Department for Energy Security & Net Zero

Annex N: Projected emissions of non-CO_2 greenhouse gases

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Executive Summary

This report presents the methodology the Department for Energy Security & Net Zero (DESNZ) used in producing the non-CO_2 greenhouse gas emission projections. The non-CO_2 gases are methane (CH_4), nitrous oxide (N_2O) and the fluorinated gases (HFCs, PFCs, SF_6 and NF_3). The projections are a best estimate of future emissions up to 2050, accounting for expected technological developments, key drivers such as population and known policy commitments. It is important to note that policies affecting these projected emissions are still being developed and will be incorporated in future updates.

1. Introduction

1.1 Overview

In 2019, the Government set a new legally binding target for net zero greenhouse gas (GHG) emissions by 2050, via an amendment to the Climate Change Act[1]. Emissions projections are used as a way of monitoring progress towards this target and to identify emission sources which would need additional measures. The UK is also required to submit projected emissions of greenhouse gases periodically in the form of National Communications and Biennial Reports to the UN Framework Convention on Climate Change (UNFCCC).

Process changes and improvements to note in this year's publication are:

- The historical GHG emissions which form the baseline for these projections undergo annual updates to comply with the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines[2]. We incorporate any annual changes into our projections to remain consistent with the latest historic estimates.
- We have produced these estimates using a baseline of the latest historical GHG emissions estimates covering the years 1990-2022[3].

1.2 Scope

Non-CO_2 emission sources this document covers

This document covers projections of the **non-CO_2** component of the Kyoto Protocol's basket of greenhouse gases. We refer to these as the 'non-CO_2 GHGs'. The gases are:

- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs) *
- Perfluorocarbons (PFCs) *
- Sulphur hexafluoride (SF_6) *
- Nitrogen trifluoride (NF_3) *

* HFCs, PFCs, SF_6 and NF_3 are also collectively known as fluorinated gases, or "F-gases".

[1] Climate Change Act 2008 (2050 Target Amendment) Order 2019: https://www.legislation.gov.uk/uksi/2019/1056/contents/made
[2] 2006 IPCC Guidelines for National Greenhouse Gas Inventories: http://www.ipcc-nggip.iges.or.jp/public/2006gl/
[3] Published in February 2024. See final UK greenhouse gas emissions statistics 1990-2022: https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2022

Geographical scope, time horizon and units

- The geographical scope of these projections is the UK only, covering emissions that occur within the UK's borders ("territorial" emissions)
- We project emissions up to 2050
- We present emissions in CO_2 equivalents (CO_2e), according to 100-year Global Warming Potentials (without climate-carbon feedback) set out in the IPCC Fifth Assessment Report.

For the purposes of reporting, we allocate greenhouse gas emissions to Territorial Emissions Statistics (TES) sectors[4]. These are a small number of broad, high-level sectors and are as follows:

- Electricity supply
- Fuel supply
- Domestic transport
- Buildings and product uses
- Industry
- Agriculture
- Waste
- Land use, land use change and forestry (LULUCF).

These high-level sectors are comprised of more detailed source categories that follow IPCC definitions for GHG emissions reporting. We submit international reporting tables against these to the UNFCCC every year. The sectors assign emissions to their source activity as opposed to where the end user activity occurred[5]. A complete mapping of IPCC sectors to TES sectors is available on the DESNZ website[6]. We use these sectoral assignments in this report.

1.3 Current UK GHG emissions and targets

As part of the UK's commitments for reporting its GHG emissions, we produce a national inventory each year. This contains estimates for the UK's historic GHG emissions from all anthropogenic sources. This is referred to as the GHG Inventory (GHGI) and is submitted annually to the UNFCCC. The latest GHGI report is available on the National Atmospheric Emissions Inventory website[7]. The most recent full year of data is for 2022.

[4] The TES sectors were introduced this year to replace the National Communication (NC) sectors used previously, see: https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2022 for more details about this change.
[5] This differs from the Digest of UK Energy Statistics which uses an economy sector-based taxonomy, see: https://www.gov.uk/government/publications/energy-balance-methodology-note
[6] See Excel table 6.1 in Final UK greenhouse gas emissions statistics 1990-2022: https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2022
[7] UK National Inventory 1990-2022: https://naei.energysecurity.gov.uk/reports/uk-greenhouse-gas-inventory-1990-2022-annual-report-submission-under-framework-convention

The GHGI forms the baseline for the projections. However, the geographical scope of the projections is slightly different to the UNFCCC GHGI submission. The UNFCCC submission covers the UK plus its Crown Dependencies and certain Overseas Territories. In contrast, this report only covers the UK. All references to the GHGI in this report refer to UK-only emissions.

- **Methane (CH_4)** – CH_4 represents the majority of non-CO_2 GHG emissions, at 69% in 2022. Agriculture was the largest sector, accounting for 49% of all CH_4 emissions that year, followed by waste which accounted for around 30%. The remaining CH_4 emissions were largely from fugitive energy emissions and the LULUCF sector.

- **Nitrous oxide (N_2O)** – N_2O represented 22% of non-CO_2 GHG emissions in 2022. Agriculture was responsible for the majority of N_2O emissions (70%). Other notable sectors include waste and LULUCF, accounting for 9% and 7% respectively.

- **F-Gases (HFCs, PFCs, SF_6 and NF_3)** – HFCs represented 9% of non-CO_2 GHG emissions in 2022, while PFCs, SF_6 and NF_3 represented about 1% between them. Refrigeration and air conditioning account for the majority of HFC emissions, accounting for 79% of HFC emissions in 2022. Other significant HFC emissions sources include aerosols and metered dose inhalers (e.g. asthma inhalers). The major sources of PFC emissions are halocarbon production and the electronics industry. SF_6 emissions largely come from electrical insulation and NF_3 emissions from the electronics industry.

The latest statistics release provides the most recent data and further details of the emissions of each of these gases by specific activities over the period 1990-2022[8].

The UK has both international and domestic targets for reducing greenhouse gas emissions. These targets encompass all GHG emissions, not just the non-CO_2 component discussed in this annex. DESNZ's Energy and Emissions Projections[9] provide more information about how we forecast the UK's overall GHG emissions and compares them with our targets.

[8] Final UK greenhouse gas emissions statistics 1990-2022: https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2022
[9] DESNZ Energy and emissions projections: https://www.gov.uk/government/collections/energy-and-emissions-projections

2. Projections methodology

2.1 Overview of methodology

Baseline

We used emissions statistics from the 1990-2022 GHG Inventory (GHGI) as the baseline for these emissions projections. The GHGI calculates emissions by combining activity data (e.g. fuel use, livestock numbers) and emission factors (e.g. emissions per kg of pollutant, per tonne of fuel used, per head of livestock). A new GHGI is produced each year detailing emissions from each source from 1990 up to two calendar years previously (e.g. the GHGI published in 2024 covers 1990-2022). This means that the base year for these projections was 2022.

We revise historical emissions estimates each year to account for methodological improvements and for new information that becomes available. We review the data and compilation methods for the GHGI annually. The most notable changes to the GHGI affecting non-CO_2 gases in the year since the last set of projections are:

- Revisions to the assumptions used for modelling HFC emissions from refrigeration, air-conditioning, and heat pumps (RACHP). The leakage deterioration factor that is applied to RACHP equipment as it ages has been changed following the incorporation of improved data. There have also been modifications to stock assumptions to reflect the rapid growth expected by DESNZ in the heat pump market.
- Revisions to the assumptions used for modelling recreational N_2O use in response to new research indicating that the previous assumptions were inaccurate.
- The models used to estimate semiconductor F-gas use now use real data from industry. Previously, estimates were based on qualitative data.

Overall impact on emissions

In total, the changes we made to the methods and data for the 1990-2022 inventory led to a decrease in total greenhouse gas emissions (including CO_2) for 2021 of 5.5 $MtCO_2e$ compared with the 1990-2021 inventory we used in the last set of projections[10], including a decrease in total non-CO_2 emissions of 2.9 $MtCO_2e$ for the same year (this is the latest year for which we can make a comparison). We describe the most important impacts of these changes in the relevant chapters of this report.

[10] DESNZ Energy and emission projections 2022-2040: https://www.gov.uk/government/publications/energy-and-emissions-projections-2022-to-2040

Projections

We project the emissions from each source in the GHGI from the latest year of historic data year up to 2050. Given the disparate nature of the emission sources, we use many different methods to project the emissions. We discuss the drivers of emissions and the methods we use in the relevant sector chapters. These drivers range from simple assumptions to complex analytical models depending on data availability and emissions magnitude.

As noted above, the baseline GHGI is defined by activity data and emission factors. The emission projections can similarly be thought of as the combination of:

- Projections of the change in activity data, e.g. changes to livestock numbers or changes in the amount of waste going to landfill.
- Projections of the change in emission factors, e.g. improvements to technology for the abatement of emissions.

Annual updates to the non-CO_2 projections involve one of the two following methods:

- If there are apparent major changes to the emissions drivers, then we perform a formal review of the methods we use to project emissions from that source.
- We rerun the existing projections model if there are no apparent major changes to the drivers, but the historical emissions have changed due to a GHGI methodology update.

We discuss changes in projections for each source in the relevant sector chapter.

Policies

The non-CO_2 projections include the effects of Government policies which mitigate GHG emissions. The standard UNFCCC definitions we use to categorise policies are:

- **Expired policies** and measures are closed policies that still provide legacy carbon savings;
- **Implemented policies** and measures are those for which one or more of the following applies:
    - national legislation is in force;
    - one or more voluntary agreements have been established;
    - financial resources have been allocated;
    - human resources have been mobilised.
- **Adopted policies** and measures are those for which an official Government decision has been made and there is a clear commitment to proceed with implementation;
- **Planned policies** and measures are options under discussion with a realistic chance of being adopted and implemented in future.

An 'existing policies' scenario includes all currently expired, implemented and adopted policies. A 'reference' scenario includes all the above policies, plus planned policies.

The policies that we have explicitly included in the projections are:

- F-gas regulations (2006[11], 2014[12] and Mobile Air-Conditioning Directive[13])
- Solid waste policies (including those that support commitments to the Waste Framework Directive and Landfill Directive. These, such as the Landfill Tax, all contribute to the waste activity projections Defra provide)[14]
- Transport policies (including the Local Sustainable Transport Fund, the Renewable Transport Fuel Obligation (RTFO), road investment strategies, fuel efficiency policies for road vehicles, rail electrification and active travel spending from the DfT activity projections)
- LULUCF afforestation policies for England[15], Wales[16], Scotland[17] and Northern Ireland[18]
- English GHG Agriculture Action Plan[19]
- The Scottish Government's Climate Change Plan[20]
- Climate Change Strategy for Wales[21].

2.2 Quality Assurance / Quality Control procedures

The business-as-usual Quality Assurance / Quality Control (QA/QC) process involves the following:

[11] REGULATION (EC) No 842/2006 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2006
http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32006R0842
[12] REGULATION (EU) No 517/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 April 2014
http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2014.150.01.0195.01.ENG
[13] Directive No 2006/40/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2006
http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32006L0040
[14] Defra waste policy:
https://www.gov.uk/waste-legislation-and-regulations
[15] Defra (2020): England Trees Action Plan
https://www.gov.uk/government/publications/england-trees-action-plan-2021-to-2024
[16] Welsh Government (2016): Climate Change Strategy for Wales
https://gov.wales/climate-change
[17] Scottish Government (2015): United Kingdom Regional Development Programme (Regional) - Scotland
https://webarchive.nrscotland.gov.uk/3000/https://www.gov.scot/Resource/0047/00477381.pdf
[18] DARDNI (2020): Forest Expansion Scheme and Small Woodland Grant Scheme
https://www.daera-ni.gov.uk/articles/daera-forestry-grants
[19] NFU (2011): Agriculture Industry GHG Action Plan
http://www.nfuonline.com/assets/2889
[20] Scottish Government (2018) The Climate Change Plan: The Third Report on Proposals and Policies 2018-2032
https://www.gov.scot/Topics/Environment/climatechange
[21] Welsh Assembly Government (2010) Climate Change Strategy for Wales
https://www.gov.wales/sites/default/files/publications/2019-04/climate-change-strategy-summary.pdf

- We quality assure all the data sources we use in the projections. Many of the data sources are publicly available (see references). Where possible we subject data to peer review.
- Sector experts provide QC on the assumptions used.
- The production team provides significant verification and error checks. These include but are not limited to the following: consistency checks when transferring data; independent checks of every calculation; verification of workbook structure through mapping; comparison of absolute/percentage changes from the previous publication, checking unusual values and checking final projections against source projections.

The main benefit of the QA/QC is that the processes aim to find any errors at any point in the methodology, rather than focusing on changes made in the last year.

3. Buildings and product uses, Domestic transport & Industry (F-gases)

Background

All F-gas emissions are in the buildings and product uses, domestic transport, and industry sectors. The F-gases are HFCs, PFCs, SF_6 and NF_3.

Compared with 1990, emissions of HFCs were 41% lower in 2022. There has been a 35% fall in emissions since 2015 following the introduction of the 2014 EU F-gas regulation. Prior to that, HFC emissions had been rising due to their use as replacement gases in the phasing out of Chlorofluorocarbons (CFCs) mandated by the Montreal Protocol. HFCs were especially used in refrigeration and air conditioning systems and these are now the dominant source of F-gas emissions. In 1990, F-gas emissions largely arose as by-products from halocarbon manufacture. There was a large fall in these emissions in the late 1990s when plants producing halocarbons applied abatement equipment.

How we project emissions

- **Primary aluminium production** — We now know the effects of all the recent abatement measures and we expect no further abatement, so we project constant emissions from aluminium production.
- **Magnesium cover gas** — We project magnesium emissions based on (i) sector expert knowledge on short-term replacement of F-gases and (ii) long-term replacement of F-gases due to the 2014 EU F-gas regulation.
- **Metered dose inhalers** — Emissions are exempt from the 2014 EU F-gas regulation and we project emissions using population growth[22] as the driver.
- **Aerosols** — We project sector growth will be zero in line with the trend in recent years. We model the gas bans and phase down resulting from the 2014 EU F-gas regulation.
- **Refrigeration & air conditioning** — We use the same model as for the historical emissions calculation. Then we apply the assumptions from the 2014 F-Gas regulation, the most important of which is the HFC phase down which caps the amount of HFCs placed on the market each year.

[22] ONS (2024), 2021-based National Population Projections: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/2014basednationalpopulationprojectionstableofcontents

- **Foams** — We extend the mapping of activity and emissions to 2050 from the historical inventory model. Then we model the gas bans and phase down resulting from the 2014 EU F-gas regulation.
- **Firefighting** — We extrapolate the latest GHGI model out to 2050 using emissions factors based on UNFCCC sectoral guidance and Article 5 of the 2014 F-gas regulations. From 2018, we assume that new fire protection systems no longer use HFCs based on our understanding from the industry.
- **Solvents** — We project sector growth will be zero, in line with the trend in recent years. We model the phase down resulting from the 2014 EU F-gas regulation.
- **High voltage switchgear (SF_6)** — We project sector growth based on expert advice which is in line with Schwarz et al (2011[23]). This assumes continuing decreasing leakage due to the 2006 EU F-gas regulation.
- **Production of halocarbons** — We project PFC emissions will be constant as they exhibit no discernible trend.
- **Electronic manufacture (HFCs / PFCs / SF_6 / NF_3)** — We project constant emissions due to limitations of the historical data.
- **AWACS (SF_6)** — We project constant emissions in line with historical data.
- **Training shoes (PFCs / SF_6)** — Emissions from this source have ceased and we do not expect they will resume. We therefore assume no emissions from this source in future years.
- **Particle accelerators (SF_6)** — Emissions are very small and we project they will be constant.
- **Tracer gas (SF_6)** — Emissions are very small and we project they will be constant.

[23] Schwarz et al (2011), Preparatory study for a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases: https://www.consultations-publiques.developpement-durable.gouv.fr/IMG/pdf/etude_preparatoire_pour_la_revue_du_reg_fgaz.pdf

4. Buildings & product uses and Industry (CH_4 / N_2O)

Background

N_2O emissions from nitric acid and adipic acid production have historically been a significant contributor to emissions. However, following plant closures (no adipic acid production facilities remain) and the adoption of improved abatement technology, these emissions have decreased significantly compared with 1990 levels.

In recent years, CH_4 emissions from domestic combustion and N_2O emissions from anaesthetic use have been the dominant CH_4 / N_2O emission sources in the buildings and product uses and industry sectors.

There are several other small emission sources in these sectors:

- **Fletton brick manufacture** CH_4 emissions are very small and correlate relatively well with the number of manufacturing plants operating. Emissions have generally been falling since 1990, with a notable drop when the last plant to burn coal closed in 2008.
- **House & garden machinery** CH_4 / N_2O emissions have decreased due to a reduction in the CH_4 emission factor as older machines are replaced with newer ones. This trend outweighs the increase in machinery usage.

How we project emissions

- **Industrial machinery (CH_4 / N_2O)** – We project activity data using EEP industrial economic drivers and emission factors by a simple vehicle turnover model.
- **House & garden machinery (CH_4 / N_2O)** – We project activity data using projected household numbers from ONS[24] and emission factors by a simple vehicle turnover model.
- **Nitric acid production (N_2O)** – We project nitric acid emissions using the Chemistry Growth Strategy Group baseline scenario for chemical sector growth, an annual 1.7% increase[25]. This follows consultation with the Environment Agency chemicals sector leads who also expect a growth in overall chemical production.

[24] ONS (2020), 2018-based household projections for England: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/householdprojectionsforengland

[25] CGA (2013), Strategy for delivering chemistry fuelled growth of the UK economy: https://www.soci.org/-/media/Files/Innovation-Group/CGP-Strategy-for-delivering-chemistryfuelled-growth-of-the-uk-economy.ashx?la=en

- **Fletton brick manufacture (CH_4)** – We project Fletton brick emissions using a simple 1:1 scaling against an index for CO_2 emissions from total brick manufacturing in the UK.
- **Anaesthetic use (N_2O)** – We project this using the EEP's population driver based on the methods the GHGI uses.
- **Cream consumption (N_2O)** – We project constant emissions in line with historical data.
- **Other chemical industry processes (N_2O)** – In the absence of a data source for projections or a discernible historical trend, we project constant emissions.
- **Recreational use of N_2O (N_2O)** – We project constant emissions as the historic data exhibits no discernible trend.

5. Domestic transport (CH_4 / N_2O)

Background

Non-CO_2 emissions are a very small fraction of all domestic transport emissions, at around 2% in 2022. Of these domestic transport non-CO_2 emissions, 61% are HFCs (see Section 3), 36% N_2O, and 4% CH_4.

- After falling from the mid-1990s, road transport N_2O emissions had increased from 2010 to 2018, before seeing a small fall in 2019 and a much larger fall in 2020 when there was a large fall in traffic on the roads as a result of restrictions due to the COVID-19 pandemic. There was a partial recovery in 2021 and 2022, but emissions were still below 2019 levels. The increases from 2010 to 2018 were due to the upward trend in diesel emissions taking over from the downward trend in petrol emissions.
- CH_4 road transport emissions have been decreasing since 1990 due to stricter European standards on emissions from new road transport vehicles.
- The remaining domestic transport CH_4 and N_2O emissions are from aircraft support vehicles, domestic aviation, domestic shipping and military vehicles.

How we project emissions

Road transport CH_4 and N_2O emissions projections follow a bottom-up calculation methodology in line with that for estimating the historical time series of emissions. We project the activity data — vehicle distance travelled — using DfT forecasts for road traffic in Great Britain[26] and for vehicle sales.

Aircraft support vehicle projections are based on forecasts of the number of UK airport terminal passengers and the driver for domestic aircraft activity is DfT's air traffic movement projections[27]. We project military transport emissions will be constant.

[26] DfT (2022), National road traffic projections 2022: https://www.gov.uk/government/publications/national-road-traffic-projections
[27] DfT (2017), UK aviation forecasts 2017: https://www.gov.uk/government/publications/uk-aviation-forecasts-2017

6. Fuel supply

Background

The fuel supply sector emissions covered in this report are fugitive emissions, i.e. those due to leakage, and they are all of methane. These emissions result from natural gas leakage, operational and closed coal mines, and solid fuel transformation.

Leakage from the gas distribution network is the largest CH_4 source in the GHGI outside of the agriculture and waste sectors, comprising approximately 6% of all CH_4 emissions in 2022. It accounted for the majority of CH_4 emissions in the fuel supply sector. Methane emissions from coal mining and handling have also historically made a substantial contribution but these have now reduced (to around 1% of CH_4 emissions). Fuel supply sector non-CO_2 emissions were approximately 34 $MtCO_2e$ lower in 2022 than in 1990, mainly because of decreased coal mining activity and a programme to fix leaks in the gas distribution network.

Economic demand drives a small percentage of combustion-related non-CO_2 emissions. We give further details about this in DESNZ's Energy and Emissions Projections report[8].

How we project emissions

- **Closed coal mines (CH_4)** — We use a model developed by WSP in 2011[28] to project closed coal mine emissions. The model catalogues mines and estimates methane gas reserves and emission rates to construct a profile of emissions up to 2050. The model was updated in 2016 to reflect more recent information about the closure dates of some mines and changes to the inventory calculation for these emissions.
- **Coal mining (CH_4)** — We project coal mining emissions will be constant based on expert advice from the Oil & Gas Authority. Deep-mined coal production virtually ceased in 2017 while surface mining could continue almost indefinitely unless policies change.
- **Charcoal/coke/solid-smokeless fuel production (CH_4)** — These are very small sources of emissions. We project emissions from charcoal and solid-smokeless fuel production will be constant. We project coke production using a driver from the EEP representing coal consumed by the iron and steel industry. The historical relationship is very strong.

  Gas supply leakage (CH_4) — Here, a 30-year programme to replace the gas distribution network drives a reduction in emissions[29]. In 2013, OFGEM set gas

[28] WSP Environmental (2011), Projections of Coal Mine Methane to 2050: http://uk-air.defra.gov.uk/assets/documents/reports/cat07/1107080945_1775-ghg-improvement-project-wsp-report.pdf
[29] HSE (2011), HSE/Ofgem: 10 year review of the Iron Mains Replacement Programme: http://www.hse.gov.uk/research/rrpdf/rr888.pdf

distribution network leakage targets[30] as part of the roll-out of a new price control period (Apr 2013-Mar 2021). This equated to an emissions reduction of approximately 20%. We linearly extrapolated these targets out to 2032 when the 30-year programme ends, and then set gas leakage from natural gas supply and transmission values to be constant after 2032. These targets form the long-term emission projections. In the short term, we revise the projections downwards to reflect the faster-than-required progress we have seen. We assume the same reductions apply to gas transmission leakage. We project gas leakage at point of use using the EEP index for CO_2 emissions from domestic gas use following consultation with GHGI experts.

[30] OFGEM (2012), RIIO-GD1: Final Proposals - Supporting Document – Outputs, incentives and innovation: https://www.ofgem.gov.uk/ofgem-publications/48155/2riiogd1fpoutputsincentivesdec12.pdf

7. Waste

Background

The major source of emissions from this sector is CH_4 from landfill sites. This contributed 16% of all non-CO_2 emissions in 2022. CH_4 and N_2O emissions from wastewater handling and composting make up most of the remaining waste emissions. There are also small contributions from Biological Waste Treatment (BWT) processes, accidental fires, and waste incineration plants without energy recovery. The last of these refers to burning of waste outside of the normal waste stream, such as clinical and chemical waste.

Landfill emissions in 2022 were approximately 79% lower than when the Landfill Directive was introduced in 2000. This had the aim of reducing the amount of waste going to landfill and improving the collection of methane from landfill sites. Emissions from wastewater treatment have been largely constant since around 2006. Emissions from BWT processes – composting, anaerobic digestion, and mechanical biological treatment – have generally been rising since 1990 and composting is the biggest emission source of the three. Meanwhile, emissions from incineration without waste recovery and accidental fires have fallen since 1990.

How we project emissions

- **Landfill (CH_4)** — Defra project the composition of the waste from the changes to BWT processes and projections of waste arisings. These projections of waste to landfill are then run through the MELMod landfill emissions calculation model[31]. MELMod is based on first-order decay IPCC methodology. The UK National Inventory report summarises this[6].

  There are no changes to landfill emissions projections since the last publication. This is because an update to waste emissions modelling is still in progress. We cannot yet quantify the impact on the capture of landfill gas of ending Renewal Obligation support for landfill gas electricity generation. The most recent estimate of the methane capture rate at landfills is approximately 56% in the GHGI. This means that each percentage point reduction in landfill gas capture would likely increase methane emissions by more than 2 per cent.

- **Wastewater treatment (CH_4 / N_2O)** — ONS population projections drive our domestic wastewater emission projections. We project industrial wastewater emissions will be constant due to lack of data.

[31] Eunomia (2010), Inventory Improvement Project – UK Landfill Methane Emissions Model: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=17448&FromSearch=Y&Publisher=1&SearchText=UK%20Landfill%20Methane%20Emissions%20Model%20&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

- **BWT (CH_4 / N_2O)** — We created a model in 2018 to improve projections from this sector. The model includes extension of existing anaerobic digestion ammonia projections to cover GHG emissions up to 2050 and utilises expert knowledge from Defra waste experts. It includes the impact of relevant policies such as the Circular Economy Package recycling targets, and the evidence base for composting and mechanical biological treatment projections.
- **Incineration without energy recovery (CH_4 / N_2O)** — We project constant emissions using the 5-year historical average.
- **Sewage and sludge decomposition (CH_4 / N_2O)** — ONS population projections drive the emissions projections. CH_4 emissions from private systems remain constant at the latest GHGI figure since we assume the biological oxygen demand per person will be the same in future years.
- **Household composting / Accidental fires (CH_4 / N_2O)** – We project these emissions sources will be constant from the latest GHGI year.

8. Agriculture

Background

Agriculture emissions result from (i) enteric fermentation from livestock, (ii) manure management and (iii) agricultural soils. The two biggest sources are enteric fermentation in cattle and fertiliser use for CH_4 and N_2O respectively. CH_4 and N_2O from manure management also represent a significant source of emissions. Agriculture emissions were roughly constant in the mid-1990s, but then decreased in all sources from the late 1990s until the late 2010s, since when they have remained fairly constant.

How we project emissions

We use agriculture emission projections produced by Defra based on activity data projections (livestock numbers, milk yield, crop areas and production) to 2032 from the UK Agricultural Market Model (UKAMM)[32]. Defra converts the UKAMM activity projections to agriculture emissions projections using the latest agriculture GHGI model.

Since the UK agricultural inventory model does not currently capture mitigation we had to adjust the GHG estimates for the impacts of existing mitigation policies. In particular, we have included the English agricultural industry's GHG Action Plan[33]. Monitoring by Defra suggests that from its implementation to 2015, the Action Plan reduced emissions from English agriculture by 0.9 $MtCO_2e$. Additionally we have also included policies from the Climate Change Strategy for Wales (reducing annual emissions by 0.2 $MtCO_2e$ by 2020) and the Climate Change Plan from Scotland (reducing annual emissions by 0.8 $MtCO_2e$ by 2032 with savings starting in 2021).

[32] Defra (2021), UK Agricultural Market Model (UKAMM): https://www.gov.uk/government/publications/uk-agricultural-market-model-ukamm
[33] NFU (2011), Agriculture Industry GHG Action Plan: http://www.nfuonline.com/assets/2889

9. LULUCF

Background

While we estimate that the land use, land use change and forestry (LULUCF) sector was a net sink of CO_2 in 2022, it was a source of non-CO_2 emissions of approximately 7.0 $MtCO_2e$. The major contributor is CH_4 and N_2O emissions from the drainage, rewetting and other management of organic and mineral soils. Direct N_2O emissions from changes in soil organic matter following the disturbance of soil in land conversion is also a significant source.

How we project emissions

The Centre for Ecology & Hydrology (CEH) and Forest Research project LULUCF emissions and removals with methods consistent with the current inventory methodology. They produce scenarios reflecting policy needs. The assumptions deal with afforestation, wildfires, peat extraction, land use change and deforestation. We developed scenario assumptions with relevant policy makers including colleagues from the UK devolved administrations. Broadly, the “Central case” scenario is a continuation of current policies over their agreed duration (especially relevant for policies involving dedicated public funding) and activity rates. This is the scenario we used in generating emissions projections for the purpose of this report. We use the difference between the “Central case” scenario and “Baseline” scenarios to evaluate policy impacts in the LULUCF sector.

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