



Department
of Energy &
Climate Change

Projected emissions of non- CO₂ greenhouse gases

2015 update

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Executive summary

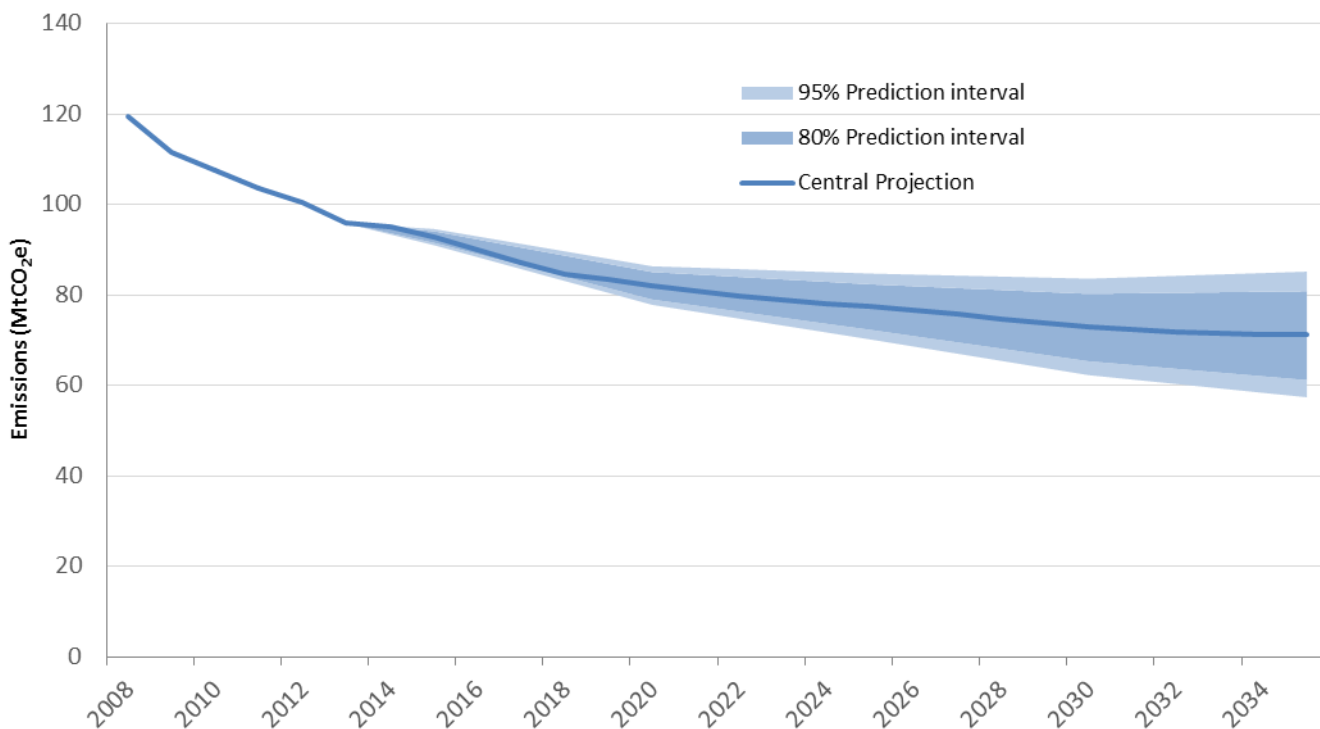
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Executive summary

This report presents the 2015 update to DECC's projections of non-CO₂ greenhouse gas emissions for the UK, as well as the methodologies used to derive them and the associated uncertainties. The non-CO₂ gases are methane (CH₄), nitrous oxide (N₂O) and the fluorinated gases (HFCs, PFCs, SF₆ and NF₃). The projections are a best estimate of future emissions, 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.

All non-CO₂ emissions sources are covered, with the exception of some non-CO₂ emissions produced as a result of combustion activities. These projections feed into DECC's Energy and Emissions Projections, which cover all UK greenhouse gas (GHG) emissions and will be published later in the year.

Figure i Summary of projected non-CO₂ GHG emissions (MtCO₂e) showing one formulation of the uncertainty associated with the projection

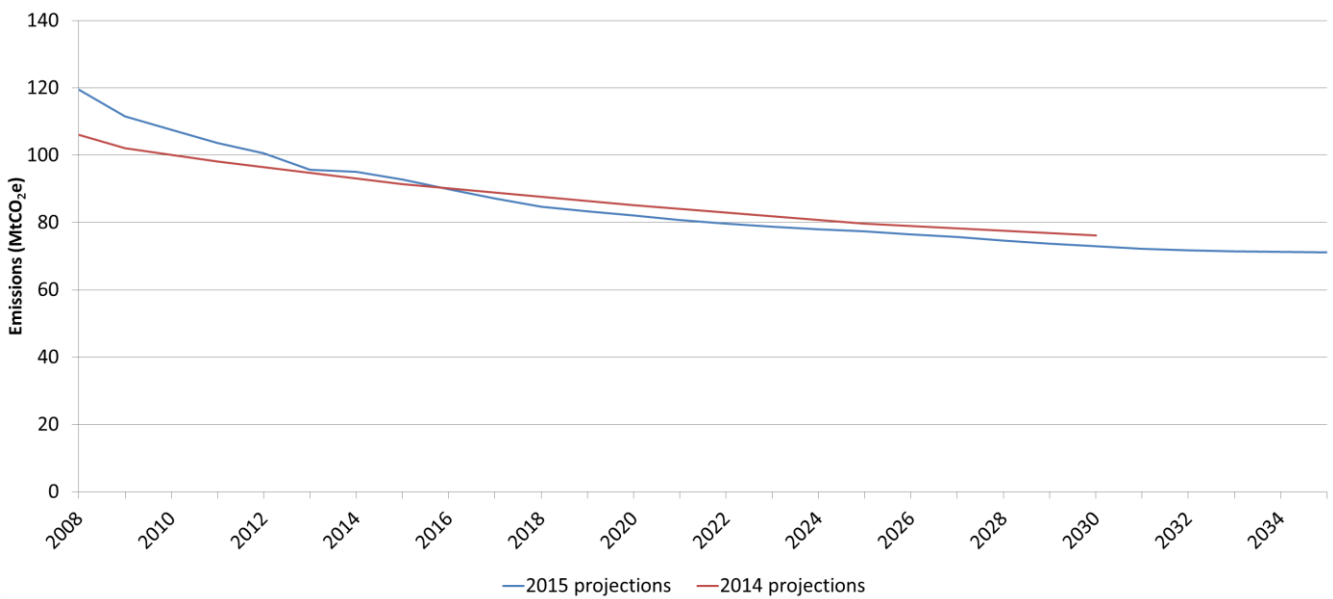


Total non-CO₂ GHG emissions within the scope of this report were 95.8 million tonnes CO₂ equivalent (MtCO₂e) in 2013, which represented 17% of all GHG emissions. They are projected to reduce to 71.1 MtCO₂e in 2035; a projected 26% decrease between 2013 and 2035, or a 65% reduction on 1990 levels. This reduction can be seen in Figure i along with one formulation of the uncertainty in these projections. Most of the projected reduction in emissions

from 2013 to 2035 comes from decreases in CH₄ emissions from gas network leakage, CH₄ emissions from landfill and hydrofluorocarbon (HFC) emissions from refrigeration and air-conditioning.

Since last year's projections there have been significant changes to both the emissions baseline, following the introduction of updated guidelines from the Intergovernmental Panel on Climate Change (IPCC), and also to the projection methodologies used. A comparison of the overall 2014 and 2015 projections can be seen in Figure ii. The 2015 projections start from a higher baseline, but decrease more rapidly. The most significant changes to emissions projections since 2014 have been to the agriculture, waste and F-gas projections.

Figure ii A comparison of total non-CO₂ GHG emissions in 2014 and 2015



Acknowledgements

We are grateful for the advice and support of the non-CO₂ GHG emissions projections Steering Group. We are also grateful for the contributions and support provided by Ricardo-AEA, The Centre for Ecology and Hydrology and members of staff at DECC, Defra and other government departments.

1. Introduction

1.1 Overview

This report presents the 2015 update to the non-energy, non-carbon dioxide (non-CO₂) greenhouse gas (GHG) emission projections. These projections will later be combined with DECC's energy non-CO₂ and CO₂ emission projections to form the complete UK emissions projection in the Energy & Emissions Projections (EEP) publication. This is usually published in the autumn ([DECC, 2014a](#)).

The UK government has set a target for a reduction in greenhouse gas emissions of 80% by 2050 ([DECC, 2011](#)). Emissions projections are used as a way of monitoring progress towards these this target and to identify emission sources which would need additional measures. The UK is also required to submit projected emissions of greenhouse gases biennially under the European Union Monitoring Mechanism Regulation, and 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 assumptions and models used in forming emission projections are updated annually where required. This is the second year that these non-CO₂ emission projections have been produced on an annual schedule – previously it was biannual – which has for the first time provided nearly a full year for the improvement programme. As such, the methodologies used to form the projections have undergone significant improvements since the previous publication. These will be discussed further in subsequent chapters.
- We have moved from a geographical scope of 'UK and Crown Dependencies' to 'UK' only. This has been done for consistency with DECC's other emissions projections publication, the EEP ([DECC, 2014a](#)).
- We now project out to 2035 rather than 2030.
- The historical GHG emissions ([DECC, 2015a](#)) which form the baseline for these projections have undergone significant changes this year in order to meet the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines ([IPCC, 2006](#)). These include changes to (i) calculation methodologies and emission factors, (ii) emission source categories, including the addition of new sources and (iii) Global Warming Potentials (GWPs) taken from the IPCC Fourth Assessment Report (4AR), rather than the IPCC Second Assessment Report (2AR) as in previous years. All these changes have been incorporated into these projections as well to remain consistent.

1.2 Scope

Non-CO₂ emission sources covered by this publication

The projections which accompany this report are for the **non-energy, non-CO₂** component of the Kyoto Protocol's basket of greenhouse gases, which we refer to as the 'non-CO₂ GHGs'.

These gases are:

- Methane (CH₄)
- Nitrous oxide (N₂O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF₆)
- Nitrogen trifluoride (NF₃)

* The HFCs, PFCs, SF₆ and NF₃ are also collectively known as the fluorinated gases, or "F-Gases". This is the first year that NF₃ has been included in the projections following the IPCC 2006 Guidelines and emissions are extremely small.

The 'non-energy' scope of these projections can be roughly considered to mean 'non-combustion'. For example, the major sources are CH₄ emissions from enteric fermentation in livestock, N₂O emissions from microbial nitrification/denitrification of fertilisers, CH₄ emissions from the decomposition of biodegradable waste and leakage of HFCs from refrigeration & air-conditioning equipment. The main exception to this 'non-combustion rule' is that our scope also covers all non-CO₂ emissions from transportation: road transport, military transport, domestic aviation and aircraft support vehicles. The exception is rail and shipping.

Projected emissions of all other GHG emissions, i.e. all CO₂ emissions and the remaining combustion related non-CO₂ emissions, are not within the coverage of this report. The next annual publication of DECC's Energy & Emissions Projections (EEP) report will include projections of the UK's entire Kyoto Protocol basket of GHG emissions, i.e. the non-CO₂ projections within this report, plus new projections of the remaining combustion related non-CO₂ emissions and all CO₂ emissions.

A full list of non-CO₂ emission sources which are modelled separately for the EEP are provided in the spreadsheet that accompanies this report on the DECC website; see spreadsheet "*Non-CO₂ GHG emission projections 2015 - accompanying tables.xls*." Categories will remain under review and additional categories may be added or removed. The UK's total non-CO₂ emissions in 2013 were 100.5 million tonnes CO₂ equivalent (MtCO₂e), with 4.8 MtCO₂e covered in the EEP publication and 95.8 MtCO₂e covered in this publication.

Geographical scope, time horizon and units

- The geographical scope of these projections is the UK only
- Emissions are projected out to 2035.
- Emissions are presented in CO₂ equivalent (CO₂e), according to GWPs set out in the IPCC 4AR.

Sector assignment

For the purposes of reporting, greenhouse gas emissions are allocated into National Communication (NC) sectors. These are a small number of broad, high-level sectors, and are as follows: energy supply, business, transport, public, residential, agriculture, industrial processes, land use land use change and forestry (LULUCF), and waste management.

These high-level sectors are made up of a number of more detailed sectors that follow the definitions set out by the IPCC for GHG emissions reporting, and are used in international reporting tables submitted to the UNFCCC every year. The sectoral assignments are based on the source of the emissions as opposed to where the end user activity occurred. A complete mapping of IPCC sectors to National Communication sectors is available on the DECC website ([DECC, 2015b](#)). These are the sectoral assignments used in this report.

1.3 Current UK GHG emissions and targets

As part of the UK's commitments for reporting its GHG emissions, a national inventory is produced each year containing estimates for the UK's GHG emissions from all anthropogenic sources. This is referred to as the GHG Inventory (GHGI) and is annually submitted to the UNFCCC. Please note that due to reporting software problems, the 2015 GHGI has not yet been officially submitted to the UNFCCC. However, emissions statistics based on the 2015 GHGI have been published ([DECC, 2015a](#)) and previous GHGI reports are available ([DECC, 2014b](#))

The GHGI forms the baseline for the projections in this report, although the geographical scope is slightly different between the UNFCCC submission and these projections. The UNFCCC submission covers the UK plus Crown Dependencies and Overseas Territories, whereas only the UK component is covered by this report. All reference to the GHGI in this report refers to this UK only scope.

Total UK emissions in 2013 were estimated at 566.5 MtCO₂e, excluding the effects of emission trading under the European Union Emissions Trading System (EU ETS). Of these total emissions, non-CO₂ GHGs consistent with the coverage of this report represented 95.8 MtCO₂e. The current situation with each of the non-CO₂ GHGs is as follows:

- **Methane (CH₄)** – CH₄ represents 56% of non-CO₂ GHG emissions. The agriculture sector as a whole accounts for 50% of all CH₄ emissions, while the waste management sector accounts for 38%. The remaining CH₄ emissions are largely attributed to fugitive energy emissions.
- **Nitrous oxide (N₂O)** – N₂O represents 26% of non-CO₂ GHG emissions. The majority of N₂O emissions, 84%, are attributed to the agriculture sector. Waste, transport, business and LULUCF make up the majority of the remaining 16%, with minor contributions from the industrial processes and the residential sectors.
- **F-Gases (HFCs, PFCs, SF₆ and NF₃)** – HFCs represent 17% of non-CO₂ GHG emissions, while PFCs, SF₆ and NF₃ represent less than 1% between them. Refrigeration and air conditioning account for 81% of HFC emissions, with the dominant source being mobile air conditioning. 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. SF₆ emissions are largely attributable to electrical insulation. NF₃ emissions come solely from semiconductor manufacture and are tiny.

Further details on breakdown of each of these gases to specific activities over the period 1990 - 2013 can be found in the latest National Statistics release ([DECC, 2015a](#)). Note that the main geographical coverage in the statistics release is UK plus Crown Dependencies although Table 14 of the accompanying data tables shows UK only emissions.

The UK has both international and domestic targets for reducing greenhouse gas emissions. These targets encompass all GHG emissions, not just the non-CO₂ component projected in this report. DECC's EEP report provides more information on the UK's complete GHG emissions projections in comparison to targets. Emissions reductions targets are summarised here. Base year usually refers to 1990, but please note there are differences in the definition.

- **Kyoto Protocol** - The UK's target for the first commitment period from 2008-2012 was a 12.5 percent reduction on base year emissions ([Defra, 2006](#)) which has been met. A UK target is yet to be finalised for the second commitment period from 2013 to 2020.
- **European Union 2020 target** - As part of the European Union (EU) Climate and Energy Package, the EU has committed to reducing overall greenhouse gas emissions across the EU28 member states by 20 per cent relative to base year levels by 2020
- **UK Climate Change Act** - This Act established a legally binding target for the UK to reduce its greenhouse gas emissions by at least 80 per cent below base year levels by 2050 ([DECC, 2011](#)). It also established a system of binding five-year carbon budgets to set the trajectory towards this target. The UK has met the first carbon budget, which ran from 2008-2012.

1.4 Structure of report and accompanying spread sheet

The next chapter of this report details the general methodology used to produce the emissions projections. This is followed by a chapter summarising the projections and then individual chapters providing a breakdown of projections for each sector. Each sector chapter will summarise the drivers on historical and projected emissions for that sector, describe how the projections are modelled and discuss changes since last year's projections. After the sector chapters, the uncertainties in the projections will be presented.

There are detailed tables of projections in a spreadsheet that accompanies this report on the DECC website; see spreadsheet "*Non-CO₂ GHG emission projections 2015 - accompanying tables.xls*."

2. Projections methodology

2.1 Overview of methodology

Baseline

Emissions statistics based on the 2015 GHG Inventory (GHGI), the estimate of the UK's historical GHG emissions from all anthropogenic sources, are used as the baseline for projections ([DECC, 2015a](#)). The GHGI calculates emissions by combining activity data (e.g. fuel use, livestock numbers) and emission factors (e.g. kg pollutant / tonne fuel used, / head livestock). A new GHGI is produced each year (x) detailing emissions from each source from 1990 to year $x - 2$ (e.g. the GHGI produced in 2015 provides emissions from 1990 - 2013). This means that the base year for these projections is 2013.

The historical emissions estimates are revised each year to account for new information that becomes available, and methodological improvements. The data and compilation methods used in the GHGI are reviewed annually and there have been significant changes this year in following the introduction of the 2006 IPCC Guidelines ([IPCC, 2006](#)).

The changes resulting from the 2006 Guidelines can be summarised as:

- GWP changes. The GWP for CH₄ has gone from 21 to 25 and for N₂O has gone from 310 to 298. F-gas GWPs have changed by varying amounts.
- Methodologies and default emission factors have changed, although many of the changes required by the 2006 IPCC Guidelines had already been implemented in previous years.
- Inclusion of new emission sources.

The most notable specific changes to this year's GHGI are:

- Agriculture – There have been considerable changes in the inventory model due to the adoption of the 2006 Guidelines. The net impact of the change in methodology has been to increase the relative importance of methane over nitrous oxide, and to reduce the overall emissions from the sector throughout the time series. In addition, improvements have been made in the activity data for beef cattle live-weights and the distribution of manure management systems. The main impact of improved activity data has been to increase emissions from beef animals due to higher live-weights than previously assumed. The combined effect of these revisions has been to reduce emissions in 1990 by 7.1 MtCO₂e and reduce emissions in 2012 by 3.6 MtCO₂e.
- Waste - In landfill emission calculations there was improved flaring data and changes to how flaring is treated. There were also methodological improvements for the estimation of methane formation within landfills, including revised biodegradability content and waste composition, revised decay rates and revised assumptions on landfill gas engine efficiency. Industrial wastewater methodology has also changed leading to a doubling of emissions. The changes lead to a 21.9 MtCO₂e increase in waste emissions in 1990, and a 4.5 MtCO₂e increase in 2012.
- F-gas – Historical emissions have increased by around 2 MtCO₂e in recent years following GWP changes.
- There has been some rearrangement of emission source categories and in addition the following is a list of new emission sources:
 - Foams HFCs for the 2006 guidelines

- Accidental fires - other buildings
- Accidental fires - dwellings
- N₂O use as an anaesthetic
- Refrigerant containers
- Airborne Warning and Control System (AWACS)
- Particle accelerators
- Electronics – HFCs
- Electronics - NF₃
- Composting (household)
- Total composting (non-household)
- Anaerobic digestion
- Mechanical biological treatment

The net effect of all the changes to this year's GHGI is that emissions are 12.7% higher in 1990 and 4.3% higher in 2012. Methane and F-gas emissions are on average higher, while nitrous oxide emissions are on average lower. All projections have been updated to account for these changes to the baseline, and the most impactful changes are described in the relevant chapters of this report.

Projections

The GHGI emissions from each source within scope of this report are projected from the latest GHGI year (currently 2013) up to 2035 to form the DECC non-CO₂ GHG projections. Given the disparate nature of the emission sources in scope, the methodologies used to define the projections are wide ranging. The drivers on emissions and methodologies used to model this are discussed 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 behaviour affecting the waste sector.
- Projections of the change in emission factors, e.g. improvements to technology for the abatement of emissions.

In a change from the previous projection methodology, we have checked and where necessary updated each individual projection. Therefore, we no longer just 'rebaseline' last year's projections to the latest inventory year. This 'rebaselining' method was previously applied to projections that didn't undergo annual updates. A 'rebaselining factor' was calculated and the projection time series was scaled by this factor. This was a useful practice to ensure all projections were consistent with the latest GHGI. However, it did not update any of the projection drivers.

We have moved to a system whereby annual updates to projections involve one of the three following methods:

- If there are apparent major changes to the drivers then we undergo a formal update of the projections from that source.
- If there are no apparent major changes to the drivers or the historical emissions, then the projections are left unchanged.
- If there are no apparent major changes to the drivers, but the historical emissions have changed due to a methodology change then the projections model is rerun.

Changes in projections for each source are discussed in the relevant sector chapter.

Policies

The non-CO₂ projections include the effects of a number of government policies which mitigate GHG emissions. The standard EU/UNFCCC definitions used to categorise policies are:

- **'Expired'** are closed policies that still provide legacy carbon savings;
- **'Implemented'** are policies that are being applied;
- **'Adopted'** are policies that have been agreed and where the process of implementation is well advanced but not yet complete.
- **'Planned'** are policies at an earlier stage towards implementation, e.g. where the government's intentions have been announced or are still being consulted on.

A 'with existing measures' scenario includes all currently expired, implemented and adopted policies. A 'with additional measures' scenario includes all the above policies, plus planned policies. As there are no planned policies within the non-CO₂ projections then they are both a 'with existing measures' scenario and a 'with additional measures' scenario.

The policies that we have explicitly included in projections are:

- F-gas regulation (2006, 2015 and Mobile Air-Conditioning Directive) ([EU 2006a](#), [2006b](#), [2014](#)).
- Solid waste policies (Waste Framework Directive, Landfill Directive, Landfill Tax etc all contribute to the waste activity projections provided by Defra) ([Defra, 2014a](#))
- Transport policies (Local Sustainable Transport Fund, road biofuels, road vehicle efficiencies are included in the DfT activity projections) ([DfT, 2015a](#))
- LULUCF afforestation policies ([Defra 2015](#), [Welsh gov 2015](#), [Scottish gov 2015](#), [DARDNI 2014](#))
- English GHG Agriculture Action Plan ([NFU, 2011](#))

2.2 Quality Assurance / Quality Control procedures

The methodology for modelling these projections has undergone an overhaul in the previous year which has had positive effects on Quality Assurance (QA). Notable improvements are:

- Documenting all assumptions, methods, models, drivers, information, etc. that feed into each projection. This has improved transparency of how each projection is produced and made it much easier to Quality Control (QC) the individual projections.
- The methodology change discussed in Section 2.1 that has moved away from 'rebaselining' previous projections to formally updating projections with new information when required. This means that we have greater confidence in how up-to-date and accurate the projections are.
- The methodology change discussed in Section 2.1 that has moved away from 'rebaselining' has also resulted in comprehensive models showing the projection calculations which can now be easily QC'd.

There have been two separate model audits carried out this year. In combination, they cover all of the models used for the non-CO₂ projections:

- The GHGI models which (i) form the baseline for the projections and (ii) produce projections for road transport, agriculture and LULUCF emissions had their QA processes audited. The audit found that "the QA policies and practices are largely fit for purpose". Note that this was in addition to core QA/QC processes within the annual

GHGI compilation cycle that have been developed over a number of years. These core processes are documented in Chapter 1 of the UK's National Inventory Report (DECC, 2014b).

- The non-CO₂ models run internally by DECC have been QA audited by the DECC Model Integrity Team whose aim is that all models achieve a QA score of over 90%. The audit found the models to be fit for purpose and they received a QA score of 94%.

In addition, the business as usual QA/QC process involves the following measures:

- A wide range of data is used in the projections and each source is quality assured. Many of the new data sources are publicly available (see references) and where possible data are subject to peer review.
- Sector experts providing QC on the assumptions used.
- Significant verification and error checking by the production team. 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 and checking final projections against source projections.
- The changes incorporated into this update have also been checked, and overseen by the non-CO₂ GHG emissions projections Steering Group.

The main benefit of the extra 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. Summary of the 2015 non-CO₂ GHG projections

Summary of projections

Non-CO₂ GHGs are projected to be 71.1 MtCO₂e in 2035; representing a projected 26% decrease between 2013 and 2035. This projected trend would represent a 65% reduction on 1990 levels in 2035.

The majority of the projected reduction in emissions from 2013 to 2035 is predicted to come from decreases in CH₄ and HFC emissions, as can be seen in Figures 3.1 and 3.2. The sectors that these projected reductions are anticipated to come from are:

- Waste Management (a result of a decrease in the volume of waste sent to landfill and decreasing emissions from waste already in landfill);
- Business (as HFCs are replaced with lower GWP refrigerants);
- Energy Supply (as a result of a decrease in the quantity of coal produced and the replacement of cast-iron pipes with plastic in the gas distribution system).

Figure 3.1 Summary of projected non-CO₂ GHG emissions by gas (MtCO₂e)

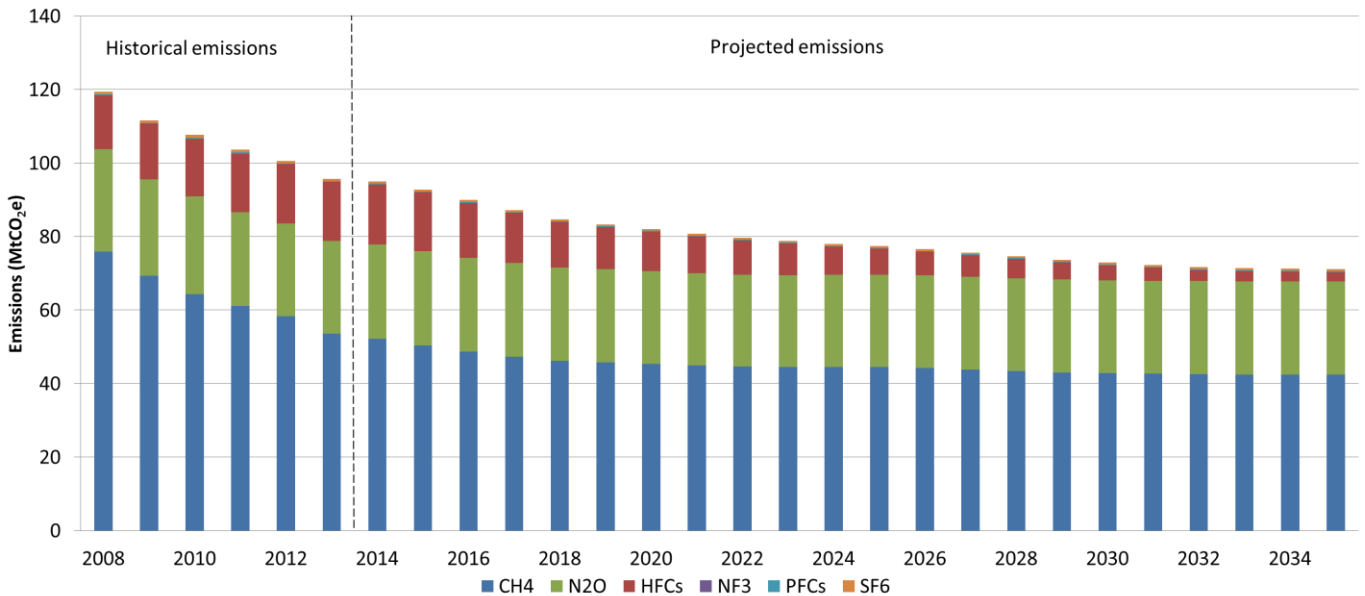
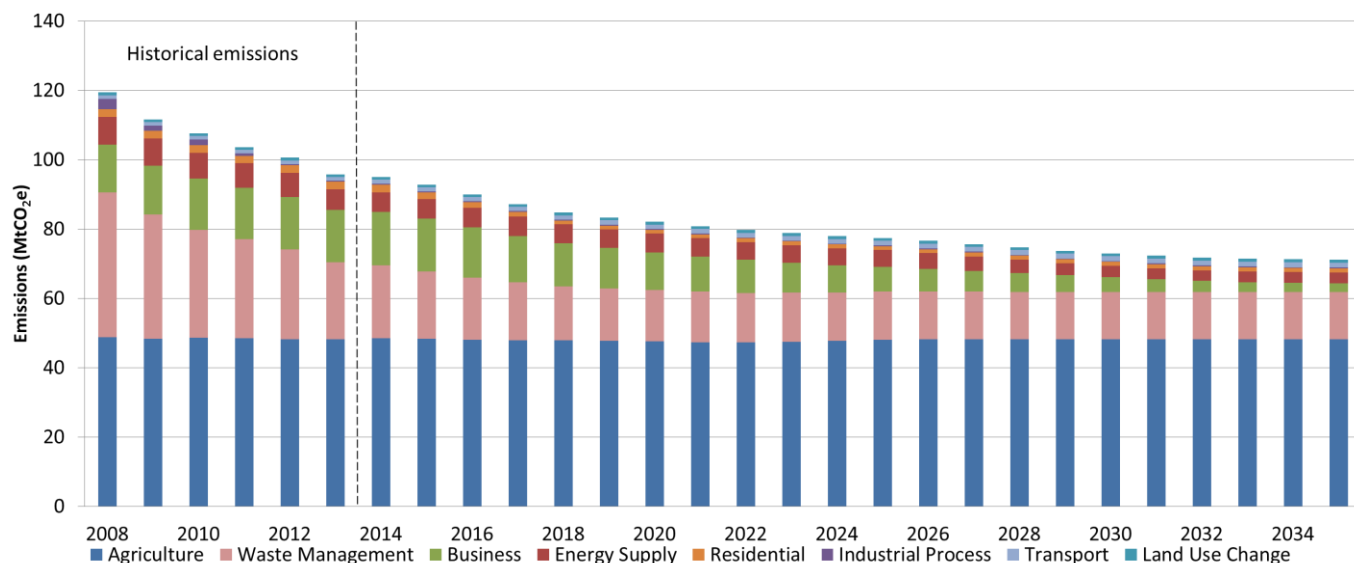


Figure 3.2 Summary of projected non-CO₂ GHG emissions by National Communication sector (MtCO₂e)

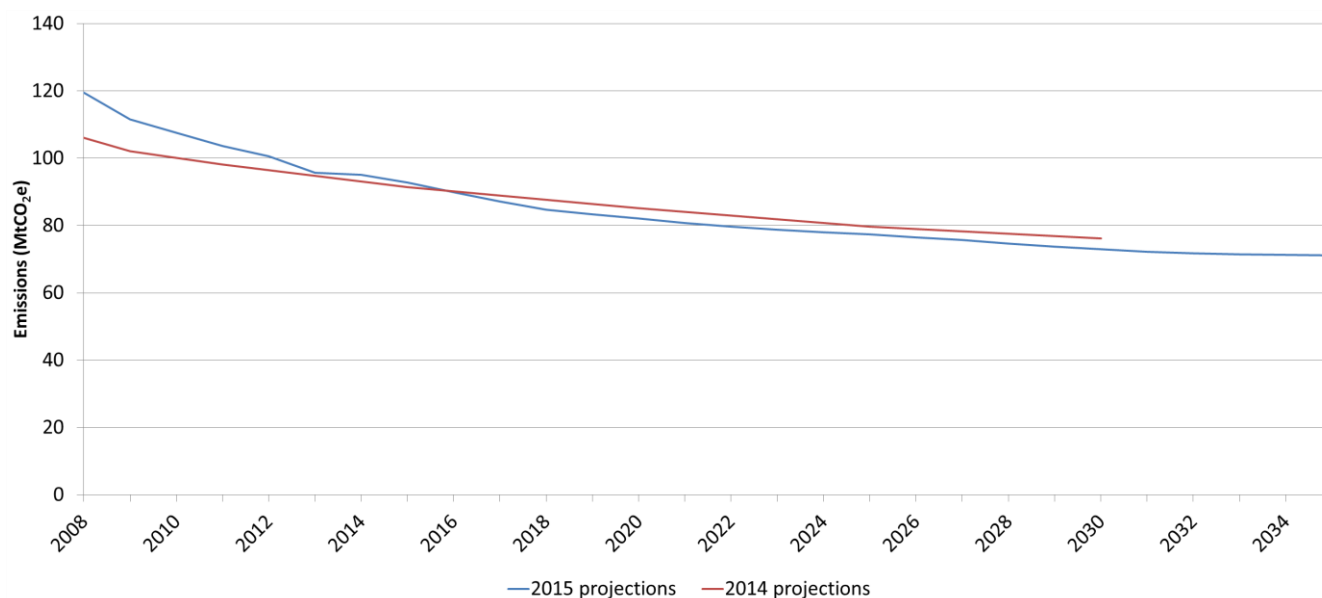


Changes since the previous projections publication

As discussed in Chapter 2, since the last publication of non-CO₂ projections in 2014 (DECC, 2014c), there have been significant changes to both the emissions baseline from the 2006 IPCC Guidelines changes and also to the projections methodologies used.

A comparison of the overall 2014 and 2015 projections can be seen in Figure 3.3. The 2015 projections start from a higher baseline, but decrease more rapidly. 2012 emissions in the 2015 projections are 4.2 MtCO₂e higher than in the 2014 projections; while 2030 emissions are 3.2 MtCO₂e lower.

Figure 3.3 A comparison of total non-CO₂ GHG emissions in 2014 and 2015

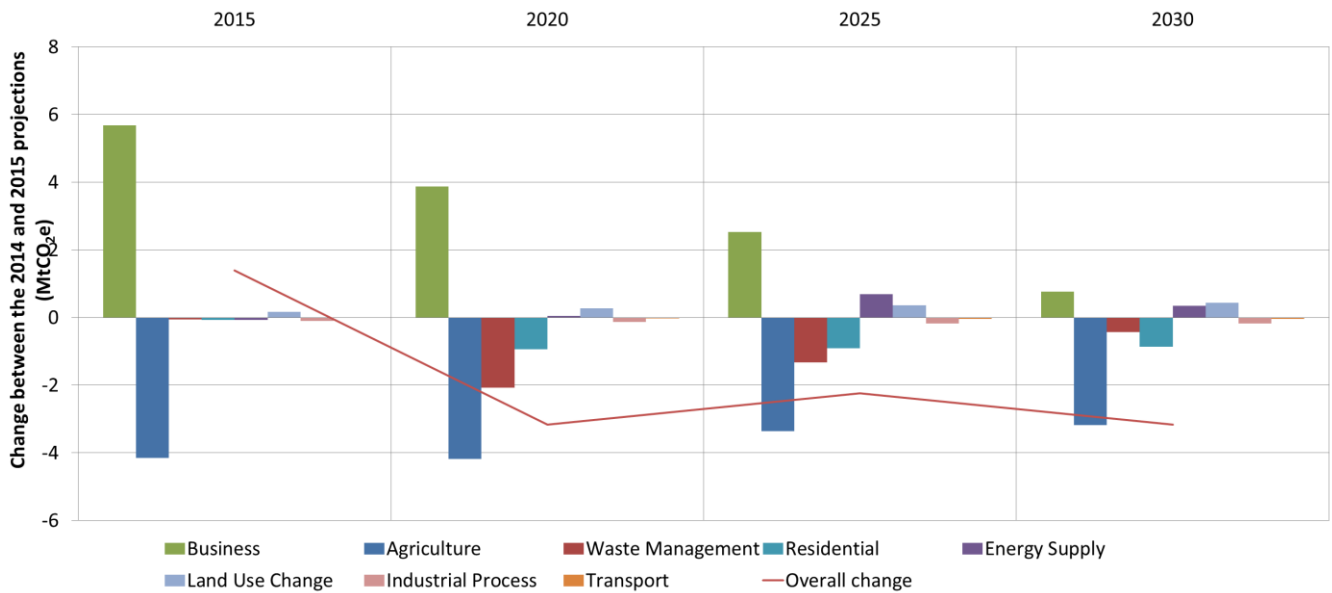


The most significant effects on emissions projections have been:

- **Agriculture:** GHGI changes which decrease baseline emissions, plus three changes to the projections, (1) updated activity data projections, (2) partial incorporation of the Dairy Growth Plan ([Dairy UK, 2014](#)) and (3) incorporation of the GHG Action Plan ([NFU, 2011](#))
- **Waste:** GHGI changes which have increased baseline emissions but also increased the rate of decrease in emissions. Additionally, the landfill projections have been updated.
- **F-gases:** GHGI changes which increase baseline emissions, plus fully incorporating the 2014 F-gas regulation ([EU, 2014](#)) which causes a later, but faster reduction in emissions (the 2014 projections only partially accounted for the 2014 F-gas regulation).

Figure 3.4 highlights the magnitude of each of the updates on the projections. Note that F-gases are largely in the business sector. Details of all of the updates are laid out in the relevant sector specific chapters below.

Figure 3.4 Magnitude of changes to the projected emissions between the 2014 and 2015 non-CO₂ projection publications.



Summary tables

Tables 1 and 2 below contain a summary of the projections presented in this report. The projections have been split by gas and by sector. For a more detailed disaggregation of the projections, please see the spreadsheet published alongside this report.

Table 1 Summary of non-CO₂ GHG projections by gas (MtCO₂e)

Gas	1990	2013	2015	2020	2025	2030	2035
CH ₄	131.5	53.5	50.3	45.3	44.5	42.8	42.5
N ₂ O	53.6	25.3	25.7	25.2	25.2	25.3	25.4
HFCs	14.6	16.1	16.0	10.8	7.1	4.1	2.5
SF ₆	1.3	0.6	0.5	0.5	0.5	0.5	0.6
PFCs	1.7	0.3	0.2	0.2	0.2	0.2	0.2
NF ₃	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grand Total	202.6	95.8	92.8	82.1	77.4	72.9	71.1

Table 2 Summary of non-CO₂ GHG projections by NC Sector (MtCO₂e)

NC Category	1990	2013	2015	2020	2025	2030	2035
Agriculture	58.1	48.2	48.3	47.5	48.0	48.2	48.2
Waste Management	67.9	22.2	19.4	14.8	13.9	13.6	13.6
Business	2.0	15.1	15.3	10.9	7.2	4.2	2.6
Energy Supply	31.3	6.0	5.7	5.3	4.8	3.2	3.0
Residential	0.0	2.2	1.9	1.1	1.1	1.2	1.3
Transport	2.0	1.1	1.2	1.3	1.4	1.4	1.4
Land Use Change	1.1	0.7	0.8	0.8	0.8	0.8	0.8
Industrial Process	40.2	0.4	0.3	0.3	0.2	0.2	0.2
Grand Total	202.6	95.8	92.8	82.1	77.4	72.9	71.1

4. Industrial Processes, Residential & Business (F-gases)

Historical emissions

All F-gas emissions are in the industrial processes, residential and business sectors. The F-gases are HFCs, PFCs, SF₆ and a new gas in this year's inventory, NF₃. F-gas emissions total 17.0 MtCO₂e which represents 18% of non-CO₂ emissions within the scope of this report in 2013. Historical emissions have increased in this year's GHGI due to updated GWPs and methodology changes in following the 2006 IPCC Guidelines.

The major trend is that emissions of HFCs have increased rapidly since 1990 due to the phasing out of Chlorofluorocarbons (CFCs) as a result of the Montreal Protocol, and the use of HFCs as replacement gases, particularly in a growing refrigeration and air conditioning sector. There was however a significant dip in emissions around 1997 – 1999 when abatement equipment was applied to plants that produce halocarbons. In 1990 F-gases emissions largely arose as by-products from halocarbon manufacture, while in 2013 refrigeration and air conditioning is the dominant source.

- Business F-gas emissions are dominated by the refrigeration and air-conditioning sector HFC emissions, making up 77% of all F-gas emissions. These emissions increased rapidly in the late 1990s and 2000s, though the increase has flattened out since 2010. Other HFC emission sources of note are foam blowing (33% of all F-gas emissions) and fire protection equipment (22% of all F-gas emissions). Emissions from both these sources have partially flattened out following big increases around 2000. High voltage switch-gear is a notable, though steadily decreasing, source of SF₆ emissions, making up 2% of all F-gas emissions, but over half of all SF₆ emissions
- The two residential HFC sources are aerosols and metered dose inhalers which make up 7% and 5% of all F-gas emissions respectively. These emissions rose rapidly in the 1990's but have flattened off in recent years.
- Industrial F-gas emissions result from magnesium, aluminium and halo-carbon production. SF₆ emissions from its use as a cover gas in magnesium production are the biggest source and have increased in recent years as SF₆ has replaced HFCs. Those emissions make up less than 1% of all F-gas emissions, but nearly a quarter of all SF₆ emissions. Emissions from aluminium production have recently dropped to very low levels following plant closure. PFC emissions from halocarbon manufacture are highly variable, but currently make up nearly half of all PFC emissions, while HFC emissions from halocarbon manufacture have decreased enormously over the years and are now very small.

2014 EU F-gas regulation

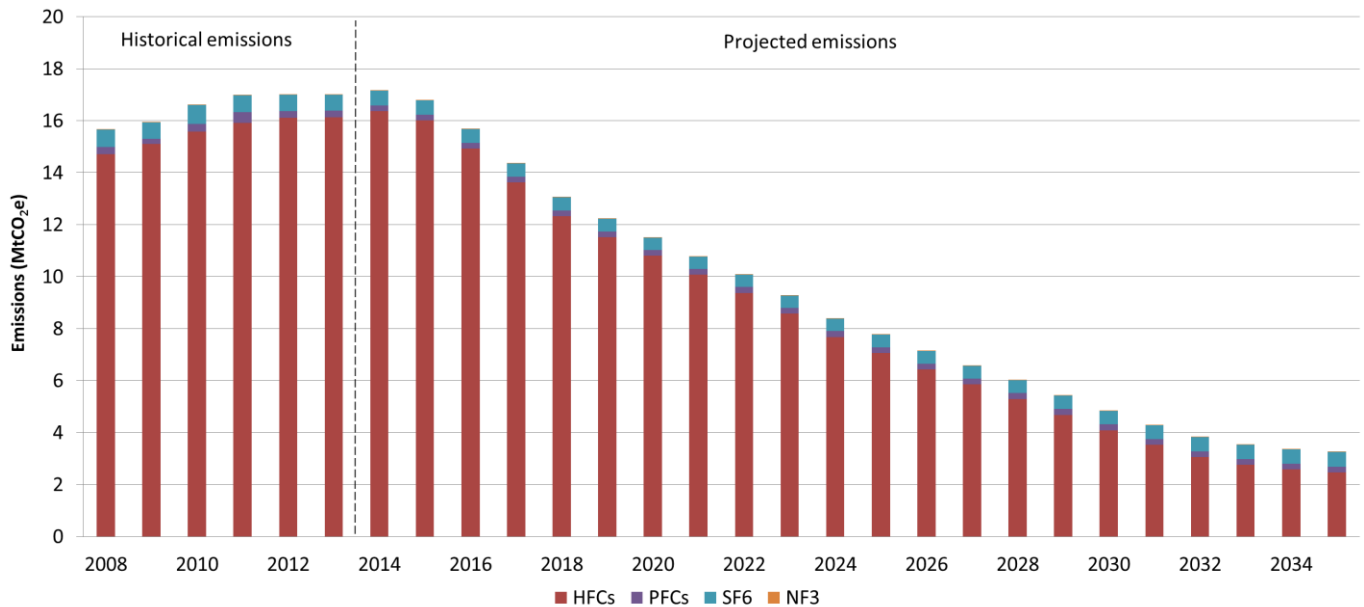
Building on previous regulation in 2006 (EU, 2006a,b) , the EU introduced new F-gas regulation in 2014 (EU, 2014). It came into effect on 1st January 2015 and does three main things:

- Limiting the total amount of the most important F-gases that can be sold in the EU from 2015 onwards and phasing them down in steps to one-fifth of 2014 sales in 2030.
- Banning the use of F-gases in many new types of equipment where less harmful alternatives are widely available

- Preventing emissions of F-gases from existing equipment by requiring checks, proper servicing and recovery of the gases at the end of the equipment's life.

The regulation was partially included in last year's projections and is fully included this year.

Figure 4.1 – F-gas emissions projections for the industrial processes, business and residential sectors



How we project emissions

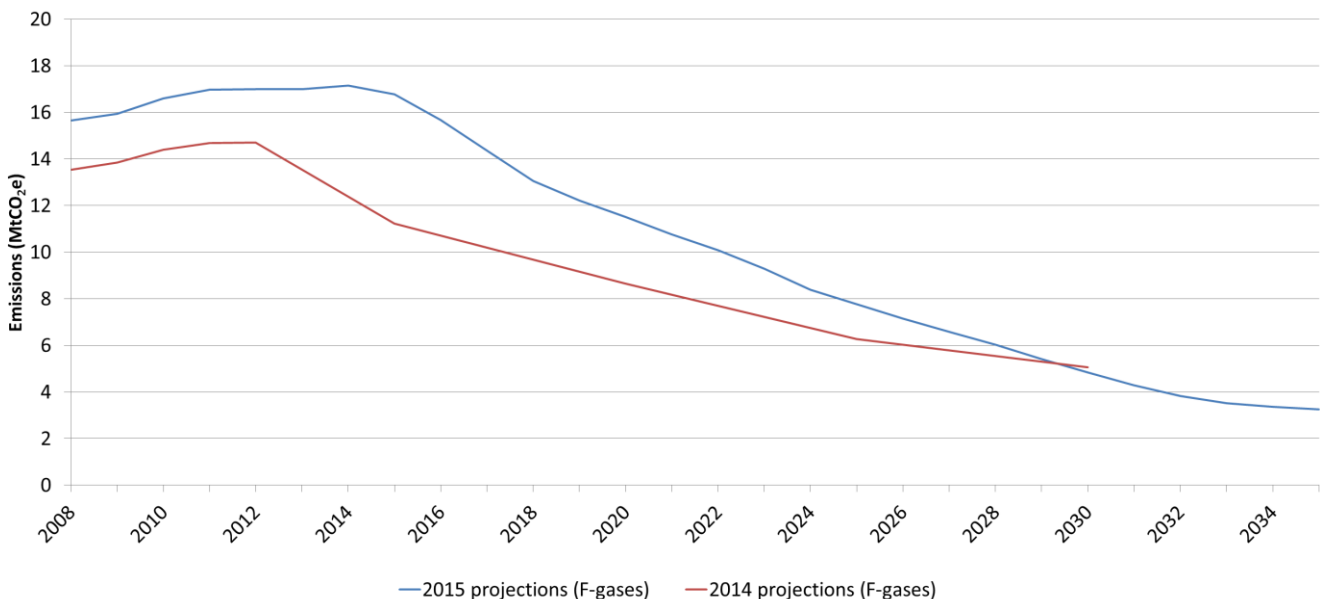
- **Primary aluminium production** – We now know the effect of all the recent abatement measures applied and we expect no further abatement so project constant emissions from aluminium production. Last year we had to estimate the effect of abatement.
- **Magnesium cover gas** – We project magnesium emissions 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.
- **Production of Halocarbons** - We project HFC emissions based on (i) short term company planning information and (ii) long term replacement of F-gases due to the 2014 EU F-gas regulation. We project PFC emissions to be constant, equal to the 10 year average as there is no discernible trend.
- **Metered Dose Inhalers** – Emissions are exempt from the 2014 EU F-gas regulation and we project emissions using population growth (**ONS, 2012**) as the driver.
- **Aerosols** – We project sector growth to be zero, in line with the trend in recent years, and model the gas bans and phase down resulting from the 2014 EU F-gas regulation.
- **Refrigeration & Air-conditioning** - We use the same model as used for the historical emissions calculation. Then interpreting the 2014 EU F-gas regulation, we assume that leakage rates reduce and the HFC mix changes. This model has been reviewed and updated in 2015 by F-gas sector experts.
- **Foams** - We recreate an EU level foam emissions model (**Schwarz et al 2011**) and constrain it to UK data. Then we model the gas bans and phase down resulting from the 2014 EU F-gas regulation.
- **Firefighting** – We use the same model as used for the historical emissions calculation and assume that both leakage rates reduce and consumption also reduces in line with the phase down due to the 2014 EU F-gas regulation.
- **Solvents** - We project sector growth to be zero, in line with the trend in recent years, and model the phase down resulting from the 2014 EU F-gas regulation.

- **High voltage switch-gear (SF₆)** – We project sector growth based on expert advice which is in line with **Schwarz et al (2011)**, assuming continuing decreasing leakage due to the 2006 EU F-gas regulation.
- **Electronic manufacture (HFCs / PFCs / SF₆ / NF₃)** - Project constant emissions due to limitations in the historical data. This will be investigated in the coming year.
- **AWACS (SF₆)** – Project constant emissions in line with historical data.
- **Training shoes (PFCs / SF₆)** – Project a reduction to zero from 2014 onwards. Manufacturing ceased many years ago and the only emissions were from disposal.
- **Particle accelerators (SF₆)** - Emissions are very small and are projected to be constant.
- **Tracer gas (SF₆)** – Project a reduction to 1 kilotonne CO₂e (ktCO₂e) in 2014 and constant thereafter following expert guidance.

Projected emissions

Overall emissions from F-gases are projected to be 3.2 MtCO₂e in 2035, representing a reduction of 81% between 2013 and 2035 (Figure 4.1). F-gases would then only represent 5% of non-CO₂ emissions in 2035. This significant reduction is caused by the various requirements of the 2014 EU F-gas regulation, particularly the specified phase down in F-gas sales and F-gas bans. The major changes from last year’s projections (Figure 4.2) are (i) a higher baseline due to updated GWPs and methodology in the GHGI and (ii) a later peak in emissions, but then a faster decrease. This latter change results from fully incorporating the effects of the 2014 EU F-gas regulation in these projections. The previous projections had overestimated how quickly the regulation would take effect.

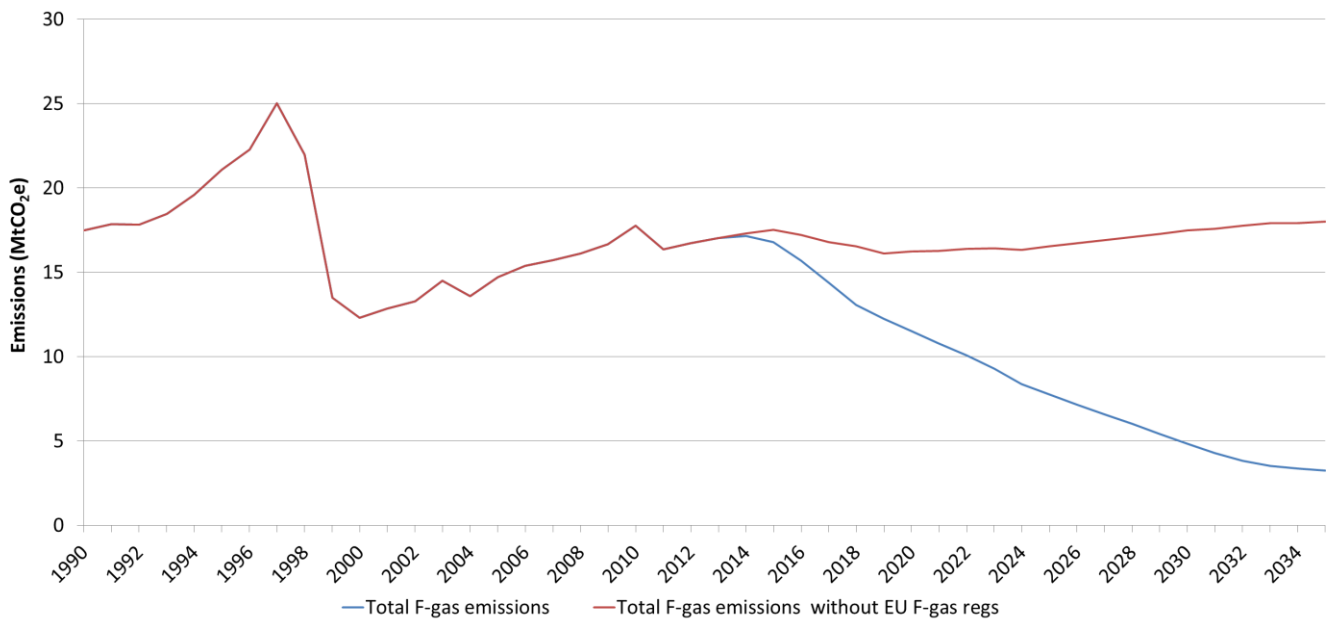
Figure 4.2 Comparison of 2014 and 2015 F-gas emissions projections for the industrial processes, business and residential sectors



Effect of the EU F-gas regulation

The projected effect of the new EU F-gas regulation on UK F-gas emissions is shown in Figure 4.3 below. The projected savings are in the region of 15 MtCO₂e by 2035. The EU state that the regulation should reduce EU F-gas emissions by around two thirds by 2030 (**EU, 2015**) and our UK projections suggest a 70% reduction over the same time period. There is therefore is broad similarity between the UK and EU level F-gas projections, though they are not identical given the different scopes.

Figure 4.3 UK F-gas emission projections from 1990 – 2035



5. Industrial Processes, Residential & Business (CH₄ / N₂O)

Historical emissions

CH₄ and N₂O emissions in the industrial processes, business & residential sectors total 0.63 MtCO₂e which represents 0.7% of non-CO₂ emissions within the scope of this report in 2013. This is a significant reduction on 1990 levels when they represented 12.2% of non-CO₂ emissions.

Nitrous oxide emissions from nitric acid and adipic acid production have historically been a significant contributor to emissions, producing 12% of the UK's total non-CO₂ emissions in 1990. However, following plant closures (no adipic acid production facilities remain) and the adoption of improved abatement technology, these emissions have decreased significantly.

In recent years, N₂O emissions from industrial off-road machinery have been the dominant CH₄/N₂O emission source in the industrial processes, business & residential sectors, representing 81% of those emissions. However, emissions have been decreasing since 2008 due to a falling N₂O emission factor and decreasing activity following the recession.

There are a number of other small sources of emissions in these sectors:

- Fletton brick manufacture CH₄ emissions are very small and have been relatively well correlated with the number of manufacturing plants in operation over the period. The closure of the last plant to burn coal in 2008 was the most notable event.
- Household composting CH₄ / N₂O emissions have risen continually since 2004, though emissions are still very small.
- Accidental fires CH₄ emissions are very small and have decreased gently since 1990, though they have levelled out more in recent years.
- Anaesthetic use has historically produced very small and constant N₂O emissions.
- House & garden machinery CH₄ / N₂O emissions have decreased due to a falling CH₄ emission factor which dominates over the increase in machinery usage.

How we project emissions

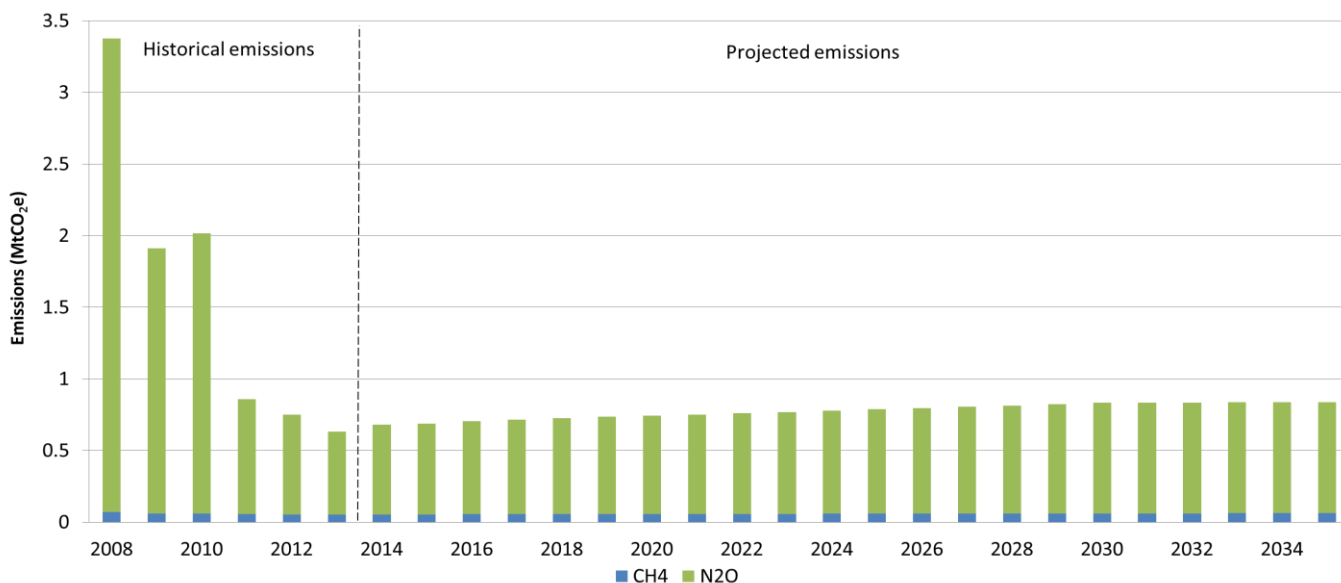
- **Industrial machinery (CH₄ / N₂O)** - Activity data is projected using 2015 EEP industrial economic drivers and emission factors are projected by a simple vehicle turnover model.
- **House & garden machinery (CH₄ / N₂O)** - Activity data is projected using projected household numbers from DCLG (**DCLG, 2012**) and emission factors are projected by a simple vehicle turnover model.
- **Nitric acid production (N₂O)** – We now project nitric acid emissions using the Chemistry Growth Strategy Group baseline scenario for chemical sector growth, an annual 1.7% increase (**CIA, 2013**). This was following consultation with the Environment Agency chemicals sector leads who also expect a growth in overall chemical production. This is a change from last year's projections when we assumed constant emissions.
- **Fletton brick manufacture (CH₄)** – We now project Fletton brick emissions using a simple 1:1 scaling with the 'Construction and Other Manufacturing' economic index from the 2015 EEP. This is to move in line with the EEP and is a change from last year's projections when we assumed constant emissions.

- **Household composting / Accidental fires / Anaesthetic use (CH₄ / N₂O)** – New, small emission sources in this year’s GHGI which we project to be constant.

Projected emissions

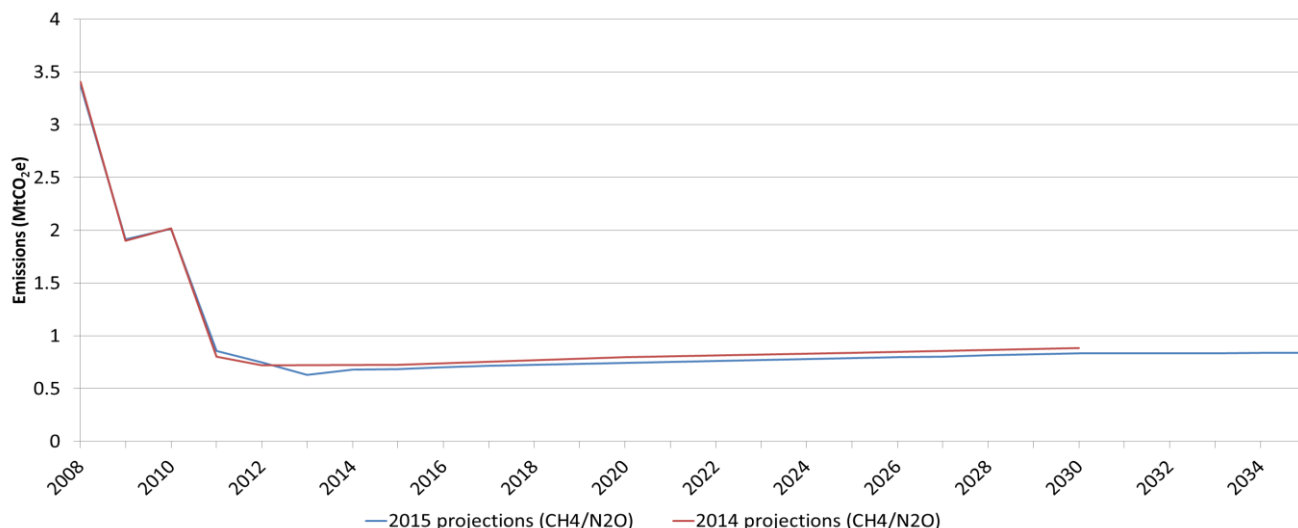
Methane and nitrous oxide emissions from the industrial processes, business & residential sectors are projected to be 0.8 MtCO₂e in 2035 which would represent 1.2% of all non-CO₂ emissions. This is an increase in emissions of 33% between 2013 and 2035. However as can be seen in Figure 5.1, the absolute increase is projected to be relatively small and emissions will remain well below 2010 levels. This is because for most major CH₄/N₂O sources in this sector, major abatement is expected to have already occurred and activity is driven by the economy which is expected to grow.

Figure 5.1 – CH₄ and N₂O emissions projections for the industrial processes, business and residential sectors



The small change from last year’s projections shown in Figure 5.2 is due to updating GDP forecasts and inventory changes.

Figure 5.2 Comparison of 2014 and 2015 combined CH₄ and N₂O emissions projections for the industrial processes, business and residential sectors



6. Energy

Historical emissions

The energy sector emissions covered in this report are fugitive emissions, i.e. due to leakage, and they are all methane. The energy sector emissions relating to combustion are covered in the EEP ([DECC, 2014](#)). In 2013, fugitive energy sector emissions were 6.0 MtCO_{2e}, representing around 6% of the UK's non-CO₂ emissions within the scope of this report. 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 CH₄ source in the GHGI outside of the agriculture and waste sectors, comprising approximately 8% of all CH₄ emissions in 2013. Methane emissions from deep mined coal also make a significant contribution. Both sources combined comprise around 86% of non-CO₂ emissions from the energy sector in 2013. Closed coal mine CH₄ emissions are the third most significant source in this sector. Historically, energy sector non-CO₂ emissions have decreased by approximately 25 MtCO_{2e} since 1990 with this being predominantly as a result of a programme to fix leaks in the gas distribution network, and decreasing coal mining activity.

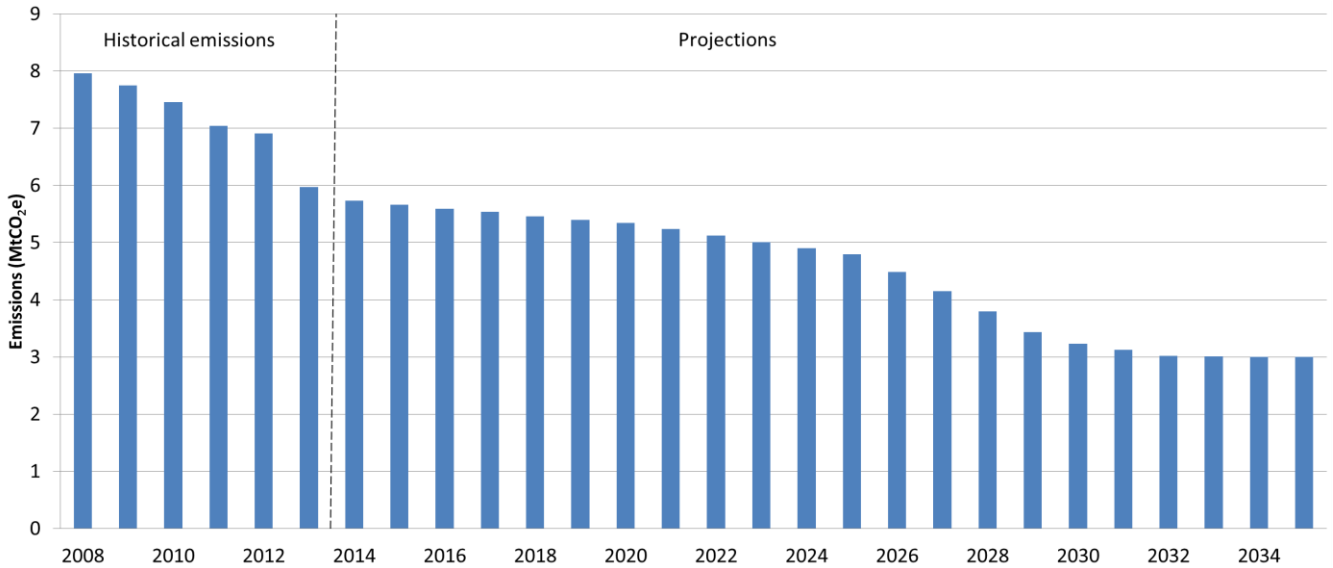
How we project emissions

- **Closed coal mines (CH₄)** – A model developed by WSP in 2011 ([WSP, 2011](#)) is used 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 2014 to reflect more recent information on the closure dates of some mines. We also now use direct model outputs rather than rebaselining older model outputs.
- **Coal mining (CH₄)** – We project coal mining emissions based on internal DECC UK coal production projections and these projections have been updated since the last publication. We expect the overall projected downward trend to be reliable, although the exact shape of this decline is subject to significant uncertainty.
- **Charcoal/coke/solid-smokeless fuel production (CH₄)** – These are very small sources of emission. Emissions from charcoal and solid-smokeless fuel production are projected to be constant in line with last year's projections. Coke production is now projected using a driver from the 2015 EEP representing coal consumed by the iron and steel industry. The historical fit is very good.
- **Gas supply leakage (CH₄)** – Emissions reduction is driven by a 30 year programme to replace the gas distribution network ([HSE, 2011](#)). In 2012, OFGEM set gas distribution network leakage targets as part of the roll-out of a new price control period (Apr 2013 - Mar 2021) ([OFGEM, 2012](#)). This equated to an emissions reduction of approximately 20%. These targets were linearly extrapolated out to 2032 and then set as constant post 2032. These targets form the long term emission projections. In the short term the projections are revised downwards to reflect the faster progress than stipulated by targets. The same reductions were assumed to apply to gas transmission leakage. We now use direct model outputs rather than rebaselining older model outputs.

Projected emissions

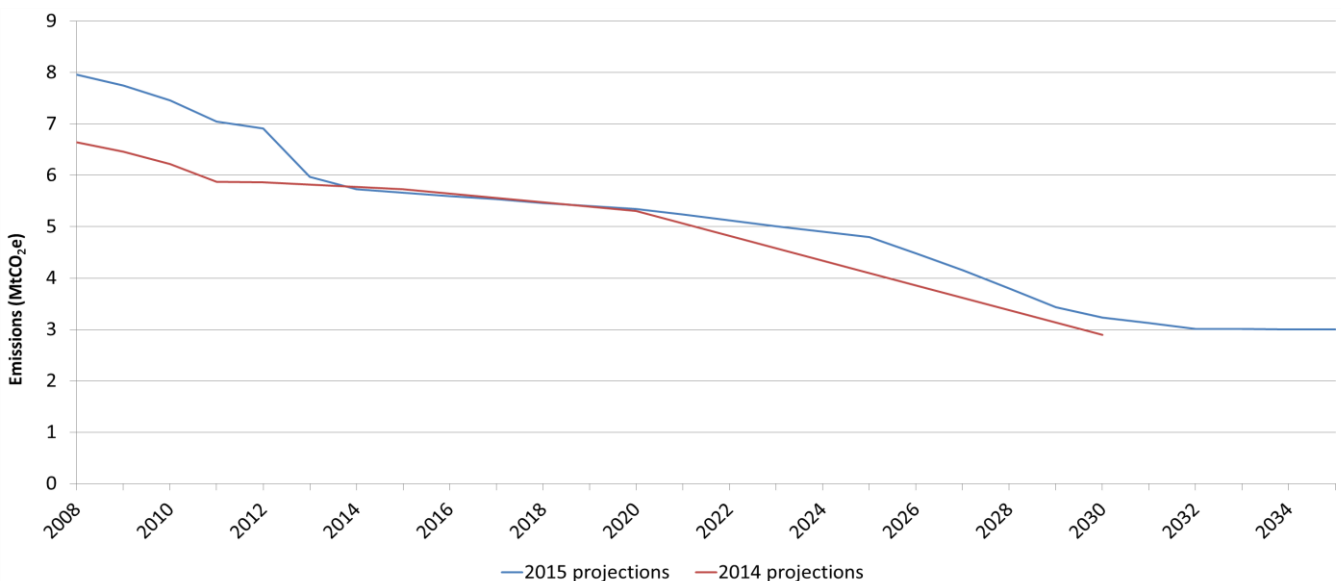
Overall emissions from the energy sector are projected to be 3.0 MtCO₂e in 2035 which would represent 4% of all non-CO₂ emissions. This corresponds to a decrease in emissions of 50% between 2013 and 2035 (Figure 6.1). This is predominantly due to reduced emissions from natural gas leakage and deep mined coal, with a smaller contribution from reductions in emissions from closed coal mines and coal storage & transport.

Figure 6.1 – CH₄ emissions projections for the energy sector



Historical emissions have increased since last year due to the increased methane GWP. This can be seen in the period up to 2013 (Figure 6.2). However, projected emissions have not increased, as the GWP increases are cancelled out in the short term by changes to the coal production projections and in the long term by changes to the modelling for gas leakage and closed coal mine emissions. The change to the coal projections results from a smaller baseline in this year’s update, which defines the short/medium term constant coal projections. In the longer term our coal projections roughly converge with last year’s assumptions. Finally, the extension out to 2035 is fairly flat due to the gas supply network replacement programme having ended.

Figure 6.2 – Comparison of 2014 and 2015 emission projections for the energy sector



7. Waste

Historical emissions

In 2013, waste sector emissions were 22.2 MtCO₂e, representing 23% of the UK's non-CO₂ emissions within the scope of this report. The major source of emissions from this sector is CH₄ from landfill sites, which produce around 17% of all non-CO₂ emissions. CH₄ and N₂O emissions from wastewater treatment make up most of the remaining waste emissions. There are also small contributions from Biological Waste Treatment (BWT) processes and waste incineration plants without energy recovery. The latter burn waste outside of the normal waste stream, such as clinical and chemical waste. Incineration of waste with energy recovery is reported in the EEP ([DECC, 2014a](#)).

Landfill emissions have decreased significantly since around 2000 when the Landfill Directive was introduced which 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 historically. Emissions from BWT processes - composting, anaerobic digestion and mechanical biological treatment – have been rising and composting is the biggest emission source of the three.

This year there were GHGI methodological improvements to landfill emission calculations relating to methane formation, flaring treatment, decay rates and landfill gas engine efficiency. This led to higher emissions and a steeper reduction in emissions. Emissions from wastewater also involved some significant methodology changes leading to increased emissions, particularly for industrial wastewater. The net effect of changes to the GHGI was a 21.9 MtCO₂e increase in waste emissions in 1990, and a 4.5 MtCO₂e increase in 2012.

How we project emissions

- **Landfill (CH₄)** – Tonnages of waste to landfill projections are provided by Defra (municipal waste) and HMRC (commercial & industrial waste). We project composition from the changes to BWT processes and Defra projections of waste arisings. These projections of waste to landfill are then run through MELMod ([Eunomia, 2010](#)), the landfill emissions calculation model. MELMod is based on the first-order decay Intergovernmental Panel on Climate Change (IPCC) methodology, and is summarised in the 2014 GHGI report ([DECC, 2014b](#)).
- **Wastewater treatment (CH₄ / N₂O)** – Domestic wastewater emission projections are driven by ONS population projections ([ONS, 2012](#)), although note that work is being done to better project the emission factor. Industrial wastewater emissions are projected to be constant due to a severe lack of data.
- **BWT (CH₄ / N₂O)** – We linearly extrapolate the previous 5 year trend in the time series out to 2020 using linear regression. We then assume constant emissions post 2020 as there is no policy in place post 2020.
- **Incineration without energy recovery (CH₄ / N₂O)** – We project constant emissions using the 5 year historical average.

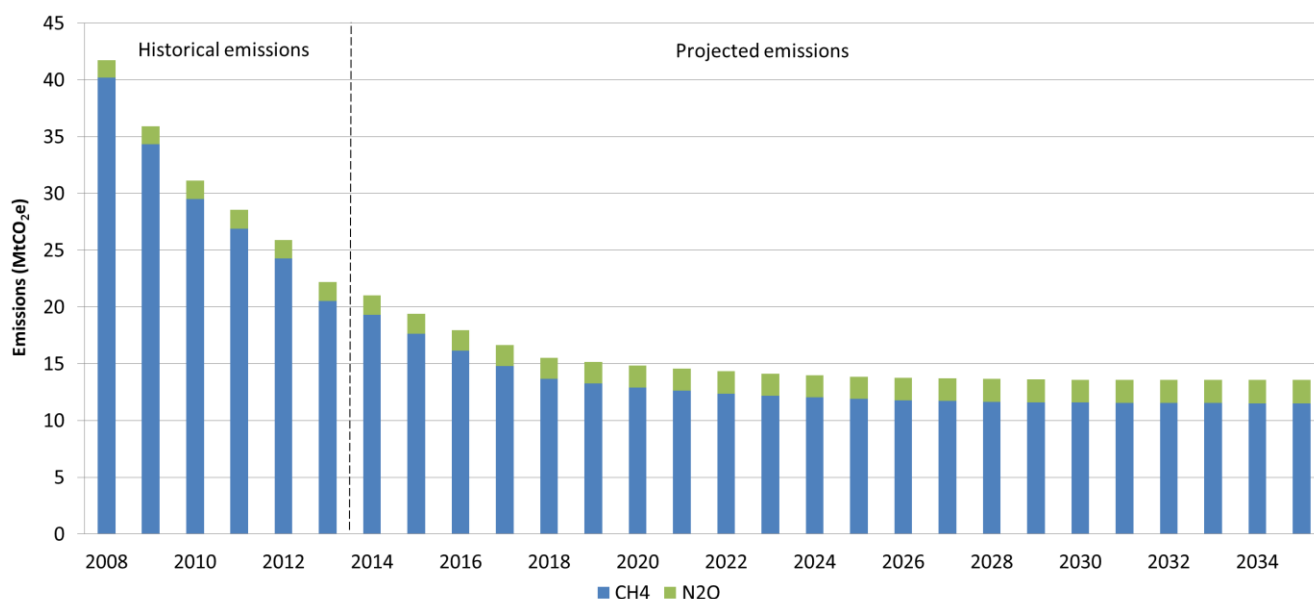
Projected emissions

Overall emissions from the waste sector are projected to be 13.6 MtCO₂e in 2035 which would represent 19% of all non-CO₂ emissions. This corresponds to a decrease in emissions of 38.9% since 2013 (Figure 7.1). This is caused by the continuing decrease in landfill emissions

as more waste is preferentially sent to alternative disposal routes (incineration, BWT and recycling) and small further improvements in landfill efficiency are made. The policy which partially drives this, the Landfill Directive, expires in 2020. Therefore the proportion of waste going to landfill stops decreasing post 2020, although emissions reductions continue as landfill emissions are lagged behind disposal. Partially counteracting the decrease in landfill emissions are increases in BWT emissions and domestic wastewater emissions.

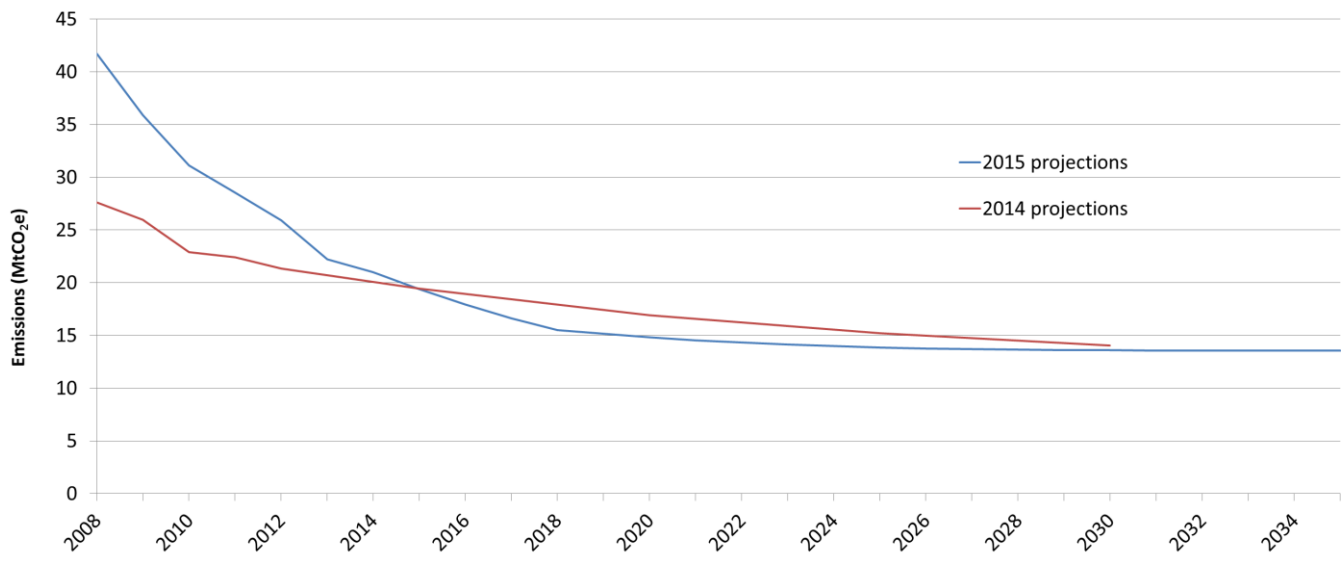
The EU Commission are due to publish their Circular Economy Package later this year which is expected to include further measures to reduce the amount of waste going to landfill after current targets for 2020. Any proposals in this package may therefore need to be considered for future projection updates.

Figure 7.1 – CH₄ and N₂O emissions projections for the waste sector



As noted above, there have been large changes to the historical landfill emissions methodology which led to both higher emissions and a steeper reduction in emissions. This feature can be clearly seen in the overall waste emissions comparison in Figure 7.2. However, this is partially balanced by (i) the new BWT sources which show an increasing emissions trend and (ii) changes to the methodology used in the wastewater inventory calculations which led to significant increases across the time series.

Figure 7.2 – Comparison of 2014 and 2015 emissions projections for the waste sector



8. Agriculture

Historical emissions

In 2013, agriculture sector emissions were 48.2 MtCO₂e, representing 50% of the UK's non-CO₂ emissions within the scope of this report. Agriculture emissions result from (i) enteric fermentation from livestock, (ii) manure management and (iii) agricultural soils. The two biggest sources are CH₄ from enteric fermentation in cattle and N₂O from fertiliser use, which represent 19% and 17% respectively of the UK's total non-CO₂ emissions. CH₄ and N₂O 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.

There have been considerable changes in the GHGI model from that used in the previous year (1990-2012 submission), mainly due to the adoption of the IPCC 2006 Good Practice Guidance (IPCC, 2006). The guidance updates the equations, emissions factors and global warming potentials used in the inventory. There have also been improvements in the activity data for beef cattle live-weights and the distribution of manure management systems. The net impact of the change in activity data and the change in methodology has been (i) to increase the relative importance of methane over nitrous oxide and (ii) to reduce the overall emissions from the sector: by 7.2 MtCO₂e in 1990 and by 3.8 MtCO₂e in 2012.

How we project emissions

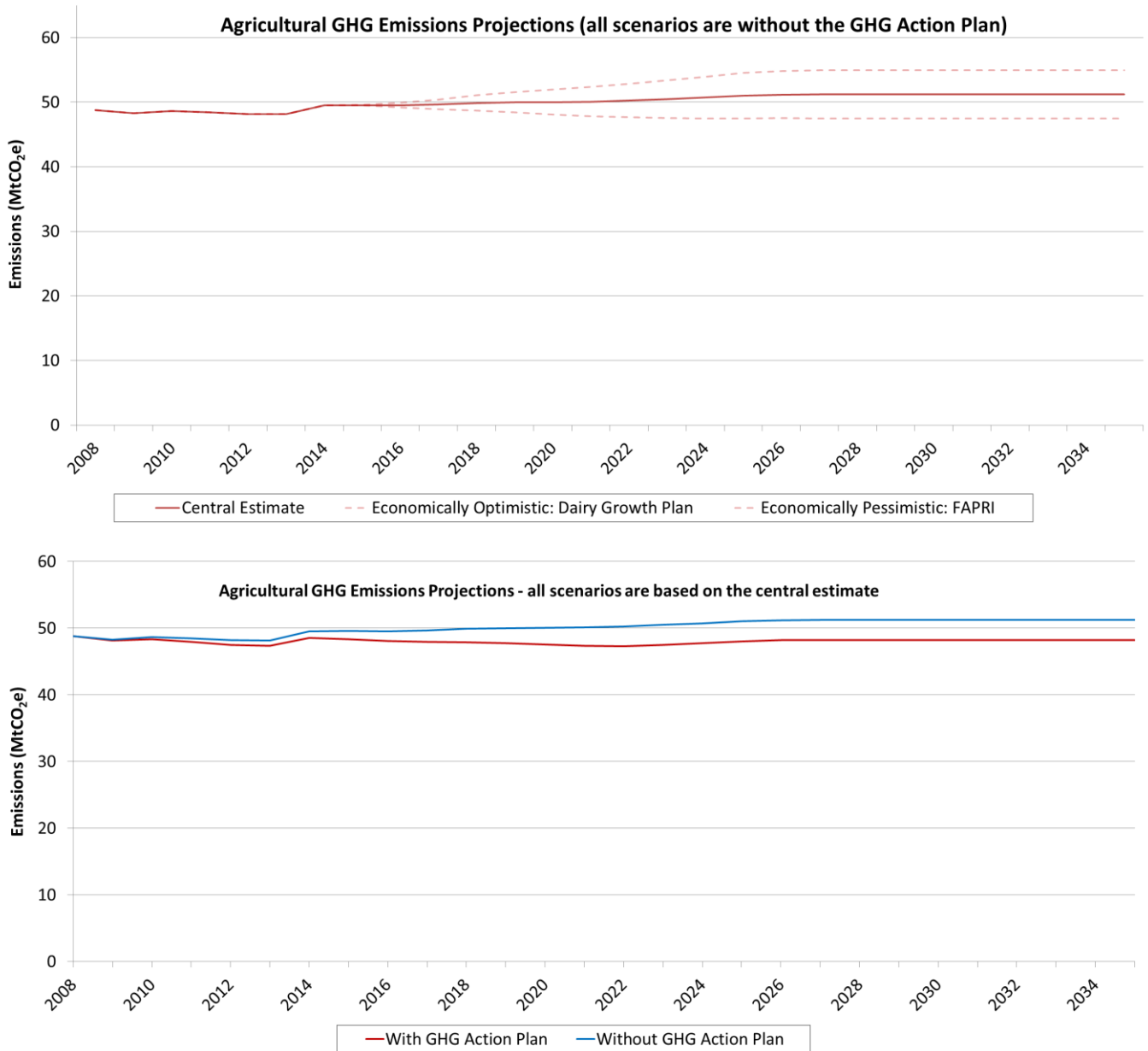
Activity data projections (livestock numbers, crop production, fertiliser N use) to 2030 (note that we flat line post 2030), were provided by Defra using the Food and Agricultural Policy Research Institute (FAPRI) methodology (FAPRI, 2010). The FAPRI projections are based on an economic model assuming a specific set of international prices for agricultural commodities and a particular path for the sterling exchange rate. Together these factors are important determinants of the returns to farmers and hence total agricultural production. The FAPRI activity projections are converted to agriculture emissions projections using the latest agriculture GHGI model.

Expert review of the FAPRI projections in Defra indicated that they could potentially be overly pessimistic for the dairy sector. This is due to an increasing global demand for livestock products, coupled with the removal of milk quotas in the EU; the UK has one of the most efficient milk production sectors in the EU and is well placed to satisfy increased demand. An alternative set of activity data projections was therefore established by Defra based on the British Dairy Industry's Sustainable Growth Plan (Dairy UK, 2014). The two sets of projections represent a plausible range of emissions under economically pessimistic or economically optimistic assumptions. A central projection that we use in these projections was then defined as the mid-way point between the economically pessimistic and optimistic projections of GHG emissions from 2014 to 2030. The effect of the Dairy Growth Plan on emission projections can be seen in Figure 8.1a

Since the UK agricultural inventory model does not currently capture mitigation it was necessary to adjust the GHG estimates for the impacts of existing mitigation policies. In particular the English agricultural industry's GHG Action Plan (NFU, 2011), which aims to reduce English agricultural emissions by 3MtCO₂e by 2022, has been included. Monitoring by Defra suggests that by 2014 the Action Plan had reduced emissions from English agriculture by 1MtCO₂e (Defra, 2014b) since its implementation in 2009. Note that we don't include Devolved Administration agriculture policy savings in these projections. The effect of the GHG Action

Plan on emission projections can be seen in Figure 8.1b. Note that the current GHGI is conservative, in line with IPCC best practice guidance, and so cannot currently account for mitigation. The GHGI improvement programme is currently addressing this.

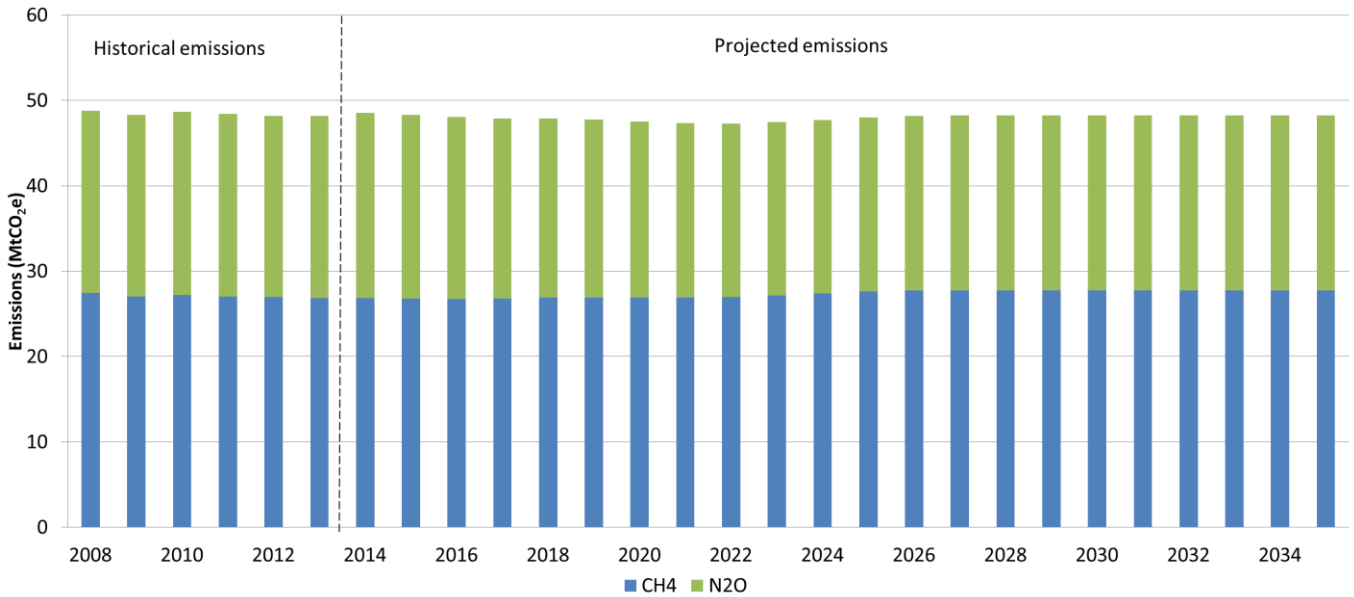
Figure 8.1 Agriculture emissions projections which demonstrates the effect of (a) the Dairy Growth Plan and (b) the GHG Action Plan



Projected emissions

Overall emissions from the agriculture sector are projected to be 48.2 MtCO₂e in 2035 which corresponds to almost zero net change since 2013 (a decrease in emissions of 0.1% - see Figure 8.2). However, there are opposing 3.4% increases in agriculture CH₄ emissions and 4.0% decreases in agriculture N₂O emissions. The increase in CH₄ emissions is partially caused by the growth in the dairy industry, while the decrease in N₂O emissions is caused by a reduction in total UK fertiliser due to a small reduction in arable area, as well as significantly reduced application rates to grasslands through better nutrient advice. Given projected emission decreases in other sectors, agriculture emissions are projected to represent 68% of all non-CO₂ emissions by 2035.

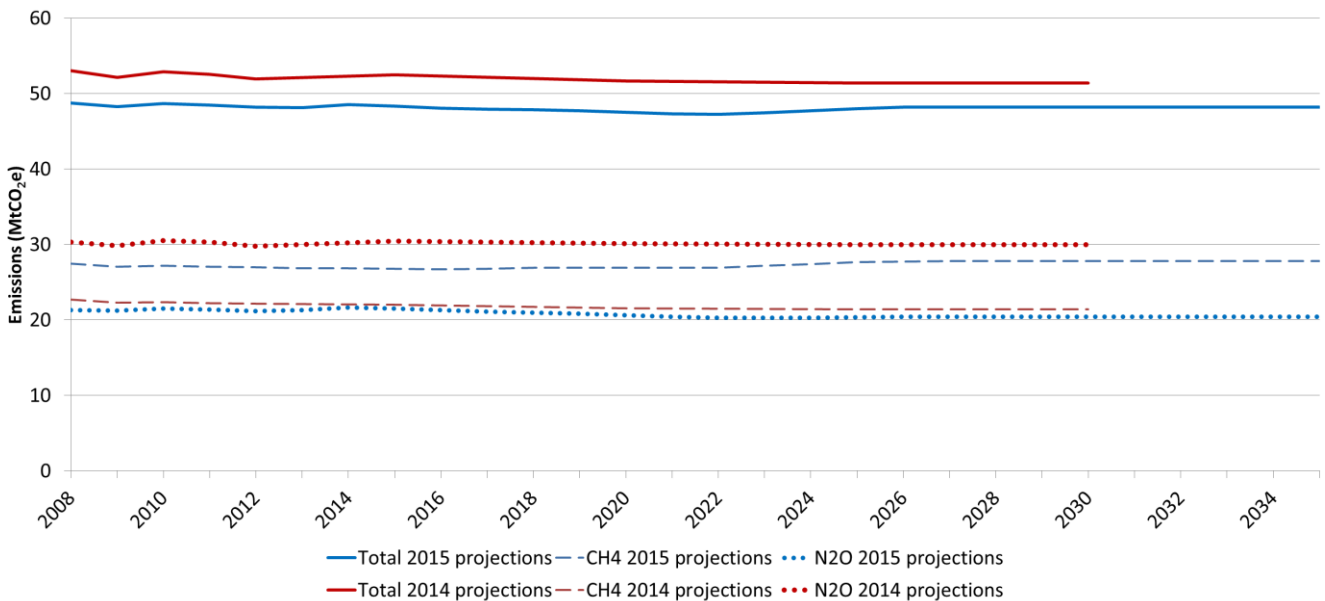
Figure 8.2– CH₄ and N₂O emissions projections for the agriculture sector



As noted above, there have been large changes to the historical agriculture emissions due to changes in the GHGI model. This has led to significantly higher CH₄ emissions and significantly lower N₂O emissions across the time series (Figure 8.2). There is also little change in the projections trend, however this masks the changes that have occurred this year:

- There has been little change in the FAPRI activity projections.
- The Dairy Growth plan has increased emissions projections and the GHG Action Plan has decreased emissions projections. However, they have had roughly cancelling effects. Note that while the GHG Action Plan was not included in last year’s non-CO₂ projections, it did appear in DECC’s Energy & Emissions Projections publication (DECC, 2014a).

Figure 8.3 – Comparison of 2014 and 2015 (i) CH₄, (ii) N₂O and (iii) combined CH₄ / N₂O emissions projections for the agriculture sector.



9. Transport

Historical emissions

In 2013, transport CH₄ and N₂O emissions were 1.1 MtCO₂e, representing 1% of the UK's non-CO₂ emissions within the scope of this report. Note that non-CO₂ is a very small fraction of all transport emissions.

- The major contributor is road transport N₂O emissions, representing 86% of non-CO₂ transport emissions. These emissions had been falling since the mid-1990s, though have started to increase since 2010. This is due to the upward trend in diesel emissions just beginning to take over from the downward trend in petrol emissions.
- CH₄ road transport emissions, which represent 5.2% of non-CO₂ transport emissions, have been decreasing due to increasing European standards on emissions from new road transport vehicles.
- Aircraft support vehicles, which represent 5.4% of non-CO₂ transport emissions, have been on an upward trend with the exception of a dip after the recession.
- The remaining transport emissions are from domestic aviation and military vehicles. See Section 1.2 for an explanation of the transport emission sources in scope here.

How we project emissions

Road transport emissions projections follow a bottom up calculation methodology in line with that used to calculate the historical time-series of emissions. The activity data - vehicle distance travelled - is projected using 2015 DfT traffic forecasts ([DfT, 2015b](#)). The emission factors are projected with a vehicle fleet turnover model.

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 ([DfT, 2013a](#)). Military transport emissions are projected to be constant.

Projected emissions

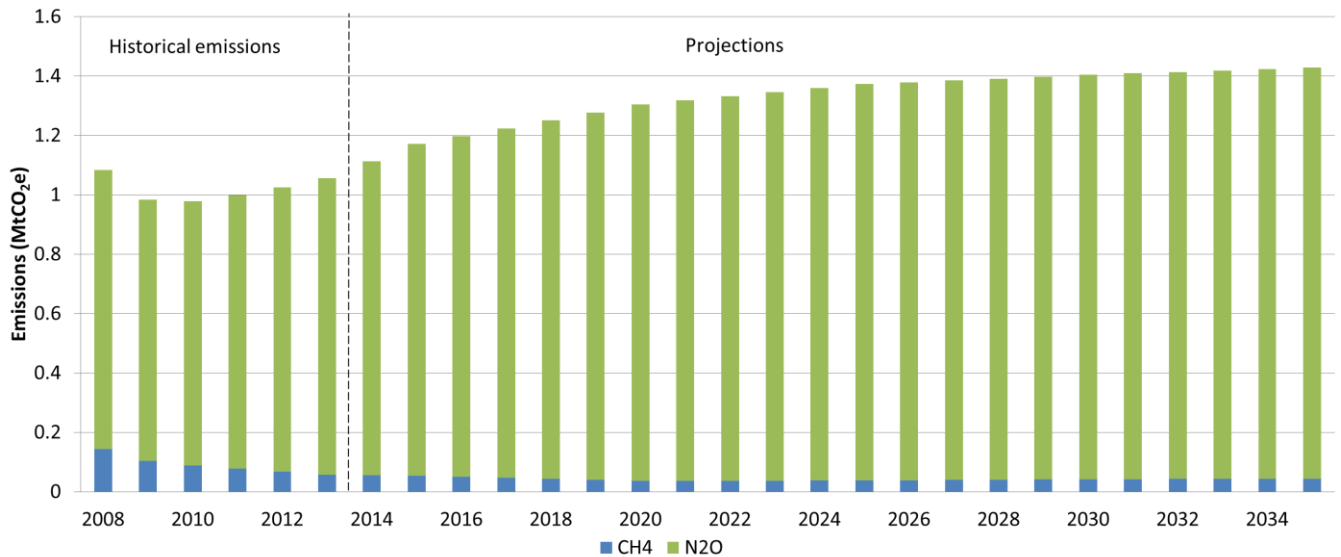
Overall emissions from the transport sector are projected to be 1.4 MtCO₂e in 2035 which would represent 2% of all non-CO₂ emissions. This corresponds to a 35% increase since 2013 (see Figure 9.1). This is largely caused by the continued increase in diesel road transport N₂O /CH₄ emissions due to a projected increase in diesel vehicle activity. The rise in road transport N₂O emissions is initially steep with accelerated penetration of the diesel car fleet, but then starts to level off after 2020 as the diesel car penetration becomes complete and the trend then becomes driven by the slower increase in overall vehicle activity. Emission factors for diesel vehicles remain unchanged since Euro 3 standards were introduced for cars and LGVs in 2000 and Euro IV standards for HGVs in 2005.

For petrol road transport N₂O /CH₄ emissions, the initial downward trend is mainly due to the continued penetration into the fleet of lower emitting vehicles, particularly petrol cars which dominate the road transport inventory. This is a consequence of the tighter European emission standards on total hydrocarbon emission introduced up to Euro 6/VI standards combined with increased penetration of lower emitting diesel cars in the new car fleet. Eventually the fleet

becomes completely refreshed with vehicles all meeting the latest Euro standard and with no further reductions in emission factors, emissions start to rise with increased vehicle activity.

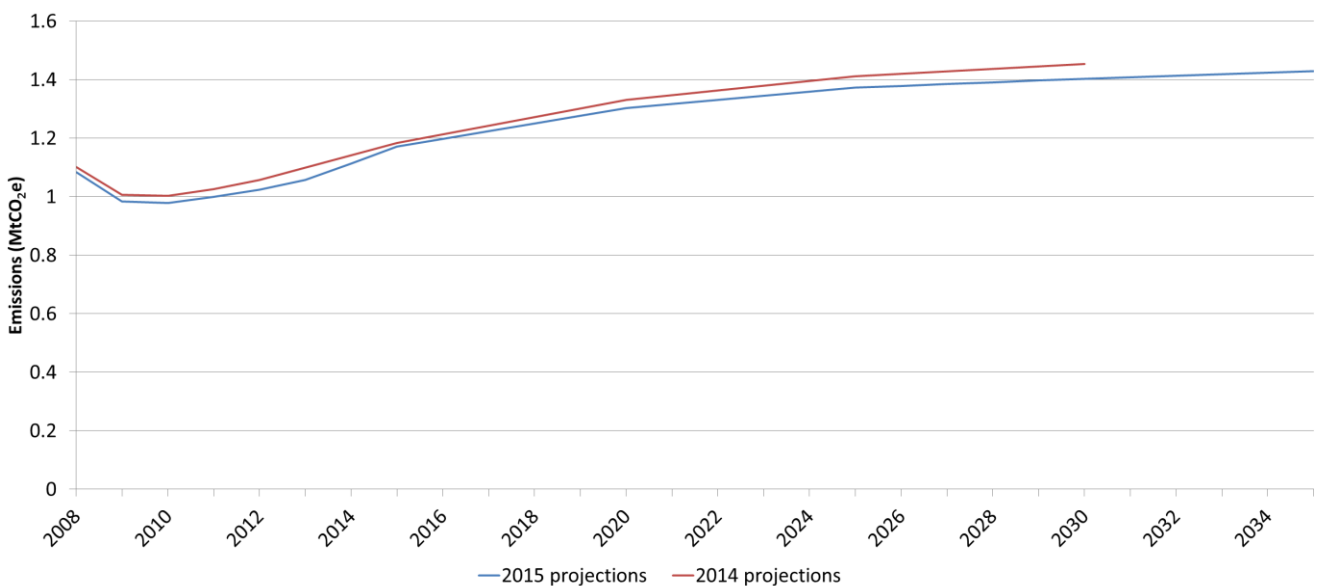
Aircraft support vehicle emissions are projected to continue to increase in line with the increase in passenger numbers and domestic aviation emissions are projected to increase in line with the increase in air traffic movements.

Figure 9.1– CH₄ and N₂O emissions projections for the transport sector



Since last year’s projections we have updated the DfT road traffic projections from their August 2013 forecasts (DfT, 2013b) to their March 2015 Central case (Scenario 1) (DfT, 2015b). The overall impact of this change is very small as seen in Figure 9.2. GHG Inventory changes, which were largely related to Global Warming Potential changes, caused a small decrease in the historical baseline that fed through to projections.

Figure 9.2 – Comparison of 2014 and 2015 emissions projections for the transport sector.



In their recent road transport forecasts (DfT, 2015b), DfT produced 5 different scenarios:

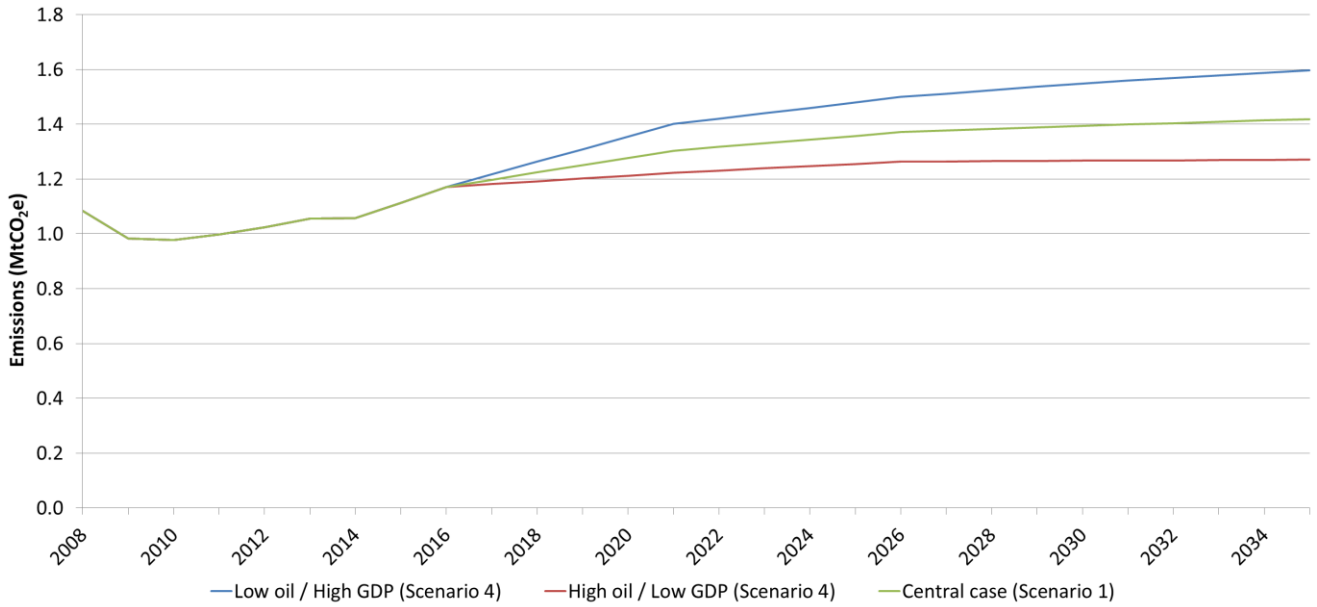
- One scenario is the central case that we use here.

Transport

- Two scenarios modified fundamental model assumptions regarding the relationship between income and car use, and the trend in trip rates.
- Two scenarios model the effects of high/low GDP/oil-price.

We present the effect of the latter two scenarios here on overall transport emission projections in Figure 9.3.

Figure 9.3 – Comparison of different DfT forecast scenarios on overall transport sector emission projections.



10. LULUCF

Historical emissions

It should first be noted that when considering all emissions (CO₂ and non-CO₂), the Land Use, Land Use Change and Forestry (LULUCF) sector is an emissions sink. However, the non-CO₂ component is a source of emissions. In 2013, LULUCF CH₄ and N₂O emissions were 0.7 MtCO₂e, representing 0.8% of the UK's non-CO₂ emissions within the scope of this report. The major contributor is direct N₂O emissions from nitrogen mineralization/immobilisation due to the disturbance of soil in land conversion. These represent 87% of non-CO₂ LULUCF emissions and have been on a downward trend since 1990. Other N₂O emissions are the result of drainage of organic soils, biomass burning and the application of nitrogen based fertiliser to forested land.

Methane is a comparatively small contributor to overall emissions from LULUCF, representing 4.8% of emissions in 2013. LULUCF emissions of CH₄ are driven by wildfires and deforestation through controlled burning. Both of these have large inter-annual variability.

There were some changes to inventory categories and calculation methodology following implementation of the IPCC 2006 guidance which led to slightly higher emissions.

How we project emissions

LULUCF emissions projections are produced by The Centre for Ecology & Hydrology (CEH) on the basis of assumptions applied to the current inventory methodology. Four scenarios (Business-As-Usual (BAU), high emissions, mid emissions and low emissions) are produced and the assumptions regard afforestation, wildfires, land use change and deforestation. The scenarios were developed by a policy maker stakeholder group and have been updated in 2015 following discussions with all of the UK administrations. Broadly, the mid emissions scenario is a continuation of current policies and activity rates; the low emissions scenario covers the most ambitious policy aspirations, focused on maximising climate change mitigation; and the high emissions scenario assumes a reduction in current activity levels (e.g. through removal of funding post-2020), with mitigation a lower policy priority. The BAU scenario assumes no new policy intervention since 2010.

Projected emissions

Overall emissions from the LULUCF sector are projected to be 0.8 MtCO₂e in 2035 which corresponds to an 11.6% increase since 2013 (see Figure 10.1). However this is largely an artefact of high wildfire emissions in 2012 causing the average value used in the projections to be comparatively high. The other projection trends net to roughly zero change.

There have been large changes since last year's projections which are largely a result of two changes to the 'with existing measures' scenario which we define in the non-CO₂ projections. The first is the inclusion of cropland to grassland rotation ('churn') which had previously only been included as an alternative scenario. The second is moving from the mid emissions scenario to the high emissions scenario. The high scenario has afforestation rates remaining the same as in 2013 until 2020, and then falling to reflect the lack of grant aid for planting after the end of the current EU Common Agricultural Policy period. There have also been some

LULUCF

smaller changes to projection assumptions including conversion to settlement land assumptions fully revised and the projections for wildfires being updated. The effect of all of the changes can be seen in Figure 10.2. A comparison of the four scenarios can be seen in Figure 10.3.

Figure 10.1– CH₄ and N₂O emissions projections for the LULUCF sector

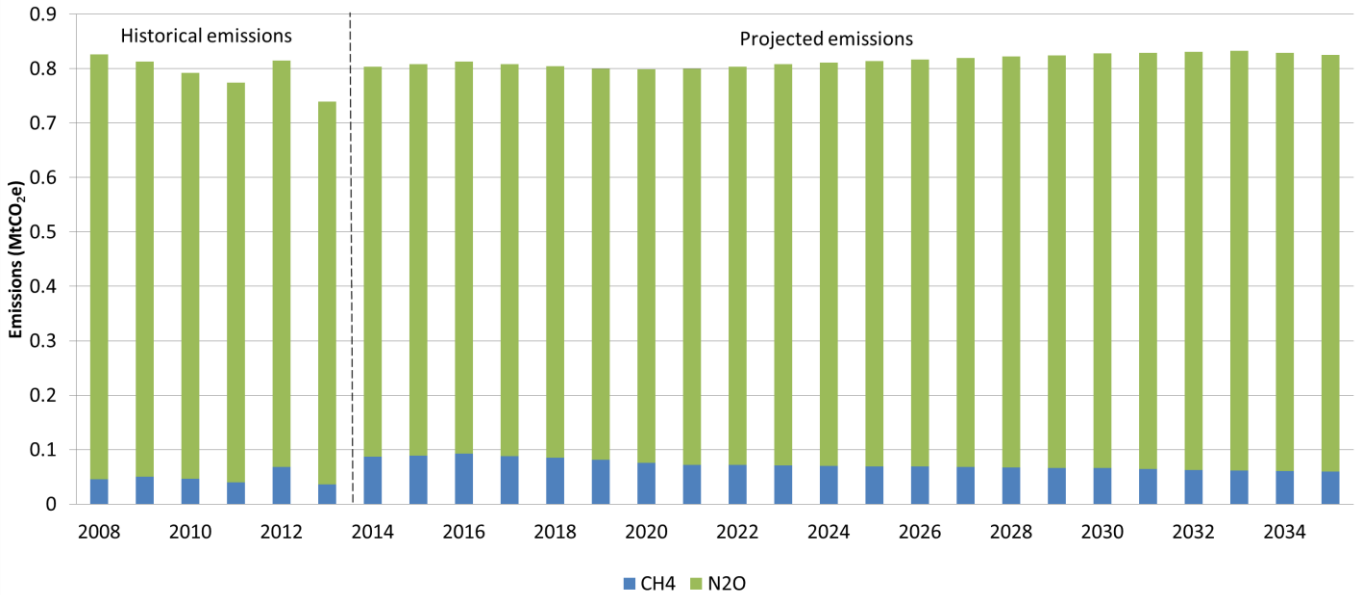


Figure 10.2 – Comparison of 2014 and 2015 emissions projections for the LULUCF sector.

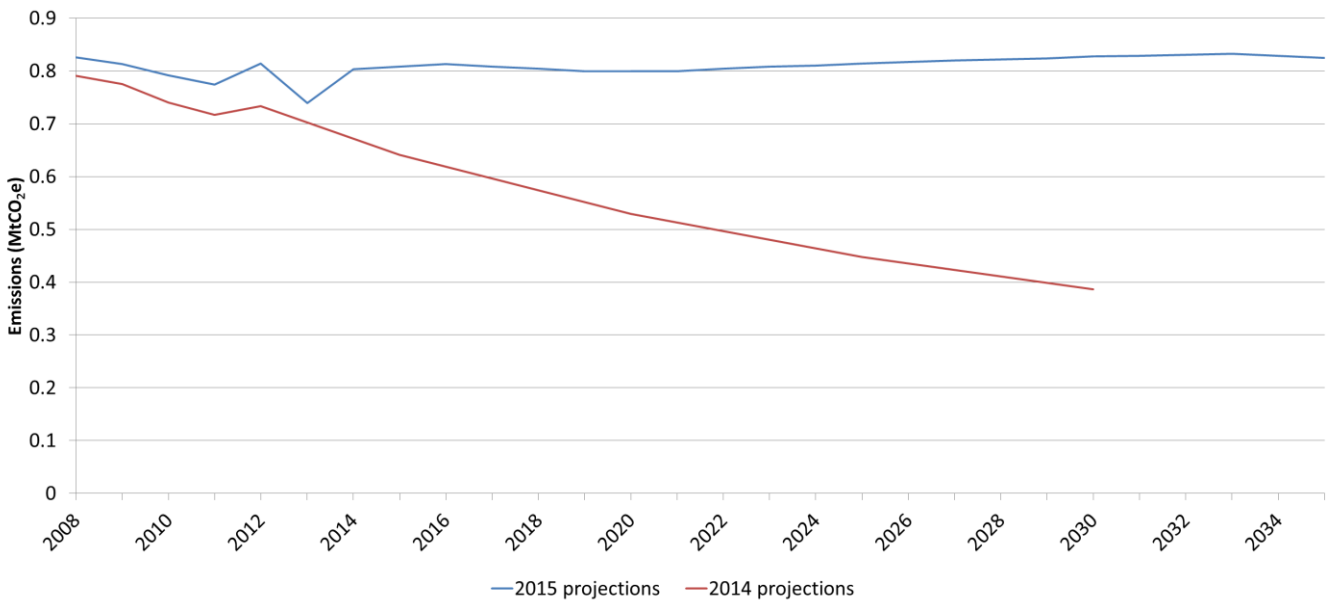
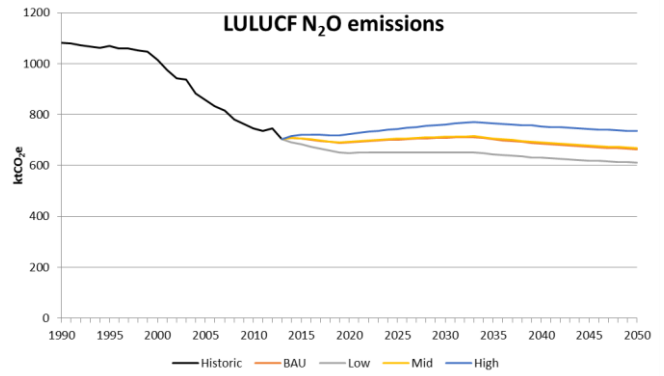
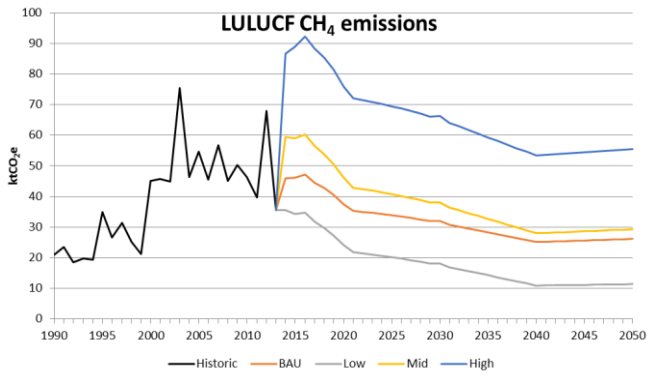


Figure 10.3 – Comparison of high, low, mid and BAU scenarios for the LULUCF sector. Note the difference in scales of the two Figures.



11. Uncertainties

Uncertainty analysis overview

The non-CO₂ emission projections presented so far have largely been central estimates, with the exception of transport, agriculture and LULUCF where we have presented alternative scenarios based on different assumptions. Scenarios are one way of presenting the uncertainty in a projection. Another method of presenting uncertainty is to produce a fan chart that shows the range of possible values of the projection in different ‘wedges’. We take the fan chart approach to present uncertainty in the overall projections.

It should be noted that the uncertainties we present here are uncertainties in the projection relative to zero initial uncertainty in 2013. This means that the uncertainties presented in projected years relate only to how different the GHGI estimate is likely to be to the projected estimate in that year, ignoring the uncertainty associated with the GHGI method. The reason for this approach is twofold. The first reason that GHGI uncertainties are significant and we want to separately present the projection uncertainties, which in some cases would be dwarfed by GHGI uncertainties. Table 3 shows the latest GHGI uncertainties ([DECC, 2015c](#)). The second reason is that revisions to GHGI methodology revisions can have a large impact on projections. These revisions are almost impossible to predict and so it is logical to present uncertainties in projections assuming that the historical baseline is fixed.

Table 3: GHG Inventory historical uncertainties

Gas	Historic GHGI uncertainty in 2013 (%)
CH ₄	19%
N ₂ O	58%
HFCs	9%
PFCs	25%
SF ₆	10%
NF ₃	47%

Uncertainty analysis methodology

To produce a fan chart showing the overall uncertainties in the projections we need to (i) define the uncertainty in the individual projections at a gas/sector level and (ii) combine these uncertainties to form the overall non-CO₂ emission projections uncertainty.

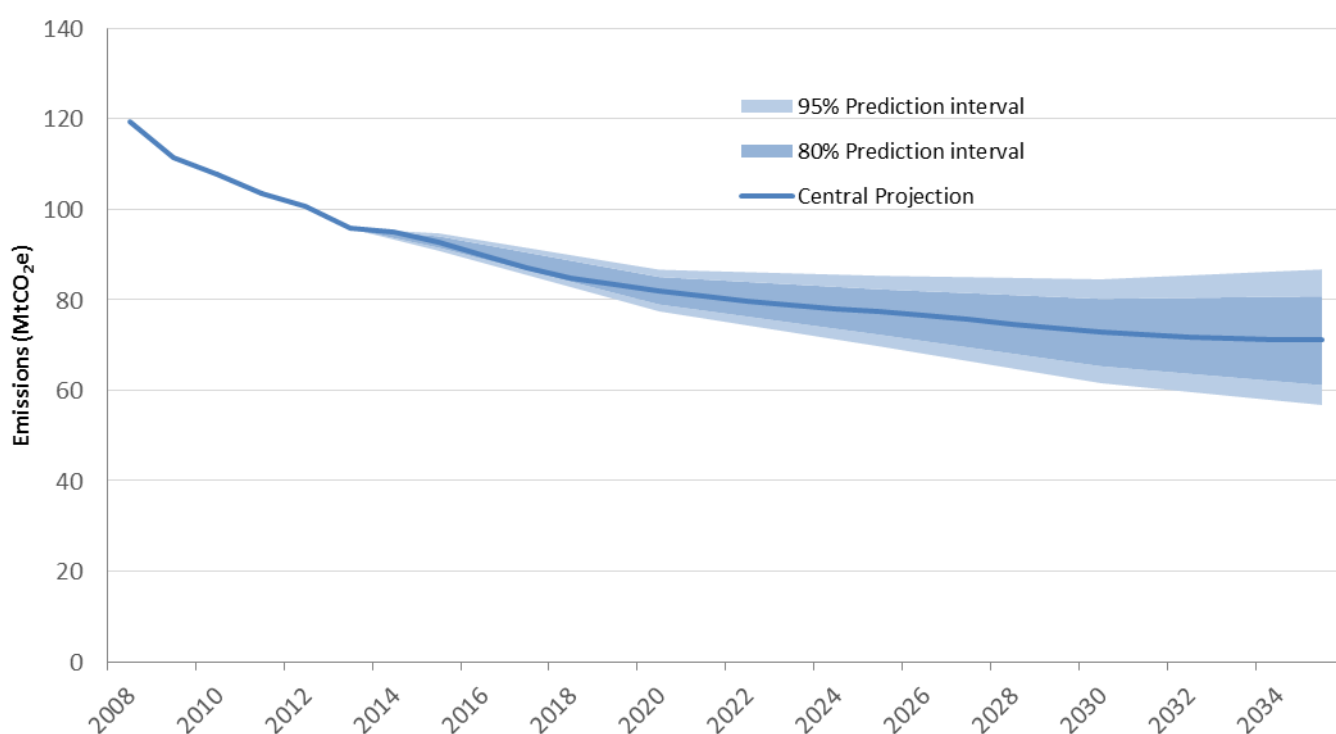
There are a number of ways to define the uncertainty in the individual projections at a gas/sector level. These include use of external forecasts with defined confidence intervals, scenarios and expert judgement. We have used a combination of these methods.

There are also different methodologies that can be used to combine the individual projections uncertainties. We will present three here. The first is the numerical approach used last year and the other two are analytical approaches. In all approaches we assume that the uncertainties are distributed in a normal distribution. A limitation to all approaches is that

uncertainties are calculated every 5 years from 2015 to 2035 and are linearly extrapolated for intervening years. The central projection is not linear between the 5 year intervals and this leads to it not being in the centre of the uncertainty range for those years that fall within the 5 year intervals (this is particularly evident on the charts for the period 2016 to 2018). This is purely due to the limitations of the approach, and there is no evidence to suggest that the uncertainty range is actually asymmetric over this period. We will be investigating ways to improve our approach over the next year.

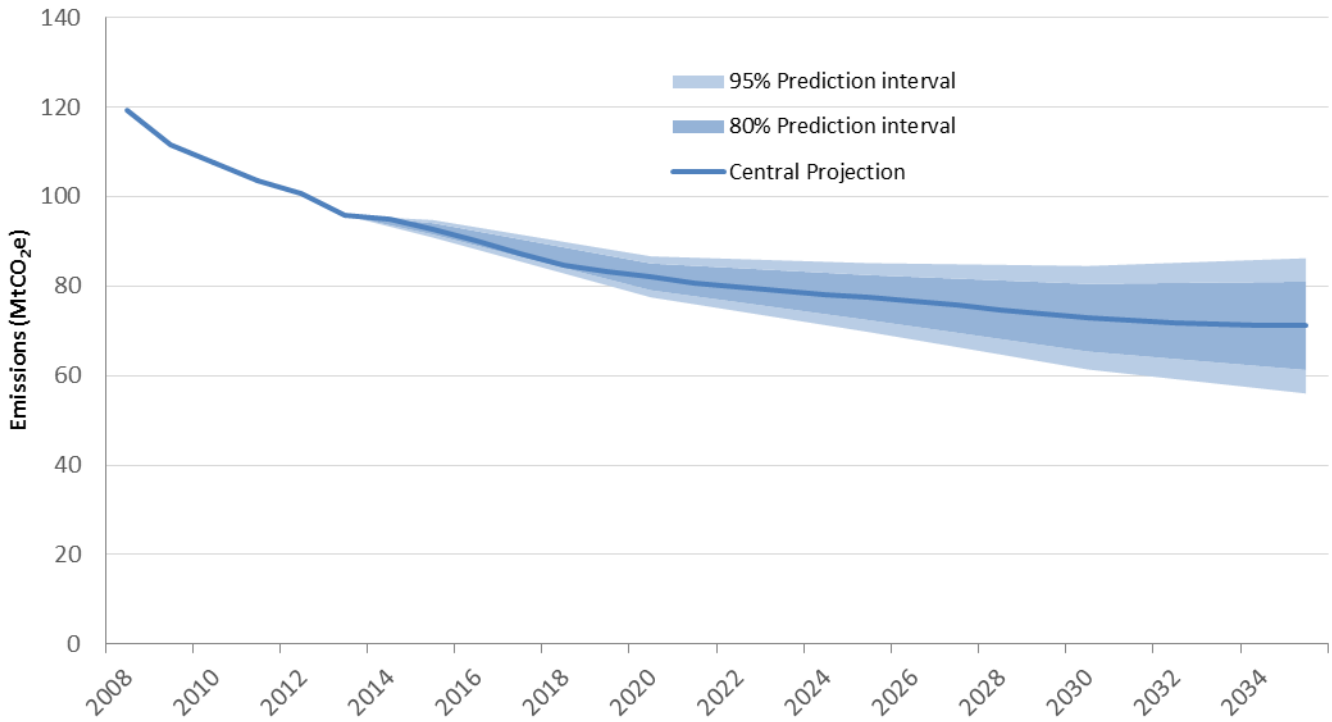
Last year's approach was to first convert the uncertainties to period to period uncertainties, i.e. the uncertainty on the growth (positive or negative) from one period to the next. These were used as an input for the Monte Carlo simulation which tracked emission paths from one period to the next. We have repeated this approach this year, again using the @Risk software. These results can be seen in Figure 11.1.

Figure 11.1 Uncertainty in the 2015 non-CO₂ projections using the numerical approach



An issue with this approach is that there are large assumptions involved in defining the uncertainties in the individual projections. While we define these inputs uncertainties as 95% confidence intervals, the reality is not that analytically robust. Therefore using a Monte-Carlo approach may then give a false sense of accuracy in the outputs. We have therefore developed an alternative analytical solution which is based on simply summing the uncertainties for the individual projections at each time period. This approach relies on the uncertainty distributions being normal, allowing a simple summing of the squares of the individual projection uncertainties. These results can be seen in Figure 11.2.

Figure 11.2 Uncertainty in the 2015 non-CO₂ projections using the analytical approach and assuming zero correlation between individual projection uncertainties



The two approaches followed so far have assumed zero correlation between input uncertainties which is very likely to be unrealistic. We have therefore applied an alternative version of the analytical approach which applies correlations between the input uncertainties. Results using a correlation of 0.5 for all uncertainties can be seen in Figure 11.3.

Uncertainty analysis results

The results derived using the analytical approach is very similar to those from the numerical approach as can be seen by comparing Figures 11.1 and 11.2. The one difference is that the numerical approach builds each uncertainty on top of the previous one which appears to introduce some positive asymmetry to the results, e.g. a 10% increase year on year for 5 years yields a 60% increase whereas a 10% decrease year on year for 5 years results in just a 40% decrease. However, the assumptions involved in defining the input uncertainties, which are not represented in these fan charts, are large enough that this small asymmetry effect should not be considered significant.

The results with a correlation of 0.5 shows a much greater spread of projections. This is to be expected because there is less cancelling out of positive/negative uncertainties. The true level of correlation will be much more complicated than assuming the same correlation between all input uncertainties. However the two approaches (correlation of 0 and 0.5) provide an idea of the possible spread of projections, given the defined input uncertainties.

We have labelled the ‘wedges’ on the fan charts as prediction intervals. However, it is important to note that the input uncertainties from which these are derived were not analytically robust enough to be able to call these true prediction intervals.

The main conclusion to derive from this uncertainty analysis is that there is significant uncertainty in the projections. We are not able to fully characterise this uncertainty, but that is a universal problem with forecasting uncertainties where there will always be large difficulties in defining the input uncertainties. This fact means that a single fan chart should not be considered the definitive description of uncertainty, although it can provide a useful guide. A summary of the prediction intervals in 2025 is provided in Table 4.

Over the next year we will revisit the formulation of input uncertainties and aim to link this work with uncertainties in DECC’s Energy and Emissions Projections ([DECC, 2014a](#)).

Figure 11.3 Uncertainty in the 2015 non-CO₂ projections using the analytical approach and assuming a correlation of 0.5 between individual projection uncertainties

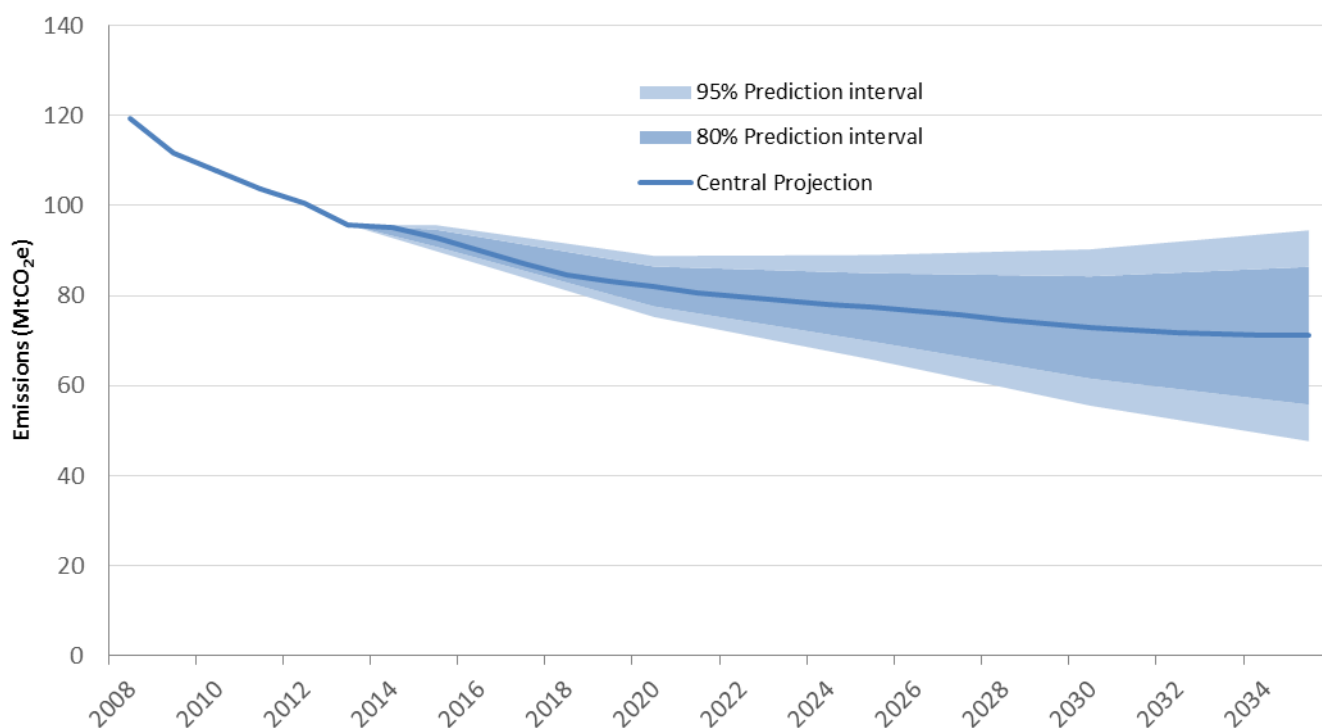


Table 4: Prediction intervals in 2025

Method	Prediction interval in 2025 (MtCO ₂ e)	
	80%	95%
Numerical	72 - 82	69 - 85
Analytical - correlation of 0	72 - 82	70 - 85
Analytical - correlation of 0.5	70 - 85	66 - 89

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