An evaluation of the ability of existing policies to achieve nitrogen-reductions within national statutory targets and international commitments

IEEP UK & Aether Ltd

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Table of Contents

List of Tables

List of Figures

1. Executive Summary

There are many types of nitrogen in the environment, with many different effects on ecosystems and human populations, both beneficial and harmful. Reactive nitrogen is essential for all life on earth; but nitrogen pollution causes multiple negative impacts on different elements of the environment. The negative impacts of nitrogen cross a wide range of policy domains, including air pollution, climate, freshwater and marine policy, biodiversity, health, agriculture and food security. This presents challenges when it comes to selecting and adopting actions to address adverse impacts of nitrogen across its many forms. Measures addressing nitrogen pollution can be relevant across a suite of policies and policy areas and while there are multiple relevant statutory and non-statutory targets in place in the UK and its constituent nations, there are few interlinkages between them.

Policy targets to limit the impacts of nitrogen are present in different policy domains within the UK, (water, air, climate, biodiversity), but they have been established separately for the most part and tackling them separately can lead to pollution swapping. In addition, some more generic environmental targets have been adopted in policies that are not specific to nitrogen, but where addressing the nitrogen contribution is a key component of any programme to meet the target as a whole (for example the net zero greenhouse gas reduction target); or where measures to address other pollutants will also help to address nitrogen pollution (for example food waste targets). This creates a web of policies and targets bearing on nitrogen but the complexity can obscure the overall picture in terms of reducing nitrogen pollution.
Drawing on the new UK Nitrogen Balance Sheet (UK-NBS), which illustrates the major flows of nitrogen around the UK and identifies the biggest and most significant flows, the report identifies and outlines the current major routes of nitrogen loss to the environment in the UK. The report uses this assessment of flows as a basis for a more holistic / systematic framework that has the potential to highlight important flows that are not subject to statutory targets at present.

Each nitrogen compound has different environmental and social impacts depending on the compound, medium and exposure of different receptors (people, ecosystems), meaning that the impact cannot be determined solely by the size of flow. As such, this report aims to consider each of these aspects when seeking to identify key priorities.
The flows that are associated with the biggest environmental problems and the most significant target failures are examined and prioritised for action. Priority flows for action include ammonia losses to air from fertilisers and livestock (notably intensive housed livestock), losses to water from fertilisers and slurries applied to soil, NO_x emissions from power generation and transport, water pollution from sewage, atmospheric deposition of nitrogen onto sensitive sites and NO emissions to air causing climate change. Trends towards the targets now in place are assessed and are mixed in their progress.

Because of the negative impacts of excess reactive nitrogen on health and the environment, targets have been established in the UK and its constituent nations to reduce emissions and impacts, some of which have their foundation in international agreements such as the UNECE Gothenburg Protocol. Several are statutory targets and the report summarises progress towards these targets with examples from the four nations, particularly England: it concludes that progress is patchy. More vigorous implementation is required across the full range of sectors in order to meet existing targets. International indicators are still under development to guide implementation of the Kunming-Montreal Global Biodiversity Framework (GBF) and UK indicator finalisation will take place once the international indicator set has been adopted. However, as it stands the ambition of current UK targets falls short of that of GBF Target 7 and further measures will be required if GBF Target 7 is to be met.

For each of the priority nitrogen flows the major gaps resulting in excess nitrogen in the environment are identified along with evidence for where action on one flow is leading to increased pollution elsewhere. Measures have been ascribed to the sectors that most clearly have influence over progress in terms of relevant policy interventions. This results in a large number of measures being ascribed to the agriculture sector; however, many measures will have co-benefits in relation to the wider climate change and nature conservation agendas. In some cases, gaps are caused by the way in which a measure is implemented, monitored or enforced, rather than due to an absence of measures, for example where measures are voluntary with uncertain take-up and implementation on the ground.

A long list of policy measures that could potentially address these gaps are identified and then refined to a shorter list of proposals. These are RAG rated based on their likely scale and uncertainty of impact, prospective cost and timescale to implement and for potential trade offs and synergies across the field of measures addressing nitrogen pollution. A summary is provided of those measures that may have the best potential for development to address excess nitrogen and achieve reduction targets. Many measures will only be fully effective as part of a broader package and some will become more or less effective when combined with other measures.

Two strategic policy scenarios are suggested, one based on further implementation of existing measures and additional selected measures; and another that looks at a new policy approach treating nitrogen as a system. The potential of these to reduce excess nitrogen to meet targets is explored, and trade-offs examined.
The central objective of Scenario A is to ramp up policy ambition with a strong focus on meeting current statutory targets and commitments, setting aside the broader systemic challenge of reducing flows across the board. Implementation of scenario A is unlikely to be sufficient to meet GBF Target 7.

Scenario B takes a system wide approach, assembling a set of measures that offer benefits both in terms of nitrogen reductions and other objectives such as lower GHG emissions, enhancement of biodiversity, greater agricultural efficiency etc. This scenario places an emphasis on both reducing losses of nitrogen and requiring greater reductions in the input of nitrogen through the system through better nitrogen use efficiency and shifting demand away from nitrogen intensive commodities.

There is a wide range of legislative, policy and other measures that the UK and the devolved administrations could put in place to better address nitrogen pollution in all of its forms. No single measure will be sufficient. The right combination of measures is needed to achieve the appropriate balance between different approaches. Specific measures need to be carefully considered to avoid pollutant swapping and, when sector or flow specific measures are put in place, to avoid negative impacts on other sectors or flows. Conclusions and findings from the research are used to inform a series of recommendations aiming to maximise the effectiveness of both existing and additional measures, including the following which are listed in full detail in the final chapter:

- **The UK needs an integrated nitrogen strategy** informed by a Nitrogen Balance Sheet and seek to achieve system-wide reductions in nitrogen losses.
- As part of this, **the UK needs a comprehensive Nutrient Management Strategy** in each of the UK nations.

- There needs to be **a programme to achieve improved implementation of existing measures, including higher take up of voluntary measures.**
- A suite of measures needs to be considered to **strengthen voluntary approaches**, **including shifts from voluntary to mandatory measures where progress is insufficient**.
- There should be a **greater role for supply side considerations, such as the pollution footprints of different products** in setting standards for food.
- Greater consideration needs to be given to **geographically specific and targeted measures**, including less livestock in better locations.
- **More and better enforcement of existing legislation** is needed as a mechanism to support better implementation. This could be supplemented by **new binding regulations** in some sectors and in relation to some flows.
- **A review should be undertaken of the use and effectiveness of incentives for nitrogen use in the agricultural and energy sectors** with the removal of perverse subsidies.
- **Include other sectors within the scope of controls and measures** that have proven effective in tackling emissions and / or pollution; and **reduce thresholds for the application of measures to avoid excluding significant flows**.
- More needs to be done on **behaviour change** with the aim of reducing demand for high nitrogen food products through less waste and dietary change; and to engage farmers, with an element of co-design, to persuade them of the importance of the initiative, adopt best practices and engage in peer-to-peer learning.
- **Government should respond to the NMEG report** as a matter of urgency.

2. Introduction

There are many types of nitrogen in the environment, with many different effects both beneficial and harmful. Reactive nitrogen is essential for all life on earth; but nitrogen pollution causes multiple negative impacts on the environment. The negative impacts of nitrogen therefore cross a wide range of policy domains, including air pollution, climate, freshwater and marine policy, biodiversity, health and food security. This presents challenges when it comes to actions to address the adverse impacts of nitrogen across its many forms.

Reductions in excess nitrogen in various forms would contribute to the objectives of a suite of policies relevant to the environment and there are multiple relevant statutory and non-statutory targets, but there are few interlinkages between them.

Nitrogen is a key building-block for life. However, losses of reactive nitrogen compounds to the air, water and soil have seriously deleterious consequences for air quality, climate change, water quality and biodiversity. [1] Losses of concern are ammonia (NH_3) and nitrous oxide (NO) to air and nitrate to aquatic systems from agriculture and nitrogen oxides (NO_x) from combustion processes.

While the UK Government and the devolved administrations have a range of policies in place to reduce nitrogen lost to the environment in its many forms, these generally have a narrow remit relating to specific impacts. Some evaluation of the UK Government's ability to reach various targets by means of these policies has been carried out, but there has been no analysis of the ability of the Government to achieve all of these nitrogen-related targets in the round without producing unintended consequences, for example through pollution swapping[2]. Hence there is a need to identify an optimal solution for the domains of climate, air and water which balances priorities while identifying the most effective solutions for reducing environmental losses of nitrogen across the board.

This report seeks to consider the ability of existing policies to achieve nitrogen loss reductions as set out in statutory targets as well as contributing towards UK implementation of Target 7 of the Montreal Kunming Global Biodiversity Framework (**Section 3**). It aims to propose solutions to help the UK Government to achieve existing statutory targets (**Section 4**) and provides scenarios to aid prioritisation of actions based on the most effective nitrogen loss reductions and greatest value for money (**Section 5**). The information accessed and the approach developed for the analysis are described below.

This introductory section (**Section 2**) identifies and outlines the current major routes of nitrogen loss to the environment in the UK. Drawing on the new UK Nitrogen Balance Sheet[3] (UK-NBS), which describes major flows of nitrogen in the UK, in terms of losses, inputs and intermediate flows. The report uses this assessment of flows as a basis for a more holistic / systematic framework that has the potential to highlight important flows that are not subject to statutory targets.

[1] Hicks W.K. & McKendree, J.; Sutton M.A. & Cowan, N.; German, R., Dore, C. & Jones, L.; and Hawley, J. & Eldridge, H., (2022) *Finding the Balance* WWF-UK (wwf.org.uk/sites/default/files/2022-02/NITROGEN_REPORT_summary_final.pdf)

[2] 'Pollution swapping' can be defined as increasing emissions of one pollutant as a consequence of controlling another pollutant.

[3] Dragosits, U., Pearson, C. (2020) *A new UK Nitrogen Balance Sheet (UK-NBS): Methodology Overview. 1*. UK Centre for Ecology and Hydrology.

Each nitrogen compound has different impacts depending on the compound, medium and exposure of different receptors (people, ecosystems), meaning impact cannot be determined solely by the size of flow. As such, this report aims to consider each of these aspects to identify key priorities.

The UK-NBS (figure 1, further described in **Annex 1**) provides a useful overview of the main losses, input flows and intermediate flows of nitrogen. These are summarised in **Annex 2**, along with a more detailed overview of the losses to air and water as well as input and intermediate flows. It is worth noting that there is potential for large emissions of reactive nitrogen from sources that are not currently fully reflected in the UK-NBS but which could grow dramatically as a by-product of decarbonisation. This includes use of ammonia as a major shipping fuel and emissions from CO_2 capture chemicals (amines). It is also worth noting that there are some discrepancies between different sources which is partly down to uncertainties in some of these flows.

Nitrogen balance sheets have been produced in other countries as well as the UK. To illustrate these, **Annex 3** outlines key insights from the nitrogen budget sheets produced in two other major industrialised countries, Germany and Japan. In these balance sheets emphasis is placed on the main flows of nitrogen.

Annex 4 presents time series data on major nitrogen flows in the UK and focuses on the main input and loss nitrogen flows highlighted in the UK-NBS, including emissions to air.
Various targets have been set that aim directly or indirectly to reduce the impact of nitrogen in the UK environment. Timely progress towards targets has been mixed but there remains too much reactive nitrogen in too many places and no sign that key targets will be met soon, including in relation to the Kunming-Montreal Global Biodiversity Framework (GBF). Details of relevant international targets pertaining to the UK can be found in **Annex 5**. Progress towards meeting targets in the UK is set out in **Annex 6**, along with details of historical trends and projections.

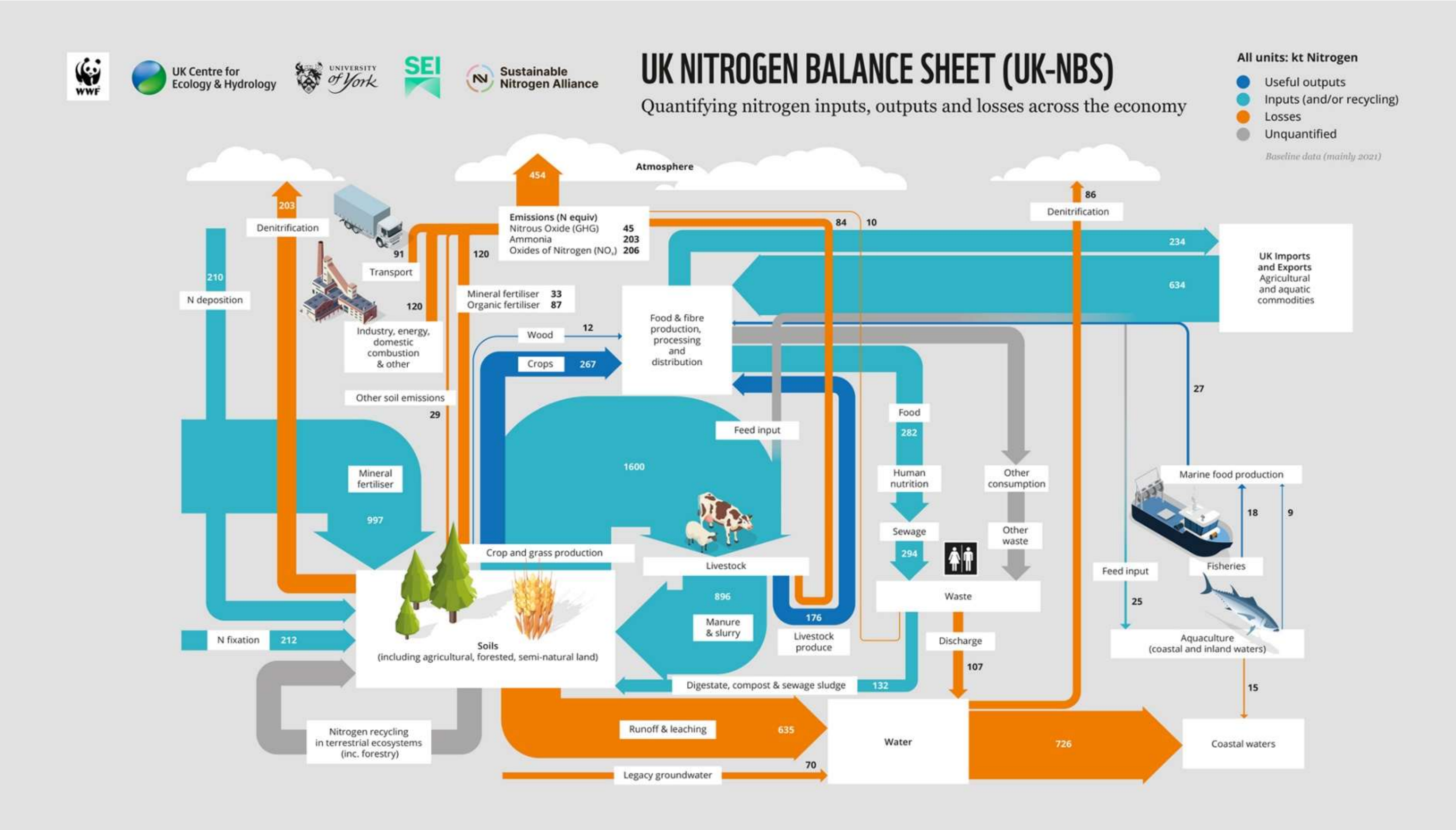

Figure 1: UK Nitrogen Balance Sheet

3. Gap Analysis

3.1 Prioritisation of Flows to examine further

When prioritising action to reduce losses, one important aspect of nitrogen flows to take into account is the magnitude of negative (or positive) impacts that the source may have on people or the environment independently of excess levels of nitrogen. For the Sustainable Nitrogen Alliance (SNA), which commissioned this report, the key issue is the negative consequences of excess nitrogen on biodiversity, water, climate, air and farming systems. Given this, a key theme running through this report is the importance of policies that can cut across sectoral or media (air, water) silos. This theme can be extended to emphasise the importance of policies not being narrowly focused on only one pollutant or type of impact. For example, fossil fuel combustion and urea fertiliser application both produce greenhouse gases as well as nitrogen losses, and mitigation of these damaging impacts is not currently linked.

Based on the analysis of flows set out in Annex 2, a selection of priority flows will be considered in further detail in this report to determine priority areas for future action. An exercise was undertaken to determine which flows to focus on, based on the magnitude of the flow and its impact; the degree of control that can be exercised over the flow in question; and association with other negative impacts (i.e. water quality, GHG emissions).

Table 1 below sets out the flows associated with a) the most significant actual or potential environmental problems associated with nitrogen and b) where there are apparent failures to progress sufficiently fast towards targets in the UK.

Table 1: Prioritised flows of nitrogen in the UK

Priority Flows	
Flow	**Rationale for prioritising**
Agriculture	
Loss of fertiliser inputs to air	Large source of loss with potential for fertiliser type substitution and some degree of control over this. Projected reductions in NH_3 emissions to air under existing policies and measures are small, so there is considerable scope for improvement. (NB link to N_2O emissions)
Cattle housing / manure management to air	Large source of N loss with potential for improved control at source and also in demand management. Projected reductions in NH_3 emissions to air under existing policies and measures are small, so there is considerable scope for improvement. (NB link to CH_4 emissions)
Agricultural soils to water bodies	This is the most significant flow in magnitude, and the Environment Act 2021 target of a 40% reduction by 2038 in England seems unlikely to be met with present policies alone. (NB link to Phosphorus and wider nutrient pollution)

Input of fertilisers to soil	Large source of loss with potential for substitution and some degree of control. Clearly shows the need for system level policies to increase circularity.
Input associated with livestock waste	Large source of loss with potential for substitution and some degree of control. Clearly shows the need for system level policies to increase circularity and points towards the need for demand-side reduction.
Combustion	
Residential / combustion	Small projected reduction only in NO_x emissions. Uptake under the current government policy on domestic boilers is very slow.
Small commercial combustion and industrial engines	Applies to installations that do not require permits. Small projected reduction only in NO_x emissions.
Transport	Road transport NO_x emissions are projected to fall rapidly under current policies, but shipping NO_x emissions are not decreasing and there is a risk of future NH_3 emissions as NH_3 gains ground as an alternative fuel. (NB link to N_2O emissions)
Wastewater treatment	
Discharges to water bodies	Significant flow and topical issue given issues around wastewater discharges and proposed increases in investment in treatment. Could become more important if agricultural losses were decreased.
Other	
Nitrogen deposition to soils	This is a cross-cutting "symptom" of pollution elsewhere, but the spatial element of policymaking is important in this context.
Denitrification	Although this is not a form of pollution, it is one of the biggest losses in the system as a whole and therefore merits consideration of ways to avoid losses and increase circularity.

Other important flows include food to waste and nitrogen in imported agricultural and aquatic commodities. Food to waste is not well characterised within the UK-NBS (Annex 1) but is an area with significant public interest (albeit not relating directly to nitrogen loss). It underlines the need for system level policies given that agriculture is both a cause of waste as well as a user of recycled nitrogen from food waste.

Imported commodities also provide a large input of nitrogen to the system, but direct negative impacts are relatively low. This highlights several issues, including the need to reduce imports of nitrogen without compensating by increasing fertiliser input and / or environmentally negative land use change to maintain production levels. The question of imported food and feed also highlights the potential significance of demand side changes i.e. the scope for dietary change, giving rise to reduced demand for imported livestock feed, freeing up land supporting livestock production to grow alternative foods such as more pulses, fruit and vegetables domestically. As there are no statutory targets for either of these flows, they will be further addressed in the solutions matrix rather than in the detailed gap analysis below.

3.2 Legislative and policy framework

The number of current policy instruments germane to the management of nitrogen and reduction of waste in the UK is large owing to the many economic sectors and environmental topics involved and the combination of UK wide and devolved primary and secondary legislation and policy measures that are in place.

As it stands, there is no single mechanism, piece of legislation or policy approach that comprehensively covers nitrogen emissions to the environment. Relevant policies and legislation are fragmented, being primarily aimed at various sources of pollution across different sectors and dealing with each sector in isolation. Whilst this approach makes sense from a sectoral perspective, it increases the risk of gaps and unforeseen consequences. As indicated by the Nutrient Management Expert Group (NMEG) in its recent report to Defra, *"addressing only one type of pollution (and from only one source) can easily cause the simultaneous increase of another type of pollution elsewhere in the system"*.[4]

The lack of a coordinated, coherent approach to nitrogen pollution also means that trade-offs and co-benefits between policies and sectors cannot be fully realised. Section 3.4 of this report will consider the gaps in policy, legislation and other interventions left by the current approach.

3.3 Relevant Targets

In this section, we provide an overview of progress towards meeting relevant statutory targets related to nitrogen flows, as well as other non-statutory targets and indicators. Targets in the UK in relation to the priority flows are set out in Table 2 below. The summary of progress given in the table is based on a more detailed analysis presented in **Annex 6**.

For the sake of clarity, targets have been ascribed to the sectors that most clearly have influence over progress towards that target in terms of relevant policy interventions. However, it is worth noting that actions across multiple sectors and linked to multiple policy interventions may have a contribution to make in terms of progress towards and in relation to individual targets. For example, steps towards meeting the National Emission Ceilings Regulation target of a 73% reduction in NO_x emissions by 2030 are influenced by combustion emissions from several sectors (transport, industry, building energy) as well as emissions from agricultural soils and wastewater treatment.

[4] Nutrient Management Expert Group (2024). *Improving policy and practice for agricultural nutrient use and management*, Report to the UK Department for Environment, Food and Rural Affairs. (https://assets.publishing.service.gov.uk/media/663234c42ea7c8bba6ebe14a/Report_of_the_Nutrient_Management_Expert_Group.pdf)

Table 2: Summary of progress towards targets in the UK (based on analysis in Annex 6)

Priority Flows		
Flow / Impact	**Target**	**Progress**
Agricultural fertilisers to soil	Reduce total ammonia (NH_3) emissions to air by at least 8% from 2005 levels in all years between 2020-2029, and by 16% from 2005 levels in 2030 onwards.	Neutral
Fertiliser to air		
Cattle housing / manure management to air		
Agricultural soils to water bodies	Reduce nitrogen, phosphorus and sediment pollution from agriculture to the water environment by 10% by end of January 2028	Neutral
	Reduce nitrogen, phosphorus and sediment pollution from agriculture to the water environment by 15% in catchments containing protected sites in unfavourable condition due to nutrient pollution by end of January 2028.	Neutral
	Reduce loss of nitrogen, phosphorus and sediment pollution load from agriculture to the water environment by 40% by 2038, compared to 2018 baseline	Negative
Discharges to water bodies	There is no statutory target that specifically focuses on achieving nitrogen reductions for wastewater at a national level. See Section 3.4.3 for a more detailed appraisal of the approach the UK government currently takes to achieve nitrogen reductions on a point source basis.	Negative
	Drinking Water Standards: Nitrate: 50mg/l; Nitrite: 0.5mg/l	Unable to assess
Residential / combustion	Reduce total nitrogen oxides (NO_x) emissions to air by at least 55% from 2005 levels in all years between 2020-2029, and by 73% from 2005 levels in 2030 onwards.	Positive
Commercial combustion and industrial engines		
Transport		
	NOx ambient air quality: All zones annual average < 40 µg / m3; all zones 1 hr average of 200 µg / m3 exceeded no more than 18 times	Positive
Cross-cutting	Reduce pollution risks and the negative impact of pollution from all sources, by 2030, to levels that are not harmful to biodiversity and ecosystem functions and services, considering	Unable to assess in absence of indicators

	cumulative effects, including: reducing excess nutrients lost to the environment by at least half including through more efficient nutrient cycling and use. (GBF Target 7)	
	Reduce UK net greenhouse gas (GHG) emissions by 100% by 2050 (including N_2O)	Neutral - Negative
	Highest annual mean concentration in the most recent full calendar year must not exceed 12 μg/m3 of PM2.5 (by end of Jan 2028)	Positive
	Reduction in population exposure to PM2.5 in the most recent full calendar year must be 22% or greater compared to 2018 (by end of Jan 2028)	Positive
	The annual mean level of PM2.5 in ambient air must be equal to or less than 10 $\mu g/m^3$ by end of 2040	Positive
	35% reduction in population exposure by the end of 2040 (compared with average population exposure 2016 to 2018)	Neutral-Positive

Details of corresponding international targets can be found in **Annex 5**. The Kunming-Montreal Global Biodiversity Framework 2022-2030 (GBF) was adopted at the Fifteenth Meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD COP15) in December 2022. Target 7 of the GBF is of direct relevance to nitrogen pollution and sets the basis for a framework for international action to tackle pollution. Since indicators are yet to be developed, a detailed evaluation of progress towards GBF Target 7 is not yet possible. This report therefore seeks to identify where policies or approaches are likely to be of relevance to future assessments of implementation of the GBF.

However, in terms of the ability of existing measures to meet GBF Target 7, it is worth noting that the ambition of current UK targets falls short of that of GBF Target 7. At its simplest level, if we assume that all flows should be targeting an equal 50% fall in losses by 2030 from current levels (whilst appreciating that indicators and baselines have not yet been adopted internationally or at UK level), it is relatively straightforward to compare this significant decrease with what percentage reduction from 2022 to 2030 is implied by current National Emission Ceilings Regulations targets:

- for NH_3, meeting the 2030 emissions reduction commitment only requires a 4.3% reduction between 2022 and 2030;
- for NO_x, meeting the 2030 emissions reduction commitment only requires a 28% reduction between 2022 and 2030;
- Using the Defra approach of the soil nutrient balance statistics as a proxy for agricultural losses to water, the UK target (40% reduction from 2018 by 2038) would be a 53.8 kg N/ha on average, which, if a linear reduction, would only mean a 16% decrease from 2022 levels by 2030 (noting that these statistics are very volatile year to year so could change in either direction).

As can be seen in Table 2 above, progress towards targets is not consistent across sectors and flows. In terms of **agricultural emissions to water**, recent projections show that the UK Government is not currently on track to achieve the 2038 target for England of a 40% reduction in the loss of nitrogen, phosphorous and sediment pollution load from agriculture to the water environment as the current rate of reductions is insufficient. However, the recent OEP review of progress under the EIP is more optimistic about reaching the 2028 interim target of a 10% reduction. The scale of uptake assumed in the EIP is, however, significantly greater than that which has been achieved to date, largely with voluntary measures, which could make the achievement of the 2028 target challenging without additional intervention.

Drinking water targets set a maximum value of 50mg/l for nitrate and 0.5mg/l for nitrite within groundwater and surface water bodies throughout the UK. No quantitative projections of likely surface or groundwater nitrate or nitrite levels could be found, however, studies suggest that groundwater is expected to continue to deteriorate for nitrates between now and 2050 unless interventions to prevent the continued deterioration and pressures of climate change and population growth are mitigated.

Emissions to air show greater improvement, with the 55% emissions reduction commitment (ERC; from 2005 levels) for NOx in 2020-2029 already being met in 2022, and the 73% ERC for NO_x by 2030 being largely on track. The latest compliance data for NH_3 show that the UK is complying with the 8% ERC for 2020-2029, but will narrowly miss the 16% ERC for NH_3 by 2030 by around 1 percentage point. However, the compliance figures for NH_3 exclude emissions from spreading of non-manure digestate (which is a growing source) and when this source is included there is almost no reduction in emissions projected between 2022 and 2030.

Therefore, whilst official compliance with NH_3 ERCs in 2030 is achievable (assuming policies are implemented as projected), this is not resulting in the level of real-world NH_3 emission reduction needed to align with GBF target 7.

Regarding $PM_{2.5}$ concentration and exposure targets (which NO_x and NH_3 emissions to air have an influence on), progress towards interim 2028 targets is good; in 2023 the annual average concentration limit of 12 µg/m^3 was already met across all monitoring sites, and the target 22% reduction population exposure from 2018 levels also was already achieved. Progress towards the more ambitious 2040 targets is harder to assess, but generally seems on track (see Annex 6 for further details).

Greenhouse gas targets are included in Table 2 however there are no nitrogen specific targets in addition to the overarching target to reduce UK net greenhouse gas emissions by 100% by 2050. The target is included as there are major co-benefits of climate action to reduce combustion CO_2 emissions through electrification, as this also reduces NO_x emissions; and the same is true for nitrogen losses from soil: action to reduce carbon losses will also reduce nitrogen losses and manure management will benefit N_2 losses through denitrification. N_2O emissions have reduced by 57% since 1990, largely due to near elimination of emissions from industrial processes. Agricultural N_2O emissions have also seen a decrease. However, more recent trends are flatter, suggesting that greater focus on implementation is required.
Further detail on progress towards targets in the UK is set out in **Annex 6**, along with details of historical trends and projections. This includes consideration of some non-statutory targets and targets that relate to more minor flows as these non-statutory targets, and the measures to implement them, are particularly relevant in relation to the wider requirements of GBF Target 7.

3.4 Gaps in policy, legislation and other interventions

This section assesses the gaps in policy, legislation and other interventions in relation to the major routes of nitrogen loss to the environment in the UK and the need for an across-the-board reduction in losses as agreed within the CBD, with a halving of excess nutrient losses (see Annex 5). A summary of the main policy targets for nitrogen reductions in the UK is presented and the most important flows for reducing nitrogen losses are defined, based on size, current degree of progress and policy relevance. Each of the priority flows is assessed by looking at historical trends and projections, any targets that are in place and the measures in place to meet those targets.

For the purpose of this section, 'gaps' are understood to be:

- areas where there are major flows but no binding legislation aimed at reducing excess flows;
- areas where there are major flows with reduction targets in place, but no implementing measures are in place;
- areas where there are both targets and implementing measures, but the measures are not being applied effectively, either through lack of uptake or lack of enforcement, suggesting that additional policies or measures are required; or
- areas where the UK approach falls short of what would be considered best practice internationally and has proven effective elsewhere.

For the sake of clarity, policy interventions and gaps have been ascribed to the sectors to which they most clearly relate. This section therefore provides a sectoral overview of policy interventions, measures and gaps related to the regulatory targets considered above and in

Annex 6. As noted above, however, actions across multiple sectors, and linked to multiple policy interventions, may have a contribution to make in terms of progress towards and in relation to individual targets. In other words, implementation is required across the full range of sectors in order to meet existing targets.

3.4.1 Agriculture

3.4.1.1 Legislation, policy instruments and measures

Most measures addressing agricultural pollution in the UK are voluntary and not generally targeted on nitrogen losses or flows. This applies both at the UK level and within the four nations. There is no overarching focus on reducing nitrogen losses in the agricultural sphere or specific strategy with this objective. The policy apparatus is not orchestrated in such a way as to provide a coherent set of interventions focused on the nitrogen problem and as such there is no credible correspondence between the policy mix and an ambitious synthetic target such as Target 7 of the Global Biodiversity Framework. This is a very significant policy gap.
The details of the current agricultural policy mix vary slightly between the four nations, but all include basic income support, although this is being phased out in England and is at around half its previous level currently, whilst the budget for agri-environment payments is being increased, creating potential for significantly greater environmental benefits from agricultural spending. At a broad level it is worth noting the main elements of the mix and observing the gaps that arise at this level. Addressing these more generic gaps is a critical element of any strategy alongside more specific and targeted measures noted in relation to specific flows below.

The regulatory baseline regarding agricultural pollution is largely the same in the four countries, with limited focus on nitrogen specific objectives. One exception is the nitrogen vulnerable zone (NVZ) related measures, derived from the EU Nitrates Directive, which aims to limit water pollution. It applies in all four nations and establishes a zonal approach within which certain limitations on agricultural practice apply, including a maximum input of nitrogen application per hectare. This is a potentially effective model, but the standards are not set at an ambitious level, enforcement levels are not high and the relatively limited progress in reducing nitrogen levels in water is testament to its shortcomings as an effective measure to date.

Alongside this there are other regulations, including the provisions under the Water Framework Directive, the Farming Rules for Water in England and its equivalents and the Environmental Permitting Regulations (EPR) which set requirements for larger intensive pig and poultry units, rules derived from the EU Industrial Emissions Directive. The requirements are based on the principle of applying Best Available Technology (BAT), lowering emissions relative to normal commercial practice on farms. Following BAT is thought to reduce emissions from farms under the EPR regime by around 30% relative to preceding management practices[5]. This regime currently covers a relatively small proportion of intensive livestock units. Wildlife Link and partner organisations have estimated that about 8% of ammonia emissions in England are derived from these regulated farms which include poultry units with 40,000 or more birds[6].
One gap in this regime is the exclusion of large indoor cattle units which are present in both dairy production (concentrated on larger farms) and beef production. The size thresholds for pig and poultry farms within the regime are also relatively high, particularly given that farms within

[5] Misselbrook, 2022
[6] This calculation uses data derived from "Emissions of air pollutants in the UK – Ammonia (NH3) - GOV.UK (www.gov.uk)" and "Review of activities regulated by the Environment Agency, 2022 - GOV.UK (www.gov.uk)".

the regime are subject to considerably more frequent inspections than smaller units so enforcement effort is concentrated in this segment.

A second gap is the absence of effective measures to control the concentration of livestock production in specific localities which may be attractive in economic terms but where limitations on the capacity to absorb the additional pressures are very evident, such as the Wye Valley in England. The system of River Basin Management Plans under the Water Framework Directive has not been sufficiently robust to contain this problem, which amounts to an implementation gap as well as a weakness in regulation.

It is clear that the number of large intensive units is increasing and that they are responsible for significant local pollution concentrations. A recent report from a coalition of NGOs published by Wildlife Link recommends *"1. Reformed Permitting Thresholds: Lowering the threshold for application of the environmental permitting regime for poultry and pig farming and setting explicit thresholds for cattle and other forms of livestock to bring these facilities within the permitting system."* whilst also setting additional operating standards and ecological conditions for being granted a permit[7]. The National Air Pollution Control Programme (NAPCP) 2023 report also highlights the growing share of production coming from bigger livestock units, and recommends adding tree shelter belts around livestock housing[8].

Another gap is the relatively undemanding standards for the storage and application of organic slurry/manure compared with best practice as applied in leading countries such as Denmark and the Netherlands, which (for example) mandate covering of slurry stores and low-emission slurry spreading. The Northern Ireland Nitrates Action Programme has taken a step towards higher standards, but so far not the rest of the UK.

It is also important to match measures to reduce nitrogen losses from storage and application of slurry/manure with adjusted application rates to soil; without such adjustment, measures risk "pollution swapping" and miss the opportunity for financial benefits. This highlights the importance of joining up policies on manure storage and application with nutrient management plans and spatial planning. The spatial distribution of nitrogen availability and potential for spatial re-distribution of excess nitrogen (as manure/slurry, or as processed products) should be a key feature of any strategy to limit reactive nitrogen emissions, and a consideration in a future Land Use Framework.

Inorganic and organic nitrogenous fertilisers (the latter including manures, slurry, digestate, sewage sludge etc) together make a very sizeable contribution to ammonia emissions and other nitrogen losses and reducing losses from this source is essential if more ambitious targets are to be met. Although the fraction from inorganic fertilisers is significantly smaller (See Annex 2) there are reasons to accord increased priority to this source. The production of inorganic fertilisers has a sizeable environmental footprint, relies heavily on fossil fuels and imported resources and its use involves costs that could be reduced if alternative and more efficient nutrient inputs e.g. from unavoidable organic sources, could be used instead. Many organic sources are by-products e.g. of livestock production and sewage treatment which will continue to be produced at some level. However, aside from measures addressing nutrient or nitrogen pollution more generally there is an absence of regulation more specifically on inorganic fertiliser inputs (see below), which marks a gap that needs addressing.

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[7] https://wcl.org.uk/docs/Link_Briefing_Permitting_June_2024.pdf

[8] Defra, February 2023. See: https://assets.publishing.service.gov.uk/media/63e508428fa8f50509bdd926/Revised_National_Air_Pollution_Control_Programme__NAPCP_.pdf

Regulation is supplemented with a system of cross-compliance, with some provisions that are additional to the statutory measures applying to farmers under the requirement to comply with Good Agricultural and Environmental Condition (GAEC). However, cross-compliance was removed in England in 2024 alongside the halving of direct payments and the system has been modified in the other nations.

There are several gaps in the regulatory system if it is compared with standards in countries which are more ambitious in this regard. One is the limited environmentally driven enforcement of regulations regarding agricultural pollution, which is weak relative to industrial sectors. Levels of inspection at farm level probably are insufficient to ensure adequate levels of compliance with environmental regulation in all four nations.[9] . Defra survey data show that the fraction of total GB arable land area where soil nitrogen tests were performed has increased from 11% to 20% between 2018 and 2022. However, there is still huge scope for improvement and the rate of testing on grassland is even lower at 3% of the overall area.[10] Failure to undertake current nutrient planning and soil tests under the Farming Rules for Water were one of the most recurring breaches identified in Environment Agency farm inspections in 2020/21.

The low rate of prosecutions for substantive breaches of environmental legislation on farms is striking. According to the most recent report on progress under the EIP in England "*During April 2023 to March 2024, the Environment Agency conducted 4,862 farm inspections in England and issued 469 warnings and notices to farms for failing to address non-compliance with regulations. In the same period, there were 6 prosecutions relating to polluting agricultural activities.*"[11]

Incentive payments for undertaking agri-environment commitments are a keystone of policy in all four nations, in essence aiming to reward the provision of environmental services by farmers via agreements stretching up to twenty or more years[12]. Progress against all the nitrogen related targets considered here in all four nations relies to a significant extent on changes to agricultural practice driven by these agreements, alongside increased compliance with current regulatory measures, more uptake of advice and developments via the market, including higher take-up of new technologies, many of which aim for greater efficiency in the use of inputs and therefore fewer losses in production systems. However, it is difficult to isolate the precise contribution that is likely to be made by the different voluntary schemes within the policy mix or the contribution of the many different elements within this relatively complex array of schemes.
In England, voluntary schemes, most but not all of which now fall within the ELM (Environmental Land Management) umbrella, are scheduled to grow in scale to account for

[9] In England, for example, farm inspections by the Environment Agency fell to around 280-400 per annum in 2016 to 2020. Subsequently, the total has risen to around 4000 annually which is probably still not sufficient as only about half of all farms are found to be compliant with the legislation when inspected and in many cases, there are multiple infractions. The Agency notified those farms that had been inspected of more than 4000 actions needing to be taken in order for them to come into compliance last year.

[10] Non-compliance identified by the Environment Agency on inspected farms would be expected to be greater than the average because of the anticipated risk factor informing the choice of farms inspected. Nonetheless, it is strikingly high, as suggested by data for 2020/2021 given in response to a FOI request. In this period, of 1021 breaches in total found on 531 farms, 96 were classified as breaches of the Nitrates regulations, 291 as breaches of the Farming Rules for Water and 634 as breaches of SSAFO. In England but not the other three nations, the inspection and enforcement effort has been reduced because of the removal of cross-compliance, as from 2024. A significant number of cross-compliance inspections by the RPA revealed shortcomings in relation to relevant cross-compliance conditions e.g. SMR1 and GAEC 1,3,4 and 5.

[11] https://www.gov.uk/government/publications/environmental-improvement-plan-annual-progress-report-2023-to-2024

[12] Most such agreements in England are for c. 3 years.

most of the currently £2.4m pa budget for agricultural support by 2028. They link up with capital grant schemes, which are flexible and have a combination of environmental and productivity objectives (currently but not permanently covering certain relevant actions such as upgrading slurry stores which are a major source of both water and air pollution). This large increase in potential resources and concurrent removal of untargeted direct payments in principle strengthens the likely contribution to be expected from voluntary schemes addressing pollution in England (but with slower progress in the same direction in the other nations).

The current Defra objective is to make a cumulative reduction in ammonia emissions in England of 4.1 kilotonnes by 2028 from a 2023 baseline. (NAO 2024). However, estimating this contribution is difficult, especially as it relies on farmer participation in relevant measures ('actions' in the jargon of the Sustainable Farming Initiative (SFI) the core scheme likely to account for the largest element of this budget in England). This potential is subject to a number of caveats, however. For example, scrutiny of the actual practices adopted within the SFI schemes in particular is limited and many of the actions are formulated in a relatively vague way, supplemented by more concrete guidance. There is no geographical or farm type/attribute targeting in the SFI, so the spatial distribution of uptake is difficult to match to local priorities (critical for water pollution and NH_3 emissions) and hard to predict. Farms are free to adopt any measure where they can meet the eligibility rules so that sub-optimal choices are made from an environmental perspective and until recently there has been no incentive to adopt environmentally desirable combinations of actions.

As Environmental targeting of SFI has been largely absent, it reduces its value as a mechanism to pursue thematically and geographically targeted goals as is required to address most nitrogen issues. There is time to change this and in mid 2024 Defra announced higher payments for a set of actions of particular environmental value and "Premium" payments could be used more for targeting. Alongside this, the more targeted higher tier ELM schemes, notably the Higher tier Countryside Stewardship and Landscape Recovery could be deployed on a faster timetable and on a larger scale than at the moment, to reduce and mitigate relevant environmental pressures and restore habitats.

The optimal deployment of voluntary measures and avoidance of gaps is a topic in its own right beyond the scope of this report. Stepping back from the detail, perhaps the critical gap at present applying to nearly all the agri-related issues covered here is the lack of a transparent pathway from Defra and its counterparts in other nations setting out how the voluntary schemes will be used to meet current binding and more aspirational environmental objectives, including the specific targets considered here. This is being called for by the OEP and others in England but applies more broadly.

In principle, there is recognition that both levels of participation in voluntary environmental schemes and improved compliance with regulatory measures is required. For example, in England, the Agriculture Transition Plan, a central plank of agricultural policy, now has an objective that "*By 2028, to achieve our challenging targets, we need to see universal adoption of farming regulatory standards and at least 70% of farmers and land managers undertaking environmental land management actions alongside food production*". However, it is not clear how the 70% participation level would read across to environmental outcomes or how far targeting would be used to steer the uptake of the most relevant measures. Furthermore, for those 30% of farms outside ELM and other voluntary schemes, there is strong reliance on regulatory levers, and a greater need to high levels of compliance. The absence of cross-compliance checks noted above, places a greater burden on routine regulatory compliance. On farm checking regimes by statutory agencies in England, currently run at around 4% per annum, which is not a large sample if the goal is to achieve significant changes in practice.

Another element in the policy mix, the advisory schemes, have potential both to increase the effectiveness of the voluntary measures and to steer farmers inside and outside these schemes towards better environmental performance. In England, the Environment Agency is strengthening its efforts in this area and was encouraged by the Conservative government to try to guide farmers more and penalise them less. The likely success of this approach is unclear and may or may not parallel some of the changes in farmer behaviour attributed to the SEPA approach in sensitive catchments in Scotland. In any case, the focus on sensitive catchments is likely to assist in meeting certain targets and this is the rationale for the recent increase in the budget and geographical scope of the Catchment Sensitive Farming schemes in England, which focuses especially on improved management to benefit soil and water quality. The budget for the Catchment Sensitive Farming Programme has been raised to £15million and the geographical scope widened significantly. However, while this is a step forward, there is scope to extend this considerably further and to increase the advisory effort in all catchments (NMEG 2024) The relatively low budget and share of overall effort allocated to advice has been a gap in agri-environmental policy and is an essential accompanying measure alongside other elements in the mix.

Often excluded from inventories of relevant policies are the perverse agricultural subsidies, especially those augmenting production and so increasing nitrogen flows, such as increased inputs of organic and inorganic nutrients to soil, a key flow considered below. Prominent examples are the continuation of coupled support for livestock, including cattle, notable in Scotland and Northern Ireland and the continued absence of taxation on red diesel increasing the scale of energy consumption in agriculture and associated emissions.

Coupled support for livestock raises production above counterfactual levels and lacks the conditionality of agri-environmental schemes applied in relation to livestock and grazing. If there is a case for supporting extensive livestock grazing systems this should be done via agri-environment schemes. The absence of a programme to remove coupled support is a further gap. Experience in Germany, where the taxation on agricultural diesel is being raised in stages, accompanied by animated farmer protest, shows that this is possible although clearly very unpopular with farmers. It might therefore be considered more of a medium term than immediate measure and more relevant to targets in the 2030-2035 window. Nonetheless, the absence of a proposal to address this subsidy in either environmental or energy policy is a gap**.** The lack of binding targets for GHG emissions reductions in the agriculture sector is a further gap. This would clarify the role of agriculture with regard to emissions reduction which is not a prominent element of the SFI for example. It would have co-benefits for the reduction of nitrogen losses.

Finally, all UK nations lack a nutrient management strategy that links targets and ambitions to proposed actions, indicators and pathways in the agriculture sector. This should provide a holistic frame and set out the steps required to address established goals in this sphere alongside those in related domains, including biodiversity restoration and climate mitigation and adaptation. This could then inform evolving land use strategies of the kind in place in Scotland and proposed but not yet published in England. This is a critical gap.

3.4.1.1.1 Inorganic and organic fertilisers to air

National targets for NH_3 emissions as outlined above are not sub-divided into segments e.g. for

fertilisers. Nitrogen fertilisers, particularly urea-based fertilisers (such as urea or urea-ammonium nitrate) are the second largest contributor to ammonia emissions.
For emissions as a whole, the latest NAEI projections count only firm and funded policy measures and anticipate a 15% reduction in emissions between 2005 and 2030, a 1% compliance gap with ERC. Within this, several sectors projected to have reductions less than required.

- Inorganic nitrogen fertilisers: emissions are projected to reduce by 4%, from 2005 to 2030, and will represent 13.8% of total NH_3 emissions in 2030
- Other organic fertilisers (e.g. digestate): emissions set to increase over 50-fold between 2005 and 2030. The huge proportional increase is due to starting from a very low base, but in 2030 these will account for almost 10% of NH_3 emissions.

According to technical advice from Defra's advisory committee on the topic, NMEG, to reduce both N_2O and NH_3 emissions from grassland, the best option could be urea with both urease and nitrification inhibitors[13].

The greatest ammonia abatement potential (approximately 14kt per year) is to mandate use of a urease inhibitor with both solid urea and liquid urea. Defra survey data show that in 2022, urea products with urease inhibitors were only used on 6% of the land area that urea was applied to[88]. Increasing this to 100% could lead to a reduction of 54kt per year in GHG emissions and may also help to reduce nitrate leaching to water and reduce reliance on ammonium nitrate as a substitute fertiliser. It has been proposed to introduce this measure in 2024, to allow farmers to use their existing stores of untreated urea and enough time for industry to provide the required increased supply of UI products.

Inorganic fertilisers make a very sizeable contribution to ammonia emissions and other nitrogen losses and reducing losses from this source is essential if more ambitious targets are to be met, including Target 7 of the Global Biodiversity Framework. However, there is an absence of regulation to minimise the air pollution footprint of nitrogenous and other fertilisers. In terms of emissions reductions, one of the most frequently recommended improvements on grassland is the use of urea only with both urease and nitrification inhibitors to reduce both N_2O and NH_3 emissions (NMEG). There is scope for a new regulatory regime to align the use of fertilisers more tightly to emission reduction goals, including where necessary banning or taxing certain products, requiring additives or authorising certain products only for particular applications. Such a regime could be created on the basis of a thorough scientific and agronomic review, ideally conducted at the UK level. The absence of a regulatory lever in this domain is a gap.

3.4.1.1.2 Cattle housing / manure management to air

As noted already, national targets for NH_3 emissions are not sub-divided into segments e.g. for the dairy sector. However, by far the greatest contributors to agricultural NH_3 emissions in the UK are beef and dairy cattle production and associated manure management. NAEI projections with existing measures forecast an increase in dairy cattle manure NH_3 emissions of 23%, from 2005 to 2030, 13.4% of total NH_3 emissions in 2030. This is a key challenge for reducing ammonia emissions over time.
Improved management of organic manures and slurries throughout the cycle from production to storage, handling and application is a critical priority, with clear scope for improvement. Best practice for slurry stores and land application systems needs to be the norm regarding emissions to air and water. For application measures, the use of shallow injection and band spreading equipment for slurry and other high nitrogen liquid organic materials on all farms is

[13] Freeman et al., 2020

recommended by NMEG. This is unlikely to be achieved purely by market forces, advice and investment aid at the current intensity.

At present, the aim is for all slurry stores to be upgraded or replaced to meet current standards, including compulsory covers by 2030. Regular updates on progress by Defra would be useful. The Defra air quality team is reported as working to define specific requirements for both new and existing stores (NMEG) and there is certainly evidence to draw on from leading countries in this sphere. According to NMEG "*Available research on slurry acidification shows that this is a reliable technique for reducing NH_3 emissions (UNECE Category 1 measure). Evidence from Defra Project SCF0215 suggests that reductions in ammonia emissions from slurry acidification can increase crop available nitrogen supply from slurry and digestate (ADAS in press).*"
Defra examined the options in a co-design exercise with stakeholders in 2023. One of the blockages that this revealed was a lack of suitable acid on the market for slurry acidification and this is one of the barriers that would need to be addressed under a systematic Nutrient Management Action Plan.

Accelerating the uptake of best practice in this sphere in all four nations is most likely to be achieved through a combination of measures, involving tightening regulatory standards, signalled well in advance, an accompanying capital grants programme with time limits for meeting standards, enhanced advice, adjustment of Red Tractor and other certification schemes. This formula also applies to losses to water.

There is also an important site-specific element with regard to the protection of sensitive habitats summarised by NMEG as follows:
"The current planning system may not adequately prevent the building of new potential point-sources of pollution (such as farming infrastructure that does not require planning consent) near sensitive sites, for example, Sites of Special Scientific Interest (SSSIs). Additional simple planning rules could be formulated, such as tighter restrictions applying within a certain radius of sensitive habitats. One concern is that while the retained law surrounding the Habitats Directive and corresponding regulations offers a high level of protection for Special Areas of Conservation in principle, this is not always achieved in practice. In particular, many potentially high-risk agricultural actions are not currently assessed as 'plans or projects' for which planning permission or environmental assessment is required. More careful redefinition of these terms and/or revised requirements for accompanying environmental information for all planning applications near to designated sites could enable the conditions of planning consent to be more carefully tailored to address such situations".

3.4.1.1.3 Agricultural Soils to water bodies

The AHDB Scenario Modelling of Rule 1 of the Farming Rules for Water indicate that the magnitude of losses will depend on the amount, timing and method of application, the soil type, etc.

On an optimised scenario: all spring slurry applications would be applied using a band-spreader, leading to a reduction of around 60% in NO_3- N losses but at the same time being likely to increase ammonia emissions by around 10% and P losses by around 30%. Hence there is a need to address trade-offs via a cross-cutting approach that is also able to combine focus on overall national emissions and elements of thematic and biogeographic targeting. This compares with a constrained scenario where current spreading practices maintained.

DEFRA claim that in England a combination of the recent agricultural policy changes, such as the expansion on ELMs and incipient measures to increase funding from private sector sources, (which could include water companies) and the impact of regulation will contribute at least 80% of progress required to deliver the Agriculture Water Target. This is difficult to assess on the basis of information in the public domain. In particular it is difficult to have confidence in the level of compliance with the current legislation on farms at present given the rate of failures detected by the Environment Agency noted above and relatively small proportion of farms being inspected.

Further progress could be made by a more ambitious approach to managing slurry and inorganic fertilisers, as outlined above.

3.4.1.1.4 Changing food consumption

Whilst not solely affecting agriculture, the absence of substantive measures to address the impact of food consumption and demand needs serious consideration (note some measures would link to the food waste section also, for example). A reduction in meat and dairy consumption, if matched with corresponding falls in domestic production, would make some contribution to overall nitrogen flows in the agri-food system. Quantifying the exact linkage between dietary changes, levels of livestock production in the UK, their distribution and management, and displacement with other production, and the associated nitrogen losses is extremely difficult. However, the direction of travel is clear. A recent UNECE report[14] on nitrogen in the food system considered scenarios with different means of achieving a 50% reduction in nitrogen losses by 2030. Of the scenarios achieving the target, those with high on-farm ambition but little action elsewhere in the food chain had poor overall scores for societal benefit, whilst those with the highest net societal benefit had some element of reduction in one or more of average energy intake, protein intake, or animal product intake. Fewer better managed livestock would reduce emissions in the UK. It would also contribute to a range of other environmental and health benefits.

Several approaches are possible here, with no single measure likely to work alone. Consumer tastes in the UK are shifting, for example with falling per capita meat consumption according to the Defra Family Food survey but with different trends for poultry than for red meat. Attitudes to eating more plant-based foods rather than meat and dairy[15], are changing in some social groups despite a lack of policy, and more due to cultural factors and an increased provision of alternatives by the market. In policy terms there are opportunities to use mechanisms to influence affordability, attractiveness and availability such as public procurement, official dietary guidelines, taxation, subsidies, emissions trading schemes, labelling, restrictions on advertising, promotion and initiatives in schools and other public institutions etc. One interesting initiative in Denmark is the introduction of a subsidy scheme to promote the production and consumption of plant-based foods to encourage the growth of the sector[16]. Similarly, these policy tools could be used to encourage purchase and promotion of foods produced using lower levels of nitrogen heavy inputs, including reduced inorganic fertilisers, such as that which is certified organic.

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[14] See footnote 6.

[15]Trends in consumption are complex and research may yield slightly contradictory results. See, for example, https://www.food.gov.uk/research/food-system-strategic-assessment-trends-and-issues-impacted-by-changes-in-consumer-attitudes, in comparison to Guadarrama, E., Spahic, A., Nosten, P., Machen, P. and Fong, B *Evolving appetites: An in-depth look at attitudes towards plant-based eating in the United Kingdom*, March 2024. See: https://smartproteinproject.eu/wp-content/uploads/UK_ProVeg_Smart-Protein-Report_2024.pdf

[16] The Plant-Based Food Grant - Plantefonden (lbst.dk)

3.4.1.2 Gaps

Summary of gaps identified:

- Exclusion of large indoor cattle units from BAT regime;
- Size thresholds for pig and poultry farms within the BAT regime are relatively high;
- Absence of effective measures to control the concentration of livestock production in specific localities;
- Lack of demanding standards for the storage and application of organic slurry/manure;
- Mandate the use of shallow injection and band spreading equipment for slurry and other high nitrogen liquid organic materials on all farms
- Spatial distribution of nitrogen availability and potential for spatial re-distribution of excess nitrogen;
- Lack of effective measures to reduce losses from inorganic nitrogenous fertilisers.
- Greater use of urease inhibitors with urea fertiliser
- Regulatory regime to align the use of fertilisers more tightly to emission reduction goals, including where necessary banning or taxing certain products, requiring additives or authorising certain products only for particular applications.
- Limited environmentally driven enforcement of regulations regarding agricultural pollution;
- Environmental targeting of the Sustainable Farming Incentive largely absent;
- Lack of a transparent pathway from Defra and its counterparts in other nations setting out how the voluntary schemes will be used to meet current binding and more aspirational environmental objectives;
- The relatively low budget and share of overall effort allocated to advice;
- Perverse agricultural subsidies;
- Absence of taxation on red diesel;
- Coupled support for livestock inflating numbers above market levels;
- Lack of binding targets for GHG emissions reductions in the agriculture sector;
- Lack of a comprehensive nutrient management strategy or implementing plan.
- Lack of plans or initiatives to support a reduction in meat and dairy consumption, or increase in plant-based diets;
- Lack of ambitious mandatory sustainability targets for public sector food
- Lack of support or promotion of certified organic production and consumption

3.4.2 Combustion

3.4.2.1 Legislation, policy instruments and measures

UK air quality legislation incorporates international commitments, as described above, retained EU law, and domestic law. Much of this also relates to agriculture, but is dealt with here, in relation to sectors including transport, building and industry. Emissions of key pollutants are regulated through a combination of national and devolved legislation.

The Environment Act 1995 required the publication of an Air Quality Strategy to set out air quality standards, objectives and measures for improving ambient air quality. Each UK nation has its own strategy:

- In England, the Air Quality Strategy 2023[17]

[17] Defra, April 2023. See: https://www.gov.uk/government/publications/the-air-quality-strategy-for-england https://assets.publishing.service.gov.uk/media/5a79b5f3ed915d07d35b789c/pb12670-air-quality-strategy-vol2-070712.pdf

- In Northern Ireland, a public discussion document[18] was published in 2020 to replace the 2007 UK-wide strategy[19] as it applies to Northern Ireland
- In Scotland, Cleaner Air for Scotland 2 – Towards a Better Place for Everyone[20]
- In Wales, the 2021 Clean Air Plan for Wales[21]

The Environment Act 1995 also established the Local Air Quality Management regime, requiring local authorities to review and assess air quality, designate Air Quality Management Areas, and develop action plans if standards were not met.

In February 2022, the UK Government published the Air Quality Common Framework,[22] which set out how the UK Government and the Devolved Administrations intended to work together to develop air quality policy following the UK's exit from the EU.

The National Emission Ceilings Regulations 2018[23] were the primary mechanism for implementing the EU National Emission Ceilings Directive, and consequently the UNECE Gothenburg Protocol. The Regulations remain in force and set UK wide emission limits or 'ceilings' for sulphur dioxide (SO_2), nitrogen oxides (NO_x), ammonia (NH_3) and non-methane volatile organic compounds (NMVOC) for the years 2010, 2020 and 2030 and for fine particulate matter ($PM_{2.5}$) for the years 2020 and 2030.

The UK Government and devolved administrations published a Revised UK National Air Pollution Control Programme (NAPCP)[24] in February 2023 setting out the individual measures that will be taken in each nation to meet the national emission ceilings legislation requirements. The NAPCP sets out measures and analysis for meeting the emission reduction commitments. The requirement on the UK Government to produce and update this document, which originally stemmed from EU law, has been removed by the EU Law Revocation and Reform Act 2023, removing a key element of accountability and transparency in relation to air quality.

Responsibility for meeting air quality limit values is devolved to the administrations in Scotland, Wales and Northern Ireland, with the UK Department for Environment, Food and Rural Affairs (Defra) retaining responsibility for coordinating assessment and air quality plans for the UK as a whole.

Concentrations of key air pollutants in outdoor air are regulated by:
- The Air Quality Standards Regulations 2010[25] (England)
- The Environmental Targets (Fine Particulate Matter) (England) Regulations 2023[26]
- The Air Quality Standards Regulations (Northern Ireland) 2010[27]

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[18] See: https://www.daera-ni.gov.uk/clean_air_strategy_discussion_document
[19] See: https://assets.publishing.service.gov.uk/media/5a758459ed915d731495a940/pb12654-air-quality-strategy-vol1-070712.pdf
[20] Scottish Government, 2021. See: https://www.gov.scot/publications/cleaner-air-scotland-2-towards-better-place-everyone/. A review of progress is scheduled for 2024.
[21] An update on progress was published in 2023. See: https://www.gov.wales/clean-air-plan-wales-healthy-air-healthy-wales.
[22] See: https://assets.publishing.service.gov.uk/media/61fa845ad3bf7f78e6c6f243/air-quality-provisional-common-framework.pdf
[23] SI 2018/129
[24] Defra, February 2023. See: https://assets.publishing.service.gov.uk/media/63e508428fa8f50509bdd926/Revised_National_Air_Pollution_Control_Programme__NAPCP_.pdf
[25] SI 2010/1001, as amended.
[26] SI 2023/96. This regulation was introduced under the Environment Act 2021, which required the UK to set a legally mandatory target for $PM_{2.5}$ for England. Interim targets are set out in the 2023 Environmental Improvement Plan.
[27] SR 2010/188, as amended.

- The Air Quality Standards (Scotland) Regulations 2010[28] and
- The Air Quality Standards (Wales) Regulations 2010[29]

These regulations set legally binding limits for concentrations in outdoor air of major air pollutants that particularly impact human health, namely sulphur dioxide, nitrogen oxides, particulate matter (PM_{10} and $PM_{2.5}$), lead, benzene, carbon monoxide and ozone. The regulations also include targets for levels in outdoor air for cadmium, arsenic, nickel and mercury as well as for polycyclic aromatic hydrocarbons (PAH). The regulations refer to 'limit values', which are legally binding, 'target values' and 'long-term objectives', which the government must take all measures to meet whilst not entailing disproportionate costs.

The UK Government's Compliance Assessment Summary of Air Pollution in the UK 2022[30] (the latest year for which data is available) showed that:

- Hourly limit value targets were met across the UK for NO_2, but nine zones (all in England) exceeding annual mean limit values,[31]
- Daily mean concentrations and annual mean concentration limits for PM_{10} were met across the UK,
- All limit values for $PM_{2.5}$ were met across the UK.

Legislation is also in place across the UK to regulate emissions from specific sources. This includes:

- The Environmental Permitting Regulations (England and Wales) 2016[32]
- The Pollution Prevention and Control (Scotland) Regulations 2012, as amended 2017[33]
- The Pollution Prevention and Control (Industrial Emissions) Regulations (Northern Ireland) 2013, as amended 2018[34]

These regulations set standards and provisions to reduce emissions of pollutants from a range of industrial sources – from intensive pig and poultry farms through to chemical manufacturing sites and power stations.

3.4.2.2 Gaps

Whilst overall, NO_x emissions from combustion sources have declined, and are projected to continue to decline, there are some specific areas where further or more rapid progress could be made.

Commercial and institutional combustion is projected to account for 3.4% of nitrogen emissions to air in 2030 and small industrial combustion (including non-road mobile machinery (NRMM) in construction and industry) is projection to account for 3.9%, both of which are only slightly reduced in comparison to 2005. The main mechanism for controlling emissions from stationary combustion installations is through compliance with an industrial installations permit. Industrial installations must use best available techniques (BAT) to reduce their

[28] SSI 2010/204, as amended.
[29] SI 2010/1433 (W. 126)
[30] Defra, September 2023. See: https://uk-air.defra.gov.uk/library/annualreport/assets/documents/annualreport/air_pollution_uk_2022_Compliance_Assessment_Summary_Issue1.pdf
[31] The UK is divided into 43 zones for air quality assessment. There are 28 agglomeration zones (large urban areas) and 15 non-agglomeration zones.
[32] SI 2016/1154
[33] SSI 2012/360
[34] SR 2013/160

emissions. These requirements only apply, however, in respect of large installations, creating a gap in relation to smaller facilities and industrial installations (which are responsible for around 40% of industrial GHG emissions. A clear strategy is therefore needed for decarbonising small facilities not covered by the Emissions Trading System. For NRMM, the main mechanism for reducing NO_x emissions is through increasingly stringent NO_x type-approval standards for new engines, which then drive down average emissions over time through fleet turnover. Revisions to the red diesel duty laws in 2022 to force NRMM in construction and industry to use white diesel may incentivise reduced diesel use, but unlike for road vehicles there is no clear UK government strategy for decarbonisation of NRMM. Domestic combustion and shipping account for significant components of remaining emissions, but reductions have been relatively good since 2005 (c. 50%), suggesting that other flows may be higher priorities for new and additional measures.

As regards domestic combustion, the UK Government has introduced the Air Quality (Domestic Solid Fuels Standards) (England) Regulations 2020,[35] which restrict the sale of wet wood and emissions from solid fuels, including a phase-out of traditional house coal. Similar controls on the sale of wood and phase-out of coal are yet to be introduced in the devolved administrations. However, these measures are mainly targeted at reducing PM emissions. To reduce NO_x emissions, tackling emissions from gas boilers is also important. As part of the Net Zero Strategy, the UK government has committed to phasing out installation of gas boilers in new housing in 2025, and sales of new gas boilers completely by 2035, thought this latter date is still subject to change. The CCC recommend bringing forward and committing to an earlier date for a full phase out of fossil fuel boilers. A shift towards electrification as the default for new buildings and replacement in existing buildings is also recommended by the CCC.

As regards transport, road vehicles are sources of air pollutants such as particulate matter and nitrogen dioxide (NO_2). The UK Government has issued several plans to reduce NO_2 levels due to zones not meeting EU limits. The most recent, and still current, plan is the "*UK plan for tackling roadside nitrogen dioxide concentrations: Detailed plan", July 2017.*[36] Mechanisms to reduce transport emissions include the introduction of road user charging zones have been put in place in some parts of the UK, such as London's low emission zone (LEZ) and ultra-low emission zone (ULEZ), England's clean air zones (CAZ) and Scotland's low emission zones (LEZ). However more can be done to encourage a modal shift, for example through investment in cycling and walking infrastructure, possibly targeting critical areas.

These zones are intended to reduce air pollution in cities by charging drivers of older, more polluting vehicles to enter them, with rules set on the basis of the Euro emission engine classification standards. Since 2017, the Government has used its powers under the Environment Act 1995 to 'direct' many local authorities to produce clean air plans. Local authorities can then charge drivers using powers granted by the Transport Act 2000. A key difference between the zones in England and Scotland is that in England, road users can pay to enter, with failure to do so attracting financial penalties; whereas in Scotland vehicles that do not meet the standard are prohibited from entry within the zone, again with financial penalties for failure to comply.

Very little has been done to date to fully address the impact of shipping emissions. Under current policies, NAEI projections show NO_x emissions in 2030 will represent 4.8% of all

[35] SI 2020/1095
[36] https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017

nitrogen emissions to air. In terms of reducing impacts of these emissions on land, a clear policy on incentivising shore power provision at ports is currently lacking[37].

Another likely trend is significant future use of green ammonia as a low-carbon shipping fuel (not currently factored into the NAEI emissions projections)[38]. One attraction of this is that it can be used in existing vessels in internal combustion engines, but there are concerns this may lead to NO_x and N_2O emissions[39]. Use of NH_3 in fuel cells would mitigate the NO_x risk, but there is also a (as yet unquantified) potential for fugitive gaseous NH_3 emissions, both from engines but also from the increased NH_3 production, transport and storage infrastructure on land. The UK government should consider NH_3 emissions to air, as well as the risk of liquid NH_3 spills to water (which is very toxic to aquatic life), in any impact assessment of policies on NH_3 emissions.

Summary of gaps identified:

- Lack of a clear strategy for decarbonising small facilities not covered by the Emissions Trading System
- Lack of a clear UK government strategy for decarbonisation of non-road mobile machinery
- More support needed to encourage a modal shift
- A fixed, earlier date is needed for a full phase out of fossil fuel boilers
- Need for stronger drivers for electrification as default option for new buildings and replacement in existing buildings.
- Lack of clear policy on incentivising shore power provision at ports

3.4.3 Wastewater treatment

The UK-NBS estimates the loss flow of total nitrogen to water through discharge was approximately 107 kt N in 2021. The discharge of industrial, agricultural and domestic sewage contains a variety of nitrogen-containing pollutants including ammoniacal nitrogen, nitrite nitrogen and nitrate nitrogen[40]. Discharging significant amounts of wastewater increases the total reactive nitrogen content, disrupting the nutrient balance of water bodies, whilst impacting other nitrogen flows through processes of denitrification and runoff.

3.4.3.1 Legislation, policy instruments and measures

Pollution from wastewater effluent is managed through a broad spectrum of policy and regulations, creating site specific compliance targets for nitrate based on environmental and human receptors and enforcement requirements for non-compliance.
Notably, there is discordance within the UK Government on how to frame nitrogen's role in wastewater pollution reduction commitments, at the national level. This is reflected in the lack of specific reference to the nitrogen component of wastewater pollution in statutory targets set for the whole of the UK.

[37] https://www.theccc.org.uk/wp-content/uploads/2023/06/Progress-in-reducing-UK-emissions-2023-Report-to-Parliament-1.pdf
[38] https://www.transportenvironment.org/uploads/files/UK-marine-e-fuel-mandate-lite-12.06.23.pdf
[39] Wong et al 2024: https://iopscience.iop.org/article/10.1088/1748-9326/ad5d07
[40] Zhou et al., 2023. See: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9967642/

In a UK Parliament House of Lords debate on private water companies in February 2024, pollution from wastewater effluent was referred to as *nutrient pollution*[41]. Responding to the Commons Environmental Audit Committee Water Quality in Rivers report, it was deemed that monitoring nutrients such as nitrogen and phosphates was *too narrow* a focus. The need for consideration of metals, pesticides, pharmaceuticals, industrial chemicals and plastics to be reflected, was cited. Yet, in a House of Lords debate in 2023, omitting nitrogen from sewage works in targets was referenced as an important oversight. The stance from the previous UK Government, prior to the 2024 election result, is that the amendment to the Levelling-Up and Regeneration Bill with the legal requirement for water companies to upgrade wastewater treatment works by 2030, will go a significant way to achieving the Wastewater Target. The target was stipulated as part of the Environmental Target (Water) (England) Regulations 2022; to reduce total phosphorus discharged into freshwaters from relevant discharges by 80% by 31st December 2038, relative to a 2020 baseline[42]. As noted in the July 2024 Environmental Improvement Plan Annual Progress Report, due to this amendment, 140 wastewater treatment works are now legally required to be upgraded by nutrient neutrality advice, and nitrogen is specifically referred to as a major cause of nutrient pollution[43]. In Section 96F Nutrient Pollution Standards, it states a "nitrogen significant plant meets the nitrogen nutrient pollution standard if the concentration of total nitrogen in treated effluent that it discharges is not more than 10 mg/l"[44]. This shows that a national requirement exists to attend to the relationship between wastewater and nitrogen and is being implemented on a more case-by-case basis. Therefore, whilst nitrogen is subsumed within the UK Government's category of nutrient pollution, the nuance of nitrogen's role is being addressed at the local level, through Environmental Permitting Regulations.

The following policy and regulations frameworks control and regulate wastewater pollution:

- The Water Resources Act 1991[45] in the UK addresses various aspects of water management, including wastewater effluent. It requires Discharge Consents to be permitted by the Environment Agency for any sewage or trade effluent directly into surface water (such as rivers, streams, canals, groundwater, or the sea). These consents are set and enforced individually, considering the quality of the water source and the surrounding catchment. The Act ensures that wastewater effluent meets specific quality standards to prevent pollution and protect water bodies.
- The Environment Act 2021[46], addresses water pollution through several measures including:
    - Legally Binding Targets: The Act sets new legally binding targets for water quality, including reducing pollution. These targets aim to improve the health of rivers, waterways, and coastlines.
    - Storm Overflow Reduction: Water companies are now required by law to secure a progressive reduction in the adverse impacts of discharges from storm overflows. This crackdown on sewage discharges into water bodies helps mitigate pollution.
- Nutrient pollution is tackled within the Levelling-Up and Regeneration Act 2023[47], which places a legal duty on water companies to upgrade wastewater treatment works by April

[41] https://hansard.parliament.uk/lords/2023-01-23/debates/61BFFCB2-F0A3-4F0A-8332-0248093008B6/EnvironmentalTargets(Water)(England)Regulations2022
[42] Environmental Targets (Water) (England) Regulations made under SS4 (8) and 143 (5) (b) of the Environment Act 2021, Regulation 10. https://www.legislation.gov.uk/ukdsi/2022/9780348242911
[43] Environmental Improvement Plan: annual progress report 2023 to 2024 (publishing.service.gov.uk)
[44] https://bills.parliament.uk/bills/3155/stages/17044/amendments/10003516
[45] https://www.legislation.gov.uk/ukpga/1991/57/contents
[46] https://www.legislation.gov.uk/ukpga/2021/30/contents
[47] https://www.legislation.gov.uk/ukpga/2023/55

2030. The nutrient pollution standard for nitrogen is set at 10mg/l[48]. Across all affected catchments, there will be an estimated 57% reduction in total nitrogen loads[49].The Bill amends the Conservation of Habitats and Species Regulations, 2017 and states *"if a planning application has been made to a local authority where an EIA has been undertaken, the local authority must assume that nitrogen significant plant meets the relevant nutrient standard from the upgrade date"*.

- The Urban Wastewater Treatment Regulations 1994[50] govern wastewater effluent from manufacturing and wastewater treatment works (WWTW). These regulations set out requirements for operators of facilities with wastewater with environmental permits for water discharge activities or point source groundwater activities. The regulations also define the need for continual water monitoring using automated equipment. This includes nitrates and ammonia, where determined by the Environment Agency within the Environmental Permit.
- Environmental Permitting (England and Wales) Regulations 2016[51] provide the legal framework for environmental permitting in the UK. These regulations cover activities that may impact the environment, ensuring that wastewater facilities comply with standards to prevent harm to human health and nature.
- Water Supply (Water Quality) Regulations 2016[52] define the standards for drinking water. These regulations implement the European Drinking Water Directive for public water supplies. The standards cover a wide range of substances, organisms, and water properties to ensure that drinking water is "wholesome" and safe for human consumption. Nitrate and nitrite limits are defined at 50 mg/l at the tap, and 0.5mg/l at the tap, respectively, as the thresholds for public health[53]. According to the UK Government Bottled Drinking Water Rules for Local Authorities guidance[54], the concentration of nitrate in milligrams per litre needs to be divided by 50, and then added to the concentration of nitrite. This is then divided by 3- and must not exceed 1. The World Health Organisation guidelines define the parameter for nitrite as 3mg/l[55].
- Conservation of Habitats and Species Regulations 2017[56] restrict damaging operations near European designated habitats. Special Nature Conservation Orders look to restrict operations where wastewater effluence may cause harm to sensitive habitats. Local Planning Authorities are advised by Natural England to object applications in areas where there are high levels of existing nitrogen input and sound evidence of nutrients causing eutrophication at proposed sites.
- Water Environment (Water Framework Directive) (England and Wales) Regulations 2017[57] provide a framework for protecting aquatic ecosystems, achieving compliance with standards, and enhancing water bodies to achieve "good" status. Drinking Water Groundwater Safeguard Zones (SgZs) are designated by Water Framework Directive (WFD), aimed at reducing deterioration[58]. The WFD also requires river basin management plans (RBMPs) to be prepared for each river basin district. Crucially, RBMPs set the legally

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[48] https://www.local.gov.uk/pas/topics/environment/nutrient-neutrality-and-planning-system
[49] https://www.gov.uk/government/publications/nutrient-pollution-reducing-the-impact-on-protected-sites/nutrient-pollution-reducing-the-impact-on-protected-sites
[50] The Urban Waste Water Treatment (England and Wales) Regulations 1994 (legislation.gov.uk)
[51] The Environmental Permitting (England and Wales) Regulations 2016 (legislation.gov.uk)
[52] https://www.legislation.gov.uk/uksi/2016/614/contents
[53] https://www.gov.uk/guidance/bottled-drinking-water-rules-for-local-authorities
[54] https://www.gov.uk/guidance/bottled-drinking-water-rules-for-local-authorities
[55] https://www.north-norfolk.gov.uk/info/private-water-supplies/private-water-supplies-nitrate-and-nitrite/
[56] https://www.legislation.gov.uk/uksi/2017/1012/contents
[57] https://www.legislation.gov.uk/uksi/2017/407/contents
[58] https://www.data.gov.uk/dataset/7fe90245-d6e8-4d7c-a13a-65a87455f429/drinking-water-safeguard-zones-groundwater

binding locally specific environmental objectives that underpin water regulation and planning activities, including permitting[59].

- Supporting these regulations is the Government's Water Industry National Environment Programme[60] (WINEP) which provides guidance to water companies in England on actions they need to take to meet environmental legislative requirements. From 1st April 2025 WINEP will apply under the new water pricing period and will require water companies to apply a wider catchment level approach to pollution management. This approach through WINEP is further supported by non-statutory obligations such as the development of Drainage and Wastewater Management Plans and Environmental Land Management Schemes.

3.4.3.2 Gaps

For many facilities the combination of aging infrastructure, increased demands on infrastructure, and adverse weather have increased the levels of enforcement on environmental permit holders. There appears to be a disconnect occurring through the increased enforcement being applied to non-compliance to environmental permits and investment into pollution prevention.

The recent judgement of the Supreme Court in the Manchester Ship Canal case[61] regarding nuisance (discharge of excess pollutants so including nitrates into water bodies) reinforces the rights of those with riparian interests relative to those discharging pollution (United Utilities in this case). In principle, this increases the legal jeopardy for those discharging nuisance wastes and therefore may increase their motivation to limit avoidable discharges and progress faster towards meeting legal standards.

Notably, between the advice given by Natural England to Local Planning Authorities in relation to the Conservation of Habitats and Species Regulations, and the Levelling-Up and Regeneration Bill's amendment to the Habitat Regulations, there is space for potential interpretation. Natural England suggests Local Planning Authorities need to go beyond accepting the results of an EIA as sufficient[62]. The assessment of risk may be partial, particularly if periodic sampling is being undertaken. It is noted that factors contributing to an increase in sewage pollution incidents are related to issues with the implementation of monitoring, risk assessments and operational management, such as exceeding hydraulic capacity of treatment facilities. The Environment Agency reported in 2023 there was a 54% increase in the number of recorded sewage spills compared to 2022, showing that the potential scale of impact of remediation of wastewater treatment facilities could be significant, but this is highly case-by-case dependent. The 21st Century Drainage Programme is a potentially useful instrument to monitor compliance, available drainage capacity and associated risk[63]. The strong commitment of the new Labour administration to increase housebuilding points towards more pressure from this source in the coming years.

Summary of gaps identified:

- Inclusion of nitrates within the minimum criteria for bathing water quality

[59] https://www.gov.uk/guidance/river-basin-management-plans-updated-2022
[60] Water industry national environment programme (WINEP) methodology - GOV.UK (www.gov.uk)
[61] Manchester Shipping Canal Company Ltd and United Utilities Water Ltd https://www.supremecourt.uk/cases/docs/uksc-2022-0121-judgment.pdf
[62] https://www.local.gov.uk/pas/topics/environment/nutrient-neutrality-and-planning-system
[63] https://www.water.org.uk/wp-content/uploads/2018/12/Assessing-the-Available-Capacity-in-UK-Sewerage-Systems.pdf

- Significantly increased remediation of wastewater treatment facilities that exceed their hydraulic capacity and cause pollution of raw effluent

3.4.4 Denitrification

The UK-NBS estimates that loss of N_2 to the air through denitrification[64] was around 289 kt N in 2021 (203 kt N from soils, 86 kt N from water), making up 39 % of all N losses to the atmosphere and c. 20% of all nitrogen losses. It occurs through microbial activity in soils, freshwater and marine waters, and wastewater treatment plants (see above), and is a product of the same chain of biochemical processes that also produce the pollutants NO_x and N_2O.

Whilst not a source of pollution in itself, denitrification losses remove potentially useful reactive nitrogen from the system, and thus decrease the nitrogen use efficiency and circularity of nutrient use of human activities. In other words, if denitrification losses could be reduced, then fewer nitrogen inputs would be required in the first place, and thus pollution from losses of reactive nitrogen would also be reduced. N_2 losses are estimated to be more than the combined emissions of the other oxidized nitrogen species (NO_x and N_2O) to the air from microbial activity, and as such are a crucial aspect of nitrogen use efficiency.

3.4.4.1 Legislation, policy instruments, and measures

A certain amount of denitrification loss from soils and water is unavoidable or difficult to control, for example from non-agricultural soils, freshwaters and the sea where nitrogen inputs are high. Nevertheless, the amount of nitrogen lost through denitrification can potentially be influenced by some existing policies or possible future policy options in agricultural soils and biological waste and wastewater treatment.

3.4.4.1.1 Denitrification in agricultural soils

Overall reduction in nitrogen loss – including denitrification - from agricultural soils could be effectively mitigated by improving nitrogen use efficiency of crop production, without increasing the quantity of nitrogen inputs. As discussed in section 3.4.1 in relation to reactive nitrogen losses, policies encouraging proper nutrient management in line with crop requirements (e.g. the Farming Rules for Water), including the 4 Rs principles, will minimize excess mineral nitrogen in the soil which can be a substrate for denitrifying bacteria.

Considering options to reduce N_2 losses specifically for a given nitrogen input, the following could be effective:

- Minimising soil compaction and waterlogging, which lead to denitrification of nitrates by creating anaerobic conditions.
- Using nitrification inhibitors with ammonium/urea-based fertilisers, as well as using coatings for slowing release. By limiting the rate of nitrate release into the soil, these measures can reduce the amount available to denitrifying bacteria.

[64] Strictly, denitrification means only the conversion of nitrate to N_2 gas, but in the UK nitrogen balance sheet and for the purposes of this report, this term is used to refer to all biological processes resulting in conversion of reactive nitrogen compounds to N_2 gas (including e.g. conversion of NH_3 to N_2 via anammox bacteria).

These measures are primarily designed to reduce N_2O emissions from soils (and indeed that may be the main driver of action), but reduced N_2 emissions would be a significant synergy. Although difficult to measure directly, the impact of all of these measures could be tracked indirectly through observing achieved improvements in nitrogen use efficiency, which requires appropriate soil and organic fertiliser testing, and farm-level nitrogen balances. As discussed elsewhere, the current enforcement of proper creation and implementation of nutrient management plans seems insufficient to ensure full uptake.

3.4.4.1.2 Denitrification in wastewater treatment plants and in freshwater following effluent discharge

The Urban Wastewater Treatment Regulation (UWWTR) sets thresholds for where different levels of wastewater treatment are needed. The majority of smaller UK UWWTPs require secondary treatment, which is aerobic and results primarily in emissions of nitrates in effluent and NO_x / N_2O to the air. Some nitrate in the effluent is then denitrified.

Tertiary treatment (nitrogen and phosphorous removal) is required for large agglomerations. Nitrogen removal is generally carried out using the activated sludge process, which combines nitrification and denitrification to convert remaining reactive nitrogen to N_2, so reduces reactive nitrogen emissions to air and water but does not reduce overall nitrogen losses.

Alternatively, reactive nitrogen can be recovered prior to tertiary treatment using a variety of techniques such as chemical ammonia stripping, struvite precipitation, microbial fuel cells or recovery using microalgae and/or cyanobacteria. These processes can recover up to 75% of nitrogen in effluent[65]. A recent scenario analysis for Europe[Error! Bookmark not defined.] found that if advanced nitrogen recovery were applied to 75% of wastewater, this would likely reduce both reactive nitrogen and N_2 emissions by around 40%.

Current legislation does not incentivise nitrogen recovery from wastewater treatment, but as recommended in the NMEG report[66], requirements for a minimum recycled nitrogen content in inorganic fertiliser products could provide market-based incentives for this.

Another key mechanism to reduce denitrification losses (as well as all other nitrogen losses) from wastewater treatment is to reduce the nitrogen load entering the wastewater system in the first place. Reduction in UK per capita protein intake to recommended levels would be effective in achieving this, though no policies are currently in place to explicitly encourage this.

3.4.4.2 Gaps

Summary of gaps identified:

- Sufficient policies/uptake to encourage proper nutrient management in line with crop requirements, such as minimising soil compaction and waterlogging, and using nitrification inhibitors with ammonium/urea-based fertilisers.
- Current enforcement of proper creation and implementation of nutrient management plans insufficient to ensure full uptake.
- Incentives for nitrogen recovery at wastewater treatment plants
- Reduction in UK per capita protein intake to recommended levels

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[65] https://www.sciencedirect.com/science/article/pii/S2211912420300213

[66] See footnote 4.

3.4.5 Food Waste

Food waste represents a flow of nitrogen which – if eliminated or completely recycled – would reduce the quantity of virgin nitrogen inputs required to produce food. Both the quantity of food produced/wasted and also the fate of this waste are therefore important.

WRAP estimate that around 10.7 million tonnes of food was wasted (including inedible parts) in 2021, of which 60% was in households, 15% on farms, 10% in hospitality and food sector, 13% in food processing and 2% in retail[67]. By way of comparison, this 10.7mt is around one quarter (by mass) of food purchased (noting however that some is wasted before it is purchasable). WRAP data shows that there has been an 18.3% decrease in food waste generation per capita between 2007 and 2021.

Regarding the fate of wasted food, in 2021, of the wasted food (+ inedible parts), ~21% went to anaerobic digestion / composting, ~57% to landspreading or thermal treatment, and ~21% to landfill or sewage treatment. Incineration and landfill are the two fates where nitrogen is completely lost; anaerobic digestion, composting and even sewage treatment all allow some of the nitrogen to be recovered.

No WRAP data on trends in the fate of wasted food could be found for this report, but Defra statistics[68] show that the quantity of biodegradable waste sent to landfill reduced by 81% between 1995 and 2021 (47% between 2010 and 2021), and a corresponding increase in anaerobic digestion has occurred through separate food waste collections.

3.4.5.1 Legislation, policy Instruments, and measures

There are no mandatory food waste reduction targets in England[69], only support for voluntary approaches, such as that set out in the Courtauld Agreement. The key target under the Courtauld agreement is for a 50% reduction in food waste arising across the UK (post-farm-gate) per person by 2030, in line with the United Nation's Sustainable Development Goal (SDG) 12.3, against a 2007 baseline.

The Scottish government published a Food Waste Reduction Action Plan[70] in April 2019. It set out an ambition to reduce per capita food waste in Scotland to 33% by 2025, compared to a 2013 baseline. The Welsh Government published its Beyond Recycling Strategy[71] in 2021. This included a target of reducing avoidable food waste by 50% by 2025, relative to a 2007 baseline, and a reduction of 60% by 2030.

As well as targets relating to food waste generation, the UK government as part of the Net Zero Strategy is consulting on near elimination of biodegradable waste to landfill by 2028. The lack of a clear UK-wide mandatory food waste reduction target backed with suitable enforcement and facilitative measures is therefore a gap. To reach this target would require more ambitious policy to reduce or recycle food waste, targeting different sectors, such as retailers, or different waste

67 https://www.wrap.ngo/resources/report/food-surplus-and-waste-uk-key-facts-updated-november-2023
68 https://www.gov.uk/government/statistical-data-sets/env23-uk-waste-data-and-management
69 https://researchbriefings.files.parliament.uk/documents/CBP-7552/CBP-7552.pdf
70 https://www.gov.scot/publications/food-waste-reduction-action-plan/
71 https://www.gov.wales/sites/default/files/publications/2021-03/beyond-recycling-strategy-document.pdf

streams and product lines.

3.4.5.2 Gaps

Summary of gaps identified:

- A UK-wide mandatory food waste reduction target
- Mandatory requirements for sectoral food waste reduction
- Implement initial extended producer responsibility
- Consistent collections of food and recycling waste in a coordinated way

3.4.6 Nitrogen deposition to land

3.4.6.1 Legislation, policy instruments and measures

Unlike the measures and targets related to emissions - which tend to be aggregated at the national or UK level – indicators of nitrogen deposition are often spatial in nature, relating to deposition in particular places with sensitive ecosystem or human receptors.

Reducing the overall level of reactive nitrogen air emissions is an important factor in reducing concentrations and deposition. But, due to the localized nature of some impacts near to strong emissions sources, policies which take into account the spatial relationship between emitters and receptors, and potential means of intercepting reactive nitrogen, can also be beneficial. The Nitrogen Futures scenario modelling project[72] found that *"spatially targeted scenarios were generally more cost-effective than the UK-wide implementation of the same measures in terms of decreased exceedance of critical loads and levels per unit of emission reduction"*. In the study, Emission Reduction Zones (ERZ) were modelled around designated site boundaries at varying distances. In areas with high nitrogen emissions and concentrations, local measures were most effective at bringing down deposition, so could be applied around sensitive sites. As discussed above in connection with agriculture, some key emissions sources such as cattle housing and manure storage are not currently covered by permitting rules, and the NMEG report suggests that whilst planning rules near to special areas of conservation offer a high level of protection in principle, that is not achieved in practice.

More broadly, the uneven distribution of livestock farming and arable farming across the UK can mean that more manure is available – and spread on land – than is required by plants. This increases all forms of nitrogen loss, and subsequent deposition in nearby habitats.

3.4.6.2 Gaps

Examples of spatial zoning or coordination at a catchment scale exist for managing water quality (NVZs, Safeguard Zones, Poole harbour) and may be facilitated through Landscape Recovery project funding, or Shared Nitrogen Action Plans. These can help to incentivise beneficial measures at a local scale.

However, a key gap here is a policy mechanism for actually changing the spatial distribution of existing livestock farming over time (or failing that a clear strategy for enforcing nitrogen

[72] https://jncc.gov.uk/our-work/nitrogen-futures/

application limits where there is an excess availability), coupled with policies encouraging nitrogen re-distribution to other areas to replace inorganic fertilisers.

Publication of the awaited Land Use Framework- including a clear mechanism for nutrient loss and deposition issues (alongside nature, climate etc.) to shape land use decisions – would be a positive step.

In the Netherlands, recent policies have provided spatially targeted funding for voluntary buyout of intensive livestock facilities near to sensitive receptors, or in catchments where phosphorus ceilings have been reached. Such models could provide inspiration for the UK government, although they would need to be handled with sensitivity, so as not to provoke a backlash from farmers and some parts of the public. Adequate levels of support and a clear plan for farmers to transition to alternative farming systems could help to mitigate a negative response from the farming sector.

Summary of gaps identified:

- A policy mechanism for changing the spatial distribution of livestock farming over time.

3.4.7 Import of nitrogen-containing agricultural and aquatic commodities

The UK NBS estimated that in 2021, net imports of nitrogen food and livestock feed were around 400 kt N (634 kt N imported, minus 234 kt N exported). Leaving aside for now the issue of "embedded nitrogen pollution" in imported products (i.e. reactive nitrogen losses occurring in exporting countries), this is around 40% of the amount of reactive nitrogen imported in mineral fertilisers, so represents a significant input of nitrogen into the system and contributor to the over-concentration of nitrogen and reactive nitrogen pollution in the UK.

Imported nitrogen in human food post consumption initially goes into the waste or wastewater system, where it is subject to reactive nitrogen losses. Imported nitrogen in livestock feed goes through manure management and application to land (as well as into human food), so is subject to more reactive nitrogen loss soon after import.

The ability to reduce this import of nitrogen is linked strongly with human diets and population. All else being equal, reducing protein intake per person would likely allow import of nitrogen in human food to be reduced. Reducing UK demand for animal products in particular would also (if this led to a reduction in domestic production) reduce the amount of animal feed imports. A scenario analysis of an agro-ecological UK in 2050 (*Ten years for agroecology-UK*[73]) showed that the UK in principle could be self-sufficient in animal feed with a diet lower in animal protein (but healthier overall than current diets), and if consumption of products from livestock species and production systems most dependent on purpose-grown protein crops (poultry, pigs, intensive cattle) were preferentially reduced, so that remaining livestock made maximum use of domestically produced feed (mainly grass and forage not dependent on additional mineral fertiliser). In fact, eliminating imports of livestock feed is a constraint of the scenario, such that the spatial density of livestock and manure production is limited by the capacity of nitrogen fixation.

Initiatives to promote home-grown high-protein feed crops (such as lupins, field beans) to

[73] https://www.iddri.org/en/publications-and-events/study/modelling-agroecological-uk-2050-findings-tyfa-regio

replace imported soy products can be part of an agroecological system (especially if these are leguminous nitrogen fixing crops as part of arable rotations) but could cause other issues (e.g. displacement of human-edible crops, requiring higher imports of these) if livestock densities are not reduced in tandem.

3.4.7.1 Legislation, policy instruments and measures

Nitrogen pollution is often thought of in local or national terms, but the GBF target 7 is global in scope, and therefore the impact of UK policies (or lack thereof) on nitrogen pollution and impacts on biodiversity elsewhere in the world should arguably be a consideration. This is one amongst other arguments for seeking to avoid imports with a higher environmental footprint than those produced domestically. This applies to trade in food and the avoidance of nitrogen losses as well as other parameters. One way to address this problem would be to impose minimum environmental requirements on agri-food imports at a level which matched domestic standards, creating a level playing field and preventing domestic producers from being undercut by imports produced to a lower standard, with a consequential price advantage.

Mechanisms to achieve this, sometimes referred to in the UK as the establishment of “core standards” or more commonly in the EU as “mirror clauses” are not without challenges but are the subject of extensive discussion as possible ways forward.

There are parallels with the introduction in the EU of a Carbon Border Adjustment Mechanism (CBAM) for imports of selected industrial goods including nitrogen fertilisers. A fairly similar system is due to be introduced in the UK in 2027. In theory, this concept could be expanded to include nitrogen within a UK system of core environmental standards, based on specific and quantifiable requirements in binding legislation to provide the benchmark standards.[74]

3.4.7.2 Gaps

Summary of gaps identified:

- Initiatives to reduce UK demand for animal products (if this led to a reduction in domestic production) to reduce the amount of animal feed imports.Initiatives to promote home-grown high-protein feed crops (such as lupins, field beans) to replace imported soy products
- Establishment of “core standards” or “mirror clauses” to avoid exporting nutrient pollution
- Expand the scope of the Carbon Border Adjustment Mechanism to encompass non-CO2 GHGs

[74] https://ieep.eu/publications/designing-environmental-regulation-of-agricultural-imports-options-and-considerations-for-the-uk/

4. Potential Solutions matrix

In this section we turn to measures that could be taken by one or more UK administrations to supplement the current approach and contribute to a successful strategy to meet all the extant targets relating to nitrogen loss and greatly reduce the pollution burden.

The measures set out in Table 4 below are indicative of the spread of different types of action that could be used to go beyond existing efforts to address nitrogen losses. Measures have been selected on the basis of evidence from the review of gaps in the previous section and assessed for their potential contribution to addressing adverse nitrogen impacts, when deployed over and above existing measures, which remain critical. For example, necessary measures to meet net zero targets need to be adopted and applied in addition to those set out here and so do measures to extend effective advice to farmers, invest in research and development, target voluntary agri-environmental measures more effectively and expand the budgets available for ELMs and other measures in the four UK nations.

As in the gap analysis set out in section 3 above, measures have been ascribed to the sectors that most clearly have influence over progress in terms of relevant policy interventions. This results in a large number of measures being ascribed to the agriculture sector, however, many of these measures will have co-benefits in relation to the wider climate change and nature conservation agendas, for example measures such as a comprehensive national nutrient management strategy (including a spatial planning element) and additional tree planting around intensive farms.

A necessarily simplified form of assessment of these additional measures has been adopted, using a RAG rating approach with respect to key criteria that affect the anticipated feasibility and potential impact of the measure. A RAG rating scheme has been used to categorise different solutions because the detailed quantitative data and analysis which would be necessary to quantitatively assess their impact on nitrogen flows largely does not yet exist and is outside the scope of this report to undertake. A certain amount of subjectivity has therefore necessarily been applied to the RAG rating where data and projections do not exist or are insufficient. In some cases the measures are more directional than formulated in prescriptive terms.

For each policy or measure, a RAG rating has been assigned against several dimensions relevant for comparing different individual or groups of measures, including the potential scale of impact, the uncertainty around that impact, the anticipated cost and timescale of implementation, and potential trade-offs or synergies across different forms of nitrogen loss. The RAG rating has not been used as a way to rank the measures, but rather as a way to flag the potential strengths, weaknesses or wider considerations arising with respect to an individual measure, and to some extent between measures, in an accessible way. As far as possible, several component factors were taken into account for rating each dimension, as detailed in

Table 3 below.

Table 3: RAG rating methodology

Scale of impact	• The current size of the N flow affected by the policy or measure • The potential efficacy of the measure, if successfully implemented • The additionality of a policy or measure compared with current policies and measures – i.e. is it likely the change would happen anyway, without the measure?
Uncertainty of impact	• The degree of scientific uncertainty in the effectiveness of measures • The extent to which the policy relies on voluntary uptake or behavioural change • The degree of dependence on other measures or contextual factors to be effective
Cost	Costs arising for several groups of actors were considered: • UK or devolved governments • Operators of N emitting businesses (e.g. farms, industrial facilities) • The general public It was unrealistic to estimate numerical costs for each measure and use specific category bounds for low, medium and high costs. Instead, costs were marked as low if savings would be expected to result or measures were largely behavioural change, medium where there may be administrative costs for government and business but no mandatory capital costs, and high where capital costs will be incurred for a reasonable number of businesses or the public (e.g. for replacement or retrofit of infrastructure), or by government to provide subsidies.
Timescale	• Timescale to devise and pass legislation • Expected timescale for real change to occur on the ground Given the time horizon of the GBF 7 and some UK statutory targets, generally timescale was rated as green (short) for implementation which could be complete <5 years, amber (medium) in 5-10 years, and red (long) for 10+ years.
Trade-offs across N losses	In some cases, a risk of trade-offs was judged to exist. These mainly related to those agriculture measures which could increase the amount of N being incorporated into agricultural soils in organic and inorganic fertilisers, by reducing NH_3 emissions during application or upstream of that. Trade-offs with emissions of a wider group of GHGs were also considered.
Synergies across N losses	Potential for synergies across different streams of N losses were judged to exist where the policy or measure is likely to reduce the overall amount of N flowing through the system, (e.g. by increasing circularity, reducing the need for imports or synthetic fertiliser inputs), and hence would be expected to reduce losses of all forms of N from that system.

It is worth noting that the merits and impacts of actions are hard to judge in isolation and many measures would only work effectively as part of a wider package of government interventions and in addition to current policies. (which is of course what is required). This will be considered further in relation to the possible scenarios set out in section 5 below. In general, the policy or measure dimension was scored conservatively, in the sense that where one of the factors taken into account for a dimension would score red but another factor green, the whole dimension was scored as red. For example, where anticipated costs are high for any actor involved in implementation, the costs criterion would be scored as high (red). However, where possible, some key considerations influencing the rating in narrative form has been provided for the measures in Table 4.

The measures set out in Table 4 are those assessed as likely to have a worthwhile impact across the assessed criteria, although as noted above there will be varying levels of efficacy and none are anticipated to be sufficient in isolation to produce the pace and scale of change that is required in the particular sphere where they would be applied. A longer list of potential solutions drawing on a range of recent literature as well as good practice observed in other countries is set out in Annex 7, which was a key source for the measures considered here. For many of the measures, a staged approach could be considered with an encouragement towards voluntary adoption through changes to good practice guidance, with a back-stop date beyond which measures will become mandatory in the absence of a defined level of measurable progress. These measures have been marked with an asterisk in Table 4.

Table 4: Summary table of potential measures

Agriculture					
• **Using nitrification inhibitors with ammonium/urea-based fertilisers, as well as using coatings for slowing release*** Potential for reduced nitrogen losses as N_2O, NO_x, nitrate and N_2, but risk of increased NH_3 if application rate not adjusted to reflect lower losses. **Source:** Nitrogen Opportunities: UNECE Guidance on Integrated Sustainable Nitrogen Management (NOPS)					
Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution
• **Using urease inhibitors with urea fertiliser (protected urea products)*** This is starting to happen already, but room for faster and fuller implementation through suitable regulation / incentives. Northern Ireland is considering measures to promote this. Full benefits are achieved if application rate is adjusted down to reflect lower NH_3 losses, otherwise NO_x/N_2O/nitrate losses could increase. UNECE guidance shows urease inhibitors can lead to a c. 70% reduction in NH_3 losses compared with surface-spread unprotected urea. Defra survey data show that in 2022, urea products with urease inhibitors were only used on 6% of the land area that urea was applied to. **Source:** National Air Pollution Control Plan (NAPCP)					
Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution
• **Mandate the use of shallow injection and band spreading equipment for slurry and other high nitrogen liquid organic materials on all farms*** Whilst an established means of reducing NH_3 pollution to air, it could increase leaching from soils if the total quantity of fertiliser applied is not adjusted downwards to reflect the higher remaining nitrogen content. Capital costs of efficient new spreaders can be significant but there are gains in the efficiency of nutrient use. **Source:** Nutrient Management Expert Group report (NMEG)					
Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution
• **Comprehensive national nutrient management strategy (including a spatial planning element)** A powerful framework and device for planning, developing measures, building case, handling trade-offs – although the uncertainty around impact is based on questions on how well designed or delivered it would be, and continued commitment of Government strategies over long periods. We assume this would include provisions for spatial planning, to alleviate pressures on the most sensitive sites and reduce some imbalances in livestock concentration. Some consensus required (cf NMEG) and the cost of serious implementation, including fewer livestock, significant for					

some actors. Scored amber on costs because of scale of (beneficial) action that would be triggered versus scope for offsetting through increased public aid schemes via Defra and counterparts. **Source:** NMEG

Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution

• **Regular updating of key guidance documents and standards, in particular the Nutrient Management Guide (RB209)** This would be an important element in the strategy and key delivery tool, such as maintaining the annual updates to the Nutrient Management Guide. Can adjust to keep pace with effort required to meet targets **Source:** NMEG

Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution

• **Promotion of farm level nutrient management planning and proper implementation** This is one of the crucial supporting measures for achieving reductions in nitrogen pollution from agriculture, without which other "end-of-pipe" measures will tend to lead to pollution swapping. 55% of farm businesses have plans and 70% undertake regular soil testing, but it isn't clear the extent to which this affects fertiliser application rates. Note that proper implementation on livestock or mixed farms may mean that export of nutrients is required, so there is an interaction with other policies which would facilitate this, and that could take time. Enforcement or incentives could be costly initially. Fewer livestock in some locations potentially. **Source:** NMEG

Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution

• **Nitrogen fertiliser charge that comes into force if targets are not respected for two consecutive years** Article 268 of the French "climate and resilience" law provides for the principle of a charge on mineral nitrogen fertilizers, which would come into force if the objectives of reducing ammonia or N_2O emissions of nitrogen set by decree no. 2022-1654 of 26 December 2022 are not respected for two consecutive years. The charge would need to be significant and to be applied diligently to have the necessary impact on fertiliser use. Reducing fertiliser application would reduce most nitrogen losses. **Source:** France

Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution

• **Tree shelter belts around pig, poultry and dairy housing**

Implement via planning controls, guidelines, legislative consents. Back up with legislation if required. Relatively low impact but bigger units are responsible for growing share of production so increasing impact of mitigation measures. **Source:** NAPCP					
Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution
• **Inclusion of large indoor cattle units within the Environmental Permitting regulations for England and Wales and their equivalent (the EPR) and reduce size thresholds for pig and poultry farms** This was an option discussed in the Clean Air Strategy 2019. It should lead to gradual reduction in emissions (given sufficient enforcement) over time as BAT is implemented. High cost to farmers and some increased inspection and enforcement costs to government. There is likely to be public support for this, though likely resistance from sections of the farming community. If the scope of BAT and reporting accounts for holistic nitrogen management such that no emissions sources are ignored, then should not lead to trade-offs **Source:** NAPCP					
Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution
• **Enhanced enforcement of pollution and related legislation applicable to farmland. All UK nations** Failings in compliance with several regulations at present and this is an important complementary measure to any wider strategy, including new regulatory initiatives. **Source:** Appetite for Change report (AFC)					
Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution
• **Controls / limits on concentrations of livestock production in specific localities** This would be a substantive addition to the current system of EIA, the habitats regulations, permitting for certain categories of farm, rules applying in NVZs etc and would require development. It would be designed to strengthen protection for the most vulnerable and important sites and might require an extension of site boundaries into adjacent parts of the relevant catchment **Source:** New					
Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution
Wider Food Systems					
• **Restrictions on / reductions in meat and dairy served in public sector food / under public sector funded contracts***					

This could be introduced quite quickly, with many precedents to draw on but with only 5% of food eaten in public institutions the impact would be relatively limited, and much work already happening on this. It may however have knock on cultural impact to normalise similar dietary choices in other settings. **Source:** Climate Change Committee (CCC)					
Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution
• **Mandatory sustainability targets for public sector food procurement – in schools, hospitals, prisons, etc.*** UK Government commitment for catering in these public sector settings to source 50% of food from local or certified sustainable sources e.g. organic. However this is not yet enacted, and the Government definition of sustainable in this context is still to be defined. This means there is less certainty over the scale of impact on nitrogen loss. Likelihood of staged approach to targets ramping up over time. **Source:** New					
Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution
• **Strategy to reduce meat and dairy consumption by 20% over 10 years** This assumes that a reduction in consumption had an impact on lowering production (rather than maintaining production and exporting more). There may be some trade-offs if we assume that consumption shifted to other products, although likely their nitrogen footprint would be lower. A strategy in itself may not have an impact, but if the targets were matched by action – particularly incentives and regulations – then the impact (and certainty) would be stronger than rated below. **Source:** Adapted from AFC (which didn't include targets/dates)					
Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution
Wastewater treatment and water quality					
• **Incentives for nitrogen recovery at wastewater treatment plants** The rise of the circular economy concept has increased appetite for measures that recover resources rather than just remove pollutants. However technologies are not widely known of and can be hard to implement due to site-specific requirements, which may limit the scale of impact. Recovery of nitrogen into stable forms from wastewater, by reducing the total N content of sewage, will help to reduce all forms of N pollution into water bodies and emissions to air, and also reduce denitrification losses. There are therefore thought to be few or no trade-offs and some synergies across N pollution. Given suitable regulation, the recovered nitrogen may be able to displace some virgin synthetic nitrogen in inorganic fertilisers, leading to further synergies of reduced virgin N inputs. **Source:** NMEG					

Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution

Transport

- **Greater support for modal shift**
  Scotland and Wales are considering additional modal shift policies in the NAPCP (The Reducing Car Use for a healthier, fairer and Greener Scotland; Wales Carbon Budget 2). There is appetite for greater financial support from the UK Government. The Mode Shift Revenue Support grant scheme is highly competitive, but currently mostly benefits freight and logistics sectors. Scale: 61% road transport emissions come from passenger travel, importance of every organisation/individual adjusting travel behaviour.
  Source: Scotland / Wales

Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution

Buildings

- **Government to affirm electrification as the default option for new buildings and replacement in existing buildings.**
  Investment in skills and technology of heat pumps are being slowed by suggestion that hydrogen heating could still play a major role. If hydrogen remains a player, this would lock-in residual NO_x emissions from boilers.
  Source: CCC

Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution

Waste

- **Mandatory requirements for retailers to donate edible food to food banks or other equivalents***
  Source: France

Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution

- **UK-wide mandatory food waste reduction target backed with suitable enforcement and facilitative measures**
  Source: New

Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution

- **Implement initial extended producer responsibility, deposit return scheme and consistent collections of food and recycling waste in a coordinated way**
  Source: CCC

Scale of impact	Uncertainty around impact	Cost to implement	Timescale to implement	Trade-offs across N pollution	Synergies across N pollution

5. Possible policy scenarios for deploying combinations of measures

This section considers the extent to which different hypothetical scenarios of different policy packages might secure changes of the magnitude needed to achieve targets and reduce nitrogen impacts to acceptable levels.

Any policies adopted to address the nitrogen challenge in the UK will arise in a future in which there are many uncertainties shaping the context of policy making in potentially significant ways. The key variables are likely to include the political priorities of the new, and future, UK and devolved Governments and other key actors, the economic situation, specific sectoral issues, such as energy prices, agricultural commodity prices bearing on farm incomes and potentially significant changes in housing and planning policies. In practice these variables will have a considerable influence on the policy choices that a government will find appealing and in an ideal world one might consider several context scenarios to present some of the possibilities and how different scenarios would bear on the optimal mix of policies that might be advocated. However, this offers far too many variables and may warrant a study of its own. Therefore, we are taking a pragmatic approach looking only at some particularly prominent contextual issues when discussing individual policy measures and combinations of them.

As an example, new measures that would require primary legislation face barriers in terms of legislative feasibility that do not apply to measures that could be enacted via secondary legislation, normally Statutory Instruments. Primary legislation on environmental issues is relatively infrequent and is expected to remain so. However, if there seems likely to be a need for primary legislation for pressing reasons not closely connected to nitrogen policy, for example in relation to climate change and GHG emissions, there might be an opportunity to insert the nitrogen dimension into this new primary legislation which would be an important contextual issue to take into account in any influencing strategy.

As noted in section 4 above, the merits and impact of individual measures and actions are difficult to judge in isolation. Many will only be fully effective as part of a broader package of measures and some will become more or less effective when combined with other measures. In the absence of quantitative data against which to assess all of the measures, it should also be noted (particularly in the agricultural sector), that quantified reductions in nitrogen losses cannot confidently be attributed entirely or directly to individual measures in a way that produces specific defined contributions that could be relied upon to achieve a given target level. This becomes particularly difficult to assess when considering a dynamic mix of incentives, regulations, promotion of best practice, impact of advice, reductions in activity levels (e.g. fewer animals) etc. This limitation is particularly pronounced in the agriculture sector, with a large number of actors, diverse and sometimes changeable conditions, varying farmgate and input prices, incomes and capacity to invest, significant geographical variations and variable lead times between the moment when the action is taken and the eventual environmental impact clearly identified and measured.

Below we examine the measures first through the prism of the current government plans and policy trajectory, and then as bundles brought together in two additional scenarios, reflecting different approaches to reducing nitrogen losses by 2030 to around half their present level. The measures featured in the scenarios characterise the type of actions that would be required to deliver the requisite pace and scale of change.

The measures given as examples in Table 5, Table 6 and Table 7 are drawn from the long list set out in Annex 7 as presented in Table 4. For the exercise below, Scenario A lists some of those measures which are more prominent when extra weighting is given to those measures where the scale of potential impact is considered to be high, the cost relatively low and the timescale relatively short., while Scenario B gives prominence to those where extra weighting is given to the scale of impact (high), the absence of significant adverse trade-offs - and relatively high potential for synergies.

The effectiveness of each package of measures would be dependent on a number of external and internal factors that will be discussed briefly below. Some of the demand side measures are likely to take a substantial amount of time before any measurable impact can be ascertained, whereas more technical supply side and end of pipe measures will be faster to show results.

Many of the measures identified, whilst delivering co-benefits in relation to both climate change and biodiversity, fall within the agriculture and food sectors. This increases the complexity of delivery, particularly where measures are voluntary, given the necessarily high reliance on a very large number of diffuse and largely unsupervised actors, which makes the projected outcome of implementation of such measures less robust than in relation to regulation of energy or combustion, for example.

5.1 Baseline Scenario – Current plans

The baseline scenario assumes no significant change from the current position, with no additional measures being introduced by the UK Government or devolved administrations and no change in either means or level of implementation. Section 3 above sets out in detail the measures that are already in place to implement existing targets and commitments and these would continue. As shown in Table 2 and Annex 6, whilst progress against some targets is on track (particularly in relation to combustion), measures in relation to agriculture and wastewater are probably insufficient to meet existing targets, suggesting that they will also be insufficient to meet GBF Target 7 as the ambition of the current targets fall short of GBF Target 7, as detailed in section 3.3 above.

The Nutrient Management Expert Group is clear in its recent report that: *"The farming community and its many partners have made important progress in better understanding and tackling nutrient pollution over the past 2 decades. However, given the scale of environmental issues at stake, current action remains insufficient to prevent significant future damage and Defra policies need to address this shortfall. A strategic, long-term approach is needed to encourage more effective nutrient management and much higher nutrient efficiency on all farms, and across all landscapes."*[75] It is also worth noting that many of the measures detailed in section 3 above rely on voluntary uptake (i.e. 80-100% uptake of Farming Rules for Water). Measuring and maintaining actual uptake at the required level and therefore achieving the assumed level of compliance is not, therefore, a given.

[75] See footnote 4 at p8.

5.2 Scenario A – Target focused

The central objective of this scenario would be to ramp up ambition with a strong focus on meeting current statutory targets and commitments, setting aside the broader systemic challenge of reducing flows across the board. This approach may be more politically palatable than a systemic approach and would favour those actions (solutions) that are relatively high impact in the shorter term, low cost and quicker to implement. This might be characterised as a primarily sectoral approach with actions that may have more unwelcome trade-offs and fewer cross cutting benefits and synergies with related agendas. These trade-offs may include a higher risk of pollution swapping.

For example, slurry injection to reduce NH_3 emissions can lead to increases in other emissions of nitrogen. To mitigate that, the amount of slurry applied needs to be adjusted down, but that in turn depends both on good farm-level nutrient management planning, and if too much nitrogen is available to be spread, potentially requires wider-scale planning either to avoid local nitrogen excesses (which can cause over-application), or to achieve spatial redistribution. Solutions such as poultry manure incineration would mitigate the local impact, but not address the causes of excess nitrogen.

Scenario A is therefore still unlikely to be sufficient to meet GBF Target 7 as, in the absence of a more systemic approach focused on reducing nitrogen flows across the board, the scale and pace of reductions is unlikely to be achieved consistently. The types of action that might characterise this scenario are set out in Table 5 below.

Table 5: Typical measures characterising a target-focused scenario

Measure	Source
Agriculture	
Using nitrification inhibitors with ammonium/urea-based fertilisers, as well as using coatings for slowing release.	NOPS
Mandate the use of shallow injection and band spreading equipment for slurry and other high nitrogen liquid organic materials on all farms	NMEG
Using urease inhibitors with urea fertiliser (protected urea products)	NAPCP
Wastewater treatment and water quality	
Incentives for nitrogen recovery at wastewater treatment plants	NMEG
Transport	
Greater support for modal shift, perhaps concentrated in critical areas.	Scotland / Wales
Buildings	
Government to affirm electrification as the default option for new buildings and replacement in existing buildings backed up with regulation and selective incentives.	CCC

5.3 Scenario B – System-wide approach

Here, the goal still would be to reach the UK targets and commitments, but the approach would try to assemble a set of measures that would offer benefits both in terms of nitrogen reductions and other objectives such as lower GHG emissions, enhancement of biodiversity, greater agricultural efficiency, etc and so might be more appealing than a "purist" nitrogen reduction approach, particularly in the longer term. This scenario would place an emphasis on both reducing losses of nitrogen **and** requiring greater reductions in the input of nitrogen through the system through better nitrogen use efficiency and shifting demand away from nitrogen intensive commodities. For example, in order to halve nitrogen losses, by reducing both the input of nitrogen and the losses per nitrogen input, each only has to be reduced by 29%, which is likely to be more effective than keeping one the same and reducing the other by 50%.

Those measures that have co-benefits and support underlying reductions in nitrogen loss across the board and so address the priorities of different government departments and sectors would have greater weight in this scenario relative to scenario A. There would be more space for measures that appear more compatible with a rounded approach even if they would have a slower pace of implementation and therefore be less assured of achieving a certain reduction level by a particular date. In terms of potential trade-offs, by way of example a river basin-scale and farm-scale nutrient management plan would mitigate potential trade-offs of low-emission slurry spreading.

A greater degree of political commitment would be required in order to ensure full and effective implementation. For example, introducing cross-cutting nitrogen targets as part of a comprehensive national nutrient management strategy could be a feature of this scenario. This scenario would include all of the actions (solutions) identified in Table 5 and in addition would include a number of further measures (solutions) such as:

Table 6: Typical measures characterising a systems-focused scenario

Measure	Source
Agriculture	
Comprehensive national nutrient management strategy (Including a spatial planning element)	NMEG
Promotion of farm level nutrient management planning and proper implementation	NMEG
Controls / limits on concentrations of livestock production in specific localities	New
Enhanced enforcement of pollution and related legislation applicable to farmland. All UK nations.	AFC
Wider Food System	
Mandatory sustainability targets for public sector food procurement	New
Strategy to reduce meat and dairy consumption by 20% over 10 years	AFC
Waste	
UK-wide mandatory food waste reduction target backed with suitable enforcement and facilitative measures	New
Implement initial extended producer responsibility, deposit return scheme and consistent collections of food and recycling waste in a coordinated way	CCC

5.4 Stepping stones or separate paths

There is an additional set of measures that would work well under either Scenario A or B. This would include the following:

Table 7: Additional measures under either scenario

Measure	Source
Agriculture	
Regular updating of key guidance documents and standards, in particular the Nutrient Management Guide (RB209**)**	NMEG
Nitrogen fertiliser charge that comes into force if targets are not respected for two consecutive years	France
Tree shelter belts around pig, poultry and dairy housing.	NAPCP
Inclusion of large indoor cattle units within EPR and reduce size thresholds for pig and poultry farms	NAPCP
Wider Food System	
Restrictions on / reductions in meat and dairy served in public sector food / under public sector funded contracts	CCC
Waste	
Mandatory requirements for retailers to donate edible food	France

Whilst the two Scenarios could be seen as alternative approaches, it is also possible to characterise them as complementary and potentially sequential routes to achieve the maximum policy and legislative effectiveness. Scenario B, as outlined above, does not include any Scenario A measures in order to highlight the difference between them. However, in practice a developed Scenario B might include many of the measures from Scenario A, but perhaps applied to a lesser or greater degree, and crucially, the combined and more strategic approach might mitigate some of the trade-offs anticipated in Scenario A. For example the agricultural technical measures in Scenario A don't appear in Scenario B due to the risk of pollution swapping. But this is a risk that can be mitigated by good nutrient management planning, which is a key part of scenario B. Without the planning (under Scenario A), the level of public funding (to pay for advice, incentives, or enforcement of regulations) put behind these technical measures would need to be higher, and the measures would need to be rolled out further and faster if not accompanied by systemic changes.

Additionally the scale of impact of these technical measures may be smaller under Scenario B because the flows of nitrogen are smaller and maybe shifted to other sources. For example, if there were a large-scale spatial shift to more mixed farming with livestock less concentrated on specialist farms, the need for supplementary synthetic nitrogen applications in currently arable-dominated areas may reduce, so relevant measures such as use of urease inhibitors would therefore have a smaller impact on overall nitrogen losses. Likewise, if the overall demand for animal products were to be reduced this may allow livestock to be reared in a much more extensive way which generates less manure in housing (with more being deposited outdoors), making large investments in manure management and storage measures less critical to achieving the targets. So, whilst the technical measures are still useful in Scenario B, the degree to which the level of uptake would need to be pushed with incentives or regulation in order to achieve the targets might be considerably lower.

Further, as noted above, demand side measures are likely to take a substantial time to make a real impact while some of the more technical measures will do so faster. Systems changes need to build on a foundation of good practice everywhere (particularly in agriculture) and as they can't address geographically targeted issues, they are mostly complementary rather than a discrete alternative.

6. Recommendations

Trends in nitrogen losses are problematic, current targets in the UK are likely to be missed. While a set of possible policy measures has been identified to plug the gaps, many of which could and should be adopted, the largely incremental improvements expected from the envisaged measures are unlikely to be enough to fully address the nitrogen problem.

Changes are required across the entire nitrogen system and several elements of the economy; consequently, sufficient enabling measures must be put in place to facilitate the interventions required. Technical interventions and process interventions will be insufficient in isolation to secure the pace and scale of change that is required. Enabling and supporting measures need to be put in place alongside policy changes to support transition across and within sectors. As the solutions matrix and scenarios clearly demonstrate, there is a wide range of legislative, policy and other measures that the UK could put in place to better address nitrogen pollution in all of its forms. No single measure will be sufficient. The right combination of measures is needed to achieve the appropriate balance between different approaches. Specific measures need to be carefully considered to avoid pollutant swapping and, when sector or flow specific measures are put in place, to avoid negative impacts on other sectors or flows. While domestic nitrogen losses are the primary concern, the wider international dimension also is important and the risks of offshoring nitrogen losses need to be avoided. Any overall strategy to reduce losses on a more demanding timetable needs to be constructed with care.

Nonetheless, a number of generic and specific recommendations can be drawn, many of which have already been raised elsewhere, for example in the NMEG report, in order to maximise the effectiveness of both existing and additional measures.

- **The UK needs an integrated nitrogen strategy**. The UK needs a coherent, comprehensive suite of legislation and policy measures to tackle nitrogen pollution. Dealing with nitrogen as a sector specific issue or problem leads to gaps and can produce negative effects on non-target sectors. This strategy should be informed by a Nitrogen Balance Sheet and seek to achieve system-wide reductions in nitrogen losses.
- As part of this, **the UK needs a comprehensive Nutrient Management Strategy** in each of the UK nations that is time bound and includes a suite of nitrogen specific targets. This could help to deliver a **cascade of interventions**, as proposed by NMEG, across all sectors and to address all flows, for example by underpinning the Nutrient Management Strategy with a 10-year Action Plan, delivered at a farm level by Nutrient Management Budgets and supported by other measures.
- There needs to be **a programme to achieve improved implementation of existing measures, including higher take up of voluntary measures**. This could include changes to best practice, better nutrient management plans on farms, significantly extended deployment of the Sustainable Farming Initiative, tripling spending on existing capital grant schemes and recalibrating guidance to focus more on sustainability.
- Voluntary measures alone are insufficient to deliver required reductions, particularly as the UK starts to consider how it will address GBF Target 7. A suite of measures needs to be considered to **strengthen voluntary approaches**, **including shifts from voluntary to mandatory measures where progress is insufficient;** incentive measures to support compliance; focused, independent and reliable advice, information exchange and training to support transition to more sustainable practices; and reform of certification schemes. This applies primarily in respect of agriculture, but the principles also apply across other sectors.

- There should be a **greater role for supply side considerations, such as the pollution footprints of different products** in setting standards for food for example in public procurement contracts.
- Greater consideration needs to be given to **geographically specific and targeted measures**, including less livestock in better locations; and a geographically focused set of intensive interventions in relation to sensitive sites, such as SSIs (i.e. extended boundaries for SACs etc).
- **More and better enforcement of existing legislation** is needed as a mechanism to support better implementation. This could be supplemented by **new binding regulations** in some sectors and in relation to some flows: some to support changes in practices and some to support changes in processes, such as extending to other sectors for example, permitting should be widened to include large scale dairy and beef production units, alongside a reduction in the permitting requirement threshold of pig and poultry units.
- **A review should be undertaken of the use and effectiveness of incentives for nitrogen use in the agricultural and energy sectors** with the removal of perverse subsidies, such as coupled support for livestock and the continued absence of taxation on red diesel. In addition to supporting the implementation of GBF Target 7, tackling this issue would help the UK to also make progress against GBF Target 18 as well as the Net Zero target.
- **Include other sectors within the scope of controls and measures** that have proven effective in tackling emissions and / or pollution; and **reduce thresholds for the application of measures to avoid excluding significant flows** (i.e. through changes to thresholds for EPR / BAT; inclusion of additional sectors such as agriculture within the ETS; inclusion of non-CO_2 GHGs within the UK CBAM).
- More needs to be done on **behaviour change** with the aim of reducing demand for high nitrogen food products through less waste and dietary change; and to engage farmers, with an element of co-design, to persuade them of the importance of the initiative, adopt best practices and engage in peer-to-peer learning.
- **Government should respond to the NMEG report** as a matter of urgency, particularly to the proposed recommendations on a strategic approach to nutrient management, improving nutrient management in food production, extending environmental permitting to the beef and dairy sectors, and proper enforcement with support, training, advice and a learning and knowledge exchange network.

Annex 1: The UK Nitrogen Balance Sheet (UK-NBS)

The UK-NBS (

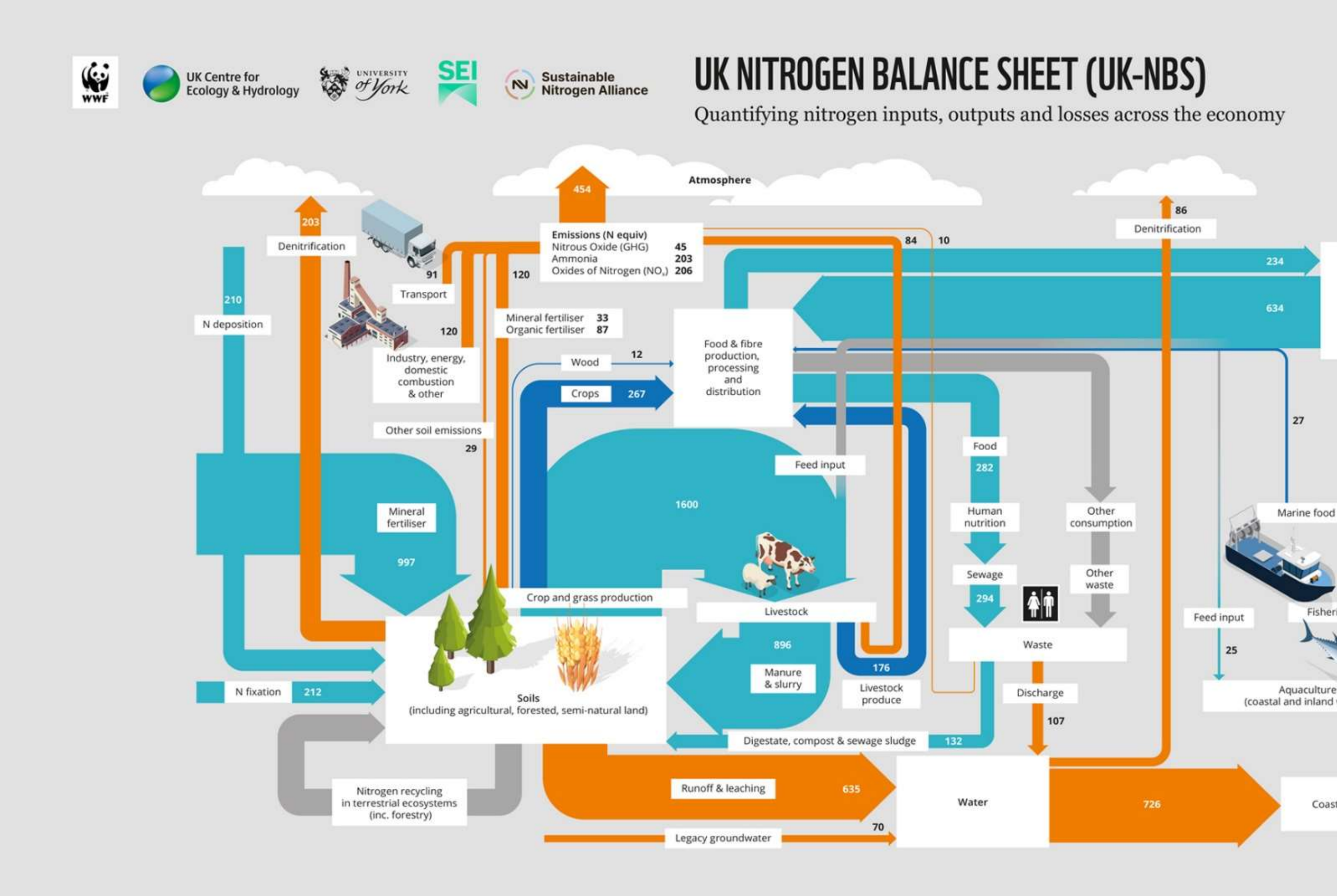

Figure 1) quantifies and summarises the main nitrogen flows within the UK. It was developed as a proof of concept, based on the Scottish approach, and would require further work to be fully operational. It was created to help better understand and track flows of nitrogen across different parts of the economy and environment and transnational flows, and via which media. The intention is to identify areas of potential waste and anticipate flow changes based on potential scenarios. Adopting a systems thinking approach allows synergies and trade-offs to be maximised and minimised.

Nitrogen balance sheets enable us to calculate nitrogen use efficiency (useful outputs divided by inputs) for different sub-systems (like agriculture) or for the whole economy, which can be a useful metric to gauge progress. Nitrogen balance sheets also serve to highlight some key principles that are important when deciding how best to manage reactive nitrogen losses:

- Flows of nitrogen between sectors are complex, and so involve a variety of different actors.
- Some flows do not produce useful outputs at all.
- It is easy to see how reducing input flows of nitrogen overall cascades through to reduced harmful losses of reactive nitrogen and that reducing nitrogen loss per se - even when emissions don't have a negative impact (e.g. denitrification back to N_2) - means (in theory) less input is needed overall.
- The way in which multiple inputs and intermediate flows feed into the same systems can easily be seen, highlighting potential for substitution.

- The (theoretical) potential for increased circularity of nitrogen flows can be seen, rather than linear ones, which reduces the total amount of nitrogen needed in the system.
- How losses occur from a given input at various downstream steps in the system can also be seen. For example, nitrogen applied to pasture is lost first from the pasture soils, then from manure management when the grass is eaten by livestock, then again from sewage treatment plants when humans eat livestock products, which highlights why simplifying flows (i.e. crop -> human, rather than crop/grass -> livestock -> human) can help to reduce emissions.

The UK-NBS does not (and is not intended to) show the constraints that influence the scope to switch, redirect or reduce particular flows of nitrogen. For example, the availability of manure and slurry for applying to soils varies regionally, leading to excess in some areas and deficits in others, as manure and slurry cannot be easily transported at an economic cost. This leads to more mineral fertiliser being applied to soils than would be expected from a naive view of the UK as a single system.
The balance sheet is not comprehensive and does not clearly identify flows associated with food waste and loss of nitrogen in food waste to landfill.

Annex 2: Major sources of nitrogen loss to the environment in the UK

The main losses, input flows and intermediate flows of nitrogen are summarised in tables 8-10 below.

A2.1 Major Sources of Nitrogen Loss

A2.1.1 Losses to Air

Nitrogen flows from anthropogenic activities and natural processes to the atmosphere, which acts as a nitrogen sink. The atmosphere also acts as input source of nitrogen for soils and habitats through the process of nitrogen deposition.

In summary, emissions to air of the greenhouse gas nitrous oxide (N_2O), ammonia (NH_3) and nitrogen oxides (NO_x) collectively total around 454 kt N/yr loss of nitrogen (in 2021). Specifically, N_2O amounted to around 45 kt, NH_3 reached around 203 kt and NO_x resulted in approximately 206 kt.

A2.1.1.1 Combustion

Combustion is the largest source of reactive nitrogen emissions to the atmosphere. Emissions from **stationary combustion** (industry, energy, domestic combustion, public combustion etc.) and from **transport**, amounted to a collective approximate total of 120 kt and 91 kt respectively in 2021, overwhelmingly in the form of NO_x.

At 82 kt in 2021, **international aviation and shipping** contributed an almost as significant nitrogen loss as the combustion sources mentioned above, but this has not been included in the UK-NBS, due to the difficulty of allocating this to any one specific country.

A2.1.1.2 Agriculture

In 2021, nitrogen emissions from **agricultural soils** and **livestock** were of a similar size to emissions from combustion (in the past, combustion emissions were much larger – see section 4 below). In 2021 emissions from **fertiliser application** totalled around 120 kt, and emissions **from livestock housing and manure management** were 84 kt. These are dominated by ammonia emissions. Investigating the relationship between these flows could lead to recycling nitrogen and avoiding new input sources.

Of the 120 kt emissions from **agricultural soils**, 33 kt arose from **mineral fertiliser application** compared with 87 kt from **organic fertilisers**. Of the mineral fertiliser application, almost half of the emissions (c. 16 kt) relate to **urea or urea ammonium nitrate** (UAN) application; urea and UAN have very high rates of ammonia loss compared with other fertilisers, especially on calcareous soils. Of the organic fertilisers, the majority of loss (53 kt) comes from **farmyard manure and slurry** application, 18 kt from urine and dung deposited whilst grazing ("**grazing**"), and other organic fertilisers 20 kt. It is noteworthy that losses to air from applied manure and slurry are so much higher than from grazing, given that a similar amount of nitrogen is deposited on the soil each year from both sources; this is because soil microbes / organisms absorb much of the reduced nitrogen before it can volatise as ammonia gas.

Of the 84 kt from **livestock**, the majority (56 kt) is emitted as ammonia from **housing**, with a smaller fraction from **yards and manure storage**.

A2.1.1.3 Denitrification

Another loss of nitrogen to the atmosphere is through **denitrification** which results in an approximate total loss of 289 kt. Denitrification for the UK comprises of **denitrification from soil in agricultural, forest and semi-natural land** which equate to an estimated 203 kt, and processes of **denitrification from water**, which amount to approximately 86 kt. This microbial process converts nitrate from soils and water bodies into a biologically inert gas (N_2) through a complex series of reactions with high degrees of uncertainty.

A2.1.2 Losses to Water

Many reactive nitrogen compounds readily dissolve in water. Nitrogen tends to originate from anthropogenic activities and natural nitrogen cycling processes.

The main loss of nitrogen in water in the UK occurs by **runoff and leaching from soils** into freshwaters. These combined processes have resulted in a direct loss of approximately 635 kt N in 2021 from agricultural soils as nitrates, dissolved organic and inorganic, and particulate forms. This flow combines with c.70 kt previously lost to groundwater and 107 kt discharged from **wastewater treatment** in freshwaters, resulting in a 726 kt flows from fresh water to the sea.

The input flows of nitrogen mostly stem from **agricultural runoff and leaching**, with 241 kt originating from **grass** and 340 kt coming from **arable**. An additional 54 kt of runoff and leaching is from **semi-natural processes**. Loss of nitrogen from agricultural land can be in drainage water or in the form of eroded soil. Loss of nitrate in drainage water is affected by soil properties, as well the relative timing of fertiliser application / mineralisation of organic nitrogen, plant demand for nitrogen and rainfall.

In comparison, loss of nitrogen in **discharge from waste treatment** (107 kt) is rather small, though when discharged untreated is accompanied by loss of phosphorus as well as organic matter and microbes having a very detrimental effect on aquatic life.

Table 8: Summary table of nitrogen flows: losses

LOSSES					
Category	**From**	**To**	**ktN**	**Flow comprises of:**	**ktN**
Losses to air	**Livestock housing and manure management**	**Air**	84	NH_3-N, NO_x -N and N_2O -N	84
	Crop and grass production	**Air**	120	Mineral Fertiliser (NH_3-N & NO_x -N)	33
				Organic Fertiliser (NH_3-N & NO_x -N)	91
	Combustion	**Air**	211	Transport (mostly NO_x-N)	87
				Stationary combustion (power stations, industry, domestic and commercial) – (mostly NO_x -N)	120
	Denitrification	**Air**	289	N_2 from water	86
				N_2 from soil	203
Losses to water	**Waste**	**Water**	107	Outflow from wastewater treatment (nitrates, organic N, ammonium)	

	Soil	**Water**	705	Legacy groundwater (mainly nitrates)	70
				Runoff and leaching (nitrates, dissolved organic and inorganic, and particulate forms)	635
	Inland water	**Coastal water**	726	Runoff from UK land to UK coastal waters (nitrates, organic N, ammonium)	

A2.1.3 Other Flows

As well as considering the losses, it is also worthwhile considering the size of the main input and intermediate/recycling flows. This is because the magnitude of losses, and nitrogen use efficiency of the whole system depends on the size and types of inputs / routes nitrogen takes through the system. Some inputs or recycling routes are associated with higher emissions overall or emissions to different media, and by reducing, diverting or simplifying flows, the emissions may be reduced. It is therefore helpful to look at the size of input and intermediate / recycling flows in the system directly. These are summarised below.

A2.1.3.1 Input Flows

The main direct input flow of nitrogen into the UK system is through **mineral fertilisers applied to soils** (997 kt N in 2021). The second largest input was an estimated 634 kt of total nitrogen contained within **agricultural and aquatic commodities consumed by people and livestock**, based on a five-year average between 2017 and 2021.[76]
Other input flows are:

- biological nitrogen fixation (212 kt)
- nitrogen deposition onto soils from the atmosphere (210 kt)
- reactive nitrogen formation through combustion (c. 211 kt) is both a loss and an input[77]
- nitrogen oxide formation by lightning (not quantified)

Table 9: Summary table of nitrogen flows: inputs

INPUTS					
Category	**From**	**To**	**kTN**	**Flow comprises of:**	**kTN**
Anthropogenic inputs	**Imports**	**Agricultural and aquatic commodities consumed by people and livestock**	634	Uncertainty in breakdown of human food and animal feed	

[76] Hicks K., O'Neill C., Simpson J. and Croft S. (2023). Trade Import/Export Nitrogen Flow Estimation for UK. SEI, University of York, Report to WWF-UK.
[77] It is a loss because the reactive nitrogen is being emitted into the air so cannot be usefully used there, but it is also an input in the sense that the reactive nitrogen emitted was largely previous in the form of inert N_2 in the air. A fraction of the emitted reactive nitrogen will be redeposited onto soils and so re-enter the terrestrial system.

	Mineral fertiliser	**Soil**	997	Urea	160
				Other fertilisers	837
Inputs from natural processes	**Nitrogen deposition**	**Soil**	210	NH_3 & NO_x and secondary compounds formed thereof (e.g. ammonium sulphate)	
	Biological nitrogen fixation	**Soil**	212	Conversion of atmospheric N_2 to NH_3 / NH_4^+ and subsequently organic N	

A2.1.3.2 Intermediate/recycling flows

The largest single flow of nitrogen estimated by the UK-NBS from **crop and grass production to livestock**, which amounts to 1600 kt N/yr in the UK in 2021. This compares to only around 267 kt going directly to humans in **edible crops or fibres**. Of the 1600 kt fed to livestock (plus an unquantified amount of nitrogen in imported livestock feed), only 176 kt is consumed by people as animal products – over half (896 kt) is recycled back into soils as manure and slurry. It is, however, worth noting that this is one area where there seems to be a discrepancy in the balance; a lot of nitrogen goes missing from livestock.

The flow of nitrogen through people and into solid waste and wastewater treatment is much smaller than the flow through livestock, at c. 282 kt

Considering the size of these flows and the multiple sources of nitrogen input to agricultural soils with different impacts, it becomes clear how the impact of - for example reducing animal protein consumption by 33-50% as modelled in recent scenarios[78] – can feed back through the system to significantly reduce the magnitude of some of the agriculture / food system nitrogen flows.

Table 10: Summary table of nitrogen flows: intermediate flows

INTERMEDIATE / RECYCLING FLOWS				
From	**To**	**kTN**	**Flow comprises of:**	**kTN**
Waste	**Soils**	134	Digestate, compost and sewage sludge (organic N)	
Food & fibre production	**Human food**	282		
Human nutrition	**Waste**	294	Sewage (uncertainty over where food waste is included)	
Useful outputs	**Food & fibre production**	455	Crops	267
			Livestock products	176
			Wood	12
Livestock	**Manure and slurry**	896	Livestock excreta	
Crop and grass production	**Livestock feed**	1600		

[78] See, for example, the balanced pathway as set out in *The Sixth Carbon Budget: The UK's path to Net Zero*, December 2020, UK Climate Change Committee (https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf); and Leip, A., Wollgast, J., Kugelberg, S., Costa Leite, J., Maas, R.J.M., Mason, K.E., and Sutton, M.A. (eds.), 2023. *Appetite for Change: Food system options for nitrogen, environment & health*. 2nd European Nitrogen Assessment Special Report on Nitrogen & Food. UK Centre for Ecology and Hydrology, Edinburgh, UK (https://unece.org/sites/default/files/2024-05/Appetite%20for%20Change%20full%20report.pdf).

A2.2 Impacts of different forms of nitrogen loss and inputs

A2.2.1 Losses associated with different inputs and intermediate flows

The UK-NBS illustrates the magnitude of nitrogen flows moving between different parts of the economy and environment, but in its current form does not easily show the different rates of reactive nitrogen loss from different kinds of input.[79] This is an important factor to take into account when considering options for substitution or emissions mitigation, or how much priority to place on reducing particular input flows.

A2.2.2 Damage costs of different forms of reactive nitrogen

The health or environmental impact of nitrogen loss depends on the nitrogen compound and medium, which is important to take into account when prioritising action.
Loss of N_2 to the atmosphere through denitrification in soils or after incineration of organic waste has no direct adverse impacts. Loss of organic nitrogen in waste to landfill or nitrates to groundwater may have very delayed impacts. For other compounds, their impact depends on many factors such as spatial location of sources and receptors and their sensitivity. Table 11 below summarises impacts of different forms of nitrogen.

Table 11: Forms of nitrogen loss and their impacts[80]

Form of nitrogen loss	Major impacts
Ammonia (NH_3) to air	Reacts with sulphur dioxide (SO_2) and nitrogen oxides (NO_x) to form secondary fine particulate matter ($PM_{2.5}$), with associated health impacts. Is deposited rapidly from the air, so causes eutrophication in sensitive sites close to major sources
Nitrogen Oxides (NO_x) to air	Exposure of sensitive people causes or exacerbates a range of health problems. When deposited, contributes to eutrophication and acidification of soils. Contributes to ground-level ozone formation.
Nitrous Oxide (N_2O) to air	N_2O is a powerful greenhouse gas, with a global warming potential (over 100 years) almost 300 times that of CO_2
N flux to freshwaters (Ammonium, nitrates, nitrites, organic N)	All forms of N flux to water can lead to eutrophication of freshwaters. Ammonium and nitrite are toxic to fish in high concentrations In high concentrations in drinking water, nitrates and nitrites impact human health.
N_2 to air	No adverse impacts, but often reflects economic inefficiencies.

[79] For example, considering inputs of reactive nitrogen to soils, applying urea fertiliser to the surface can be associated with substantial and very rapid loss of ammonia to the atmosphere (10-20% of applied nitrogen). In contrast, biological nitrogen fixation does not (at least initially) cause losses to air.
[80] See footnote 1.

The impact pathway approach has been extensively used in the past to derive health impact damage costs, but monetisation of ecosystem impacts has not been given as much attention. A recent Defra-commissioned study on damage costs of air pollution[81] found that ammonia emissions are associated with slightly higher costs on average than NO_x emissions, though there is a more than 10-fold range between low- and high-sensitivity receptors (Table 12).

Table 12: Damage costs of air pollution emissions in the UK[81]

Pollutant Emitted	Central Damage Cost (£/t)	Low – High damage cost sensitivity range (£/t)	
		Low sensitivity damage cost	High sensitivity damage cost
NO_x	8,148	1,567	30,282
SO_2	16,616	6,615	43,850
NH_3	9,667	3.727	26,172
VOC	172	104	309
$PM_{2.5}$	74,769	29,631	212,839

Considering other forms of reactive nitrogen and losses to other media, van Grinsven et al[82] published a comprehensive study of damage costs in the EU as a whole in 2013 (Table 13). The highest values were for the impact of NO_x emissions to air on health (€18/kgN), followed by nitrate losses to surface waters and ammonia emissions to air on health (both €12/kgN). The climate impact of nitrous oxide emissions to air was valued at €10/kgN. Nitrate emissions to groundwater have much lower costs (€1/kgN).
Surprisingly, the ecosystem impact of NO_x and NH_3 emission to air are valued at only €2/kgN. However, this is an average for all emissions; emissions close to sensitive habitats will have a very high impact, whereas those distant from sensitive sites will have very small impact. Moreover, due to the nitrogen cascade, many of these costs are not mutually exclusive. Emissions of one form of nitrogen to air can first impact biodiversity in terrestrial systems, then be converted to nitrate and impact aquatic systems.

Table 13: Damage cost estimates in the EU for a variety of nitrogen compounds, loss media and impact categories

Effect	N Form	Loss to	Estimated cost (€ kgN^{-1})
Human health (particulate matter, NO_2 and O_3)	NO_x	Air	10-30 (18)
Crop damage (ozone)	NO_x	Air	1-2
Ecosystems (eutrophication, biodiversity)	N_r (nitrate) N_r (deposition)	Surface water	5-20 (12)
Human health (particulate matter)	NH_3	Air	2-20 (12)
Climate (greenhouse gas balance)	N_2O	Air	4-17 (10)
Climate**	NO_x	Air	-9 to 2 (-3)
Climate**	NH_3	Air	-3 to 0 (-1)

[81] https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2301090900_Damage_cost_update_2023_Final.pdf
[82] van Grinsven, H.J.M., *et al.,* 2013. Costs and benefits of nitrogen for Europe and implications for mitigation. *Environ Sci Technol,* 47, 3571–3579. https://doi.org/10.1021/es303804g

Ecosystems (eutrophication, biodiversity)	NH_3 and NO_x	Air	2-10 (2)
Human health (drinking water)	N_r (nitrate)	Groundwater	0-4 (1)
Human health (increased UV radiation from ozone depletion)	N_2O	Air	1-3 (2)
Climate (N-fertiliser production)	N_2O, CO_2	Air	0.03-0.3

Annex 3: International Comparisons

A3.1 Nitrogen Budgets in Japan and Germany

For the UK, Japan and Germany, the main nitrogen losses to the environment largely stem from the same source categories: **industry**, **transportation**, **cropland and grassland agriculture** and **wastewater**. Japan's sheet tracks time series data over a fifteen-year period whilst Germany measures a five-year period. Over the time series, they both record a reduction in reactive nitrogen losses in atmospheric NO_x emissions and loss of reactive nitrogen to territorial water.

In Japan, ammonia, NO_x transportation and NO_x energy conversion were the main losses in the atmosphere, likely due to artificial nitrogen fixation being a dominant process. In terrestrial water, discharge and runoff were the main processes of nitrogen loss. In Germany, ammonia synthesis is the largest flow of reactive nitrogen, followed by the release of reactive nitrogen from the organic nitrogen compounds in fuel and import of animal feed. Japan was the world's largest net importer of nitrogen considering the reactive nitrogen emissions associated with the production of exports to Japan.

A3.2 Methodological differences with the UK

The nitrogen balance system boundary for the UK and Japan are limited to territorial waters and the atmosphere, whereas for Germany, the nitrogen balance system boundary is extendable in recognition of Germany's rivers and air being connected to Europe and the EU. All three nitrogen balance sheets utilise a mass balance model approach to characterise nitrogen flows and nitrogen pools. Japan's nitrogen budget is additionally divided into subsystems and refers to the CHANS model for estimating the nitrogen budgets of China.

In Japan's nitrogen budget sheet (Figure 2), two pressure indicators are proposed to track losses. One is the Trends in Loss of Reactive Nitrogen to the Environment (TLRNE), per capita reactive nitrogen loss to the environment (Bleeker et al., 2013; BIP, 2021a). The other is the Trends in Nitrogen Deposition (TND), per area nitrogen deposition. Other indicators of loss include ratio of chemical fertiliser production to artificial nitrogen fixation, per capita food nitrogen supply, GDP, trade balance and the old age dependency ratio. Japan's nitrogen balance sheet is distinguishable by its focus on integrating wider impact considerations into the measurement of nitrogen loss potential. Emphasis is placed on recognising how Japan's ageing population may be contributing to a reduction in some nitrogen loss-intensive flows, such as per capita supply and consumption of food and energy. However, a linear relationship between wider impact changes and nitrogen loss is not assumed. Whilst consumption of food is noted to have reduced, the discrepancy between supply and consumption has widened. By drawing attention to this disconnect, the sheet explores the importance of connecting context to nitrogen flows and losses. Indicators of nitrogen loss need to help identify and address trade-offs and synergies.

In Germany's nitrogen budget sheet (Figure 3), existing reduction potential is suggested to be a helpful measurement against which recommendations to reduce losses can be formulated. To reduce losses of reactive nitrogen from wastewater, effective measures have focused on harnessing the existing reduction potential of emissions from nitrogen oxides in the manufacturing and transport sectors. To make similar improvements for agriculture, existing reduction potential is used to identify key measures to avoid losses, such as applying manure to untilled soil and applying urea-based fertiliser, using low emissions methods.

Emphasis is placed in the German nitrogen budget on the importance of integrated policy making for effective reductions in nitrogen emissions. The 7th Environmental Action Programme

of the EU binds Germany to a commitment to gain sustainable and resource efficient control of nutrient cycles by pursuing an explicit nitrogen strategy with demanding quantitative indicator targets on all sectors. The aim being to harmonise at national and European levels. One such indicator of nitrogen losses from agriculture is nitrogen surplus, calculated as gross nutrient balance. Establishing global nitrogen efficiency targets with ambitious measures and strategies to improve nitrogen efficiency are argued to be key factors in successfully reducing of nitrogen losses. Nitrogen use efficiency was used as a performance indicator in Japan's nitrogen budget to evaluate nitrogen flows relating to food production.
Japan's nitrogen budget sheet makes a direct link between policies introduced to reduce nitrogen losses and the improvements in nitrogen loss over the fifteen-year period. The first policy centres around reducing the input flows of nitrogen by controlling emissions for point and mobile sources and reducing surplus input by nutrient management for non-point sources. The second policy focuses on converting nitrogen into N_2 through denitrification of water measures and denitrification of exhaust gas of point and mobile sources. Two factors are identified as being key to the decreasing trends of reactive nitrogen loss after 2000: the effects of active emission controls and the decreasing activity numbers. However, Japan's nitrogen budget makes an important link between specific policy changes, identifying the 2001 amendment to the Automobile NO_x law as instrumental in the reduction of NO_2 concentrations in subsequent years.

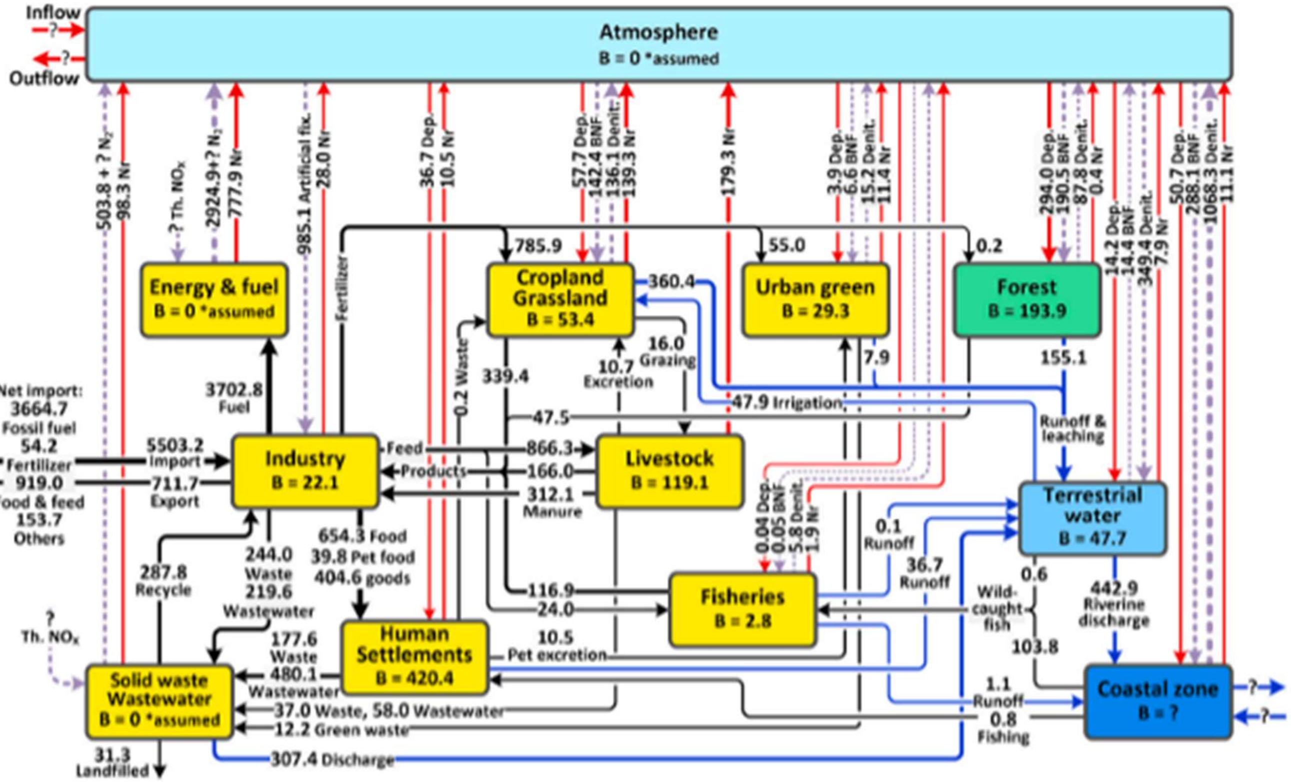

Figure 2: Nitrogen Budgets in Japan in 2010 (unit: Gg N yr-1).[83]

[83] Black solid arrow, reactive N flow connected with human sectors; red solid arrow, reactive N flow via the atmosphere; purple dashed arrow, dinitrogen (N2) flow via the atmosphere; blue solid arrow, reactive N flow with water; B, balance subtracting the total outflow from the total inflow. Hayashi, K., Shibata, H., Oita, A., Nishina, K., Ito, A., Katagiri, K., Shindo, J., Winiwarter, W. (2021) Nitrogen Budgets in Japan from 2000 to 2015: Decreasing trend of nitrogen loss to the environment and the challenge to further reduce nitrogen waste. Environmental Pollution. 286. Pp. 117559 https://www.sciencedirect.com/science/article/pii/S0269749121011416

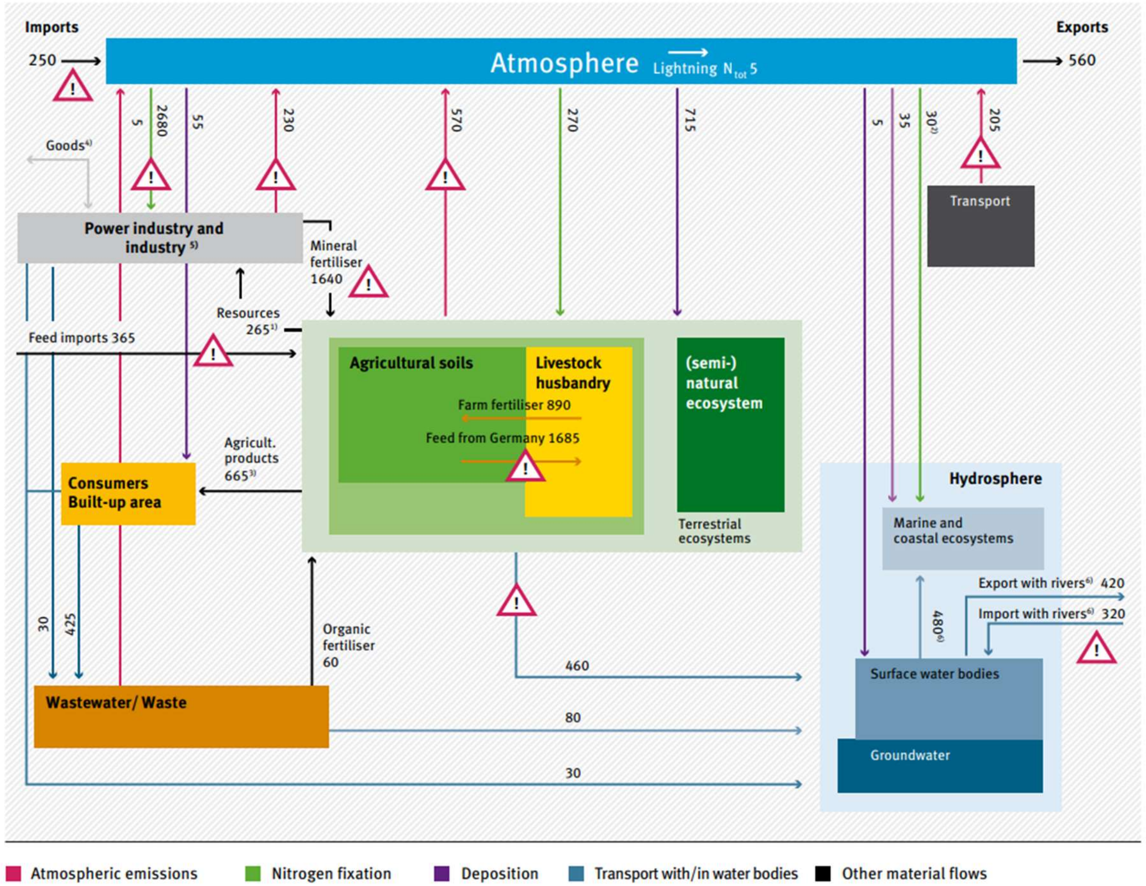

Figure 3: Germany's Nitrogen Budget[84]

[84] Häußermann et al. (2021) 'National Nitrogen Budget for Germany'. Environmental Research Communications. 3. pp. 095004. https://iopscience.iop.org/article/10.1088/2515-7620/ac23e5/pdf

Annex 4: Trends over time in the UK

The aim of this Annex is to illustrate changes over time for nitrogen concentrations, and to focus on which flows have remained the same. This will help inform which flows might be most effective to target with interventions. Maximising positive effects for reduction of nitrogen loss throughout the cycle is a priority for achieving national statutory targets and international commitments.

A4.1 Emissions to air of reactive nitrogen (N_2O, NO_x and NH_3) per flow per year

Figure 4 below presents the emissions to air of reactive nitrogen (N_2O, NO_x and NH_3) per "flow" per year from the UK National Atmospheric Emissions Inventory (NAEI)[85]. The graph excludes emissions from international aviation and international shipping.

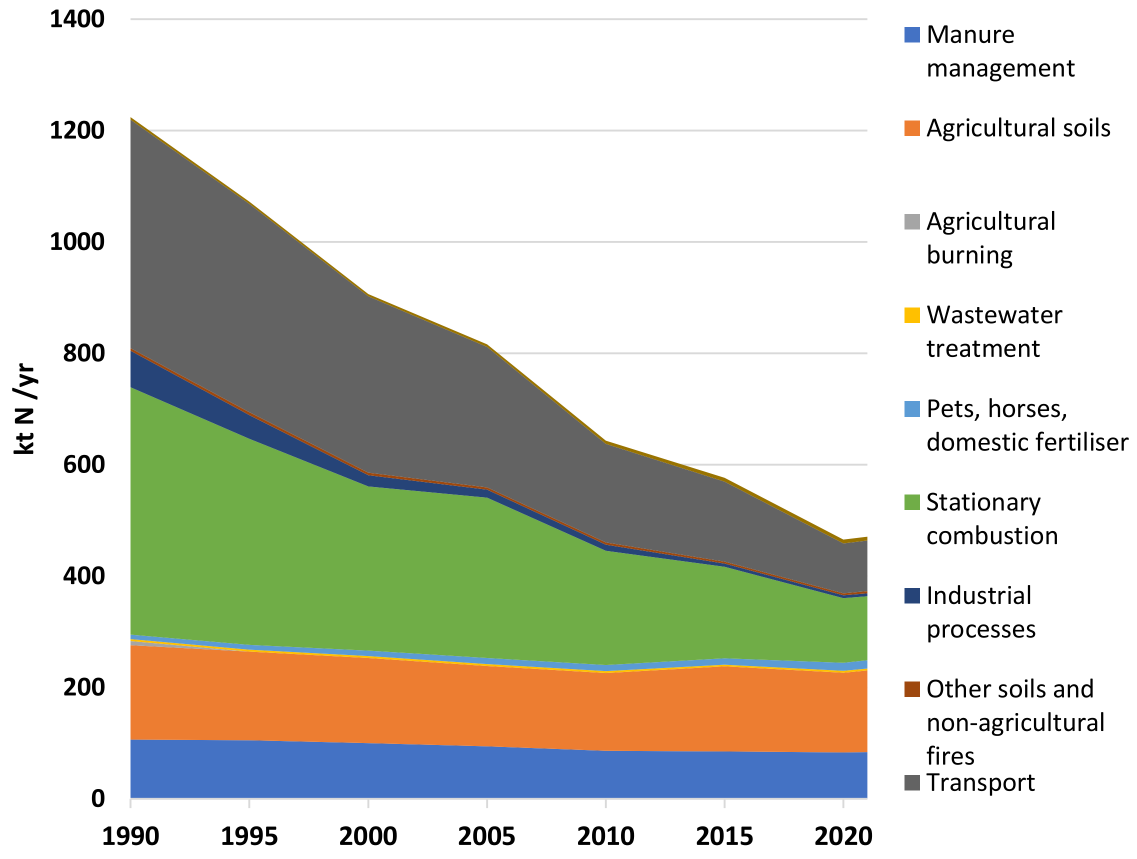

Figure 4: Emissions to air of reactive nitrogen per flow per year

Between 1990 and 2021, there has been a 62% decrease in total reactive nitrogen emissions to air. Industrial processes, stationary combustion and transport have all reduced considerably. For industrial processes there has been a 91% reduction, for stationary combustion, a 78% reduction and for transport, a 74% reduction. The greatest reduction levels were of NO_x. By contrast, manure management and soils emissions to air, mostly ammonia, have only reduced by 16%, so the relative contribution of these has increased over time. In 1990 agriculture only

[85] https://naei.beis.gov.uk/data/data-selector

accounted for less than one quarter of total reactive nitrogen emissions to air, but for around half in 2021.

A4.2 Other Nitrogen Flows

Table 14 below presents a compilation of data from the NAEI, Defra Soil Nitrogen Balance statistics[86] and the UK's UNFCCC GHG inventory submission[87].

In terms of the changes that can be seen over time, key trends include:

- Both mineral fertiliser and manure input to soils have declined substantially, by 39% and 22% respectively, related to an overall reduction in nitrogen harvested in crops and grass. The estimated 16% reduction in agricultural nitrogen emissions to air and estimated 19% reduction in leaching since 1990 are based on these observed declines in nitrogen inputs (due to the calculation methodology used in the UK GHG inventory).
- Overall, the per hectare soil nitrogen balance has reduced from 137.9 kg N / ha in 1990, to 90.8 kg N / ha in 2020, a reduction by 34%. Underlying this overall trend is a reduction in both nitrogen inputs and nitrogen offtake since 1990, such that, although the absolute soil nitrogen balance has reduced substantially, the implied nitrogen use efficiency (total offtake / total inputs) has barely increased. Different trends are also apparent on arable and grassland – average inorganic nitrogen application rates on arable land are variable but have not decreased consistently since the mid-1990s, whereas inorganic nitrogen application rates on grassland have reduced substantially[88].
- Some flows, such as other organic fertiliser (compost, digestate etc.) and sewage effluent, have increased.

However the impact of the reduction in soil nitrogen balance has not translated into similar reductions in nitrate levels in groundwater or surface water[89]. Nitrate levels in rivers across England have only shown modest decreases since the mid-1990s, largely because of the time-lag in the flow of nitrates in groundwater. Net storage of nitrogen in groundwater was evident in 1980, but net export from groundwater to freshwaters was evident in 2000 onwards (some geologies are much slower than others). [90]

It should be noted that the estimate of agricultural leaching from the UK GHG inventory is lower than the one used in the UK NBS originating from the Long-Term Large Scale (LTLS) hydrological model[90], but both sources shows the same trend and are in a similar range.

It is also worth noting that an agricultural nitrogen balance will be compiled for the NAEI in future, which may include a more sophisticated methodology to estimate nitrogen losses to water from agricultural soils than is currently used in the UK GHG inventory.

Table 14: Compilation of data on nitrogen flows over time

	1990	2020	% change

[86] https://www.gov.uk/government/collections/soil-nutrient-balances#:~:text=Soil%20nutrient%20balances%20provide%20a,quality%20and%20on%20climate%20change

[87] https://rt.unfccc.int/locator. Estimate of human sewage generation is found under 5.D.1 Domestic wastewater -> N in effluent. Estimate of agricultural leaching is found under 3.D.2 Indirect N2O emissions from managed soils -> 3.D.2.2 Nitrogen leaching and runoff -> N from fertilisers and other agricultural inputs that is lost through leaching and runoff.

[88] https://www.gov.uk/government/statistics/british-survey-of-fertiliser-practice-2022

[89] https://consult.environment-agency.gov.uk/++preview++/environment-and-business/challenges-and-choices/user_uploads/nitrates-pressure-rbmp-2021.pdf

[90] Bell et al https://www.ceh.ac.uk/sites/default/files/2023-01/LTLS-RS-Integrated-model.pdf

Inputs to soils			
Inorganic fertiliser input[86]	1582	967	-39%
Organic fertilisers (excl. manure) [86]	30	61	+103%
Manure[86]	1264	982	-22%
Atmospheric Deposition[86]	172	105	-39%
Biological fixation[86]	149	155	+4%
Intermediate flows			
Total Harvested Crops[86]	518	447	-14%
Total Forage[86]	985	697	-29%
Crop residues[86]	43	34	-21%
Human sewage generation[87]	346	373	+8%
Losses – air emissions			
Manure management[85]	106	84	-21%
Agricultural soils[85]	170	143	-16%
Agricultural burning[85]	8	0	-100%
Wastewater treatment[85]	3	3	+6%
Pets, horses, domestic fertiliser[85]	9	14	+62%
Stationary combustion[85]	444	116	-74%
Industrial processes[85]	65	6	-91%
Other soils and non-agricultural fires[85]	5	4	-26%
Transport[85]	411	89	-78%
Solid waste treatment (inc. incineration) [85]	4	7	+55%
Losses - water emissions			
Agricultural leaching[87]	545	444	-19%

A4.3 Change over time in hydrological nitrogen flows

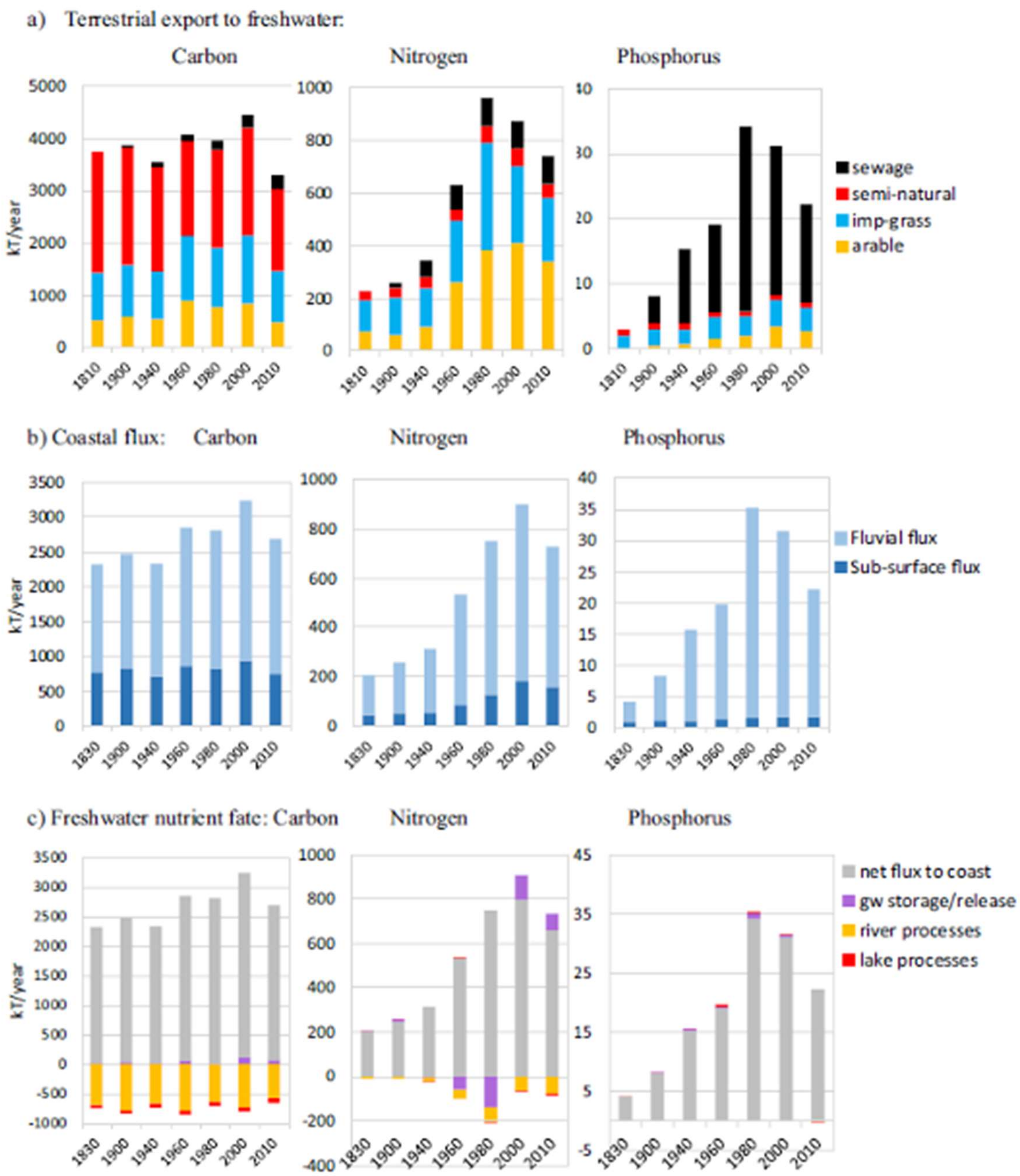

Figure 5: Results of the Long-term Large-scale Freshwater Ecosystems modelling.[91]

[91] Trends in terrestrial export of nitrogen, carbon and phosphorus to freshwaters, Bell et al., 2021

Annex 5: International Targets applicable to the UK

A5.1 UNECE Gothenburg Protocol, as amended 2019

Target: Against a 2005 baseline, by 2020 to reduce NO_x emissions by 55%, NH_3 emissions by 8% and $PM_{2.5}$ emissions by 30%
Status: Binding
Implemented through: National Emission Ceilings Regulations

A5.2 Kunming-Montreal Global Biodiversity Framework

Target 7: *Reduce pollution risks and the negative impact of pollution from all sources, by 2030, to levels that are not harmful to biodiversity and ecosystem functions and services, considering cumulative effects, including: reducing excess nutrients lost to the environment by at least half including through more efficient nutrient cycling and use.*
Status: non-binding.
Implemented through: still to be determined, but many of the measures identified in this report will contribute to UK progress towards GBF Target 7.
International level indicators to measure progress against the GBF, including Target 7, are still under negotiation and are expected to be adopted at the 16th Meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD COP16), which will take place in Cali, Colombia, in October 2024[92]. Indicators are split into four distinct categories, headline and binary indicators, which will be included in the national reporting template; and component and complementary indicators, which are optional.
To prepare for COP16, further negotiations took place in Nairobi in May 2024, with the outcome that the following will be presented in October as the basis for the final negotiations (noting that these have not yet been agreed and are still therefore liable to significant change):
Headline indicators:

- Index of coastal eutrophication potential;[93]
- Aggregated total applied toxicity.[94]

Component indicators:

- Cropland nutrient budget;
- Proportion of domestic and industrial wastewater flow safely treated;
- Floating plastic debris density (by micro and macro plastics)
- Red List Index (impact of pollution)

Complementary indicators include:

- Trends in loss of reactive nitrogen to the environment; and
- Trends in nitrogen deposition.

Following the adoption of international indicators, each country that is Party to the CBD will be expected to develop its own indicator framework and set out how it intends to meet each of the

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[92] UNEP-WCMC is monitoring progress towards the development of international indicators up to 9th April 2024 on a dedicated website (https://gbf-indicators.org/). At the point of the last update to the site, two headline indicators had been proposed in relation to Target 7: 7.1, index of coastal eutrophication potential; and 7.2 aggregated total applied toxicity.
[93] Proposed optional disaggregations: by type of nutrient; by sub-basin.
[94] Proposed optional disaggregations: by pesticide type; by sectors use of pesticide products.

targets set out in the GBF. This will be set out in countries' national biodiversity strategies and action plans. Until international indicators have been agreed and a national strategy for implementation of the GBF has been set out by the UK government, it is impossible to properly assess UK progress towards Target 7 (or indeed any of the Goals or Targets of the GBF).

Annex 6: Progress towards relevant targets in the UK, including historical trends and projections

A6.1 Agriculture

A6.1.1 Environment Act 2021: Agriculture Water Target

Reduce loss of nitrogen, phosphorus and sediment pollution load from agriculture to the water environment by 40% by 31st December 2038, compared to 2018 baseline[95] in England.
This target is set out in the Environmental Targets (Water) (England) Regulations 2022 (made under ss4(8) and 143(5)(b) of the Environment Act 2021), Regulation 5, with further interim targets (listed below) made in the Environment Improvement Plan.

The Agriculture Water Target has been set by the UK Government to improve the water environment and reduce the damaging effects of nutrient pollution in water, stemming from excess nitrate in drainage water[96]. Usefully, this target directly relates to the agricultural soils to water bodies loss flow. This means it is possible to assess more easily than in most other spheres whether current policy instruments and measures are effective in reducing losses for this specific flow. However, other factors such as key commodity prices and other policy interventions will also have a role.

The target has an indirect effect on other identified major flows including loss of nitrogen from inorganic fertilisers to air, loss of nitrogen from dairy cattle manure to air, input of inorganic fertilisers to soil, and input of manure to soil.

An interim target has been set in the Environmental Improvement Plan published in 2023[97]; to reduce loss of nitrogen, phosphorus and sediment pollution load from agriculture to the water environment by "10% by 31 January 2028, or 15% in catchments containing protected sites in unfavourable condition due to nutrient pollution[98]".

A6.1.1.1 Quantitative Projections

The latest Defra EIP annual progress report[99] uses the Defra soil gross nutrient balance statistics[86] as the best proxy available to track changes in nitrogen loadings into the water environment from agriculture. These show that N excess per hectare in 2022 (79.1 kg) was 12% lower than in 2018 (the baseline year for the target), but also that the 2021 value was 3% higher than 2018, and more generally that the N balance has fluctuated and shown no overall downward trends since around 2005. It remains to be seen whether then low 2022 value is the start of a downward trend, or a fluctuation in the overall static picture since 2005.

The Defra logic model in the 2022 Water Targets report[100] predicts the Agricultural Water Target will achieve a 40% reduction of nitrogen loss in the water environment from agricultural

[95] https://www.legislation.gov.uk/ukdsi/2022/9780348242911#:~:text=Agriculture%20water%20target,-5.&text=entering%20the%20water%20environment%20through%20agricultural%20diffuse%20pollution%20is%2C%20by,40%25%20lower%20than%20the%20baseline.

[96] https://www.cla.org.uk/news/in-focus-reducing-water-pollution-from-agriculture/

[97] https://assets.publishing.service.gov.uk/media/64a6d9c1c531eb000c64fffa/environmental-improvement-plan-2023.pdf

[98] https://lordslibrary.parliament.uk/river-pollution-and-the-regulation-of-private-water-companies/

[99] https://www.gov.uk/government/publications/environmental-improvement-plan-annual-progress-report-2023-to-2024/environmental-improvement-plan-annual-progress-report-2023-to-2024

[100] https://consult.defra.gov.uk/natural-environment-policy/consultation-on-environmental-targets/supporting_documents/Water%20targets%20%20Detailed%20Evidence%20report.pdf

sources. This is on the basis of 85-100% uptake of regulatory measures and future farming schemes such as Sustainable Farming Incentive.
The Environmental Improvement Plan (EIP) predicts that after 2028, there will be an 'S-shaped' trajectory, with an acceleration in reduced losses[101]. Maximum reductions are predicted on the assumption that incentives will be used to precisely target habitat creation. Technological innovation is expected to reduce the proportion of nutrients lost from agricultural systems whilst maximising yields with reduced inputs[102].
However, the progress report also highlights the limitations of using N balance as a proxy (in particular the need for consideration of spatial patterns of excesses), and the need for a better suite of models to track and project the impact of agriculture and measures on nitrogen loadings to water, and these are being developed currently.

A6.1.1.2 Measures Contributing Towards Implementation

- Farming Rules for Water.
- Nitrates Regulations.
- Incentive schemes e.g. capital grants under the Farming Investment Fund, including for slurry stores and Countryside Stewardship; Sustainable Farming Incentive; Landscape Recovery.
- Advice and guidance such as the Code of Good Agricultural Practice for Reducing Ammonia emissions; Nitrate Leaching Tool; Agricultural Compliance Tool.
- Catchment Sensitive Farming and other catchment specific measures (i.e. Poole Harbour Catchment; Solent Catchment Market).
- Nutrient Mitigation Scheme (Natural England).

A6.1.1.3 Progress Towards Target

Currently, the UK Government is not on track to meet the 2038 target. In 2021, the River Basin Management Plans (RBMPs) showed that nitrate vulnerable zones (NVZs) with catchment sensitive farming have only reduced leaching slightly; a trend not sufficient to meet the target[103].
The recent independent Office for Environmental Protection review of progress under the EIP in England is optimistic about achieving the 2028 interim target with catchment sensitive farming, but not about reaching the 2038 target[104]. The scale of uptake assumed in the EIP is significantly greater than that which has to date been achieved with largely voluntary measures.

A6.1.2 National Emission Ceilings Regulation: NH_3 Reduction Target

Reduce total ammonia (NH_3) emissions to air by at least 8% from 2005 levels in all years between 2020-2029, and by 16% from 2005 levels in 2030 onwards.
Under the National Emission Ceilings Regulations, Emission Reduction Commitments, these targets apply to the UK as a whole. The targets originate from EU Directive 2016/2284/EU, and from the Gothenburg Protocol to the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP)[105], which have been transposed into UK legislation through the National

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[101] https://assets.publishing.service.gov.uk/media/64a6d9c1c531eb000c64fffa/environmental-improvement-plan-2023.pdf
[102] https://ukagritechcentre.com/news/drive-change-nutrient-management/
[103] https://consult.environment-agency.gov.uk/environment-and-business/challenges-and-choices/user_uploads/nitrate-pressure-narrative-021211.pdf
[104] Government remains largely off track to meet its environmental ambitions, finds OEP in annual progress report | Office for Environmental Protection (theoep.org.uk)
[105] https://unece.org/environmental-policy-1/air

Emission Ceilings Regulations. The target relates to the total NH_3 emissions to air from all sources, as quantified in the UK NAEI[106].

A6.1.2.1 Quantitative Projections

Over 80% of NH_3 emissions arise from agriculture, in particular livestock housing, manure management, manure application to land, and inorganic fertiliser application to land.

Table 15: Emission totals in 2005 and 2022, and projected for 2025 and 2030 under current measures for NH3, compared to emission reduction commitments (ERCs). Totals are given for adjusted and unadjusted emissions[107]. The adjusted emissions are used to assess compliance with ERCs, so unadjusted emissions are presented for context only.

NH_3 measure	2005	2022	2025	2030
Air emissions (kt) - adjusted	280	246	242	240
Change from 2005 (%)		-12.2%	-13.7%	-14.6%
ERC (%)		-8%	-8%	-16%
Air emissions (kt) - Unadjusted	*281*	*259*	*256*	*260*
Change from 2005 (%)		*-7.7%*	*-8.7%*	*-7.6%*

A6.1.2.2 Measures Contributing Towards Implementation

- Clean Air Strategy.
- Nitrates Regulations.
- Incentive schemes e.g. the Equipment and Technology Fund, including for slurry covers, scrapers and low-emission slurry-spreaders; capital grants under the Farming Investment Fund, including for slurry stores; Farming Ammonia Reduction Grant; Countryside Stewardship; and Countryside Productivity.
- Advice and guidance such as the Code of Good Agricultural Practice for Reducing Ammonia emissions.
- Catchment Sensitive Farming.
- Red Tractor assurance standards limiting the use of unprotected urea.
- Environmental Permitting Regulations (inc. development of Best Available Techniques (BAT) for dairy and intensive beef farming).
- Evidence gathering around new housing standards.
- Environmental Land Management Scheme / devolved farm payment schemes.

A6.1.2.3 Progress Towards Target

The latest historical and projected emissions estimates in the NAEI (Table 15) show that – based on official totals for assessing compliance - the UK is currently meeting the 2020-2029 emission

[106] https://naei.beis.gov.uk/
[107] Source: UK NFR tables reported under CLRTAP, March 2024 (https://webdab01.umweltbundesamt.at/download/submissions2024/GB_NFR2024.zip?cgiproxy_skip=1). Adjusted emissions are the "Compliance total (CLRTAP)", which excludes emissions from spreading of non-manure digestate because there was no method available to estimate emissions from that source when ERCs were established. This is the emission value officially used to assess compliance with ERCs. Unadjusted numbers include emissions from spreading of non-manure digestate, and are likely to more accurately represent real emissions and trends over time

reduction commitments for NH_3. In 2030, under current policies and measures, emissions projections suggest **the UK will narrowly miss the ERC for NH_3** by around 1.4 percentage points.

However, the official totals for assessing compliance are not the best estimate of actual NH_3 emissions to air, because the emissions from spreading of non-manure digestate on land has been excluded from these totals. Whilst this exclusion is legitimate under the rules of the legislation, it is worth noting that the trend in unadjusted emissions (including spreading of non-manure digestate) is less encouraging; by 2030, unadjusted NH_3 emissions are projected to be only 7.6% below 2005 levels, a compliance gap of over 8 percentage points, and almost no change from current levels. Non-manure digestate is a growing source of emissions, due to the ongoing increase in separate food waste collections.

These projections are probably the most reliable quantitative indication of the sufficiency of current policies and measures in the relevant sectors to achieve the target and suggest that additional measures will be needed to meet the 2030 NH_3 ERC.

A6.2 Combustion

A6.2.1 National Emission Ceilings Regulation: NO_x emissions target

Reduce total nitrogen oxides (NO_x) emissions to air by at least 55% from 2005 levels in all years between 2020-2029, and by 73% from 2005 levels in 2030 onwards.

These targets originate from EU Directive 2016/2284/EU, and from the Gothenburg Protocol to the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP), which have been transposed into UK legislation through the National Emission Ceilings Regulations.

A6.2.1.1 Quantitative projections

The majority of NO_x emissions arise from various combustion sources.

*Table 16: Emission totals in 2005 and 2022, and projected for 2025 and 2030 under current measures for NO_x, compared to emission reduction commitments (ERCs)*Error! Bookmark not defined.

NO_x measure	2005	2022	2025	2030
Air emissions (kt)	1725	643	575	459
Change from 2005 (%)		-63%	-67%	-73%
ERC (%)		-55%	-55%	-73%

A6.2.1.2 Measures Contributing Towards Implementation

- Grants for home energy efficiency, including boiler upgrade scheme; home upgrade grant; sustainable warmth competition; social housing decarbonisation fund; energy company obligation; Great British Insulation Scheme; schemes administered by Home Energy Scotland.
- Clean Air Strategy 2019.
- Air Quality Plan for NO_2.
- UK BAT regime requiring continuous improvement.
- Industrial energy efficiency accelerator.
- Ban on sales of new petrol & diesel cars by 2035 (indirect effect).
- Incentives for electric vehicles (preferential capital allowances; lower VED; plug in vehicle grants).
- Clean air zones and low / zero emission zones.
- Speed limit reductions to alleviate local problems (Wales).

- Encouraging modal shift through investment in cycling and walking infrastructure.
- Targets in the Devolved Administrations for walking and cycling; support for remote working; and commitments to decarbonise the government fleet.
- Transport Decarbonisation Plan.
- Clean Maritime Plan.
- Cycling and Walking Strategies.
- Clean Air Strategy 2019.
- Air Quality Plan for NO_2.

A6.2.1.3 Progress Towards Target

The latest historical and projected emissions estimates in the NAEI show that the UK is currently meeting the 2020-2029 emission reduction commitments for NO_x. In 2030, under current policies and measures, emissions projections suggest **the UK will just meet the ERC for NO_x.**

These projections are probably the most reliable quantitative indication of the sufficiency of current policies and measures in the relevant sectors to achieve the target and suggest that additional measures will be needed to be sure of meeting the 2030 NO_x ERC.

A6.3 Wastewater treatment to water bodies

A6.3.1 Phosphorous reduction

Environment Act 2021 Target: To reduce phosphorus loadings from treated wastewater by 80% by 2038 against a 2020 baseline, sets out the ambition a nitrogen-specific target would require[108]. The interim target is for a 50% reduction by 31st January 2028, as set in the Environmental Improvement Plan[109].

A6.3.1.1 Quantitative Projections

Environment Agency data shows that between 1995 and 2020, there was an 80% reduction in ammonia entering rivers from wastewater treatment discharge in England[110]. However, only 16% of surface water bodies meet the Water Framework Directive regulation's objective of 'good ecological status' and 0% meet 'good chemical status'[111]. 35% of water bodies are being polluted by discharges of wastewater from the water industry, including treated and untreated sewage[112]. Just over 55% of lakes in England failed to meet 'good' status due to an excess of nitrates. Nitrogen compounds, such as nitrate and ammoniacal nitrogen, are the reason that 70 groundwater DrWPAs are classed as being at poor chemical status.

No official data was found on historical or projected trends in release of nitrates from treatment plants into waters, but nitrate levels have been deemed responsible for 65% of failures to

[108] https://questions-statements.parliament.uk/written-statements/detail/2022-12-16/hlws449

[109] https://assets.publishing.service.gov.uk/media/64a6d9c1c531eb000c64fffa/environmental-improvement-plan-2023.pdf

[110] https://oifdata.defra.gov.uk/themes/water/B1/

[111] https://earthwatch.org.uk/blog/government-is-not-on-track-to-meet-the-environmental-objectives-under-the-water-framework-directive/

[112] https://committees.parliament.uk/writtenevidence/22353/pdf/#:~:text=Only%2016%25%20of%20water%20bodies,polluted%20by%20diffuse%20urban%20pollution

achieve good chemical status[113] for groundwaters protected for drinking water. By 2027, the projected level of ammonia loads discharged to rivers from water company sewage treatment works, in England and Wales, are estimated to be almost the same as 2020. This amounts to approximately 3,000 tonnes per year and is based on measures included in the PR14 and PR19 WINEPs[114]. Increased monitoring has led to a 27% increase in the number of sewage spills from overflows being officially recorded by water companies, between 2019 and 2020[115]. UK Government estimate an upgrade of wastewater treatment plants in designated catchments by April 2030, will lead to around a 57% reduction in nitrogen loads in total from wastewater treatment works.

A6.3.1.2 Progress Towards Target

No specific UK target for the reduction of losses of nitrogen has been set. However, the target to reduce phosphorus loadings from treated wastewater sets out the ambition a nitrogen-specific target would require.

A6.3.2 Maximum value in sensitive water catchment areas

In sensitive water catchment areas, including potable water extraction, the Water Supply (Water Quality) Regulations 2016 set a maximum value of 50mg/l for nitrate and 0.5mg/l for nitrite within groundwater and surface water bodies.
This regulation ensures that nitrate levels in drinking water remain below this threshold to protect public health.

A.6.3.2.1 Quantitative Projections

The UK River Basin Management Plan report on nitrate pressures[89] reported data on nitrate concentrations in surface and groundwaters for the 2014-15 reporting period. Based on this data, 44% of England is classed as a nitrate vulnerable zone (NVZ) because rivers breach the 50 mg/l limit, and 25% because groundwater breaches the 50 mg/l limit. There have been widespread but modest declines on average in river nitrate concentrations over time, from a peak of around 6mg/l in the mid-1990s, to around 5.5 mg/l in 2018. In England, 12 surface water bodies have been identified as failing WFD Article 7 'no deterioration objective' due to high levels of nitrate. Nitrogen compounds, such as nitrate and ammoniacal nitrogen, are the reason that 70 groundwater Drinking Water Protected Areas are classed as being at poor chemical status. Within those 70, there are 227 Safeguard Zones (SGZ) aimed at reducing deterioration. Trends for rivers are partly related to trends in groundwater, as many rivers in the South and East of the UK are predominantly groundwater fed.
For groundwaters, from 1945 to1996 the average nitrate trend for 13 of the major aquifers was an increase of 0.4 mg/l/yr. 37% of groundwater bodies are currently classed as having poor chemical status because of high or rising nitrate levels. There has been a net decrease in the number of groundwater bodies meeting good chemical status, with 45% at good in 2019 compared to 53% in 2015[116].
No quantitative projections of surface or groundwater nitrate levels could be found, but the evidence found suggests that groundwater nitrate levels in some parts could take decades to

[113] https://assets.publishing.service.gov.uk/media/5b03e097ed915d3968dc5a78/State_of_the_environment_water_quality_report.pdf
[114] https://www.gov.uk/government/publications/regulating-for-people-the-environment-and-growth/regulating-for-people-the-environment-and-growth-2019
[115] https://publications.parliament.uk/pa/cm5802/cmselect/cmenvaud/74/report.html#heading-3
[116] https://www.gov.uk/government/publications/river-basin-management-plans-updated-2022-progress-report/river-basin-management-plans-updated-2022-progress-report

fall following reductions in nitrogen inputs, and in groundwater fed catchments in particular river nitrate levels will also fall relatively slowly.

A6.3.2.2 Measures Contributing Towards Implementation

- Effective Water Safety Planning: Environmental Impact Assessments, WHO Water Safety Plan Manual.
- Sampling and monitoring for Regulation 8 supplies (private distribution systems), monitoring of Group A and B parameters.
- Levelling Up and Regeneration Bill Amendment NC77: Legal requirement for wastewater treatment works designated by the DEFRA Secretary of State to be upgraded by 2030.
- Nutrient Pollution Standards[117]: A nitrogen significant plant meets the nitrogen nutrient pollution standard if the concentration of total nitrogen in treated effluent that it discharges is not more than 10 mg/l.

A6.3.2.3 Progress Towards Target

It is difficult to assess progress towards the target without quantitative projections. However, the study cited above suggested that "*Groundwater is expected to continue to deteriorate for nitrates between now and 2050 unless interventions to prevent the continued deterioration and pressures of climate change and population growth are mitigated.*"

A6.3.3 Other relevant targets

Other targets that may facilitate a reduction in losses for this flow include:

- **25 Year Environment Plan**[118] 'Clean and Plentiful Water' goal for England : By 2030, minimise the harmful bacteria in our designated bathing waters and continue to improve the cleanliness of our waters. Key indicator of progress: monitoring and improving the 'state of the water environment'.
- **Environmental Improvement Plan 2023**[119]: Restore 75% of protected sites in England to a favourable condition by 2042[120]; and require water companies to have eliminated all adverse ecological impact from sewage discharges at all sensitive sites by 2035, and at all other overflows by 2050.
- **Water Framework Directive Regulations 2017**[121]: Achieve 'good ecological status' and 'good chemical status' for all waterbodies by 2027. Applies throughout UK.

A6.3.3.1 Quantitative Projections / Progress against targets

A6.3.3.1.1 State of the water environment – bathing waters

The OEP report on progress in improving the natural environment[122] states that: "*From 2017 to 2022, the percentage of bathing waters meeting at least sufficient status has remained largely unchanged, decreasing by approximately 1% to 97%. Over the same period, there has been an increase in the percentage of bathing waters in excellent condition, from 66% to 72% and an*

[117] https://bills.parliament.uk/bills/3155/stages/17044/amendments/10003516
[118] https://www.gov.uk/government/publications/25-year-environment-plan
[119] https://assets.publishing.service.gov.uk/media/64a6d9c1c531eb000c64fffa/environmental-improvement-plan-2023.pdf
[120] https://www.gov.uk/government/publications/nature-recovery-network/nature-recovery-network#:~:text=restore%2075%25%20of%20terrestrial%20and,condition%20by%2031%20January%202028
[121] https://www.legislation.gov.uk/uksi/2017/407/contents
[122] https://www.theoep.org.uk/sites/default/files/reports-files/E02987560_Progress%20in%20Improving%20Natural%20Environment_Accessible_v02.pdf

increase in the percentage of bathing waters in poor condition from 2% to 3%". This indicates some progress, but also scope for improvement to eliminate bathing waters in poor condition.

A6.3.3.1.2 Eliminate all adverse ecological impact from sewage discharges at all sensitive sites by 2035, and at all other overflows by 2050

As mentioned in section A6.3.1, there have been successive reductions in phosphorus, biochemical oxygen demand, and ammonia loads released from wastewater treatment into surface waters since 1995[110]. However, the total number of pollution incidents (including combined sewer overflow events) increased slightly between 2016 and 2021[OEP progress report]. This suggests that whilst some indicators are on track, others require more action.

A6.3.3.1.3 Achieve "good ecological status" and "good chemical status for all waterbodies by 2027

Information on trends in water body status for England only are available from the Environment Agency[123] [RBMP progress report]**Error! Bookmark not defined.**. In 2019, only 16% of surface waters attained good or high ecological status, a similar level to 2015. However, for ammonia concentrations (a component of the overall status), 92% of surface water bodies attained a good or high score, in both 2015 and 2019. The % of surface waters with good or high chemical status has remained similar at 0% between 2015 and 2019.

Of the 166 surface waters set an objective of reaching good or better status by 2021, only 20 had achieved this by 2019. Barriers cited were additional recovery time needed, additional measures needed, or expected measures not implemented.

No quantitative projections have been found for any of these indicators, so progress against these targets has not been possible to assess fully. One potential gap here is **the lack of more frequent and dense monitoring** in itself to gauge progress and enable corrective action, as the updates to river basin management plans only happen every 6 years [OEP progress report][124]. Progress against these targets will contribute to UK implementation of Target 7 of the Global Biodiversity Framework.

A6.4 Denitrification from soils and wastewater

There are no UK targets for reducing denitrification specifically, nor are there targets specifically for nitrogen use efficiency, which would be the main benefit of reducing denitrification.

Nevertheless, climate change targets may be a relevant proxy, as N_2O and N_2 emissions from manure management and agricultural soils (the main sources of N_2O in the UK) are formed by related processes. Therefore, action to reduce N2O emissions towards climate change targets will likely be effective in reducing N_2 losses.

A6.4.1 Quantitative Projections

No data were found on historical or projected trends in N_2 losses to the atmosphere. To a certain extent N_2 losses will track the overall quantity of nitrogen going through the soil and water system but it is not clear if there may have been trends in the proportion of nitrogen inputs being lost through denitrification over time.

As mentioned above, for soils and wastewater treatment the best proxy for likely historical trends and projections of N_2 losses from treatment may be the trends and projections for N_2O

[123] https://www.gov.uk/government/publications/river-basin-management-plans-updated-2022-progress-report/river-basin-management-plans-updated-2022-progress-report

[124] See footnote 122.

emissions from those sources, because of the linked underlying processes. Indeed, the default method of estimating N_2 losses from manure management in the IPCC Guidelines[125] is simply multiplying direct N_2O emissions by 3.

As described in Section 3.3, only modest reductions in N_2O emissions from agriculture have occurred since 1990 and are projected under existing measures[126] to 2030 and 2040, and increases have been observed and are projected from wastewater treatment. It is likely therefore that N_2 losses would follow similar trends.

A6.4.2 Progress Towards Target

Impossible to assess: no target against which to measure.

A6.5 Food waste

There are no mandatory food waste reduction targets in the UK, although targets are in place in voluntary agreements and devolved strategies.

A6.5.1 Quantitative Projections

The Environment Act 2021 provides for separate food waste collections in all local authorities. No official projected data on food waste generation could be found, but the NMEG report[127] refers to an increase in the quantity of food waste collected separately for anaerobic digestion of 1.71 million tonnes.

A6.5.2 Progress towards targets

Trends in food waste generation and treatment are going in the right direction with significant reductions achieved in recent years and policies are in place to maximise the recycling of nutrients in food waste, but continued progress is needed. From a nitrogen loss perspective, it is more efficient to grow less food (and use less nitrogen fertiliser) in the first place than to waste food then try to recycle the nitrogen, as there is leakage of nitrogen at all steps. One gap is that there is no binding food waste reduction target for England, and this could be effective in promoting continued action.

In addition, the NMEG report highlights that the increase in food waste recycling represents an opportunity that farmers could take to use recycled nitrogen in digestate but also a risk of high NH_3 emissions. The UK government's policies are not being primarily driven by the desire for a more circular nutrient economy, but rather by more direct climate and air quality concerns. The government could consider this as part of a more holistic nitrogen strategy, along with support for nutrient recovery in ways which help to alleviate risks (e.g. allowing for use of recycled N in mineral fertiliser products).

A6.6 Impact-related targets

There are no statutory targets related to biodiversity impacts of nitrogen in the UK, but several non-binding targets and indicators are likely to contribute to UK implementation of GBF Target 7 once the international monitoring framework has been agreed and a UK approach put in place.

[125] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch10_Livestock.pdf
[126] https://www.gov.uk/government/publications/energy-and-emissions-projections-2021-to-2040
[127] See footnote 4.

A6.6.1 Clean air strategy 2019: Deposition target

Reduce damaging deposition of reactive forms of nitrogen by 17% over England's protected, priority, sensitive habitats by 2030 from 2016 levels.

The clean air strategy (CAS) set this goal to reflect the hoped-for impact of ammonia reduction measures, potentially helping to protect an additional 200,000 ha of habitat. It does not include all nitrogen deposition, only that occurring in protected areas.

Between 2016 and 2020/21, an annual modelling exercise found that there was a 13.4% decrease in nitrogen deposition onto protected, sensitive priority habitats across the UK as a whole (Scotland -18.3%, Wales -12.1%, England - 9.4%, NI +0.4%). However, most of the decrease was from 2019/20 to 2020/21, so may be due to the (temporary) observed reduction in road traffic during 2020 and 2021 related to Covid-19 restrictions[128]. Whether the reduction trend has continued will be seen in the 2024 update to the exercise.

A6.6.1.1 Quantitative Projections

The Nitrogen Futures scenario modelling project[72] explored the impact of different actions on meeting the 17% reduction target. The BAU scenario (firm & funded measures only) from predicted only a 10.9% decrease in deposition for UK as a whole from 2016-2030. However, all scenarios considered which meet the 2030 NECR emission reduction commitments achieved at least an 18% reduction, so would meet the 17% target. Spatially targeted scenarios prioritising SSSIs were able to achieve over 21% reductions in deposition.

A6.6.1.2 Progress towards target

Based on the Nitrogen Futures work, it seems that some additional measures to those currently in place will be required to achieve the 17% target. The work is, however, now several years old so the conclusions may no longer be robust. An updated analysis is currently underway, due to be published in 2025.

The target is not currently ambitious enough to ensure that all – or even the majority – of protected sites meet critical loads and levels. However, the CAS also proposed to review what longer-term targets should be. A more ambitious over-arching target for nitrogen deposition may be more widely understandable than the critical load and critical level exceedance targets.

A6.6.2 Nitrogen critical load and NH3 critical level exceedances

Nitrogen critical loads refer to maximum rates of nutrient-nitrogen deposition that can be sustained without adverse impacts on an ecosystem. The rate varies across different habitats, soil types and parts of the UK. NH_3 critical levels refers to the maximum atmospheric concentration of NH_3 before harm is caused to higher (vascular) plants, such as ferns and conifers (3 µg / m^3), and lichens and mosses (1 µg / m^3).

There is no specific target for this metric, but the implication of GBF Target 7 is likely to be that, ideally, there would be no critical load and critical level exceedances by 2030.

The UK area of nitrogen-sensitive habitats with exceedance of nutrient nitrogen critical loads fell from 94% in 2003, to 86% in 2020. This decline was largely driven by changes in Scotland – in England, Wales and Northern Ireland there was little change in area exceeded over this period[128].

NH_3 Critical levels: In 2020, 2.6% of the UK land area was exposed to ammonia concentrations above the critical level set to protect higher plants (3 µg m-3), and 64% (91% of England, 60% of Wales, 16% of Scotland and 97% of NI) exposed to ammonia at concentrations above the

[128] https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2401111009_Air_Pollution_Trends_Report_2023.pdf

critical level set to protect lichens and mosses (1 µg m-3). The area where the critical level for higher plants is exceeded has increased by 0.9% of UK land area since 2003. The area where the critical level for lichens and mosses is exceeded has increased by 7.6% of UK land area since 2003 [128].

Excess Nitrogen (Average Accumulated Exceedance for nutrient nitrogen) for all UK habitats combined decreased from 10.6 kg N ha_{-1} $year_{-1}$ in 2003 to 7.6 kg N ha_{-1} $year_{-1}$ in 2020.

A6.6.2.1 Quantitative Projections

The Nitrogen Futures scenario modelling project[72] studies the impact on critical load and critical level exceedances across protected sites.

Nutrient-nitrogen Critical loads: In the 2017 baseline, 86% of SSSIs exceeded the nitrogen critical load. In 2030, under the BAU scenario this falls slightly to 84%, and falls to 80% under the more ambitious scenario meeting the NECR commitments.

NH_3 Critical levels: In the 2017 baseline, 73.5% of SSSIs exceeded the critical level set to protect lichens and mosses (1 µg m-3). In 2030, under the BAU scenario this increases to 76%, but under the more ambitious scenario, this was reduced to 71.3%. For the 3 µg / m^3 level, 7.4% of sites in 2017 were in exceedance, rising to 8% in 2030 under the BAU scenario, but falling to 4.7% under the more ambitious scenario.

A6.6.2.2 Progress towards target

Some progress in reducing critical load and critical level exceedances is likely if measures are put in place to achieve the NOx and NH_3 NECR commitments. However, except for the critical level set to protect higher plants (3 µg m-3), the fraction of SSSIs exceeding critical loads or critical levels for lichens and mosses is still a long way from zero.

A6.6.3 NO_2 ambient air quality target for human health and to protect ecosystems

Human health: all zones annual average < 40 µg / m3; all zones 1 hr average of 200 µg / m3 exceeded no more than 18 times.

Ecosystems: all non-agglomeration zones annual average < 30 µg / m3

This target originates from the Ambient Air Quality and Cleaner Air for Europe Directive 2008/50/EC[129] which has been transposed into UK legislation in England through the Air Quality Standards Regulations 2010.[130] Equivalent regulations exist in Scotland, Wales and Northern Ireland. These were amended by the Air Quality Regulations 2019, which also amended the National Emission Ceilings Regulations 2018[131].

Urban background nitrogen oxide concentrations in the UK have been reducing, both in the long-term and in recent years. In 2022, the lowest annual mean concentration at an urban background site was recorded, reaching 14.2 µg/m^3 according to the latest air quality statistics published for the UK for 1987 to 2023[132]. In 2022, 34 out of 43 zones achieved the 40 µg / m3 annual limit. All those exceeding were urban zones. All zones met the 1 hourly limit, and all non-agglomeration zones met the 30 µg / m3 average limit.

[129] https://www.europarl.europa.eu/RegData/etudes/STUD/2016/578986/IPOL_STU(2016)578986_EN.pdf

[130] https://assets.publishing.service.gov.uk/media/62330db88fa8f504a584cfc9/Appendix_1e_-_Air_quality.pdf

[131] https://www.scottishairquality.scot/air-quality/legislation

[132] https://www.gov.uk/government/statistics/air-quality-statistics/ntrogen-dioxide#:~:text=Urban%20background%20NO2%20pollution%20has,9%20per%20cent%20since%202022.

A6.6.3.1 Progress Towards Target

Progress towards the statutory NO_2 targets has been good and given projected further decreases in NO_2 emissions from road transport due to fleet turnover and increased number of LEZs and ZEZs, it is likely all zones will be compliant within the next few years. Therefore, these limits will no longer be a driver of decreasing emissions.

However, the latest WHO guidelines recommend much lower target levels for NO_2 of 10 μg/m^3 annual average, and 25 μg/m3 24-hour mean[133]. If the UK were to adopt these lower limits, it could provide a regulatory foundation for prompting further action to reduce NO_x from combustion sources if current decarbonisation and other policies do not deliver the required reductions.

A6.6.4 $PM_{2.5}$ ambient air quality and human exposure targets

Highest annual mean concentration in the most recent full calendar year must not exceed 12 μg/m3 of PM2.5 (by end of Jan 2028)

Reduction in population exposure to PM2.5 in the most recent full calendar year must be 22% or greater compared to 2018 (by end of Jan 2028)

The annual mean concentration target is that by the end of 31st December 2040 the annual mean level of $PM_{2.5}$ in ambient air must be equal to or less than 10 μg/m^3.

The population exposure reduction target is that there is at least a 35% reduction in population exposure by the end of 31st December 2040 ("the target date"), as compared with the average population exposure in the three-year period from 1st January 2016 to 31st December 2018.

These targets originate from the Environmental Targets (Fine Particulate Matter) (England) Regulations 2023 (regulations made under the Env Act 2021).

$PM_{2.5}$ (particulate matter < 2.5 μm in size) in the atmosphere is made up of a wide variety of different substances. Primary PM is emitted as solid or liquid particles (including both filterable and condensable fractions). Secondary PM comprises particles which are formed from chemical reactions in the atmosphere. It is secondary PM formation to which nitrogen emissions to air are chiefly linked; NOx and NH_3 react with other gases (and each other) to form ammonium and nitrate compounds. The $PM_{2.5}$ emissions estimated in the UK National Atmospheric Emissions Inventory and the associated emission reduction commitment (ERC) under the National Emissions Ceiling Regulations refer to primary PM only, and are not related to nitrogen losses. For this reason, the $PM_{2.5}$ ERC is not included in the list of relevant $PM_{2.5}$ targets.

Whilst the ambient air quality and human exposure $PM_{2.5}$ targets above are affected by many other factors apart from NH_3 and NO_x emissions (with their contribution varying locally), measures to reduce NH_3 and NO_x emissions will have a beneficial impact on $PM_{2.5}$ concentrations.

A6.6.4.1 Quantitative projections

The 2023-2024 EIP progress report[134] provides a summary of progress against the $PM_{2.5}$ targets listed above.

- Regarding the interim (2028) targets, population exposure to PM2.5 in 2023 (the latest data available in the EIP report) is 22% lower than 2018, so is already equalling the

[133] https://www.c40knowledgehub.org/s/article/WHO-Air-Quality-Guidelines?language=en_US#:~:text=PM10%20(particulate%20matter%20with,m3%2024%2Dhour%20mean

[134] https://assets.publishing.service.gov.uk/media/66a8cf3ece1fd0da7b592f6c/Environmental_Improvement_Plan_annual_progress_report_2023_to_2024.pdf

interim target. The max concentration in 2023 was 12µg/m^3 so again, the interim target has also been met in 2023.

- Regarding the 2040 targets, 2023 data shows that the majority of monitoring sites already had annual average concentrations below 10 µg/m^3. No projections of modelled $PM_{2.5}$ concentrations and population exposure in future years were found, so it is not possible to directly compare projected 2040 values against the targets.

A6.6.4.2 Progress Towards Targets

The UK appears to be well on track to meet interim 2028 targets. The language in the EIP progress report around compliance is cautious, as the monitoring network is being improved and expanded up to 2027, so only at that point can compliance be definitively established. In addition, it is unclear how much of the reduction so far from 2018 is transitory following the Covid pandemic. Nevertheless, even with these caveats, it seems likely that the targets will be met.
Progress towards the more ambitious 2040 targets is more difficult to assess, given the lack of projected concentration or exposure data found. With current measures, by 2040, primary PM emissions are projected to decrease a further 15% from 2022 levels, and NOx emissions (a contributor to secondary PM formation) by a further 43%[106,107]. These reductions – all else being equal - will help to bring down $PM_{2.5}$ concentrations and exposure, but trends in other important factors such as transboundary import of $PM_{2.5}$ and in natural sources will have a large impact on the outcome. Therefore, whilst there are no clear shortfalls in current policies to achieve $PM_{2.5}$ targets, the uncertainty makes it difficult to draw a confident conclusion.

A6.7 Greenhouse Gas Targets

Reduce UK net greenhouse gas (GHG) emissions by 100% by 2050.
There are no specific targets for N_2O, but as it currently makes up c. 4.5% of UK GHG emissions (in CO_2 equivalent, GWP100), reducing it is crucial to reaching net zero. There are also major co-benefits of climate action to reduce combustion CO_2 emissions through electrification, as this also reduces NO_x emissions.

The same is true for nitrogen losses from soil when soil organic matter is lost – action to reduce carbon losses from soils (i.e. peatlands) will also reduce nitrogen losses. This is often related to the agriculture sector, but also other areas affected by drainage or other disturbance. Specific action to reduce N_2O from soils and manure management will also benefit N_2 losses through denitrification, as they are formed through some of the same processes.

In 2021, total N_2O emissions were c. 20 Mt CO_2e: 4.6% of total UK GHG emissions (excluding international aviation and shipping). Of this, around 66% came from agriculture in 2021 (53% from agricultural soils, mainly fertiliser and manure application, and 13% from manure storage). No more detailed breakdown is available. 4.4% came from wastewater treatment and discharge.[135]

A6.7.1 Quantitative Projections

[135] https://www.gov.uk/government/publications/energy-and-emissions-projections-2021-to-2040

In the UK Government's Energy and Emissions Projections (EEP) *With Existing Measures* Scenario[136], N_2O emissions overall are only projected to fall from 2021 levels by 4.4% to 2030, and 6.7% to 2040. This compares with a 17% and 20% fall in total GHG emissions to 2030 and 2040 respectively.

By 2040, N_2O emissions will represent 5.5% of remaining GHG emissions, with 68% and 69% of the N2O emissions coming from agriculture in 2030 and 2040 respectively

Agricultural N_2O emissions are only projected to fall by around 1% between 2021 and 2030, and 2% between 2021 and 2040. Larger falls are expected for LULUCF sector and the energy sector, but these are minor sources in comparison with agriculture. N_2O emissions from wastewater treatment and discharge are actually projected to increase from 2021 levels, by 2% and 4% by 2030 and 2040 respectively.

These small overall falls in N_2O are not in line with the goal of halving N loss, and it is clear action on N_2O will be slower than for other GHGs.

The key measures affecting N_2O specifically, quantified based on government forecasts for the Fifth Carbon Budget (2028-2032) (CB5) are:

- Avoiding use of Nitrogen in excess through the development of an agronomist led nutrient management plan. Saving: 0.02 kt N / yr.
- Biological fixation of nitrogen on grassland using grass-legume mixtures. Saving :0.24 kt N/yr.
- Use of nitrification Inhibitors (chemical additives to fertilisers) to reduce nitrous oxide emissions. Saving: 0.06 kt N/yr.
- Precision Farming (arable/grassland) using machine guidance and other technologies to control and adjust fertiliser application. Saving 0.05 kt N/yr.

A6.7.2 Progress Towards Targets

N_2O emissions have reduced by 57% since 1990, largely due to a near-elimination of emissions from industrial processes (down 97%). In 1990, industrial processes and product use made up 49% of N_2O emissions, but in 2021 only 4%.

Agricultural N_2O emissions fell by 18% between 1990 and 2021 (similar decrease for both manure storage, and agricultural soils).

More recent trends are much flatter; between 2010 and 2021 total N_2O emissions only fell by 8%. So, recent trends are not showing the rate of decline in line with the overall reduction in GHGs needed to meet net zero.

Whilst savings within the timescale of CB5 are small, larger savings are forecast in the Sixth Carbon Budget (2033-2037), which suggests that a greater focus on implementation is required.

136 https://assets.publishing.service.gov.uk/media/640af26f8fa8f5560f2ebd8d/Annex_C_CO2_by_IPCC_category_Mar2023revision.ods

Annex 7: Potential solutions Matrix

Key to sources:

- NMEG: Nutrient Management Expert Group report
- EU / France / Netherlands / Denmark / Germany / Scotland / Wales: Policies and measures from other EU countries, sourced from the Governance Regulation and NECD PaMs databases, as well as Informative Inventory Reports; or derived from UK nations but not currently implemented at a UK level.
- NAPCP: Additional policies and measures for consideration analysed in the 2023 UK National Air Pollution Control Plan (not yet implemented)
- CCC: CCC progress report to Parliament 2023
- CAO3: 3rd Clean Air Outlook report
- NOPS: Nitrogen Opportunities: UNECE Guidance on Integrated Sustainable Nitrogen Management
- AFC: Appetite for change report, 2nd European Nitrogen Assessment
- New: IEEP/Aether suggestion or from multiple sources

Table 17: Long list of potential solutions derived from recent literature

Measure	Source
Measures with general applicability	
Enhanced advice	NMEG
Regular updating of key guidance documents and standards, in particular the Nutrient Management Guide (RB209)	NMEG
Expand the scope of the Carbon Border Adjustment Mechanism to encompass non-CO_2 GHGs	New
Agriculture - nutrient and soil management	
Comprehensive national nutrient management strategy (Including a spatial planning element)	NMEG
Promotion of farm level nutrient management planning and proper implementation	NMEG
Develop national nutrient action plans for all 4 nations to deliver the new strategies referred to above.	New (based on NMEG)
Review boundaries of nitrate vulnerable zones in all 4 UK nations in light of new nutrient management strategies, likely triggering stricter nitrogen application limits	EU
Mandatory targets for specific services from the soil	NMEG
Nitrogen fertiliser charge that comes into force if targets are not respected for two consecutive years	EU (FR)
Binding targets for GHG reductions in the agriculture sector	EU (DK)
Awareness raising on the need to address the excess of N, improve financial value of organic materials and nutrients.	NMEG
New regulatory regime to align the use of fertilisers more tightly to emission reduction goals, including where necessary banning certain products , requiring additives or authorising certain products only for particular applications	New
Encourage proper nutrient management in line with crop requirements, such as minimising soil compaction and waterlogging	New

Using nitrification inhibitors with ammonium/urea-based fertilisers, as well as using coatings for slowing release.	NOPS
Develop programme to accelerate availability, performance and uptake of recycling derived fertilisers.	NMEG
Mandate the use of shallow injection and band spreading equipment for slurry and other high nitrogen liquid organic materials on all farms	NMEG
Using urease inhibitors with urea fertiliser (protected urea products)	NAPCP
Agriculture livestock housing and manure/slurry management	
Subsidies for NH_3 reducing measures for new and retrofit animal housing	EU (NL)
Keeping ruminant animals at pasture longer as part of revised approach	NAPCP
Tree shelter belts around pig, poultry and dairy housing	NAPCP
Tighten standards for the storage and application of organic slurry / manure	NAPCP, EU (NL/DK)
Mandatory covering of slurry stores	EU (NL/DK)
Mandatory immediate incorporation of manure and slurry	EU (NL)
Subsidy scheme for high-quality manure processing	EU (NL)
Communal manure banks for use by arable farms	EU (NL)
Inclusion of large indoor cattle units within EPR and reduce size thresholds for pig and poultry farms	NAPCP
Controls / limits on concentrations of livestock production in specific localities	New
Voluntary buy-out schemes for livestock farms near to sensitive areas and more widely for NH_3 intensive farms	EU (NL)
Mandatory limit on crude protein intake of dairy cattle	EU (NL)
Agriculture - general	
Enhanced enforcement of pollution and related legislation applicable to farmland. All UK nations	AFC
Expand the scope of the Emissions Trading System to include additional key sectors (i.e. agriculture)	EU/IEEP work
Improved livestock genetics	NAPCP
Livestock carbon tax	EU (DK)
Environmental targeting of the Sustainable Farming Initiative	New
Policy mechanisms to improve spatial distribution of nitrogen availability e.g. through livestock farming, and potential for spatial re-distribution of excess nitrogen;	New
Reduction of perverse agricultural subsidies e.g. address coupled support for livestock	New
Taxation on red diesel	EU (Ger)
Promotion of certified organic production (and consumption)	EU
Establishment of Plant Based Fund (for production and consumption)	EU (DK)
Wider Food System	
Substantially reduce food & animal feed imports (and increase domestic production)	New
Reduction in UK per capita protein intake to recommended levels	AFC
Reduction in meat and dairy consumption [Strong incentives / regulation]	AFC
Updating dietary guidelines to include sustainability	CCC
Mandatory sustainability labelling	CCC

Restrictions on advertising and promotion of meat and dairy products	New
Restrictions on / reductions in meat and dairy served in public sector food / under public sector funded contracts	CCC
Daily vegetarian option mandatory in collective catering	EU (FR)
Compulsory weekly vegetarian menu in school catering	EU (FR)
Mandatory sustainability targets for public sector food	New
Wastewater treatment and water quality	
Remediation of wastewater treatment facilities that exceed their hydraulic capacity and cause pollution of raw effluent	New
Inclusion of nitrates within the minimum criteria for bathing water quality	New
Incentives for nitrogen recovery at wastewater treatment plants	New (based on NMEG)
Transport	
Confirm the zero emission vehicles mandate in legislation	CCC
Mandatory national target for reducing car use	Scotland
Greater support for modal shift	Scotland / Wales
Greater controls on shipping emissions, including of NH_3 emissions from fuel systems	CCC / New
Roll out of shore power infrastructure at major UK ports	CCC
No airport expansion without a UK-wide capacity management framework	CCC
Frequent flyers tax	Tom
More ambitious air quality standards (i.e. consistent with WHO limits)	CAO3
Industry	
Extend ETS to cover smaller installations / facilities	NAPCP
Review of BAT regime to raise standards over time for BAT sectors across the UK (industry)	NAPCP
Cap on operating hours for generators under 50 MWth unless they comply with tightened emissions limits	NAPCP
Application of BAT style NOx emissions standards to crematoria in England and Wales	NAPCP
Promote uptake of cleaner non-road mobile machinery (stage V)	NAPCP
Support the decarbonisation of off-road mobile machinery	CCC
Policies to drive industrial electrification, including clear incentives for manufacturing facilities not currently covered by the ETS	CCC
Buildings	
Bring forward dates for phasing out fossil fuel boilers in new buildings and replacements of existing boilers	CCC
Government to affirm electrification as the default option for new buildings and replacement in existing buildings.*	CCC
Waste	
UK-wide mandatory food waste reduction target backed with suitable enforcement and facilitative measures	New
Mandatory requirements for retailers to donate edible food	EU (FR)
Promotion of circular food economy	New

Fiscal measures on food waste, i.e. unit-based pricing methods targeting consumers; addressing retailers through waste taxes or rental emission permits.	CCC
Implement initial extended producer responsibility, deposit return scheme and consistent collections of food and recycling waste in a coordinated way	CCC