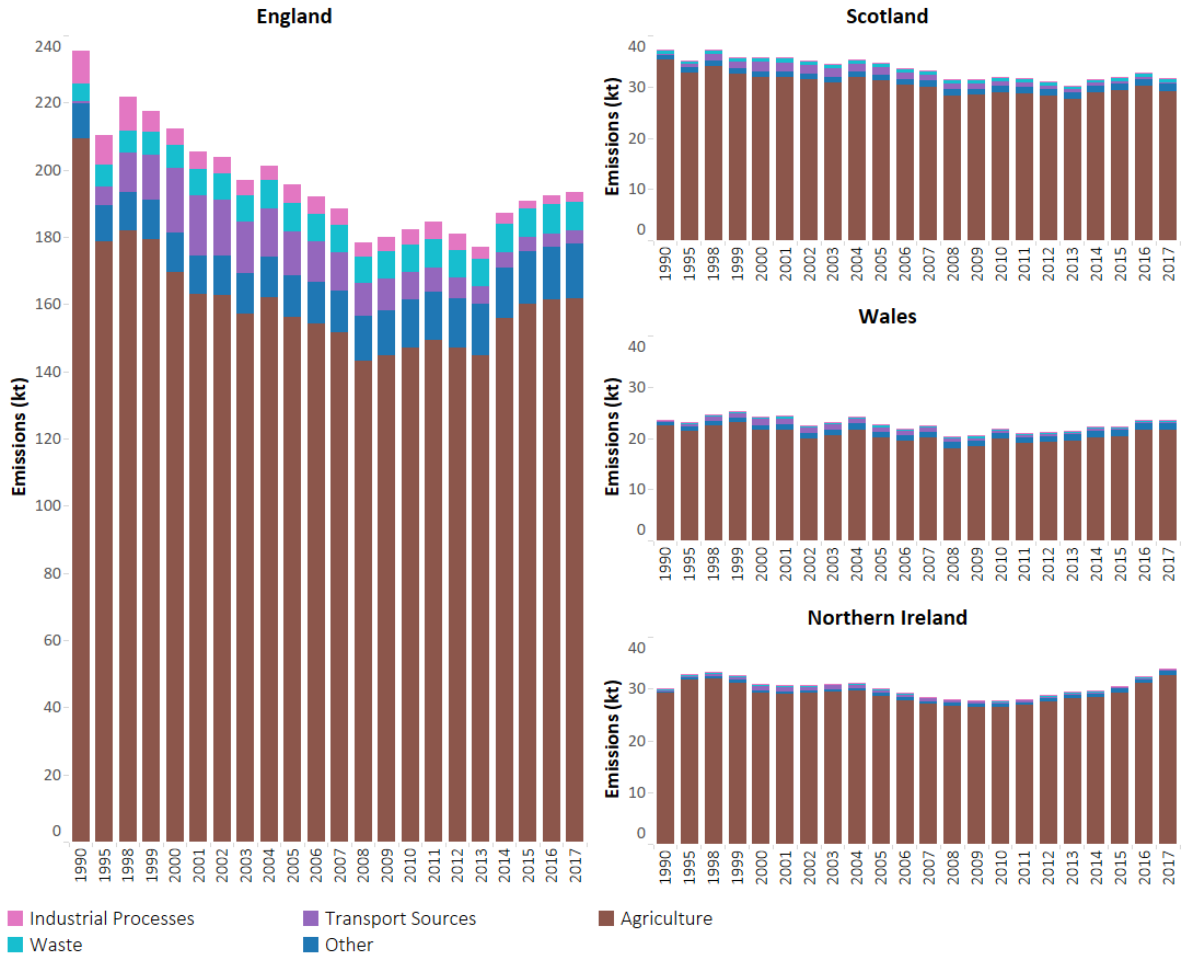

Figure 4a. NH_3 emissions – breakdown by UK countries and emission sectors.

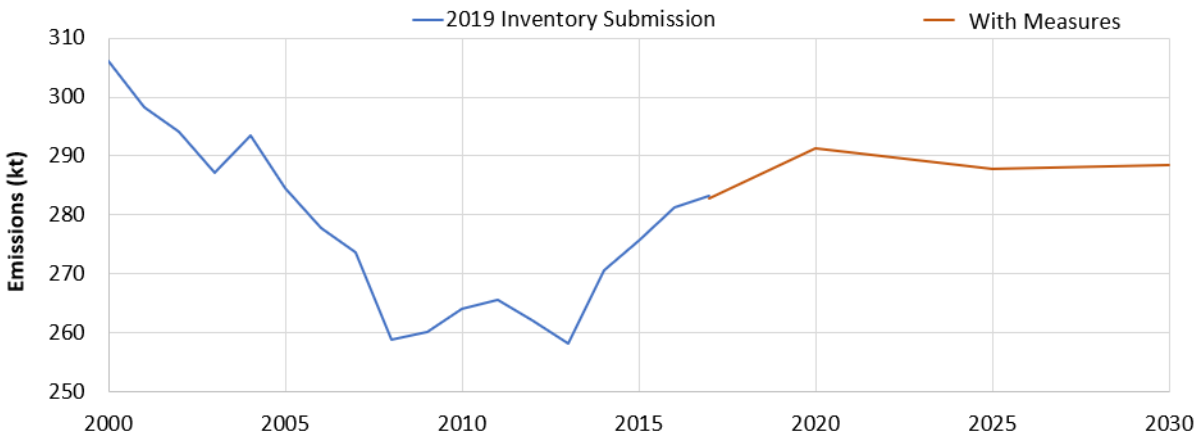

Figure 4b. NH_3 emissions - National total for the entire territory.

The PaMs selected by the UK for NH_3 result in a very wide range of expected reductions in emissions, between 0.1 and 62.7 kt in 2030 (Figure 5) over the WM scenario (the upper limit of the PaMs scenario cannot be distinguished from the WM scenario in the figure).

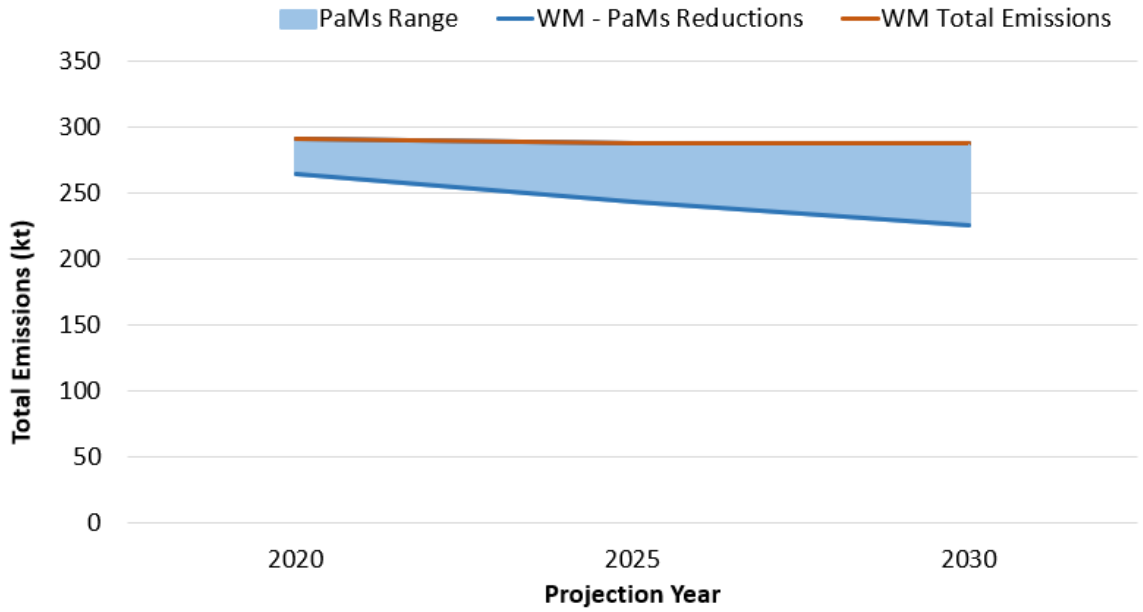

Figure 5. Total projected NH_3 emissions - breakdown of projected emissions With Measures (WM) and the range of predicted emission reductions through Policies and Measures (PaM).

2.1.4 2030 Projections: Sector contributions and key sources

The data in Table 2 are taken from the official UK emissions inventory, and shows how individual sectors and groups of sources contribute to the total emissions of NO_x and NH_3 in the UK in 2017 and 2030. The data is presented with individual sources in the Nomenclature for Reporting (NFR) format. This is the format used for reporting national air pollutant emissions to international Conventions and Directives. Any sources or groups of sources that contribute over 10% to total emissions are highlighted in orange. The table illustrates that the sources and sectors contributing or predicted to contribute the most to emissions of each pollutant are expected to remain the same between 2017 and 2030. However, for NO_x, the order of the ranking shifts between 2017 and 2030 as the relative importance of the sources change. In 2017, the largest contribution to emissions is from 1A3b (road transport) but by 2030 this has the 3rd largest contribution behind 1A1 (energy industries) and 1A2 (manufacturing industries and construction).

For NH_3, the main source sectors are consistent between 2017 and 2030, in terms of both overall and relative importance, i.e. 3D (agricultural soils) and 3B (manure management). The main driver of the proportional increase in NH_3 emissions from 3D compared with 3B (Table 2) is the increase in the application of digestates to soils. While differences exist across the DAs regarding the proportional breakdown of NH_3 emissions, the predicted change from 2017 to 2030 is essentially the same for all DAs, with emissions from soils (3D) becoming marginally more important and those from manure management (3B) marginally less important.

The following sections consider road transport and animal husbandry and manure management in more detail.

Table 2. Source contributions to total emissions. Orange cells highlight sources that contribute greater than 10% to total emissions for the given year. For full detail on nomenclature see Appendix 1.

Nomenclature for Reporting (NFR)	NO_x		NH_3	
	2017	2030	2017	2030
1A1 Energy industries	21.3%	22.2%	0.0%	0.1%
1A2 Manufacturing industries and construction	16.5%	21.9%	1.0%	1.1%
1A3b Road transport	32.2%	18.2%	1.6%	1.6%
1A3a, c,d,e Off-road transport (includes aviation, shipping and rail)	14.5%	17.2%	0.0%	0.0%
1A4 Residential and Commercial combustion	10.2%	13.2%	0.8%	1.0%
1A5 Military	1.4%	2.0%	0.0%	0.0%
1B Fugitive emissions	0.2%	0.3%	0.1%	0.1%
2A, B, C, H, I, J, K, L Industrial processes	0.2%	0.3%	1.0%	0.9%
2D, G Solvent and other product use	0.0%	0.0%	0.5%	0.5%
3B Animal husbandry and manure management	0.2%	0.3%	36.7%	34.9%
3D Plant production and agricultural soils	2.9%	4.2%	49.9%	51.2%
3F, I Field burning and other agriculture	-	-	-	-
5 Waste	0.2%	0.3%	3.6%	3.9%
6A Other	0.0%	0.1%	4.7%	4.9%

1A3b Road transport

Despite being the largest source sector of NO_x emissions in 2017, emissions from 1A3b road transport have fallen by 63% between 2000 and 2017 and are projected to fall by a further 62% up to 2030 (Figure 6).

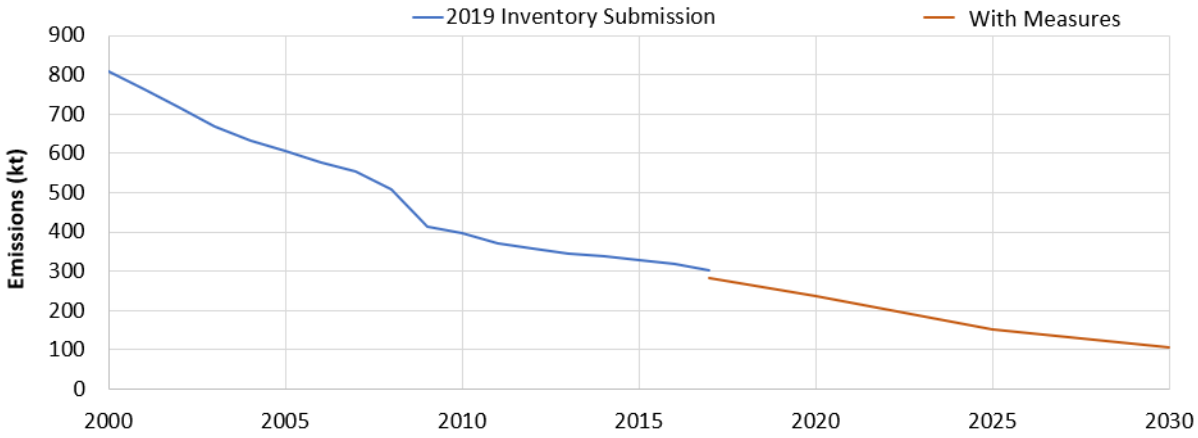

Figure 6. NO_x emissions from 1A3b road transport.

In both 2017 and 2030, the main sources of road transport emissions are the same, however their percentage contribution to total emissions falls. Between 2017 and 2030, the contribution of passenger cars to total NO_x emissions is projected to decrease (16.1% to 10.8%) however the proportion of total road transport emissions that come from passenger cars is expected to increase (Figure 7). This is despite the availability of low/zero emission

vehicle technologies for passenger cars that are not applicable for other modes of transport such as Heavy Goods Vehicles.

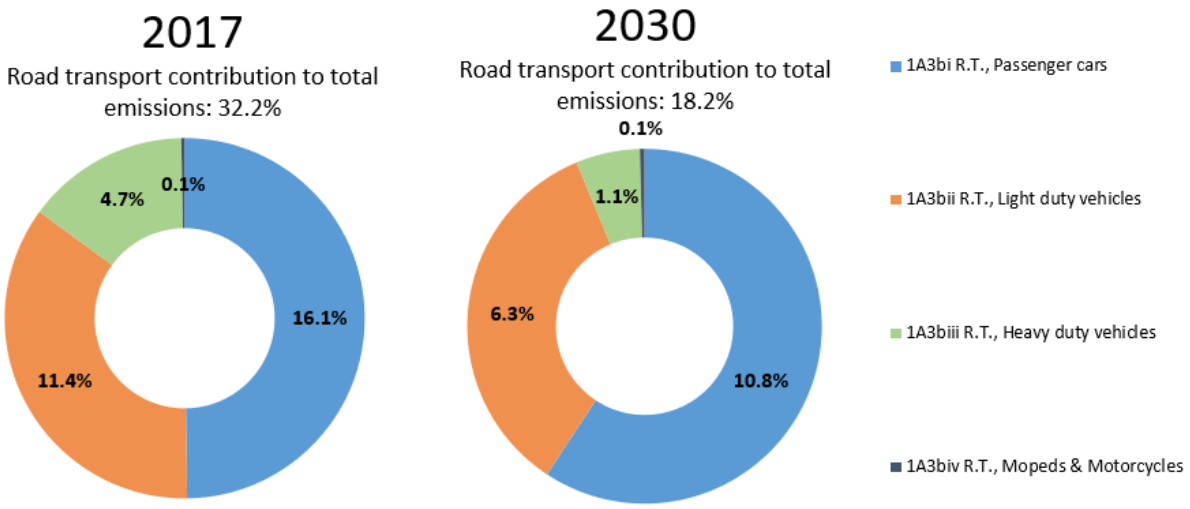

Figure 7. Category breakdown of road transport contribution to total NO_x emissions in 2017 and 2030.
Note: The percentages shown on the pie chart are the contribution of each source to total emissions

3B Animal husbandry and manure management
NH_3 emissions from animal husbandry and manure management fell by 13% between 2000 and 2017. However almost all of this reduction occurred between 2000 and 2010, with emissions remaining relatively constant from 2010 to 2017. This is mostly associated with trends in livestock numbers, with long-term declines in numbers of pigs and dairy cows in particular being reversed in more recent years and poultry numbers also showing a marked increase since 2010. Uptake of mitigation practices has been relatively low but would have also had some impact on the emission trend.

Emission projections to 2030 are based on forecasts of activity data (livestock numbers, milk production, crop areas and yields, nitrogen fertiliser use) provided by FAPRI-UK[3] (April 2019). FAPRI-UK is a modelling system which captures the dynamic interrelationships among the variables affecting supply and demand in the main agricultural sectors of England, Wales, Scotland and Northern Ireland, e.g. major policy instruments, world agricultural commodity prices, currency exchange rates. FAPRI outputs have been widely used within UK Government in assessing the impacts of policies, including the abolition of milk quotas, changes to the Single Farm Payment and various forms of CAP reform. FAPRI does not provide any forecasts regarding agricultural management practices, which can greatly influence emissions, and these are largely assumed to remain constant under the current WM scenario. Emissions are projected to decrease by a further 3% between 2017 and 2030 (Figure 8). Emissions within this sector are dominated by emissions from cattle (dairy and non-dairy), pigs and poultry. There are differences in the projected changes in livestock numbers across the UK countries. Total cattle numbers are projected to decline by 5.0% in the UK, but this decline is offset to some extent by projected increases in milk yield per dairy cow. Projected declines are greatest for Northern Ireland (7.5% decrease) compared with the other DAs (4.9, 0.6 and 5.7% for England, Wales and Scotland, respectively). Total sheep numbers are projected to decline by 7.7% for the UK, with no projected change for Scotland, but projected declines of 6.3, 14.7 and 9.6% for England, Wales and Northern Ireland, respectively. Total pig numbers are projected to increase by 2.7% for the UK, with increases of 3.3, 0.7 and 14.7% for England, Wales and Scotland,

[3] FAPRI – Food and Agricultural Policy Research Institute.

respectively, but a decline of 9.6% for Northern Ireland. Finally, poultry numbers are projected to increase by 4.4% for the UK and increase in all DAs, by 4.0, 4.0, 5.2 and 5.7% for England, Wales, Scotland and Northern Ireland, respectively. Dairy and non-dairy cattle both contribute 12.7% to total NH_3 emissions in 2017 and are estimated to remain relatively constant, both contributing 12.2% to total NH_3 emissions in 2030. Similarly, contributions from pigs and poultry to total NH_3 emissions are expected to decrease by only 0.5% and 0.3%, respectively, between 2017 and 2030 (Figure 9).

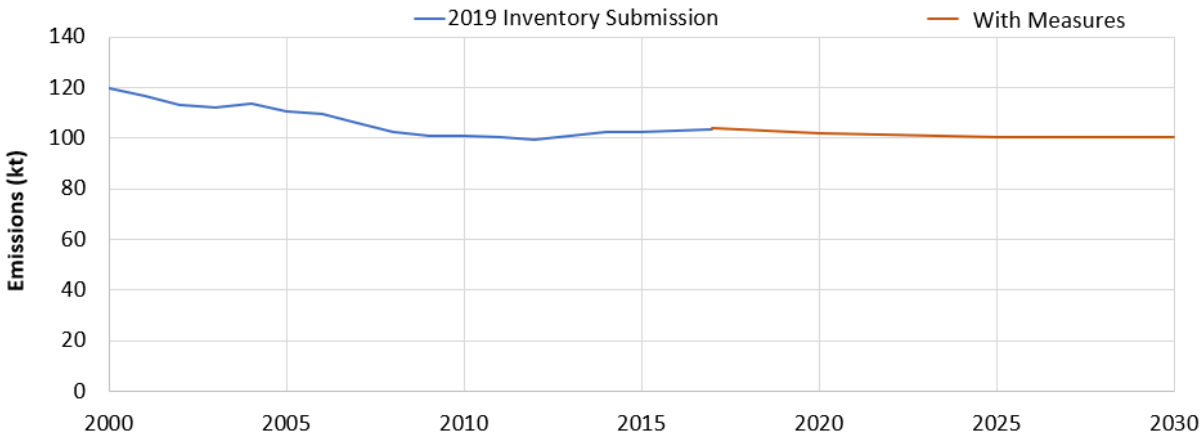

Figure 8. NH_3 emissions from 3B animal husbandry and manure management.

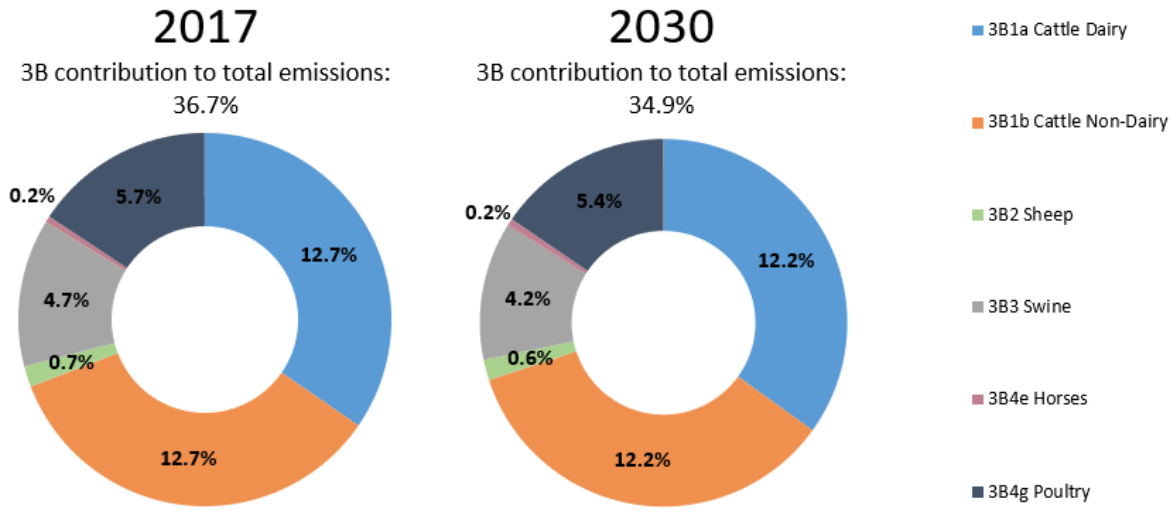

Figure 9. Category breakdown of animal husbandry contribution to total NH_3 emissions in 2017 and 2030.
Note: The percentages shown on the pie chart are the contribution of each source to the total emission contributions.

2.1.5 Compliance with commitments

Table 3 and Table 4 show emission reduction commitments for the UK under the NECD/NECR and compare these to the UK's WM scenario emissions projections for 2020 and 2030.

The tables show that, whilst NO_x projections forecast compliance with the 2020 emission reduction commitment, NH_3 projections for 2020 and both NO_x and NH_3 projections for 2030 are forecast to be non-compliant. The UK has not yet submitted With Additional Measures (WAM) scenario emissions.

Table 3. 2020 emission reduction commitments and compliance for NO_x and NH_3.

Pollutant	Commitment			With Measures (WM)	
	2005 total emissions (kt)	2020 emission reduction commitment (% of 2005)	2020 emission reduction commitment target (kt)	2020 WM total emissions (kt)	Is the 2020 WM projection compliant?
NO_x	1749.02	-55%	787.06	731.14	Yes
NH_3	284.54	-8%	261.78	291.37	No

Table 4. 2030 emission reduction commitments and compliance for NO_X and NH_3.

Pollutant	Commitment			With Measures (WM)	
	2005 total emissions (kt)	2030 emission reduction commitment (% of 2005)	2030 emission reduction commitment target (kt)	2030 WM total emissions (kt)	Is the 2030 WM projection compliant?
NO_x	1749.02	-73%	472.23	561.30	No
NH_3	284.54	-16%	239.02	288.57	No

The NAPCP includes actions beyond those proposed in the WM scenario. As part of this project, it is not possible to formally assess compliance after the application of the PaMs reported in the NAPCP, and any WAM scenarios should be compliant, as their purpose is to show how targets will be attained. Many member states have not submitted scenarios that show how they will meet their commitments, however it is possible to investigate the potential impacts.

2.1.6 Current policy intentions reported in the NAPCP

An overview of the policy intentions reported in the NAPCP is presented in Table 5[4]. Member States can report information on individual PaMs or groups of PaMs. For NO_x, the most significant emissions savings in 2030 are anticipated to result from policies associated with shipping and the industrial sector. For NH_3, the agricultural sector, which is the largest contributor to UK NH_3 emissions, is the focus of policies and measures for targeting emissions reductions. The table also highlights the range of savings that could be achieved, for example NH_3 savings from agriculture policies could be anywhere between 0 and 61.8 kt per annum in 2030. As mentioned above, this highlights the high degree of uncertainty in the emissions savings estimates. This is caused by the dependence on a number of factors, for example the way in which the policy is implemented, the speed at which it is implemented and the scope of the policy. For this project, it was necessary to have absolute values for the projections, rather than the ranges reported in the NAPCP. Defra provided “central estimates” for the PaMs included in the NAPCP, allowing absolute values to be determined for the 2030 projections under the WaM scenario.

[4] More detail is available directly from the UK’s NAPCP report: https://www.gov.uk/government/publications/air-quality-uk-national-air-pollution-control-programme.

Table 5. Overview of Policies and Measures (PaM) under the National Air Pollution Control Plan (NAPCP). Ranges in projected emission savings taken from the NAPCP.

Sector	PaMs/ group of PaMs	Objectives	Timeframe	NO_x savings in 2030	NH_3 savings in 2030
Road transport [5]	• Road to zero for cars and Light Goods Vehicles • Influence modal shifts in urban areas	• Vehicle efficiency improvements • Modal shift to public transport and non-mobilised forms • Alternative fuel vehicles • Improved behaviour • Improved transport infrastructure	2019 - beyond 2030	2.1 – 15.6 kt/annum	0.1 – 0.7 kt/annum[6]
Shipping	• Domestic regulation change • Extend ECAs7 to all UK coastal waters • Manage port AQ plans	• Pollution abatement technologies on vessels • Alternative fuels • Improved behaviour • Improved transport infrastructure	2019 – beyond 2030	19 – 50.1 kt/annum	-
Other transport	• Aviation AQ strategy • Action to reduce rail emissions • Action on Non-Road Mobile Machinery (NRMM) via publicly funded infrastructure projects	• Alternative fuels for vehicles and aircraft • Improved transport infrastructure • Improved behaviour	2019 – beyond 2030	6.2 – 15.1 kt/annum	-
Domestic	• Legislate to prohibit sale of most polluting fuels • Local Authority enforcement	• Other energy supply	2019 – beyond 2030	5.2 – 5.8 kt/annum	0 – 0.2 kt/annum

[5] Reducing emissions from road transport: Road to Zero Strategy: https://www.gov.uk/government/publications/reducing-emissions-from-road-transport-road-to-zero-strategy

[6] Ammonia emissions from road transport relate to the use of early generation catalytic converters in cars, and the use of urea in more recent emissions abatement equipment for heavy goods vehicles.

[7] ECA – Emission Control Area.

Sector	PaMs/ group of PaMs	Objectives	Timeframe	NO_x savings in 2030	NH_3 savings in 2030
Agriculture	• Funding for low-emission equipment • Regulation to reduce urea-based and other fertiliser use emissions • Requirements for manure management and application • Mandatory standards for livestock housing • Environmental permitting for dairy and intensive beef units	• Low emission fertiliser and manure application • Improved livestock management and rearing installations • Improved animal waste management systems	2019 - 2027	-	0 – 61.8 kt/annum
Industry	• Implementation of MCPD and IED[8] measures • Industry roadmaps • Closing of regulatory gap and regulation for small sites • Challenge industry on VOCs	• Abatement technology installation • Improved control of fugitive emissions	2019 – beyond 2030	42.7 – 51.7 kt/annum	-

2.1.7 Other policy statements

There are other policy statements published in the UK, for example at Devolved Administration and Local Authority level, which could deliver emissions reductions beyond those estimated in the NAPCP. Some of these policy statements are detailed below. Table 6 provides an example of the overview information that was included from England and Devolved Administrations' Clean Air Strategies. However, for the 2030 NAPCP+DA baseline selected for the high-resolution modelling under Nitrogen Futures, these additional strategies were not taken into account to match the NECD/NECR commitments. More ambitious scenarios were then developed based on this baseline (see Annex 2), with a focus on spatial targeting of measures and specifically for agricultural ammonia. More information on discussions with the Devolved Administrations can be found in Section 3, and these discussions informed the further scenario development described in Annex 2 and the main report.

[8] MCPD – Medium Combustion Plant Directive / IED – Industrial Emissions Directive.

Table 6. Overview of England Clean Air Strategy.

England Clean Air Strategy	
Transport measures	• Target emissions from shipping and aviation • End sales of conventional diesel and petrol cars by 2040 • Reduce emissions from rail
Domestic combustion measures	• Legislate to end sale of most polluting fuels • Only cleanest stoves on sale by 2022 • Updated legislation on chimney smoke
Agriculture measures	• National code of good farming practice • Require farmers to invest in infrastructure and equipment that reduces emissions • Future Environmental Land Management (ELM – currently in development) system to fund NH_3 emission reduction measures, for the protection of habitats from NH_3 • Regulate to reduce NH_3 emissions
Industry measures	• Maintain policy of continual improvement • Continue to work with industrial sector to develop roadmaps • Consideration of closing the regulatory gap to tackle emissions from smaller plants
Expected impact in 2030	• -75 to -150 kt NO_x • Up to -65 kt NH_3

2.2 European context

Many air pollutants have a long residence time in the atmosphere, and hence transboundary considerations are important. Therefore, the project considered how European emissions are expected to change in future years. This defines the changes to the boundary conditions for the modelling studies i.e. the wider atmospheric transport and chemistry.

The anticipated changes in emissions across Europe due to the implementation of the NECD (National Emissions Ceilings Directive, as transposed into UK law as the NECR) will have an impact on emissions from Republic of Ireland and mainland Europe (and shipping) that enter the UK's atmosphere. This is particularly relevant for NO_x, NH_3 and SO_2, which reacts with NH_3 in the atmosphere to form ammonium compounds that are transported longer distances than NH_3. Therefore, declining SO_2 emissions result in less opportunity for these chemical reactions, which in turn results in a longer atmospheric lifetime of NH_3 gas in the atmosphere before it is transformed into less reactive ammonium compounds.

The United Kingdom forecast non-compliance with their emission reduction commitments by 2030 under the WM scenario (Table 7) of NECD/NECR.

Table 7. UK projections compared to Emissions Reduction Commitments (ERCs).

Pollutant	2005 total emissions (kt)	2030 ERC (% of 2005)	2030 ERC target (kt)	2030 WM total emissions (kt)	Projection compliant?
NO_x	1749.02	-73%	472.23	561.30	No
NH_3	284.54	-16%	239.02	288.57	No
SO_x	772.80	-88%	92.74	102.59	No

The UK has not, however, reported a With Additional Measures (WAM) scenario that demonstrates how they will be compliant with their emission reduction commitments for 2030. Seventeen European Union (EU) Member States reported a WAM scenario with their NECD projections submission. Under a WAM scenario, 7 EU Member States who were non-compliant for NH_3 by 2030, project compliance with their emission reduction commitments. Similarly, for NO_x and SO_x, 8 and 4 EU Member States who were forecasting non-

compliance in 2030 under a WM scenario, predict compliance under a WAM scenario. So, while many EU Member States have made progress in their planning, there are still some who have not yet reported information on how they intend to comply with their emission reduction commitments in 2030.

Table 8 presents emission projections for EU Member States for 2030. These are best estimates based on current reporting[9]. N.B. *This table and subsequent tables in this section have been compiled using a submission that was made prior to the UK exiting the European Union. The UK is therefore included in the tables as an EU Member State*.

Where an EU Member State currently reports projections for 2030 that are compliant with the NECD's emission reduction commitments, it is assumed that these values represent the best estimation of emissions in 2030. Projections from With Additional Measures (WAM) scenarios have been used if these were reported – the UK did not report WAM projections. For Member states who did not report WAM projections, the With Measures (WM) scenarios were used. Compliant values are coloured in green in Table 8.

Where an EU Member State currently reports projections that are not compliant with the NECD's 2030 emissions reduction commitments, it has been assumed that the Member State will take steps across the coming years to ensure compliance. Therefore, emissions in 2030 are expected to meet the reductions required by the NECD's emission reduction commitments, but not be any lower. As a result, the emission reduction commitments themselves have been used as the predicted emission for 2030 in the table below. Non-compliant values are coloured in red in Table 8.

One minor complication is that the emission reduction commitments exclude NO_x emissions from 3B Livestock and 3D Agricultural Soils, so these have had to be added to the "compliance totals" to give a more accurate estimate of the national emissions. Italy and Luxembourg have not reported NO_x projections for agricultural sources, so values from 2017 have been used.

Table 8. EU Member States compliance with their emission reduction commitments and their projected emissions for 2030 under WM and WAM scenarios. Green cells represent compliance with targets and red cells represent non-compliant values. N.B. This table was compiled using a submission that was made prior to the UK exiting the European Union. The UK is therefore included here as an EU Member State.

	NH_3		NO_x		SO_x	
Member State	2030 Projection (kt)	Commentary	2030 Projection (kt)	Commentary	2030 Projection (kt)	Commentary
Austria	55.17	Assume compliance by 2030	81.70	Assume compliance by 2030	13.31	Current projections
Belgium	60.88	Current projections*	108.38	Current projections*	33.07	Current projections*
Bulgaria	43.85	Current projections*	74.94	Current projections*	83.41	Current projections*
Cyprus	4.64	Current projections	7.82	Current projections	1.33	Current projections
Czechia	56.51	Current projections*	96.81	Current projections*	53.90	Current projections*
Germany	436.45	Current projections*	633.64	Current projections*	161.23	Current projections*

[9] Reported data is stored in the Eionet Central Data Repository: http://cdr.eionet.europa.eu/.

	NH_3		NO_x		SO_x	
Member State	2030 Projection (kt)	Commentary	2030 Projection (kt)	Commentary	2030 Projection (kt)	Commentary
Denmark	67.28	Assume compliance by 2030	74.54	Current projections*	10.53	Current projections*
Estonia	10.51	Assume compliance by 2030	12.21	Current projections*	10.83	Current projections*
Spain	395.76	Current projections*	452.89	Current projections*	99.06	Current projections*
Finland	27.96	Current projections	84.79	Current projections	24.33	Current projections
France	524.83	Current projections*	370.32	Current projections*	72.66	Current projections*
United Kingdom	239.02	Assume compliance by 2030	498.65	Assume compliance by 2030	92.74	Assume compliance by 2030
Greece	67.36	Current projections*	213.30	Current projections*	44.16	Current projections*
Croatia	26.70	Current projections*	40.94	Current projections*	6.52	Current projections*
Hungary	58.51	Assume compliance by 2030	76.89	Assume compliance by 2030	11.61	Assume compliance by 2030
Ireland	107.67	Assume compliance by 2030	77.61	Assume compliance by 2030	7.64	Current projections*
Italy	358.56	Assume compliance by 2030	479.56	Assume compliance by 2030	107.96	Current projections
Lithuania	28.11	Assume compliance by 2030	38.16	Assume compliance by 2030	9.23	Current projections*
Luxembourg	4.58	Assume compliance by 2030	10.18	Assume compliance by 2030	0.98	Current projections
Latvia	14.44	Current projections*	34.00	Current projections*	4.23	Current projections*
Malta	1.11	Assume compliance by 2030	2.05	Assume compliance by 2030	0.13	Current projections*
Netherlands	106.71	Current projections*	128.09	Current projections*	30.97	Current projections*
Poland	269.18	Assume compliance by 2030	544.74	Current projections	351.48	Assume compliance by 2030
Portugal	47.15	Current projections	83.54	Current projections	26.22	Current projections
Romania	82.81	Current projections*	141.35	Assume compliance by 2030	72.58	Assume compliance by 2030
Sweden	48.07	Assume compliance by 2030	69.25	Assume compliance by 2030	17.87	Current projections
Slovenia	16.88	Current projections	18.14	Current projections	3.23	Assume compliance by 2030

	NH_3		NO_x		SO_x	
Member State	2030 Projection (kt)	Commentary	2030 Projection (kt)	Commentary	2030 Projection (kt)	Commentary
Slovakia	24.70	Current projections*	50.48	Current projections*	15.48	Assume compliance by 2030

** Indicates projections under a 'With Additional Measures' scenario.*

The NECD reporting does not require detail of the uncertainties associated with emission projections, and it is challenging to quantitatively calculate the uncertainties. However, after considering the typical uncertainties in historical emission estimates, and the added uncertainties of projecting these into future years, the values in Table 9 are proposed as indicative uncertainties for 2030 emission estimates. Uncertainty estimates are presented in Table 9 for returns which report 2030 emission projections that are compliant with their emission reduction commitments. There is very limited information in the NAPCP and national emission projections reporting on the uncertainties associated with emission projections, so the data presented in Table 9 draw heavily on expert judgement. Higher uncertainties are presented for countries which are currently reporting non-compliance in 2030. Whilst it is assumed that these countries will implement further measures to ensure compliance by 2030, there is assumed to be an added level of uncertainty. This added level of uncertainty is because it is not clear what the exact impact of the added measures will be, and also because the lack of a compliant WAM scenario is typically associated with countries who have not done detailed projections assessments resulting in their reported emissions having higher uncertainties. There will be significant variation in the uncertainties between countries, but this has not been considered for the purposes of this project, as the analysis would be a time-consuming task.

Table 9. Overview of indicative uncertainties associated with 2030 emissions projections reported under NECD.

	EU Member States[#] reporting compliance in 2030	EU Member States[#] reporting non-compliance in 2030*
NH_3	±20%	±25%
NO_x	±10%	±20%
SO_x	±5%	±10%

[#] This table was compiled using a submission that was made prior to the UK exiting the European Union. The UK is therefore included here as an EU Member State.
*It has been assumed that these EU Member States will implement additional measures that bring them into compliance before the 2030 deadline.

3 Devolved Administration Information

3.1 Data availability

To be able to model and examine the spatial distribution of future nitrogen emissions for both the 2030 baselines and Nitrogen Futures mitigation scenarios, there is a need for data at a higher spatial and category resolution than is currently publicly available. Publicly available projections data for the UK are available in a format that resolves the data into a relatively small number of source sectors. Therefore, assumptions would need to be made to disaggregate these data into a suitably detailed dataset for use in this project. To avoid this, detailed Nomenclature for Reporting (NFR) code level data was used (Annex 2). These data are split by pollutant and are for the years 2020, 2025 and 2030. These detailed data enabled more accurate modelling of the spatial distribution of projected emissions and the impact of policies (existing or under development) on specific sectors.

In the NAPCP, emissions savings from each of the UK PaMs or groups of PaMs are given as a range with no indication of the most likely value. For the purposes of this project, Defra provided “central estimates” for the agricultural policies included in the NAPCP, including uptake rates and the abatement of emissions. This allowed the project team to model future emissions based on the most likely outcome, thereby considerably reducing uncertainty in the 2030 baseline and the scenarios based on it. For agriculture, the assumptions regarding uptake of specific mitigation methods for the UK-wide central estimate scenario were circulated to the Devolved Administrations to give opportunity for amendment at the Devolved Administration level based on their own estimates regarding policy implementation and measure uptake. UK Country-specific baseline projections for NH_3 emissions from agriculture for 2030 were developed from these (Table 10). Further details of the % uptake of measures are in Annex 2.

The National Atmospheric Emissions Inventory (NAEI) 2017 maps were used, providing the most up to date mapped emissions data for different pollutants on a 1km by 1km resolution at the time the project was being completed. The NAEI emissions are aggregated to sector level, such as road transport, combustion in industry and agricultural, forests and land use change[10]. Detailed spatial data at a sub-SNAP (Selected Nomenclature for reporting of Air Pollutants) sector level for key emission sources (e.g. transport, combustion) was used to map and understand the spatial distribution of emissions of NH_3 and NO_x.

For access to the detailed agricultural statistics on livestock and crops/grassland, data access agreements were put in place for Nitrogen Futures. These data agreements enabled the project team to model emissions at the highest level of detail, using the same methodology as for the publicly available 1 km agricultural emission maps via the NAEI[11]. This produced non-disclosive emission maps for all scenarios.

[10] Interactive viewer for the NAEI 2017 maps is available at: https://naei.beis.gov.uk/emissionsapp/
[11] Carnell, E.J., Thomas, I.N., Tomlinson, S.J., Leaver, D. & Dragosits, U. (2019) The spatial distribution of ammonia, methane and nitrous oxide emissions from agriculture in the UK 2017. (Contribution to the UK National Atmospheric Emission Inventory and Greenhouse Gas Inventory). Annual Report on Defra Project SCF0107. CEH Report. 13pp.

Table 10. Assumptions regarding the central With Additional Measures (WAM) NH_3 emission projection for 2030 for UK country-specific likelihood for uptake of agricultural emission reduction measures (NAPCP+DA baseline).

Policy	**Applicability**	**Uptake rate (% of animals/manure, *not* % of holdings)**			
		England	**Wales**	**Scotland**	**N Ireland**
Urease inhibitors	Urea fertiliser only (not UAN, ammonium nitrate)	100	100	100	100
Rapid incorporation (within 12h) of Farmyard manure (FYM) applied to arable soils	Dairy, beef and pig FYM applied to arable land. Assumes incorporation method is the same as the existing mix (plough, disc and tine)	70	Slurry 20; FYM 70	70	No change
Rapid incorporation (within 12h) of poultry manure applied to arable	Assumes incorporation method is the same as the existing mix (plough, disc and tine)	80	80	80	No change
Low emission slurry spreading to grassland	Small amount (c5%) by shallow injection; remainder by trailing shoe	70	70	70	95[a]
Low emission slurry spreading to arable	Small amount (c10%) by injection; remainder by trailing hose	70	70	70	95[b]
Spreading of digestate	Low emission spreading giving 30% reduction	95	95	95	95
Slurry store covers – above ground tanks	Rigid covers applied to tanks	100	100	100	30
Slurry store covers – earth-banked lagoons	Floating covers applied to lagoons	100	100	100	30
Cover manure field heaps	Sheeting cover on field heaps of manure	-	Poultry 95; Cattle & pigs 5	-	-
Digestate store covers	Rigid covers applied to digestate tanks; 95% emission abatement	100	100	100	50
Washing dairy collecting yards	Dairy cattle associated with outdoor collecting yards	80	50	80	15
Acid air scrubbers	Livestock housing for intensive pig and poultry housing	20	50	20	10
Grooved flooring for dairy cattle housing	Applicable to new build	25	25	25	25
Low protein diets - dairy	Dairy only; assume that pig and poultry already close to ideal	30	30	30	30

[a]5% by shallow injection, 45% by trailing shoe, 45% by trailing hose; [b]10% by injection, 85% by trailing hose.

3.2 Discussions with the Devolved Administrations

The project team held discussions with each of the Devolved Administrations to gain more information on policy intentions that differ to those stated in the NAPCP. This included policies that offer additional emissions savings that are already planned or policies that the Devolved Administrations would be interested in exploring further. Results of these discussions are provided in Table 10.

3.3 Spatial considerations/applicability of measures across the UK

A recent Defra project (Ammonia Futures)[12] investigated spatial variability in the feasibility/ applicability of NH_3 mitigation measures for England, across the 13 Natural England Areas, through workshops with farming stakeholders.

In summary, the project reports that feedback across all workshops was similar in terms of a range of mitigation actions assessed, despite differences in farming systems, soil types and climate. Regional differences regarding perceived practicality of measures did not reveal any spatial patterns related to known regional characteristics. For example, extended grazing was expected to be less practical in wetter regions in the west, or straw-based measures were expected to be more practical in regions with arable crops/high straw availability. The UKCEH team translated the bar charts by Natural England Regions provided (forming Appendix 1 of the project report) into maps, which also did not show any patterns requiring regional variation in emission factors for each measure.

[12] https://uk-air.defra.gov.uk/library/reports?report_id=995.

4 Appendix 1 Sector Lookup Table

The following table shows how detailed sources are aggregated into the NFR structure.

Table A1. Sector lookup table.

Nomenclature for projections reporting	Categories included
1A1 Energy industries	1A1a Public electricity and heat production 1A1b Petroleum refining 1A1c Combustion in manufacture of solid fuels and other energy industries
1A2 Manufacturing industries and construction	1A2a Iron and steel manufacturing 1A2b Non-ferrous metals manufacturing 1A2c Chemical manufacturing 1A2d Pulp, paper and print manufacturing 1A2e Food processing, beverages and tobacco manufacturing 1A2f Stationary combustion in manufacturing industries and construction: Other 1A2gvii Mobile combustion in manufacturing industries and construction: Other (please specify in IIR) 1A2gviii Stationary combustion in manufacturing industries and construction: Other (please specify in IIR)
1A3b Road transport	1A3bi Passenger cars 1A3bii Light duty vehicles 1A3biii Heavy duty vehicles 1A3biv Mopeds & motorcycles 1A3bv Gasoline evaporation 1A3bvi Automobile tyre and brake wear 1A3bvii Automobile road abrasion
1A3a,c,d,e Off-road transport	1A3ai(i) International aviation – take-off and landing 1A3ai(ii) Civil aviation – domestic take-off and landing 1A3c Railways 1A3dii National navigation 1A3ei Pipeline transport 1A3eii Other
1A4 Other sectors	1A4ai Commercial/institutional: Stationary 1A4bi Residential: Stationary 1A4bii Residential: Household and gardening (mobile) 1A4ci Agriculture/forestry/fishing: Stationary 1A4cii Agriculture/forestry/fishing: Off-road vehicles and other machinery 1A4ciii Agriculture/forestry/fishing: National fishing
1A5 Other	1A5b Other, mobile
1B Fugitive emissions	1B1a Fugitive emission from solid fuels: Coal mining and handling 1B1b Solid fuel transformation 1B2ai Oil (exploration, production, transport) 1B2aiv Oil (refining, storage) 1B2av Distribution of oil products 1B2b Natural gas (exploration, production, processing, transmission, storage, distribution and other) 1B2c Venting and flaring

	1B2d Other fugitive emissions from energy production
2A,B,C,H,I,J,K,L Industrial processes	2A1 Cement production 2A3 Glass production 2A5a Quarrying and mining of minerals other than coal 2A5b Construction and demolition 2A6 Other mineral products 2B2 Nitric acid production 2B3 Adipic acid production 2B6 Titanium production 2B7 Soda ash production 2B10a Other chemical industry 2B10b Storage, handling, transport of chemical products 2C1 Iron and steel production 2C3 Aluminium production 2C4 Magnesium production 2C5 Lead production 2C6 Zinc production 2C7a Copper production 2C7b Nickel production 2C7c Other metal production 2H1 Pulp and paper industry 2H2 Food and drink 2H3 Other 2I Wood processing 2K Consumption of POPs and heavy metals
2D,G Solvent and other product use	2D3a Domestic solvent use 2D3b Road paving with asphalt 2D3d Coating applications 2D3e Degreasing 2D3f Dry cleaning 2D3g Chemical products 2D3h Printing 2D3i Other solvent use 2G Other product use
3B Animal husbandry and manure management	3B1a Manure management – Dairy cattle 3B1b Manure management – Non-dairy cattle 3B2 Manure management – Sheep 3B3 Manure management – Pigs 3B4a Manure management - Buffalo 3B4d Manure management – Goats 3B4e Manure management – Horses 3B4f Manure management – Mules and asses 3B4g Manure management – Poultry 3B4h Manure management – Other animals
3D Plant production and agricultural soils	3Da1 Inorganic N-fertilisers (includes also urea application) 3Da2a Livestock manure applied to soils 3Da2b Sewage sludge applied to soils 3Da2c Other organic fertilisers applied to soils 3Da3 Urine and dung deposited by grazing animals 3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products

	3De Cultivated crops 3Df Use of pesticides
3F,I Field burning and other agriculture	3F Field burning of agricultural residues
5 Waste	5A Biological treatment of waste – solid waste disposal on land 5B Biological treatment of waste – composting 5B2 – Biological treatment of waste – Anaerobic digestion at biogas facilities 5C1a Municipal waste incineration 5C1bi Industrial waste incineration 5C1bii Hazardous waste incineration 5C1biii Clinical waste incineration 5C1biv Sewage sludge incineration 5C1bv Cremation 5C2 Open burning of waste 5D1 Domestic wastewater handling 5D2 Industrial wastewater handling 5E Other waste
6A Other	6A Other