Projected emissions of methane, nitrous oxide and F-gases

A report to accompany the Autumn 2012 update to the UK's projections of non-CO2 Kyoto Protocol greenhouse gas emissions

14 September 2012

4. September 2012

Executive summary

This report presents the Autumn 2012 update to projections of methane, nitrous oxide and f-gases (non-CO2 greenhouse gases (GHG's)), the methodologies used to derive them and the associated uncertainties.

The following have been updated since the previous non-CO_2 projections (DECC, 2012a), hereafter referred to as 'the Spring 2012 update', was published:

- Projected emissions of methane and nitrous oxide from agriculture;
- Projected emissions of methane and nitrous oxide from road transport;
- Projected emissions of PFCs from the primary production of aluminium in the industrial processes sector;
- Projected emissions of methane and nitrous oxide from the waste management sector.
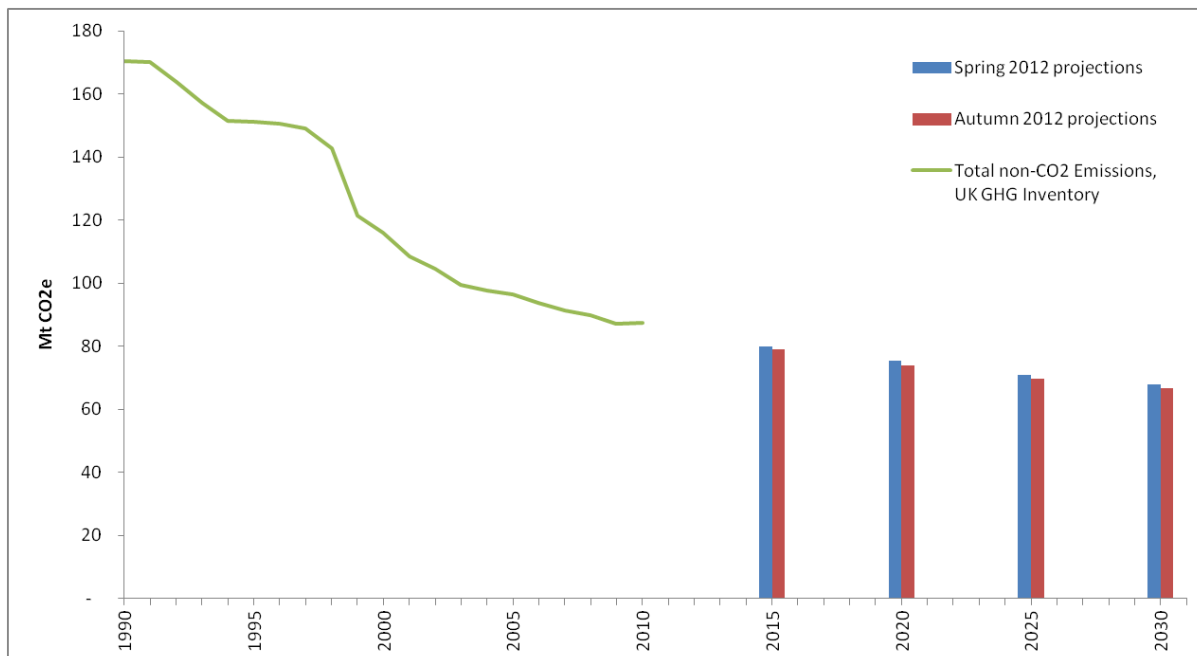
Non-CO_2 GHG's are now estimated to be 67 Mt CO_2e in 2030; representing a projected 24% decrease between 2010 and 2030. This would represent a 61% reduction on 1990 levels. The two greatest contributors to this projected reduction are methane emissions from waste management, where emissions reductions of 6.6 Mt CO_2e are estimated at 2030 compared with 2010, and a reduction of approximately 9.1 Mt CO_2e in business sector HFC emissions.

The Autumn 2012 non-CO_2 GHG projections predict that UK emissions will decrease at a marginally quicker rate between 2010 and 2030 than was projected in the Spring 2012 update. The magnitude of this change results in projected emissions in 2015 being approximately 1.5% lower, and in 2030 being approximately 2% lower than in the Spring 2012 update.

The most significant changes since the Spring 2012 update are due to the inclusion of updated agriculture sector projections, which have had the effect of reducing N_2O and CH_4 emissions from this sector as well as the inclusion new road transport projections which have decreased CH_4 and increased N_2O emissions. A change in projected PFC emissions from industrial processes has also occurred in order to reflect the closing of a primary aluminium production plant, which has decreased PFC emissions from this source. Additionally, a small error in the Spring 2012 projections has been corrected which has resulted in waste sector emissions being marginally lower in the Autumn 2012 update, across the projected time series.

	Summary of projected non-CO2 emissions in the Autumn 2012 update, Kt CO2e					
	UK GHG Inventory		Projections			
	1990	**2010**	**2015**	**2020**	**2025**	**2030**
CH4	92813	39062	35806	33080	30624	28599
N2O	63895	32992	31444	31429	31564	31669
HFCs	11386	14283	10794	8610	6496	5409
PFCs	1402	220	143	161	183	183
SF6	1030	690	664	665	681	681
Total	170524	87247	78850	73945	69549	66541

Total non-CO₂ GHG emissions, Autumn 2011 projections Vs Spring 2012 projections

Acknowledgements

Contents

1 Introduction

1.1 Overview

1.1.1 Projections of greenhouse gases

Emissions projections are used as a way of monitoring progress towards the UK's emission reduction targets. The UK government has set targets for reductions in greenhouse gas emissions out to 2050. Therefore a regularly updated set of projections is required as UK policy and understanding of likely future emissions evolves. The UK is also required to submit projected emissions of greenhouse gases biennially under the European Union Monitoring Mechanism, and periodically in the form of National Communications to the UNFCCC.

1.2 Gases considered

The projections which accompany this report are for the non-CO_2 component of the Kyoto Protocol's basket of greenhouse gases (GHG) and are collectively referred to as the non-CO_2 GHG's. These are:

- Methane (CH_4);
- Nitrous oxide (N_2O);
- Hydrofluorocarbons (HFCs);
- Perfluorocarbons (PFCs); and,
- Sulphur hexafluoride (SF_6).

* The HFCs, PFCs and SF_6 are also collectively known as the "F-Gases"

Projected emissions of CO_2 are reported in DECC's Updated Emissions Projections (UEP, **DECC 2011b**) and are not included within the coverage of this report or associated projections.

This report contains descriptions of the methodologies, data and assumptions used to estimate emissions of the above listed non-CO_2 GHG from all UK anthropogenic (man-made) sources out to 2030. Projected emissions are presented in CO_2 equivalent (CO_2e), according to Global Warming Potentials (GWP) set out in the International Panel on Climate Change (IPPC) Second Assessment Report (SAR).

1.3 Current UK GHG emissions

As part of the UK's commitments for reporting it's GHG emissions a national inventory is produced each year containing estimates for the UK's GHG emissions from all anthropogenic sources. The latest GHG Inventory was published in February 2012 and contains estimate for emissions from 1990-2010 (**DECC, 2012b**). Total UK emissions in 2010 were estimated at 590.4 $MtCO_2e$ (excluding EU ETS). Of this, non-CO_2 GHG's consistent with the coverage of this report represented 87.2 Mt CO_2e. Based on the data in

the most recent Inventory, the current situation with each of the non-CO$_2$ GHGs is as follows:

1.3.1 Methane (CH$_4$)

The Agriculture sector as a whole accounts for approximately 46% of all methane emissions; the Waste Management sector accounts for approximately and additional 39%. The remaining 15% of methane emissions are largely attributed to the Energy Supply sector.

1.3.2 Nitrous oxide (N$_2$O)

The majority of N$_2$O emissions, approximately 85%, are attributed to the Agriculture sector. The remaining 15% are split relatively evenly between Business, Energy Supply, Industrial Processes, Transport, Waste, and LULUCF sectors. An additional minor (0.02%) fraction originates from the Residential sector

1.3.3 F-Gases (HFC's, SF$_6$ and PFC's)

HFC's comprise the majority of the combined F-gas emissions, accounting for 94% of emissions as total Carbon Dioxide equivalent (CO$_2$e).

Refrigeration and air conditioning account for 70% of HFC emissions; this includes mobile air conditioning HFC emissions which alone account for 34% of all HFC emissions. Other significant HFC emissions sources include aerosols and metered dose inhalers (MDIs, e.g. asthma inhalers), both of which comprise between 8 and 7% of total HFC emissions each.

SF$_6$ emissions accounted for the remaining 4% of F-gas emissions, attributable largely to electrical insulation. See also the projection tables for more detailed information.

PFC's comprised just 1.5% of all F-gas emissions (CO$_2$e); the major sources of PFC emissions are primary aluminium production and the electronics industry.

1.4 Geographical coverage and UK projections

The projections of non-CO$_2$ GHG emissions in this report include the emissions from the Crown Dependencies (CDs): Guernsey, Jersey, Isle of Man, but exclude the emissions from the Overseas Territories (OTs): Bermuda, Cayman Islands, Falkland Islands, Montserrat and Gibraltar. This coverage is consistent with the geographical coverage of the UK energy projections.

1.5 Spreadsheet of tables of data accompanying this report

There are detailed tables of projections in a spreadsheet that accompanies this report and is available on the DECC website; see spreadsheet **Non-CO$_2$ GHG emission projections summary tables Autumn 2012.xls** .

2 Projections methodology

This section provides descriptions of the approaches taken and general methodology used to produce the non-CO_2 GHG emissions projections. Detailed methodologies used to project individual source category emissions are available in **Annex A** of this report.

2.1 Overview of method and database used

2.1.1 General approach to estimating emissions projections

Emissions in the historic greenhouse gas and air quality pollutant inventories are calculated by the GHG Inventory Agency (currently a consortium led by AEA) under contract to DECC using a central database (the NAEI database), containing activity data (e.g. fuel use, livestock numbers) and emission factors (e.g. kg pollutant / tonne fuel used, / head livestock). In order to maintain consistency with the historic inventory, projected emissions are calculated with reference to the most recent GHG Inventory data. This means that the base year for the projections is taken to be the latest year in the GHG inventory – this is important, since the historic estimates can be revised each year to account for any new information, recalculations or methodologies that become available.

As well as utilising the NAEI database, the DECC non-CO_2 GHG projections are also based on a number of independently produced emissions projections, available from various sources. The emissions projections from these sources will change in the future depending on variations in:

- Activity data (AD), for example projected changes to livestock numbers or changes in behaviour affecting the waste sector.

- Emission factors (EF), for example due to improvements to technology for the abatement of emissions.

- A combination of both factors.

Predicted changes in either the emissions factors or activity data for each sector will be reflected in the projections which form the basis of the DECC model.

These updates are rebaselined against the most recent GHG Inventory emissions estimate for that year. The 'rebaselining factor' is then applied to all future emissions estimates in that time series. **Table 2.1** Illustrates this process with a simple example.

Table 2.1   Simple rebaselining example

Rebaselining process	2010	2015	2020	2025	2030
GHG Inventory estimate (baseline)	**675**				
Previous projections	675	624	495	395	320
New projections (before rebaselining)	*645*	*600*	*475*	*320*	*250*
Rebaselining factor (previous 2010/ 'new' 2010)	**1.05**				
New time series rebaselined to the 2010 GHG Inventory (rebaselining factor ✗ 'new' time series)	675	628	497	335	262

2.1.2 Projections scenarios and nomenclature

2.1.2.1 The central projection estimate

The UNFCCC Guidelines for the preparation of National Communications[1] require that policies and measures included in the central projection must correspond to those policies and measures that are implemented and adopted.

Implemented policies and measures are those for which one or more of the following applies: (a) national legislation is in force; (b) one or more voluntary agreements have been established; (c) financial resources have been allocated; (d) human resources have been mobilized. These are termed 'with measures' emissions projections, or sometimes referred to as "firm and funded". 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 not included in the central projection; these are defined as options under discussion and having a realistic chance of being adopted and implemented in future.

The emissions projections included in this report are based on all currently implemented and adopted policies and measures in accordance with the UNFCCC reporting guidelines. They are distinct from 'with additional measures' projections that encompass planned policies and measures, and distinct from 'without measures' projections that excludes all policies and measures implemented, adopted or planned after the base year.

2.2 QA/QC procedures

A wide range of data are used in the projections and each source is quality assured. New data sources are required to be publically available for scrutiny for a minimum period of two weeks prior to being included in the projections, and where possible data are subject to peer review.

Data (activity data, emission factors and calculated emissions) that are part of the core GHG inventory are subject to rigorous QA/QC processes within the annual inventory compilation cycle by the Inventory Agency, a consortium led by AEA, using a set of QC procedures developed over a number of years. These procedures are documented in Chapter 1 of the UK's latest National Inventory Report (NIR).

The changes incorporated into this Autumn 2012 update have been quality checked, and overseen by the non-CO_2 GHG emissions projections Steering Group.

2.3 Coverage of emissions in the non-CO_2 GHG projections

The non-CO_2 projections consider all anthropogenic (man-made) sources of emissions with the exception of those excluded due to the reasons explained below.

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 inventories, and are used in international reporting tables submitted to the UNFCCC every year.

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[1] FCCC/CP/1999/7

A complete mapping of IPCC sectors to National Communication sectors is available on the DECC website (**DECC, 2012c**).

Since the Autumn 2011 update, some categories of non-CO_2 GHG projections are excluded, where their projected trend is reliant on information within DECC's Updated Energy Projections (UEP). This decision was taken to improve the quality and processes involved in the production of both CO_2 and non-CO_2 GHG projections. Examples of these categories include CH_4 and N_2O emissions from power stations and oil and gas production, which are driven by energy consumption, as well as a number of business categories such as 'combustion from iron and steel plants', 'auto-generators' and 'blast furnaces', which had previously been projected using UEP growth indexes as the drivers. A full list of categories which are included in DECC's UEP is given in **Annex B**. These projections are produced and presented in DECC's UEP publications.

Categories will remain under review and additional categories may be added or removed.

In order to maintain consistency and prevent a step change in the historical time series due to the removal of these categories, the transferred sectors have been removed from the series as a whole.

3 Summary of Autumn 2012 non-CO$_2$ GHG projections

The historic trend in non-CO$_2$ GHG emissions shows a significant reduction from 1990 to 2010 levels, decreasing by approximately 49% in this period. The Autumn 2012 update projects non-CO$_2$ GHG's to be 67 Mt CO$_2$e in 2030; representing a projected 24% decrease between 2010 and 2030. This would represent a 61% reduction on 1990 levels. The historic reduction comes from decreases in nitrous oxide (N$_2$O) and methane (CH$_4$) emissions, whereas the majority of the projected reduction is predicted to come from decreases in methane emissions, and also some decreases in HFC emissions, as shown in **Figure 3.1**.

Figure 3.1 Summary of projected non-CO$_2$ GHG emissions by gas (Mt CO$_2$e)
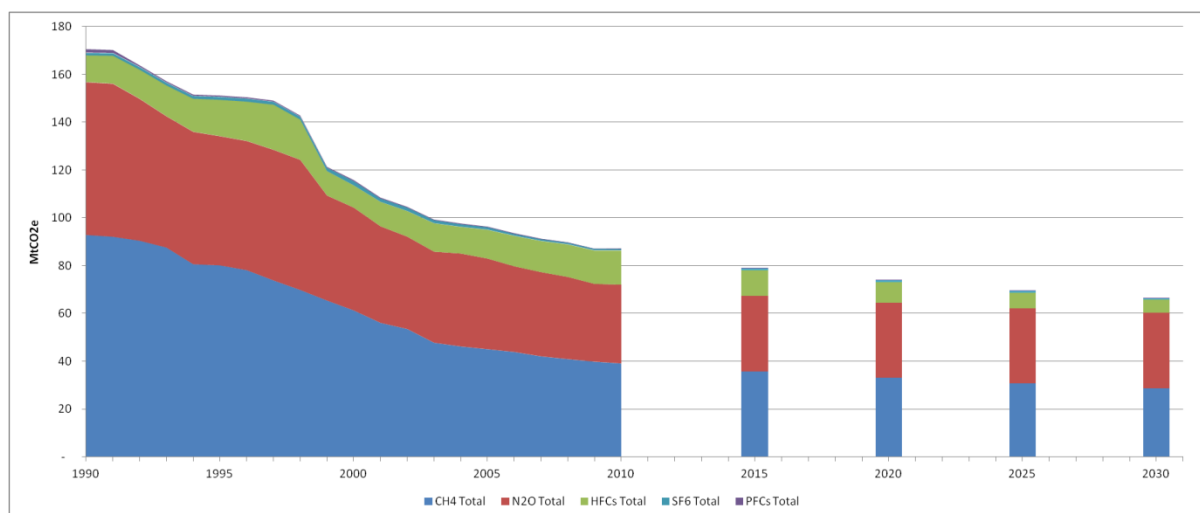
The historic reduction is attributable to emissions from a number of sectors (**Figure 3.2**) – Waste Management, Industrial Processes and Energy Supply have all seen large decreases in emissions from 1990-2010**.**

Projected reductions from 2010 to 2030 are anticipated to come from:

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

In addition to these anticipated reductions but of smaller magnitude (~1Mt CO$_2$e reduction) a 72% percent decrease in Industrial Processes emissions are projected, as a result of the opt-in of nitric acid production plants to the European Union's Emissions Trading Scheme (EU ETS).

Figure 3.2 Summary of projected non-CO$_2$ GHG emissions by National Communication sector (Mt CO$_2$e)
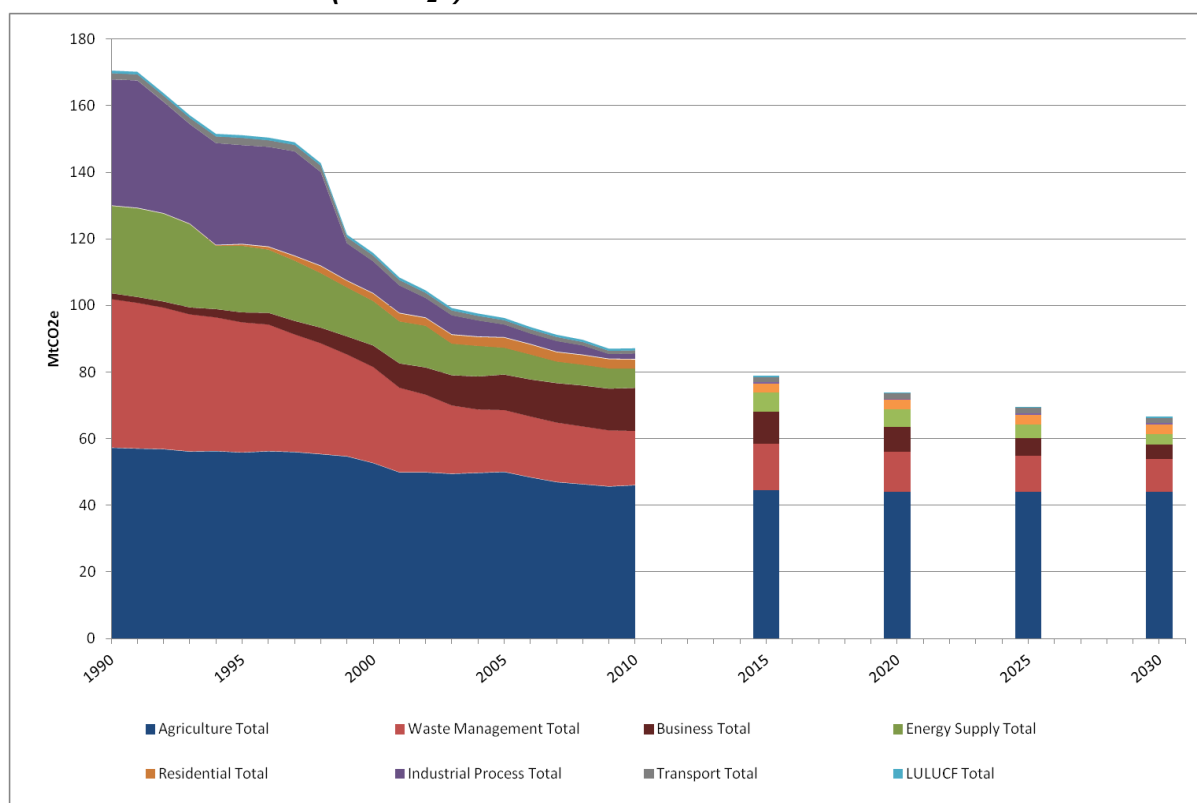
The Autumn 2012 non-CO$_2$ GHG projections predict that UK emissions will decrease at a marginally quicker rate between 2010 and 2030 than was projected in the Spring 2012 update. The magnitude of this change results in projected emissions in 2015 being approximately 1.5% lower, and in 2030 being approximately 2% lower than in the Spring 2012 update (see **Figure 3.3**).

The most significant changes since the Spring 2012 update are due to:

- updated projections of agricultural emissions, which reduce N$_2$O and CH$_4$ emissions;
- updated projections of road transport emissions, which decrease CH$_4$ and increase N$_2$O emissions;
- updated projections of industrial processes emissions, which decrease PFC emissions;
- correction of an error in the waste management sector, which decreases CH$_4$ and N$_2$O emissions.

Figure 3.3 Total non-CO$_2$ GHG emissions, Autumn 2011 projection Vs Spring 2012 projection
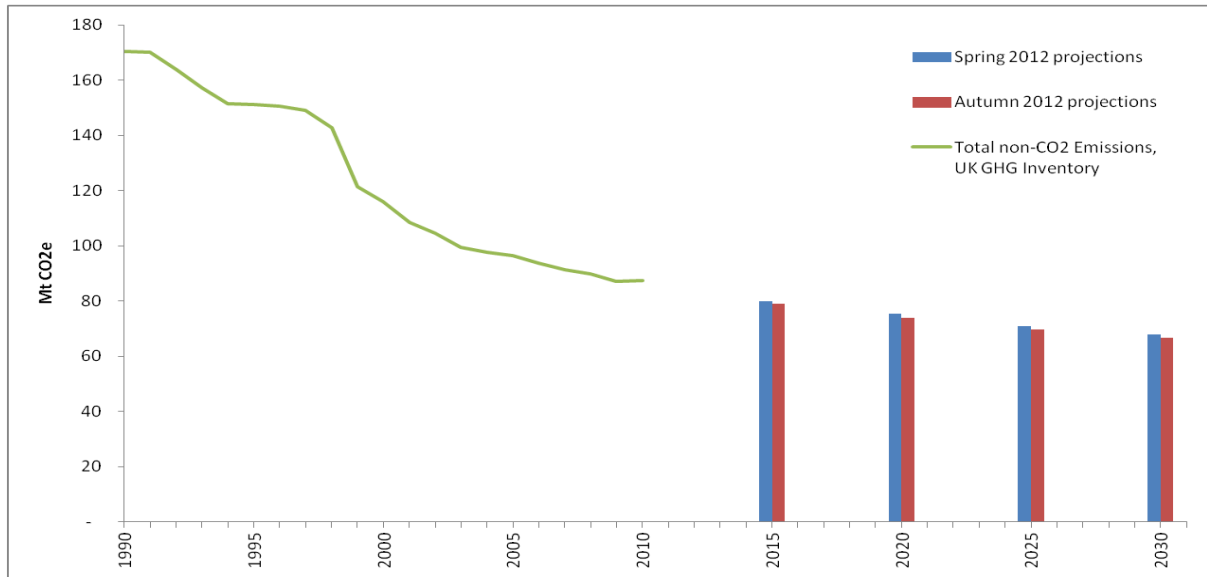
4 Projections of non-CO$_2$ GHG by National Communication Sector

4.1 Agriculture Sector

The Agriculture sector is the single largest contributor to overall non-CO$_2$ greenhouse gas emissions presented in this report. In 2010 non-CO$_2$ emissions from agriculture were approximately 46 Mt CO$_2$e which represented approximately 53% of the UK's total non-CO$_2$ emissions. Two gases represent the non-CO$_2$ contribution to emissions from this sector, nitrous oxide (N$_2$O) and methane (CH$_4$).

Since the Spring 2012 update to the projections a new set of agriculture projections have been produced by Defra and have been included in this update, see **Section 4.1.1** for further details.

Figure 4.1 – Overall Agriculture sector emissions projections

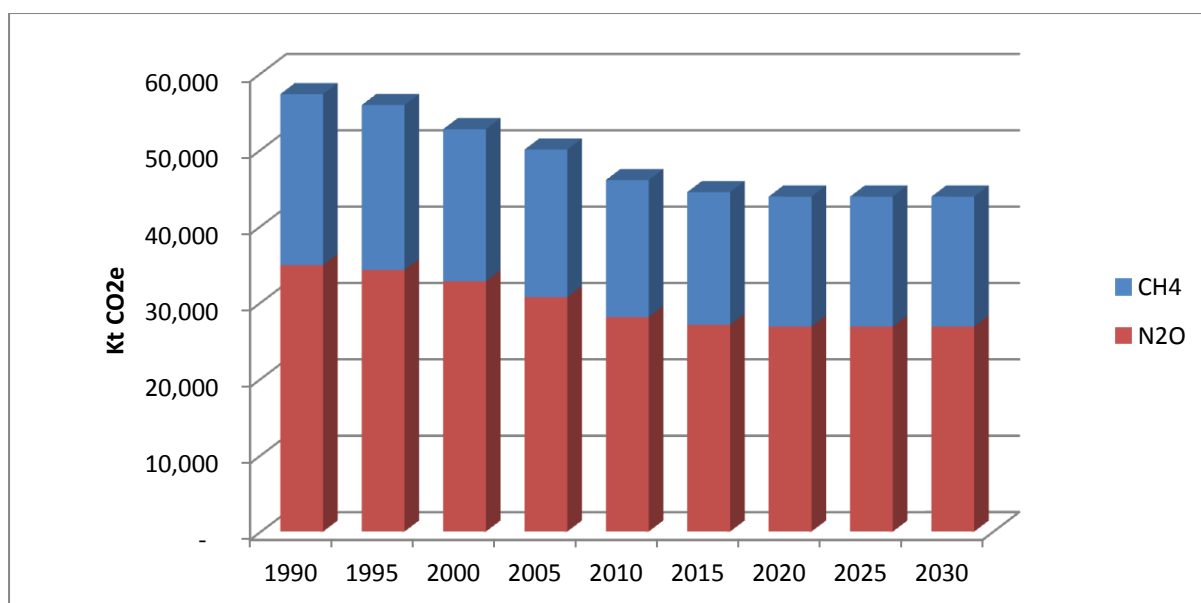**Overall emissions from the agricultural sector are projected to be approximately 44 Mt CO$_2$e in 2030 which corresponds to reduction in emissions of approximately 4% on the 2010 level.**

Emissions are predicted to decline until 2020 at which point they remain at a constant level. The presence of the flat line in emissions is due to limitations in Defra's agriculture projections, which only projects activity from the sector out to 2020 (Defra 2012).

The key driver for the reduction in emissions during the projected time series is the anticipated contraction in the UK's agriculture sector, leading to a reduction in land area used for arable farming and, therefore, associated fertilizer application, as well as reductions in the nation's beef, dairy and pig herds.

These reductions are the result of macroeconomic assumptions that impact on the UK agriculture sector. A key driver for the changes is the pound sterling to Euro exchange rate with the pound projected to strengthen against the Euro over the period. This will affect UK

agriculture in a number of ways: i) through a reduction in the prices paid to UK farmers relative to European farmers and associated relative returns; ii) through a reduction in demand for UK exports as these become less competitive with European products; and, iii) through reductions in the domestic value of the single farm payment which is set in Euros.

4.1.1 Agriculture sector nitrous oxide emissions

Agricultural N_2O represents the most significant contributor to overall UK N_2O emissions, and represents approximately 85% of the total N_2O emissions in the non-CO_2 GHG projections. Emissions of N_2O in the agriculture sector come from a variety of sources such as agricultural soils, manure management systems and field burning. The most significant contributor of which are agricultural soils which represents approximately 93% of agricultural N2O emissions in 2010 and 80% of total N_2O from all sectors covered by this report.

Figure 4.2 Historical trend and projections of nitrous oxide emissions from agriculture
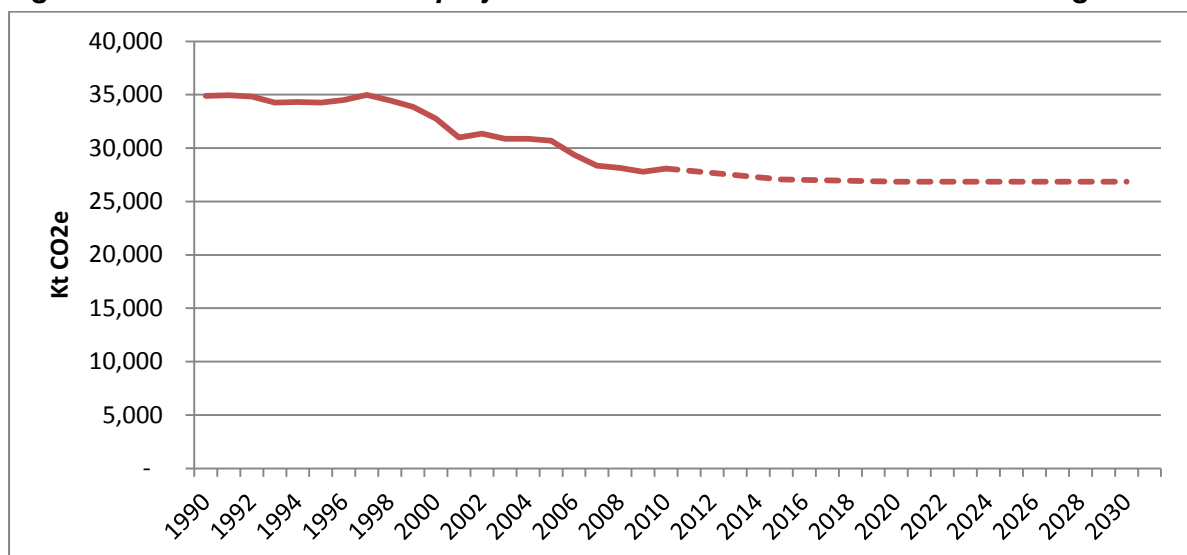
N_2O from the agriculture sector is projected to decline from approximately 28 Mt CO_2e in 2010 to approximately 27 Mt CO_2e in 2020, the trend then flat-lines to 2030 due to the limitations of the Defra FAPRI-UK model, see **Figure 4.2**.

Defra's agriculture projections estimate approximately 10% reduction in total UK fertiliser application by 2020. This is driven by a small reduction (2%) in arable area as well as significantly reduced application rates to grasslands through better nutrient advice. This contributes to the overall reduction in N_2O emissions from the sector. Decreases in the number of livestock out to 2020 also impact the level of N_2O emissions by leading to fewer N_2O emissions from manure management.

Since 2011 Defra have used an updated methodology for their projections for agricultural emissions in order to make use of the AFBI FAPRI model of UK agriculture (**Defra, 2011**). The FAPRI-UK model has greatly increased the accuracy of the activity drivers behind Defra's emissions projections.

Since the Spring 2012 update Defra have produced a new set of projections for N_2O and CH_4 from the agricultural sector. Defra's agriculture projections are now based on activity data from the latest FAPRI modelling of activity drivers in the agriculture sector. These projections have been incorporated into the Autumn 2012 update.

Figure 4.3 Spring 2012 and Autumn 2012 agriculture sector nitrous oxide projections
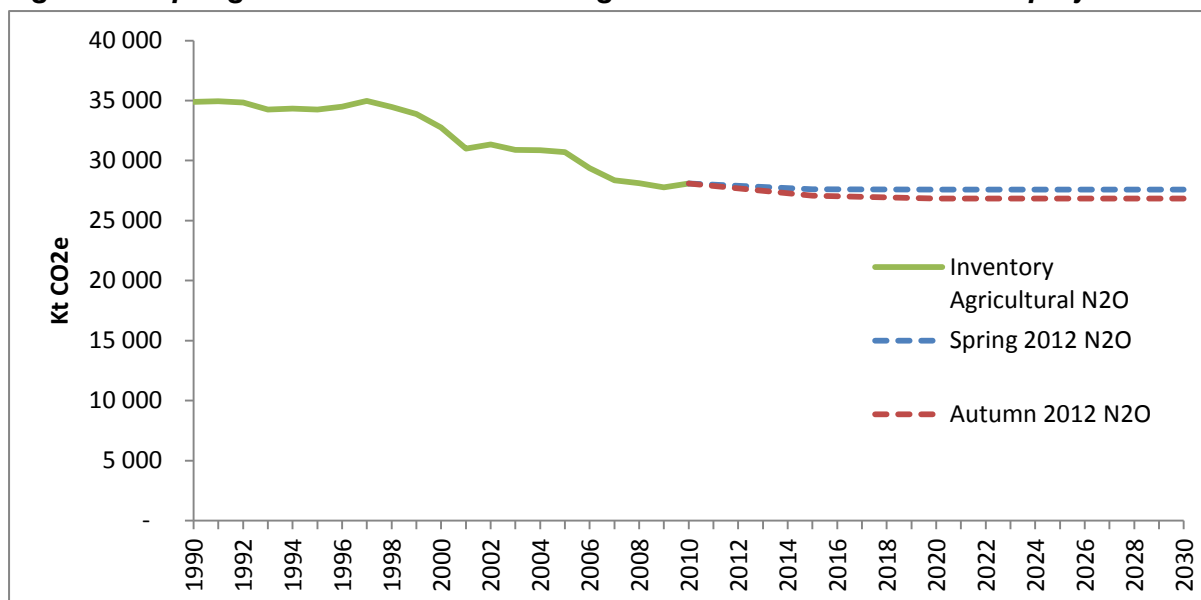
Figure 4.3 above highlights the changes the Defra projections update has had on agricultural N_2O emissions going forward. The Defra projections have been re-baselined against the latest GHG Inventory publication following the method explained in **Section 2.1**.

The effect of the new Defra projections is to reduce the projected emissions by approximately 550 Kt CO_2e in 2015 and 730 Kt CO_2e in 2020, before remaining at this lower level out to 2030 due to the flat-lining process explained above.

4.1.2 Agriculture sector methane emissions

As with N_2O emissions, agriculture is the highest contributing sector to total CH_4 emissions for the UK, representing approximately 46% of total CH_4 emissions from the sector s considered in this report in 2010. Major sources of CH_4 in the agriculture sector are enteric fermentation by livestock, particularly cattle, which accounts for approximately 66% of total CH_4 emissions from this sector, and livestock wastes which account for a further 15%.

Figure 4.4. Historical trend and projections of methane emissions from agriculture
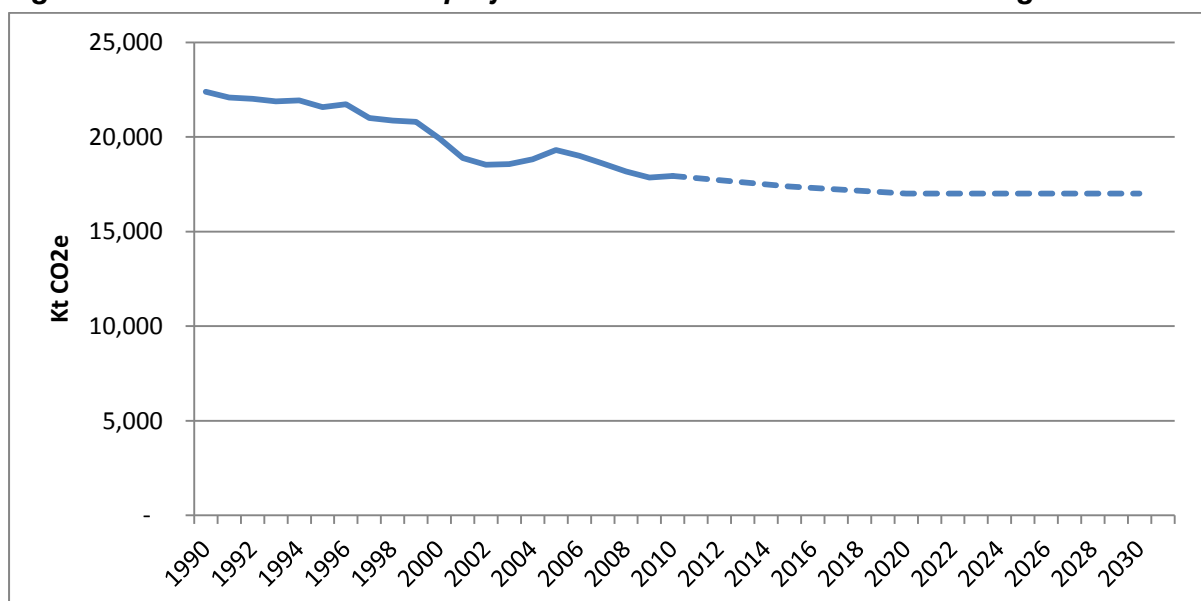
Methane emissions from the agriculture sector have declined in an almost linear fashion since 1990, with emissions in 2010 being approximately 20% lower than the base year (see **Figure 4.4**).

Methane from the agriculture sector is projected to decline from approximately 18 Mt CO_2e in 2010 to approximately 17 Mt CO_2e in 2020, a reduction of just over 5%. This is due to an overall reduction in activity in the sector as explained in **Section 4.1.1**. The decrease in the projected trend is specifically due to an anticipated reduction in the size of livestock herds and therefore their associated enteric fermentation and waste emissions. As is the case with the agricultural N_2O emissions, the trend then flat lines to 2030 due to limitations in the Defra FAPRI-UK model.

4.1.2.1 Changes in agriculture sector CH_4 emissions since the previous update

As explained in **Section 4.1.1**., the new Defra projections for agricultural emissions have been included in this update to the non-CO_2 emissions projections. **Figure 4.5** highlights the differences the new Defra projections have had on the agriculture sector's CH_4 emissions.

The revised figures are as a result of the projected decline in the number of livestock as well as some productivity losses. Notable downward revisions in the previous projections of numbers of pigs, beef cattle and dairy cattle and their associated emissions have led to the lower CH_4 projections from this sector. The projected reduction in livestock numbers is due to the continuing high commodity prices and therefore the price of feed. The reduction in pig numbers is the most significant of these and is a result of the relatively large amounts of artificial feed required to raise them as opposed to other livestock such as grazing cattle.

Figure 4.5 Spring 2012 and Autumn 2012 agriculture sector CH4 projections
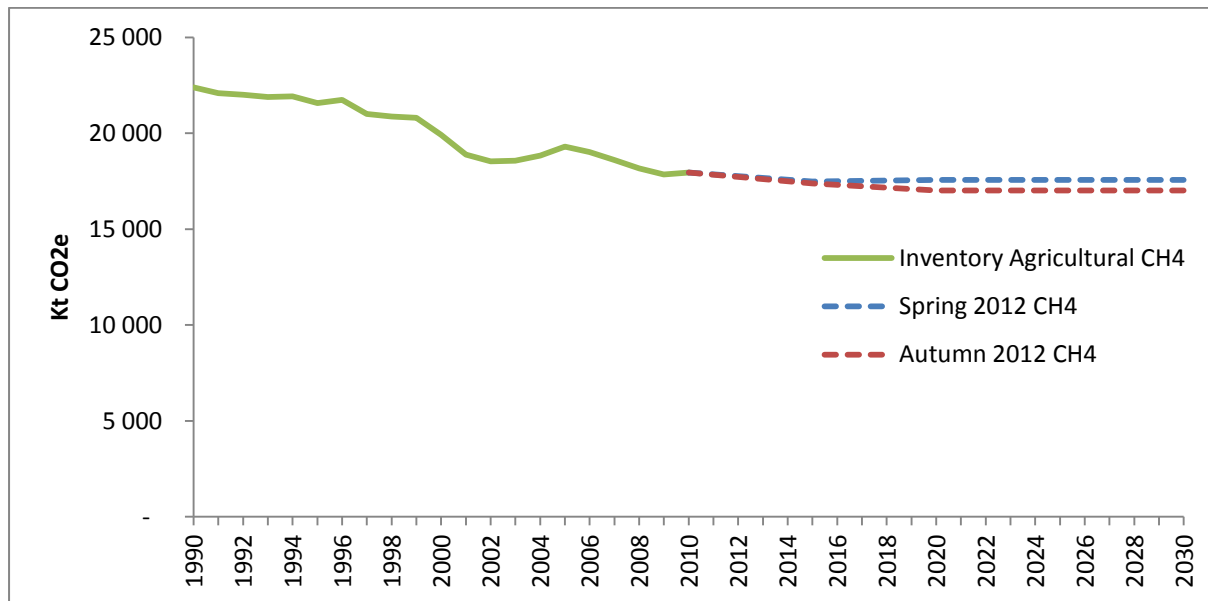
The update has resulted in projections for CH_4 from the agriculture sector being approximately 105 Kt CO_2e lower in 2015 and 554 Kt CO_2e lower in 2020 when compared with the Spring 2012 update; reductions of approximately 1% and 5% respectively.

4.2 Business Sector

In 2010 non-CO_2 greenhouse gas (GHG) emissions from the business sector were approximately 12.9 $MtCO_2e$, representing around 15% of the UK's total non-CO_2 emissions. All non-CO_2 GHG's contribute to emissions from this sector: Nitrous oxide (N_2O), methane (CH_4) and the f-gases (HFC, PFC & SF6). **Figure 4.2.1** highlights how each of the gases considered account for non-CO_2 emissions from this sector.

There have been no changes to projected emissions in the business sector in this update.

Figure 4.2.1 – Non-CO2 GHG emissions projections for the business sector
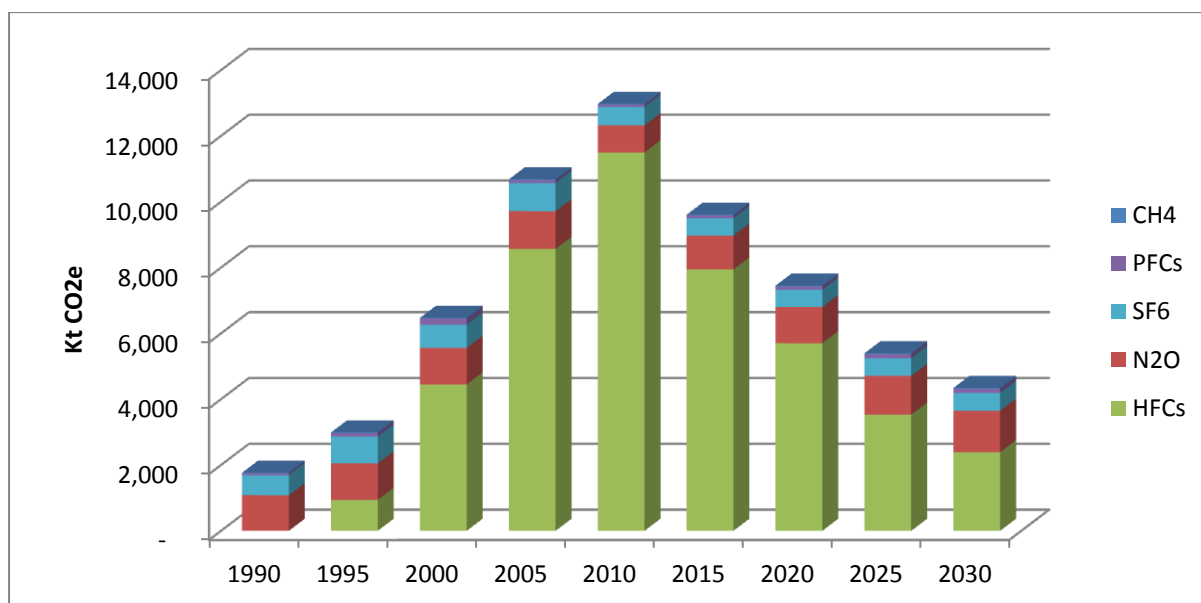
Overall emissions from the business sector are projected to be approximately 4 Mt CO_2e in 2030 which will correspond to a decrease in emissions of approximately 67% since 2010. Historically, business sector emissions have increased by 11 $MtCO_2e$ since 1990, reaching their highest point in 2010.

4.2.1 Business sector F-Gas emissions

F-gas emissions were estimated to be approximately 12 $MtCO_2e$ in 2010, representing 93% of non-CO_2 GHG emissions from the business sector. These emissions result mainly from refrigeration and air conditioning, with contributions also from foams, fire fighting, solvents, electronics, electrical insulation and sporting goods. Emissions of f-gases have increased rapidly since 1990 due to the phasing out of CFC's as a result of the Montreal Protocol, and the use of HFC's as replacement gases in a growing refrigeration and air conditioning sector. F-gas emissions are projected to decline by approximately 9 $MtCO_2e$, or 75%, between 2010 and 2030. This reduction is expected due to the impact of the EU F-gas regulation driving the replacement of HFC's with new lower GWP refrigerants, and because leakage rates from refrigeration equipment are now much better controlled than in the 1990s, thus reducing fugitive emissions.

Emissions of **HFC's** were approximately 11.5 MtCO2e in 2010, representing 89% of non-CO_2 GHG emissions from the business sector. The majority of these emissions were from refrigeration and air conditioning (RAC). Emissions of HFCs can occur at various stages of the RAC product life-cycle:

- During the refrigeration equipment manufacturing process;
- Over the operational lifetime of the refrigeration or air-conditioning unit; and
- At disposal of the refrigeration or air-conditioning units.

RAC emissions are estimated using a model developed by ICF International (**ICF, 2011**), based on industry input and a modelling approach consistent with IPCC guidance. The model is organized into 13 end-uses, and uses a bottom-up approach based on equipment stocks and average charge size from available market data. The model has been validated by comparing estimated refrigerant consumption (calculated as the amount of refrigerant used to manufacture new equipment produced in the UK plus the amount used to service leaking equipment) with annual refrigerant sales data from the British Refrigeration Association (BRA). HFC emissions are visualised in **Figure 4.2.2** below.

Emissions of **SF6** (**Figure 4.2.3**), all of which are attributable to semiconductors, electrical and sporting goods, were 0.6 MtCO$_2$e in 2010. They are projected to decrease by approximately 4% between 2010 and 2030.

Emissions of **PFCs** (**Figure 4.2.4**), which are also wholly attributable to semiconductors, electrical and sporting goods, were 68 ktCO$_2$e in 2010. They are projected to increase by approximately 85% between 2010 and 2030.

Figure 4.2.2 - HFC emissions projections for the business sector

Figure 4.2.3 – SF6 emissions projections for the business sector
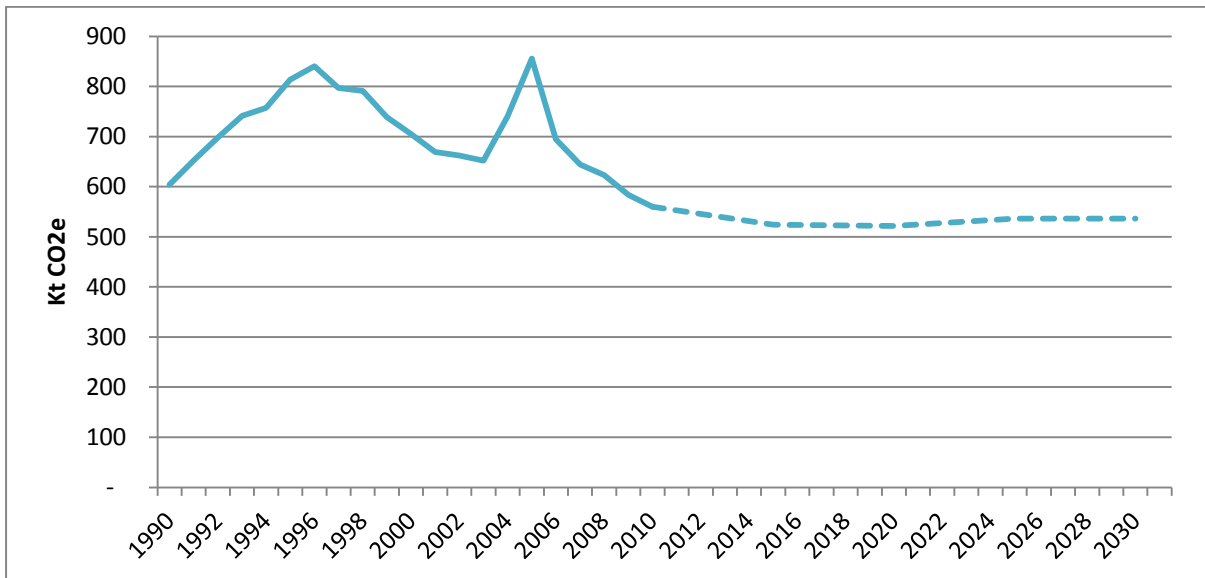
Figure 4.2.4 - PFC emissions projections for the business sector
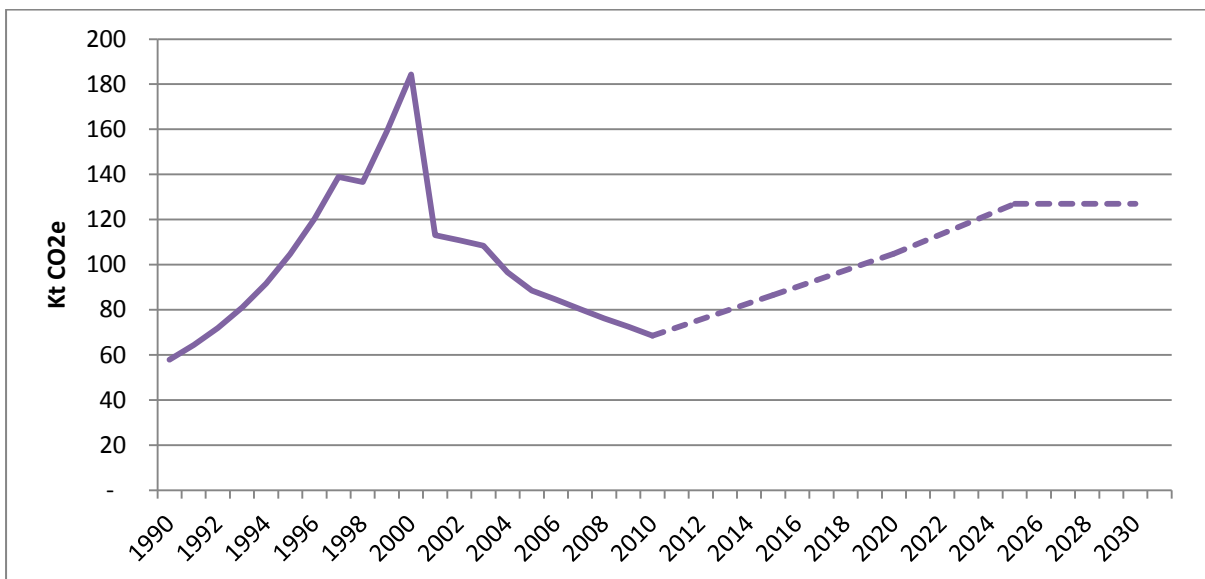
4.2.2 Business nitrous oxide emissions

Nitrous oxide emissions were estimated to be 0.8 $MtCO_2e$ in 2010 (**Figure 4.2.5**), representing approximately 6% of non-CO_2 GHG emissions from the business sector. These emissions result from iron and steel combustion, and other industrial and commercial combustion. There has been no significant change in the emissions trend since 1990, except for a slight decrease in 2009-2010. As year-on-year fluctuations in emissions are small in terms of absolute values, it is difficult to attribute the changes to a particular cause. Emissions are projected to increase by approximately 0.4 $MtCO_2e$, or 53%, between 2010 and 2030.

Figure 4.2.5 – N2O emissions projections for the business sector
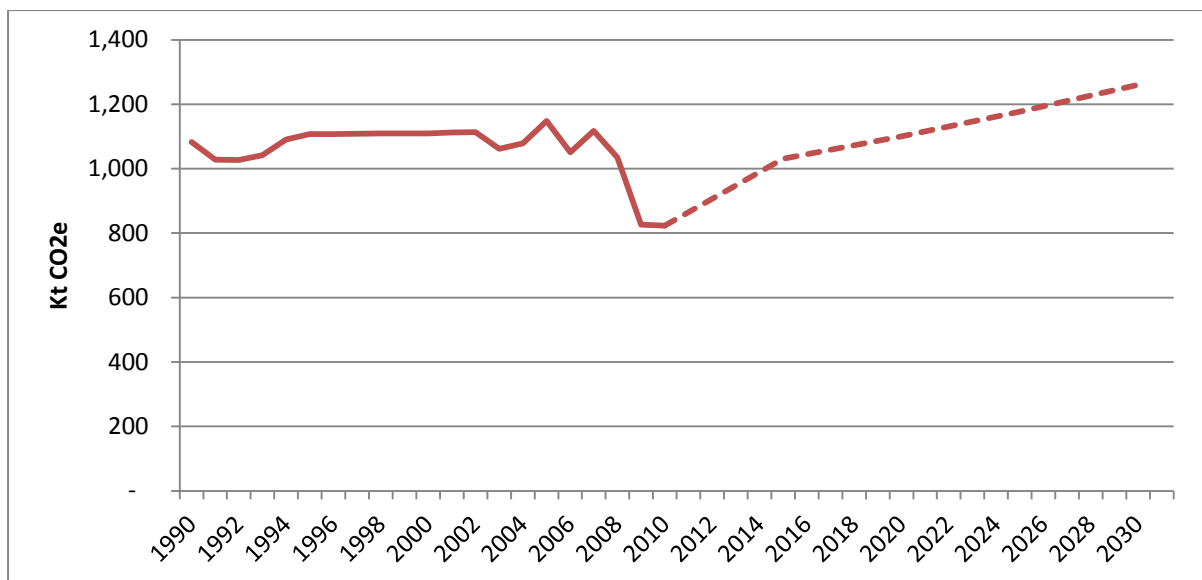
4.2.3 Business methane emissions

Methane emissions were estimated to be 20 ktCO$_2$e in 2010 (**Figure 4.2.6**) , representing less than 1% of non-CO$_2$ GHG emissions from the business sector. These emissions result from iron and steel combustion, and other industrial and commercial combustion. There has been no significant change in the emissions trend since 1990, except for a slight decrease in 2009. Emissions are projected to increase by approximately 5 MtCO$_2$e, or 23%, between 2010 and 2030. These percentage increases may be misleading though, as the absolute emissions values are very small.
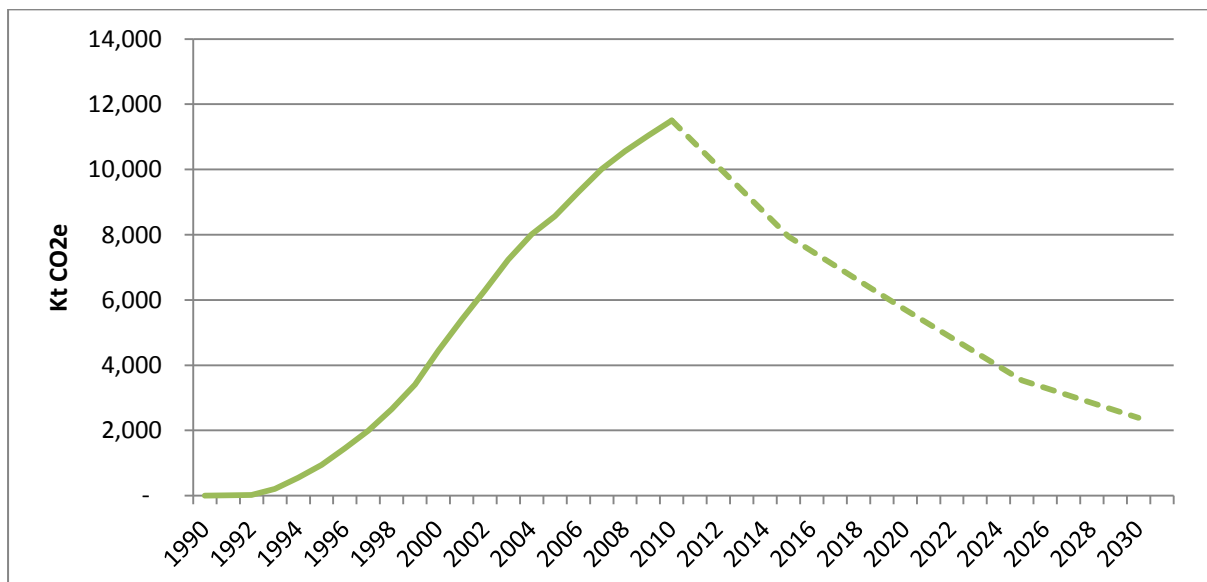
Figure 4.2.7 – Methane emissions projections for the business sector
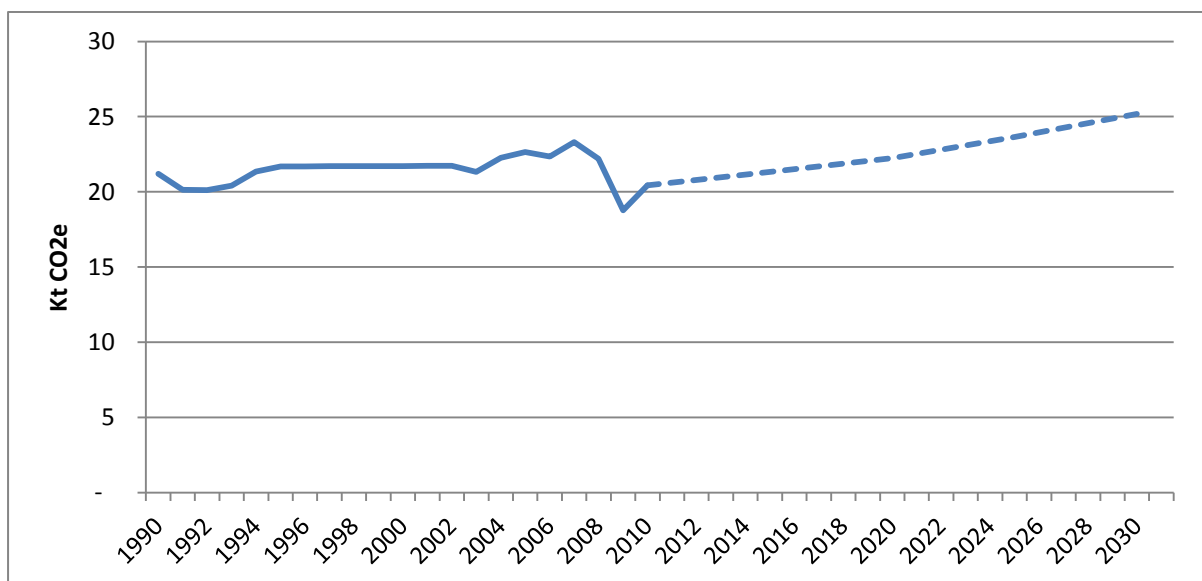
4.3 Energy Sector

In 2010 non-CO_2 greenhouse gas (GHG) emissions from the energy sector were approximately 6 $MtCO_2e$, representing around 7% of the UK's total non-CO_2 emissions. Methane (CH_4) is the only non-CO_2 GHG contributing to emissions from this sector.

Figure 4.3.1 – Non-CO2 GHG emissions projections for the energy sector
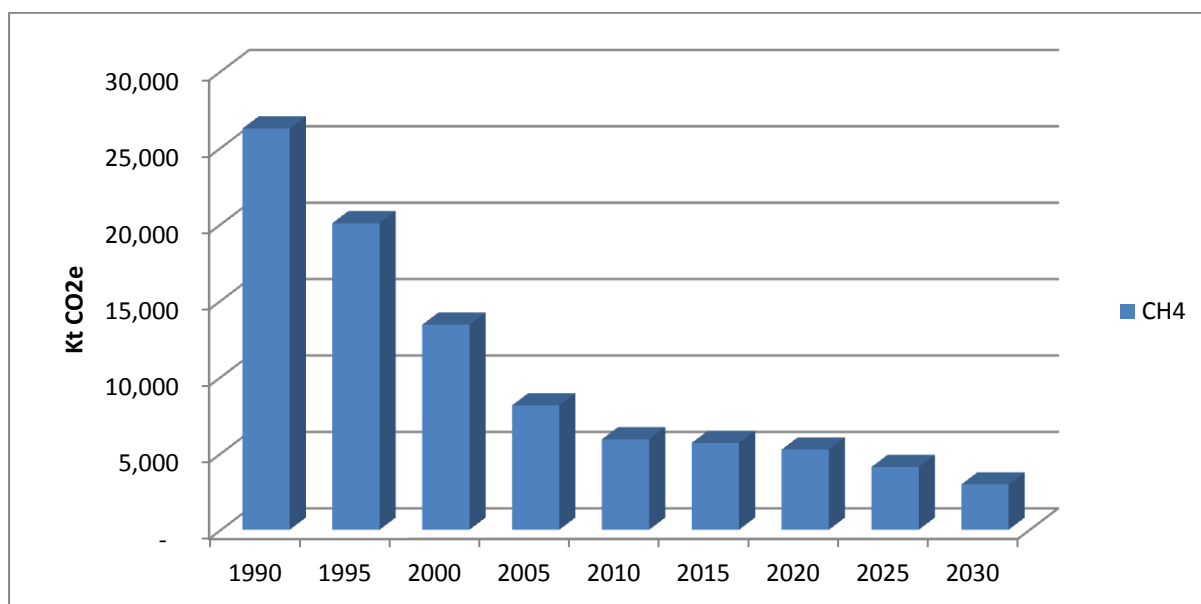
Overall emissions from the energy sector are projected to be approximately 3 Mt CO_2e in 2030 which will correspond to a decrease in emissions of approximately 50% since 2010 (**Figure 4.3.1**). This is predominantly due to reduced emissions from natural gas leakage and from deep mined coal. Historically, energy sector emissions have decreased by approximately 20 $MtCO_2e$ since 1990.

There have been no changes to projected emissions in the energy sector in this update.

4.3.1 Energy methane emissions

Methane emissions in the energy sector result from natural gas leakage, operational and closed coal mines, and coke production. Historically, the decreasing trend in emissions is as a result of a reduction in emissions from natural gas leakage of around 48% and deep mined coal of around 92%; both of which are the dominant contributors to emissions in this sector (still comprising around 90% of emissions in 2010). Emissions are projected to continue to decrease from natural gas leakage and deep mined coal to 2030 (see **Figure 4.3.2**), because of an expected decrease in the quantity of coal produced, and the replacement of cast-iron pipes in the gas distribution system. Note that these projections are also influenced by limitations in the projected time-series for deep mined coal emissions, which only extends to 2025.

Figure 4.3.2 – Methane emissions projections for the energy sector
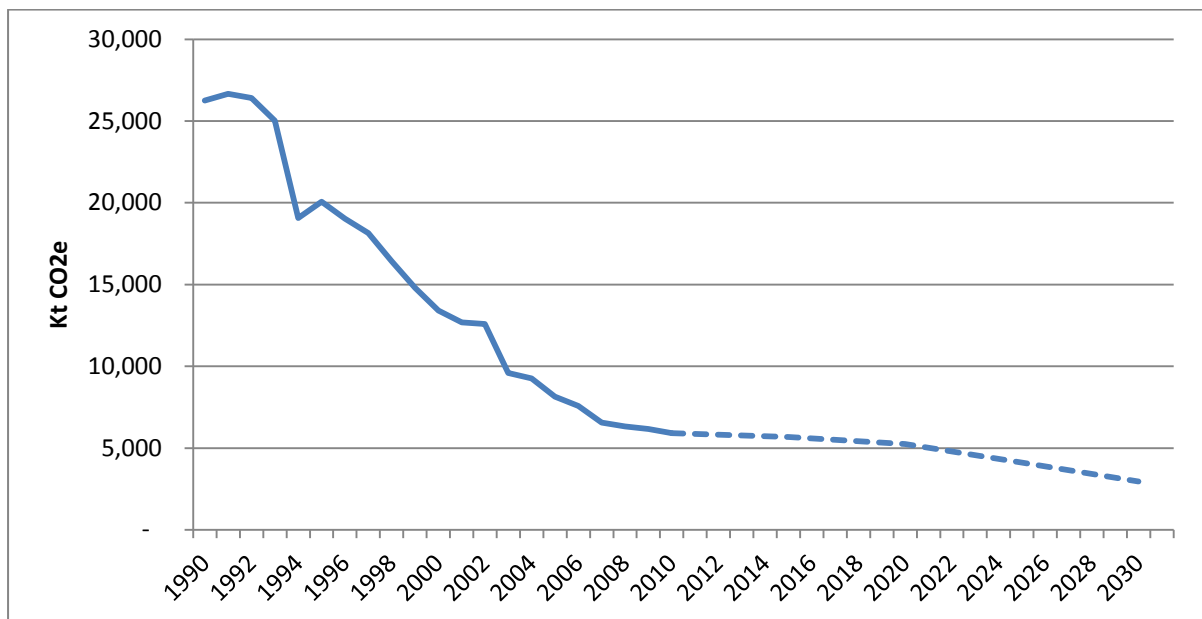
Closed coal mine CH_4 emissions are the third most significant source in this sector. Projections of these emissions were recently updated (**WSP Environmental, 2011**). The model uses a bottom-up approach incorporating physical properties of individual mines and mine areas, includes actual closure and re-commissioning dates up to 2010, and uses a single-value long-term emissions factor obtained from abandoned mine CH_4 reserves of eight UK mines, and flow rate of methane from those mines. Emissions are estimated to have already been significantly reduced and likely to remain approximately constant out to 2030.

4.4 Industrial Processes Sector

The industrial processes sector has historically been a significant contributor to emissions, producing the equivalent of approximately 22% of the UK's total non-CO_2 emissions in 1990. However, by 2010 emissions from the industrial process sector have reduced to less than 1% of total non-CO_2 emissions. Industrial processes do remain a source of nitrous oxide (N_2O), methane (CH_4) and F-gas emissions, albeit on a much smaller scale than historically.

Since the Spring 2012 update to the projections, projections from this sector have been updated to reflect the closure of one of the UK's primary aluminium manufacturing plants. Further details of this adjustment are present in **Section 4.4.2.1**.

Figure 4.4.1 – Overall Industrial Processes sector emissions projections
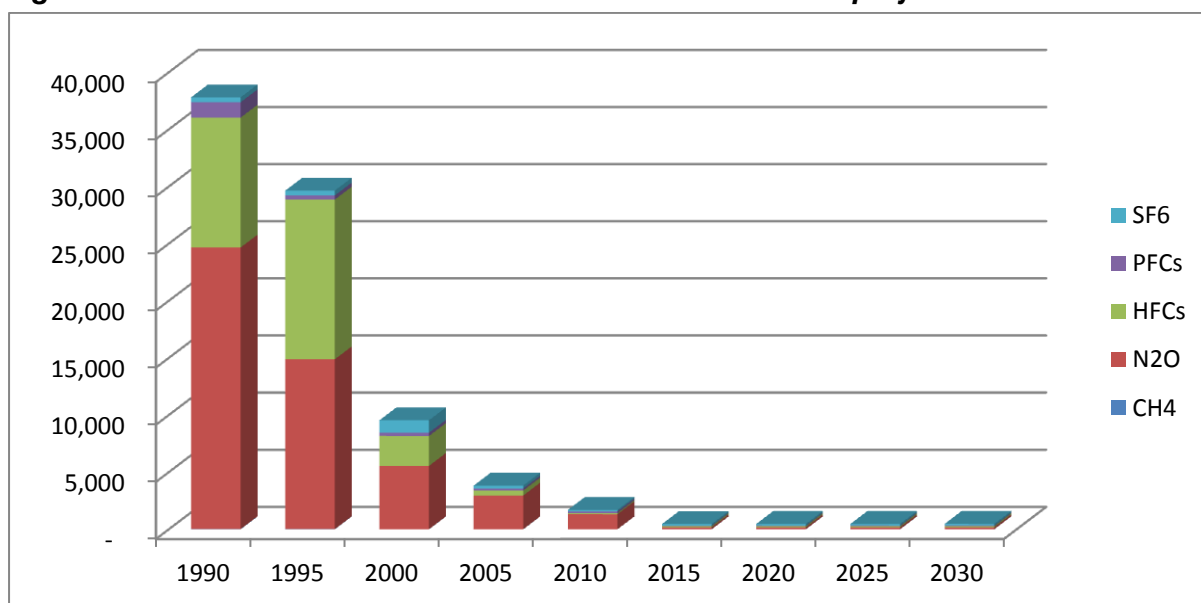
Overall emissions from the industrial processes sector are projected to be 0.4 MtCO2e in 2030, representing a reduction of approximately 72% between 2010 and 2030 (see Figure 4.4.1). Historically, N_2O emissions from nitric acid and adipic acid production have contributed significantly to overall emissions from this sector, as well as by-product emissions from the production of HFCs. Changes in industrial activity and the adoption of improved abatement technology has led to the significant reductions seen in this sector. Historically emissions have decreased 95% from 1990 to 2010.

4.4.1 Industrial Processes nitrous oxide emissions

Historically, N_2O emissions from industrial processes have been significantly higher than they are today and are projected to be in the future. In 2030, these emissions are projected to be 0.1 Mt CO_2e. **Figure 4.4.3** shows the historical and projected trend for N_2O from this sector.

The key driver of N_2O emissions from this sector has historically been the production of adipic and nitric acids. The UK's only adipic acid production facility ceased operation in 2009 and plant closures coupled with early adoption of emissions abatement technology in the production of nitric acid has resulted in significant reductions from these sources.

Figure 4.4.3 Nitrous oxide emissions projections from the Industrial Processes sector
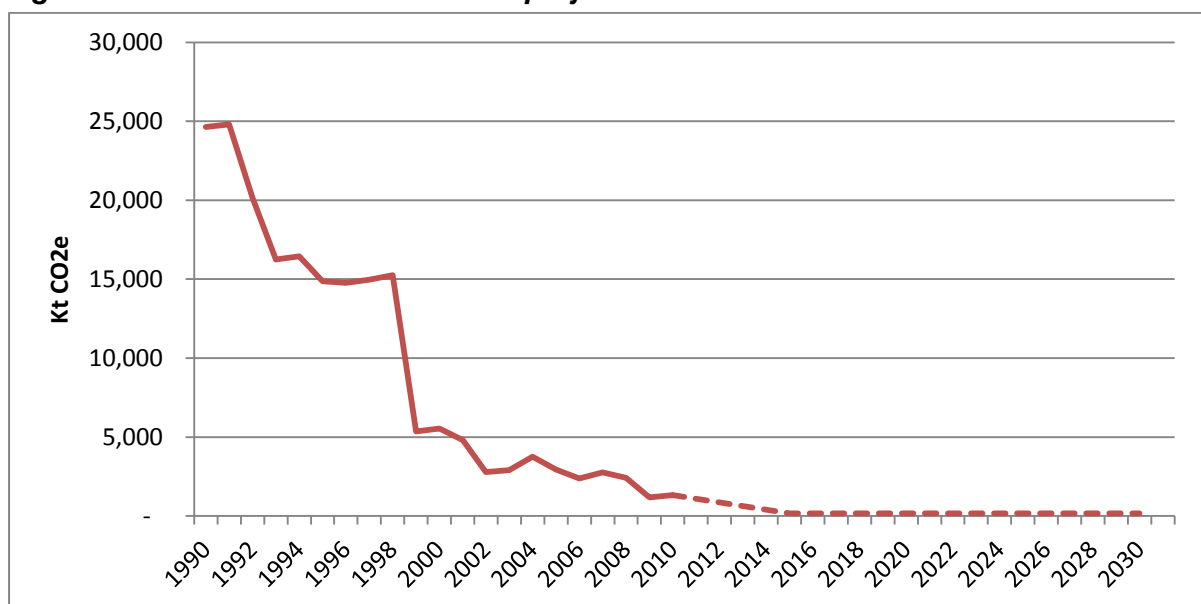
4.4.2 Industrial Processes F-Gas emissions

F-gas emissions from the industrial processes sector have, as with other gases, reduced markedly since 1990. F-gas emissions were approximately 13 Mt CO_2e in 1990, estimated at 0.4 Mt CO_2e in 2010, and are projected to be 0.3 Mt CO_2e by 2030. These emissions are predominantly as a result of HFC by-product emissions from halo-carbon productions as well as PFC emissions from the primary production of aluminium.

The projected trend for each of the F-gases is expected to flat-line from 2010 (**Figures 4.4.4 -4.4.6**) as the majority of abatement measures expected in this sector are already in place. Abatement technology has been fitted to two of the three UK producers of HCFCs, significantly reducing by-product emissions.

PFC emissions from this sector have historically been driven by the primary production of aluminium. Reductions in industrial activity (i.e. the production of primary aluminium) have led to projected emissions from this source decreasing to approximately 8% of the 1990 level in 2010, and by a further 99% by 2030. Further details on the projected trend in emissions from this source are presented in **Section 4.4.2.1** below.

Figure 4.4.4 HFC emissions projections from the Industrial Processes sector
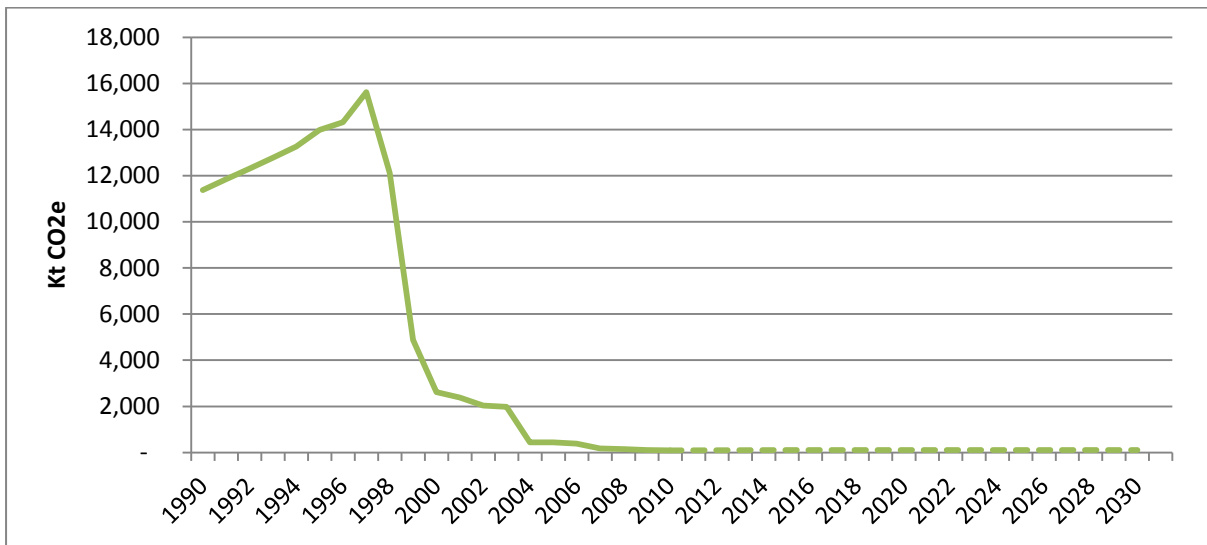
Figure 4.4.5 PFC emissions projections from the Industrial Processes sector
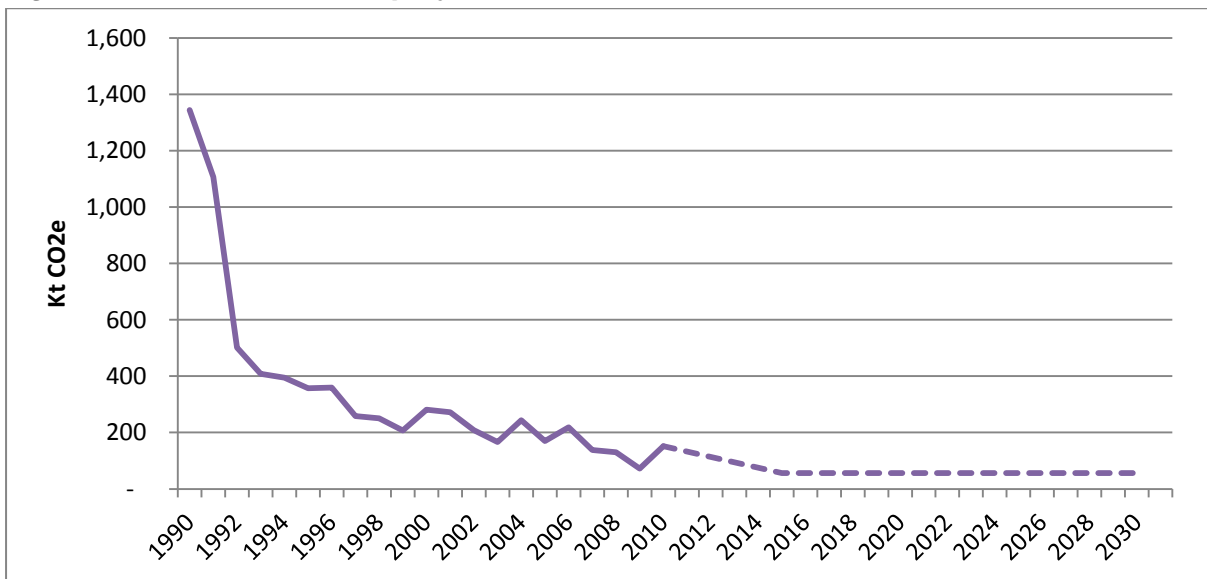
Figure 4.4.5 SF6 emissions projections from the Industrial Processes sector
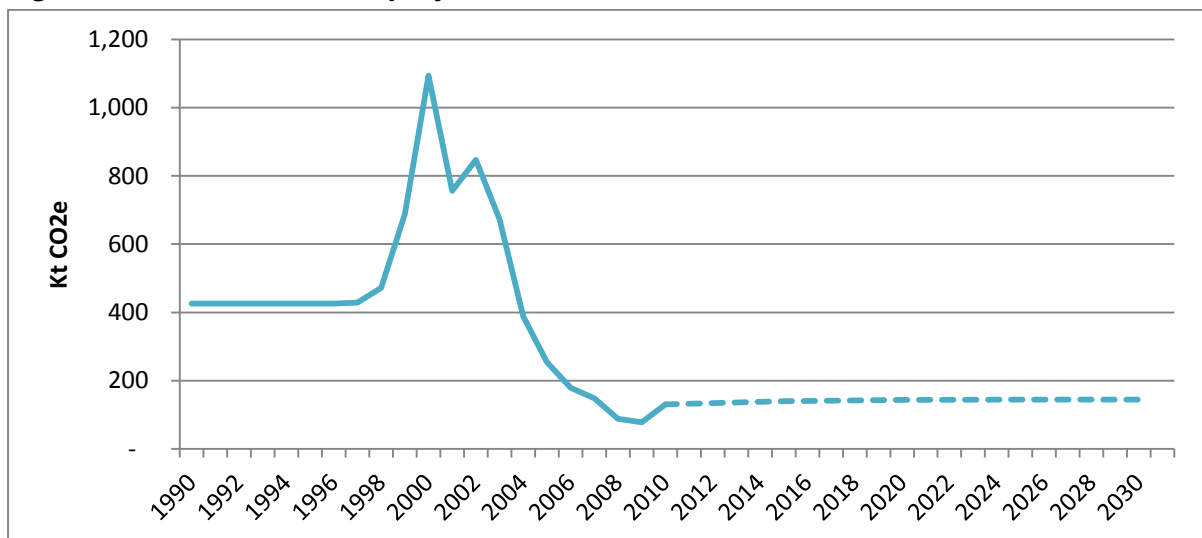
4.4.2.1 Changes in industrial processes sector perfluorocarbon emissions since the previous update

Since the production of the Spring 2012 update to the non-CO_2 projections, new information has become available regarding primary aluminium production in the UK. In 2009, there were 3 sites producing primary aluminium in the UK. Previous projections of PFC emissions from this source had assumed the continued operation of three UK sites, however, of the three sites only one remains operational.

One site ceased operation in 2009, and the resulting reduction in emissions is now reflected in the 2012 UK GHG Inventory, the baseline for these projections. A second site ceased operation in early 2012, so projected emissions from this site are reflected in these projections.

The effect of this change is to reduce emissions from this source by approximately 51% across the projected time series, as compared to the Spring 2012 update (**Figure 4.4.6**).

Figure 4.4.6 Spring 2012 and Autumn 2012 industrial processes sector PFC projections
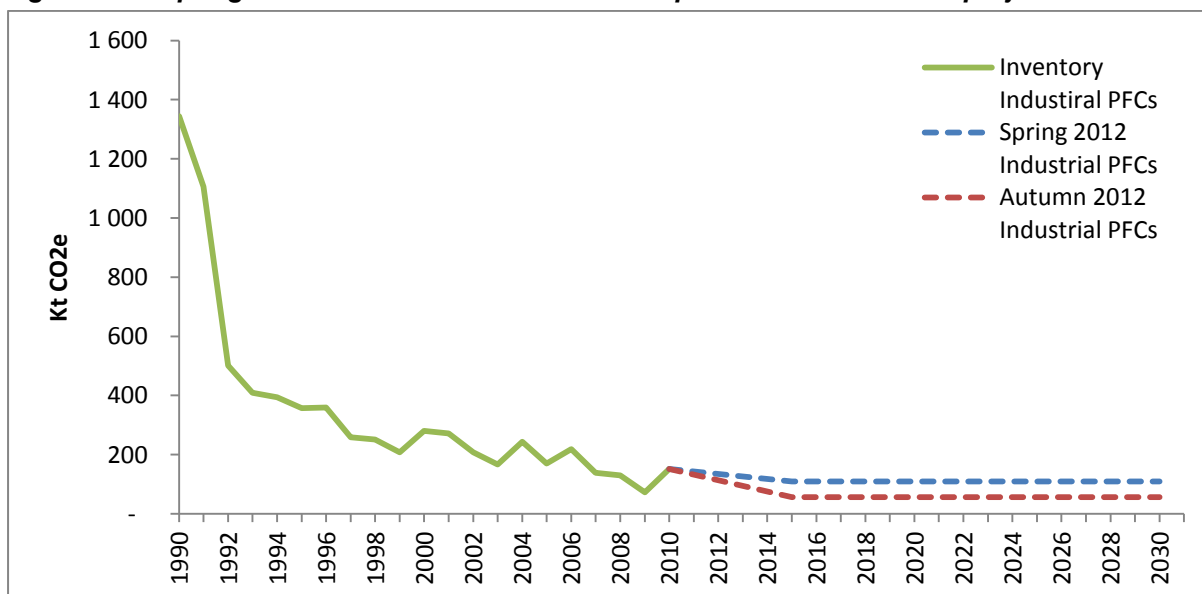
4.4.3 Industrial Processes sector methane emissions

Methane emissions from the industrial processes sector originates exclusively from fletton brick manufacture. Methane has historically contributed a relatively small amount to overall emissions from the Industrial Processes sector. **Figure 4.4.2** shows the historical and projected trend for CH_4 emissions from the Industrial Processes sector.

Similar to the business sector, reductions in emissions in the 2008 to 2010 time frame could be associated with a slowdown in overall economic activity due to the recession. However, fluctuations of this small magnitude are difficult to attribute to a single cause. Static growth is projected forward due to the relatively small emissions from this gas in this sector and relatively high inter-annual variability.

Figure 4.4.2 Methane emissions projections from the Industrial Processes sector
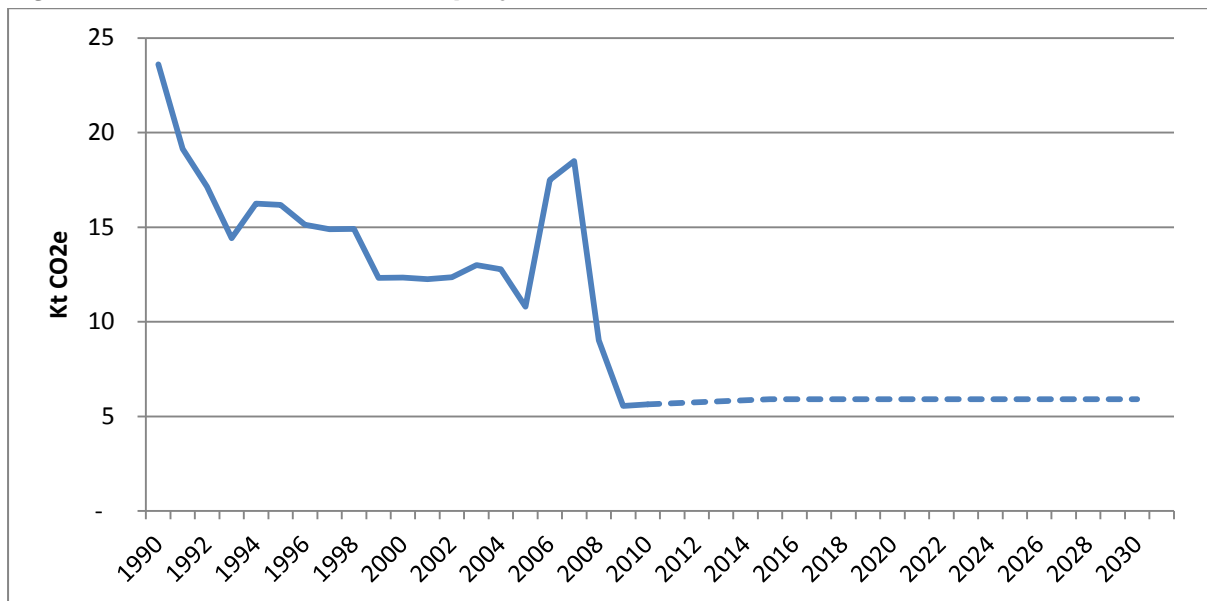
4.5 LULUCF Sector

The land use/land use change (LULUCF) sector is the smallest sector in terms of contribution to overall non-CO_2 emissions considered in this report. Emissions in 2010 were approximately 0.7 Mt CO_2e, of which approximately 95% were from nitrous oxide (N_2O), which equates to approximately 0.8% of total non-CO_2 emissions from all sectors. Remaining emissions are from methane (CH_4).

There have been no changes to projected emissions in the LULUCF sector in this update, however, an update to DECC's LULUCF projections is expected in the Spring 2013 update to the non-CO_2 projections.

Figure 4.5.1 – Overall LULUCF sector emissions projections
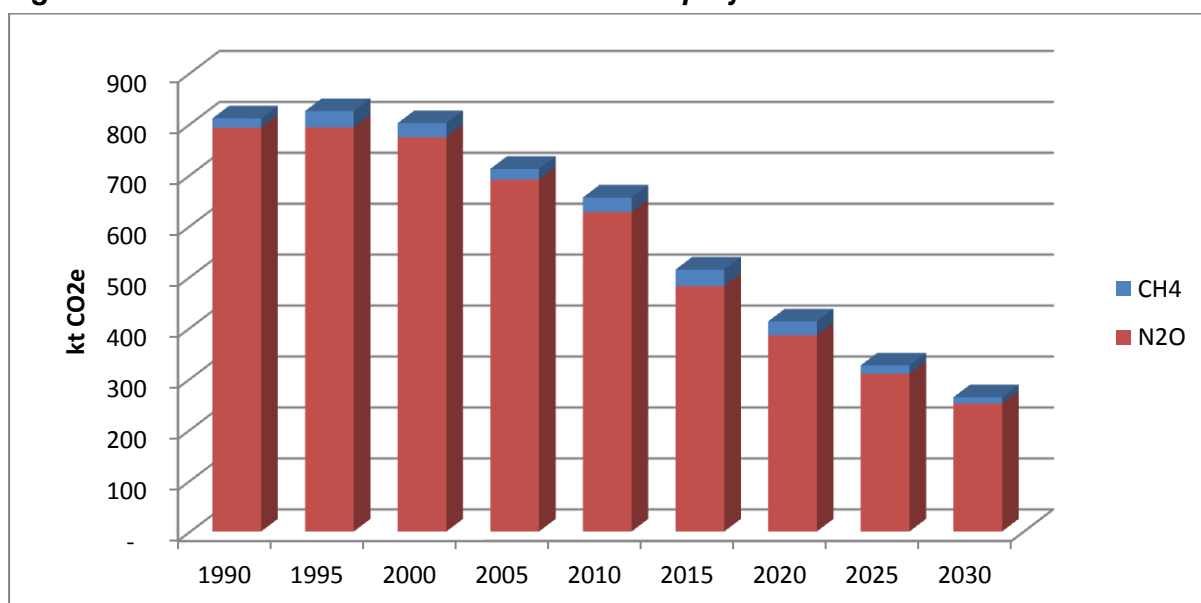
Overall emissions from LULUCF are projected to be approximately 0.26 Mt CO_2e in 2030, representing a reduction of approximately 60% on the 2010 level and 68% on the 1990 level (see Figure 4.5.1). The decline in emissions is predominantly due to reduced land disturbance from the conversion of land to crop-land.

4.5.1 LULUCF Sector nitrous oxide emissions

Emissions of N_2O accounts for approximately 95% of non-CO_2 GHG emissions in the LULUCF sector. The major source of N_2O is the conversion of land to crop land and the associated disturbance of soil. This source alone results in approximately 99% of N_2O emissions from LULUCF, with the remaining 1% being the result of biomass burning and the application of nitrogen based fertiliser to forested land.

Nitrous oxide emissions had remained broadly static from 1990 until 2000 before declining to approximately 80% of the 1990 level by 2010. This trend is projected to continue at a roughly even pace to 2030, when N_2O emissions are projected to be 0.3 Mt CO_2e (see **Figure 4.5.3**). The slow reduction in projected emissions from this source is due to an estimated slow decline in the rate at which land is converted to crop land, specifically in Wales. The

total area of crop land in Scotland, England and Northern Ireland is expected to remain unchanged beyond 2010.

Figure 4.5.3 – Nitrous oxide emissions projections for the LULUCF sector
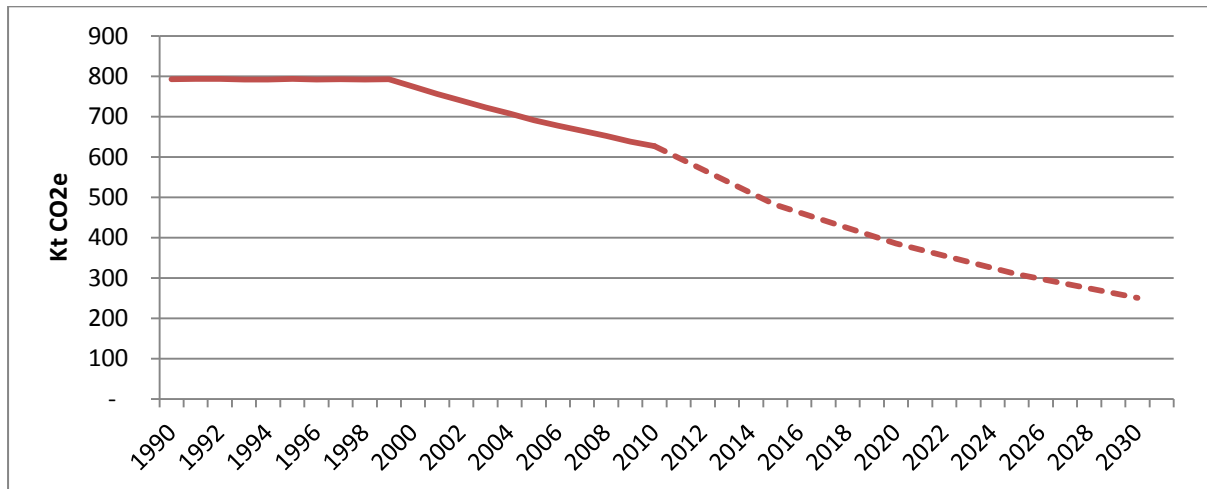
4.5.2 LULUCF Sector methane emissions

Methane is comparatively a small contributor to overall emissions from LULUCF, representing approximately 5% of emissions in 2010. Emissions of CH_4 from LULUCF are largely driven by biomass burning (wildfires) and deforestation, both of which have large inter-annual variability. **Figure 4.5.2** highlights this high level of inter-annual variability in the historic inventory data. In order to account for this in projecting wildfire emissions, an extrapolated trend and associated probability distribution function with lagged terms are fitted to 1990 Forestry Commission data, which is reported to the Food and Agriculture Organisation of the United Nations as part of the Global Forest Resource Assessment.

In order to account for variability in the deforestation rate, it is assumed that rates remain constant to 2030, with emissions projected to be 13 kt CO_2e in 2030.

Figure 4.5.2 – Methane emissions projections for the LULUCF sector
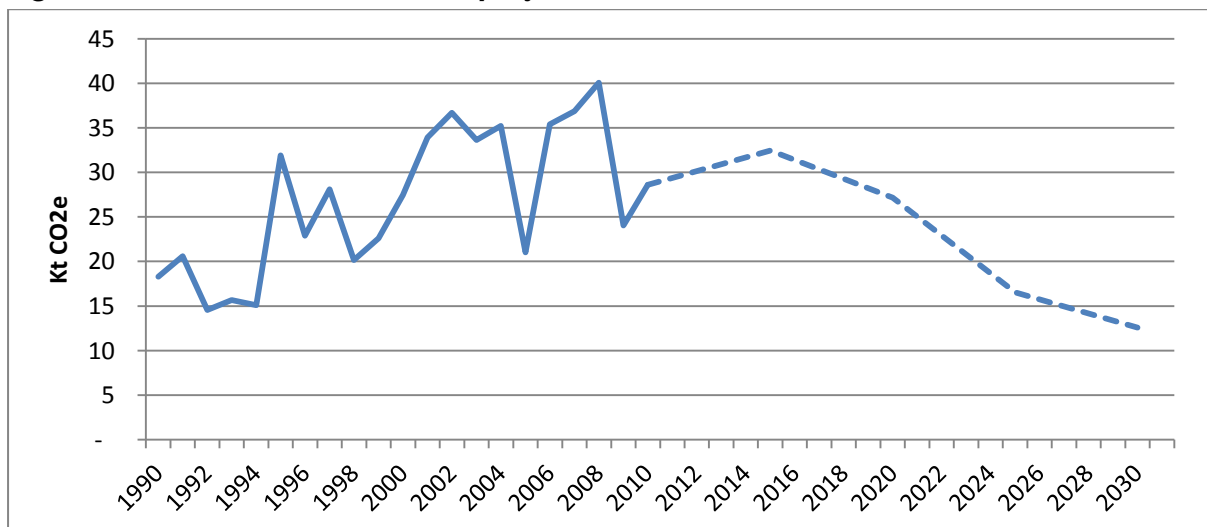
4.6 Residential Sector

In 2010 non-CO_2 greenhouse gas (GHG) emissions from the residential sector were approximately 2.7 $MtCO_2e$, representing around 3% of the UK's total non-CO_2 emissions. Nitrous oxide (N_2O), methane (CH_4) and HFC's contribute to non-CO_2 GHG emissions from this sector.

There have been no changes to projected emissions in the residential sector in this update.

Figure 4.6.1 – Overall Residential sector emissions projections
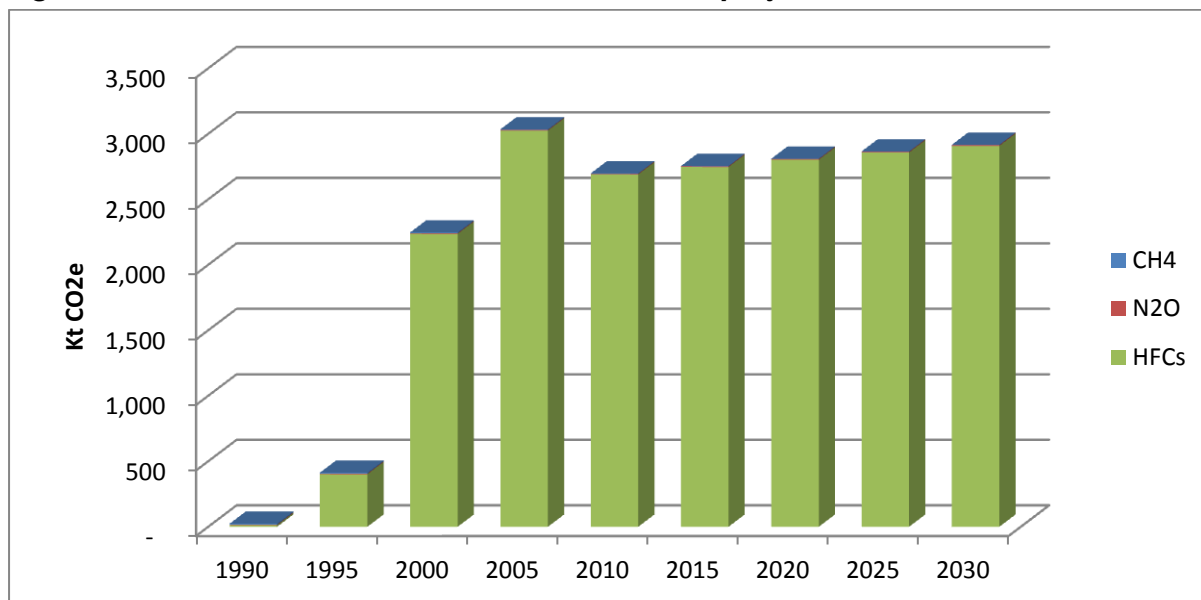
Overall emissions from the residential sector are projected to be approximately 2.9 Mt CO_2e in 2030. From 2010, they are projected to increase approximately 8% by 2030, due to a projected increase in HFC emissions. Historically, residential sector emissions have increased approximately 2.7 $MtCO_2e$ since 1990.

4.6.1 Residential Sector Hydrofluorocarbon emissions

Emissions of HFCs in the residential sector were estimated to be 2.7 $MtCO_2e$ in 2010, representing approximately 99.7% of non-CO_2 GHG emissions from the residential sector, (**Figure 4.6.2**).

These emissions result from aerosols and metered dose inhalers (MDI). Emissions of HFC's have increased rapidly since 1990 due to the phasing out of CFC's via the Montreal Protocol, resulting in the use of HFC's as replacement gases. Residential HFC emissions are projected to increase by approximately 0.2 $MtCO_2e$, or 8%, between 2010 and 2030, due to increased emissions from MDI as a result of increased UK population size (**AEA, 2008**).

The EU's F-gas regulation is not expected to drive the replacement of HFC's with new lower GWP replacement gases in this specific sector, because no alternative compounds have been identified that meet the stringent criteria for delivering inhaled medication. Emissions from aerosols are expected to remain constant because no clear trend in emissions is observed in the historic time-series (**AEA, 2010**).

Figure 4.6.2 – Hydrofluorocarbon emissions projections for the Residential sector
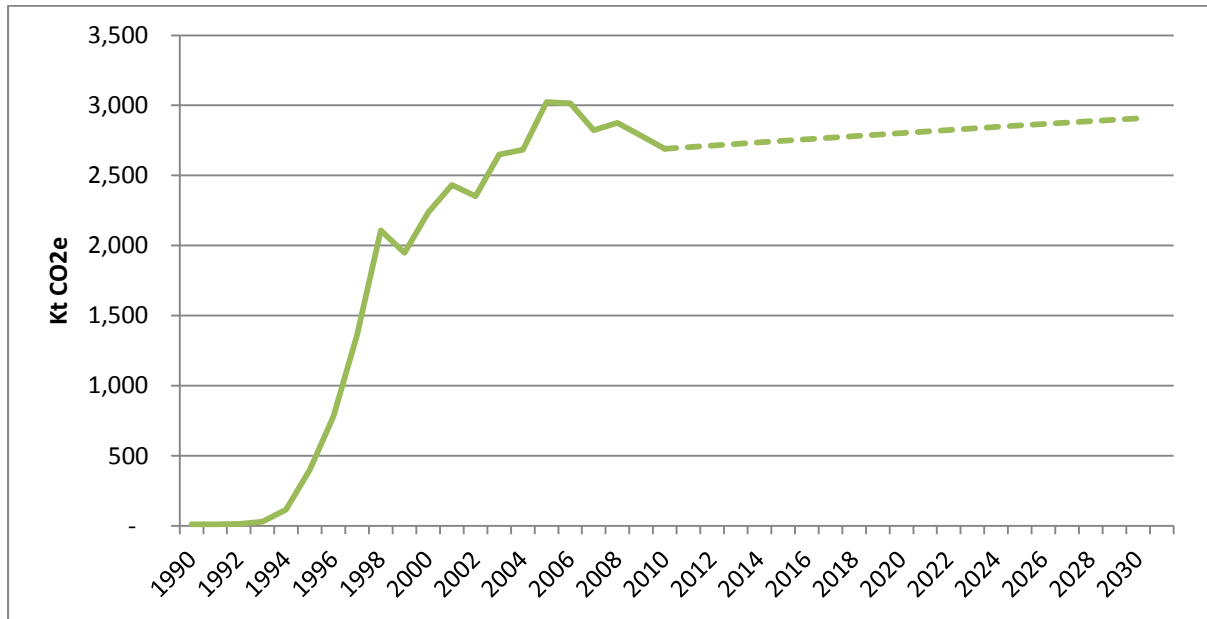
4.6.2 Residential Sector nitrous oxide emissions

Nitrous oxide emissions were estimated to be 5.1 $ktCO_2e$ in 2010, representing approximately 0.2% of non-CO_2 GHG emissions from the residential sector. These emissions result from the use of house and garden machinery.

Historically, N_2O emissions have increased approximately 19% since 1990. Emissions are projected to increase by approximately 1.2 $ktCO_2e$, or 22.6%, between 2010 and 2030 (see **Figure 4.6.3**). These percentage increases may be misleading though, as the absolute emissions values are very small.

Figure 4.6.3 – Nitrous oxide emissions projections for the Residential sector
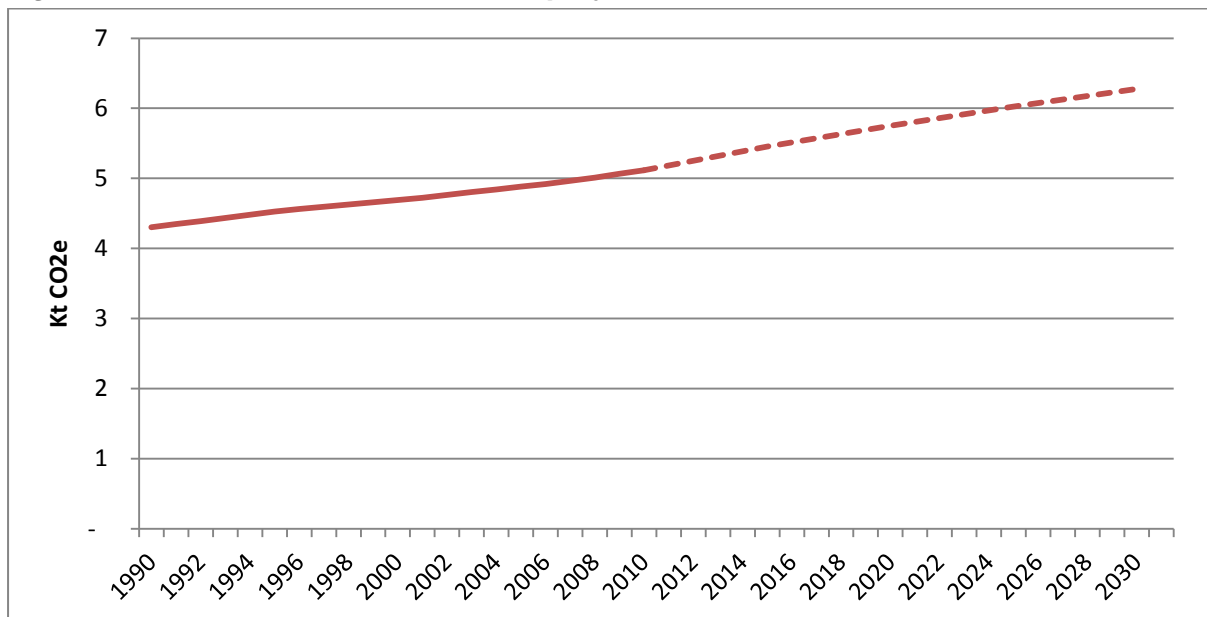
4.6.3 Residential Sector methane emissions

Methane emissions were estimated to be 3.0 $ktCO_2e$ in 2010, representing approximately 0.1% of non-CO_2 GHG emissions from the residential sector. These emissions result from house and garden machinery, and accidental fires - vehicles. Historically, CH_4 emissions have decreased approximately 58.7% since 1990. Emissions are projected to decrease by approximately 0.8 $ktCO_2e$, or 26.4%, between 2010 and 2030. These percentage increases may be misleading though, as the absolute emissions values are very small.

Figure 4.6.4 – Methane emissions projections for the Residential sector
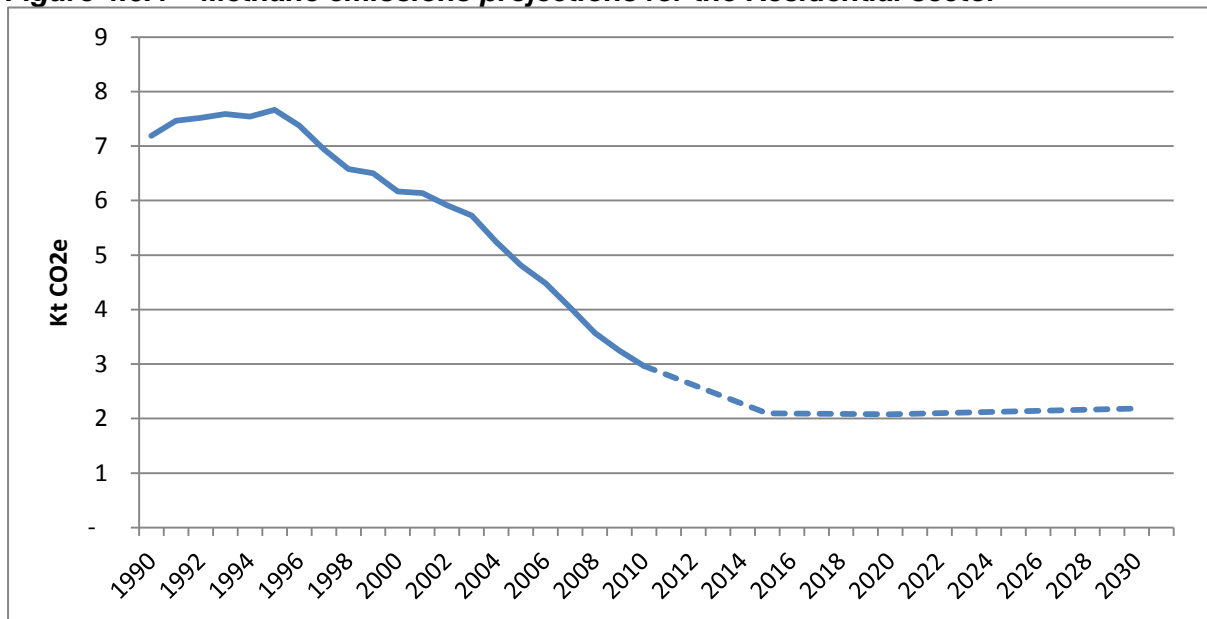
4.7 Transport Sector

The transport sector is the second smallest contributor of total non-CO_2 emissions. In 2010 it represented approximately 1 Mt CO_2e, equivalent to approximately 1% of total non-CO_2 greenhouse gas emissions. Two gases represent the non-CO_2 contribution to emissions from this sector, nitrous oxide (N_2O) and methane (CH_4).

Since the Spring 2012 update to the projections a new set of road transport projections have been produced by AEA and have been included in this update see **Section 4.7.1.1** for further details.

Figure 4.7.1 – Overall Transport sector emissions projections
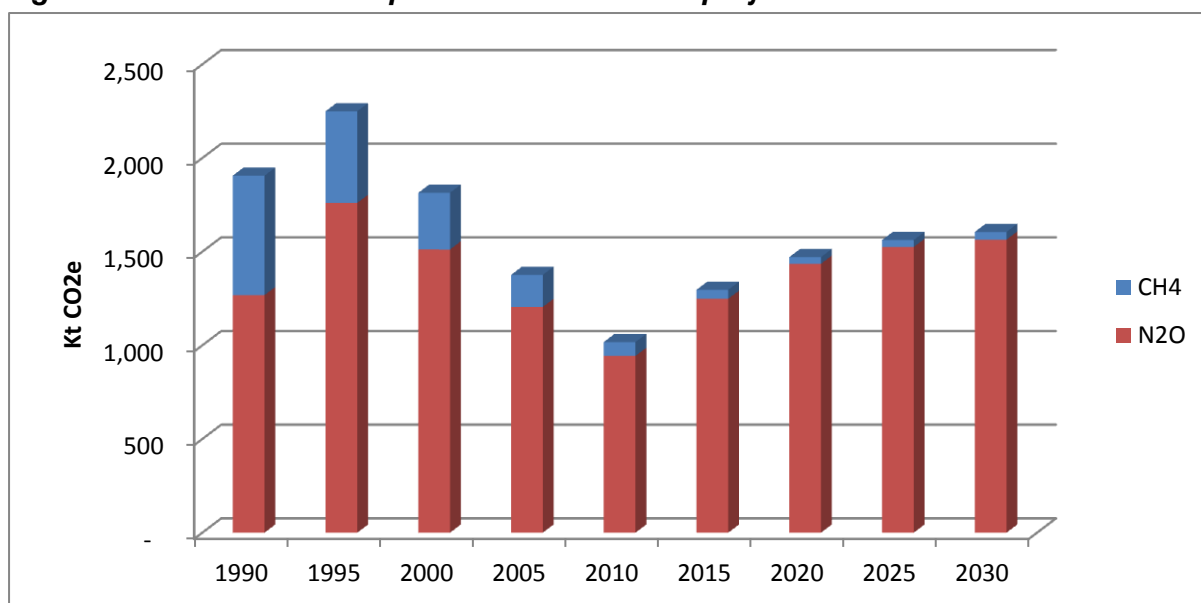
Overall emissions from the transport sector are projected to be approximately 1.6 Mt CO_2e in 2030, which corresponds to a projected increase in emissions of approximately 58% on the 2010 level (See Figure 4.7.1). However, overall emissions from the transport sector have decreased by 47% from 1990 level, resulting in projected emissions in 2030 being approximately 16% lower than in 1990.

The increase in projected overall emissions from the transport sector is being driven by N_2O emissions from new road transport vehicles with emissions constraints on nitrogen oxides (NO_x), which emit higher amounts of N_2O. Further explanation of this is contained in **Section 4.7.1.1.**

4.7.1 Transport sector nitrous oxide emissions

Nitrous oxide provides by far the most significant contribution to non-CO_2 emissions from the transport sector. In 2010 N_2O represents approximately 92% of non-CO_2 emissions from transport, rising to approximately 97% by 2030.

Road transport, particularly cars, are the highest contributor to the transport sector's N_2O emissions across the projections time series, emitting approximately 80% of the N_2O from transport in 2010, rising to approximately 88% in 2030.

Figure 4.7.2 Historical trend and projections of nitrous oxide emissions from transport
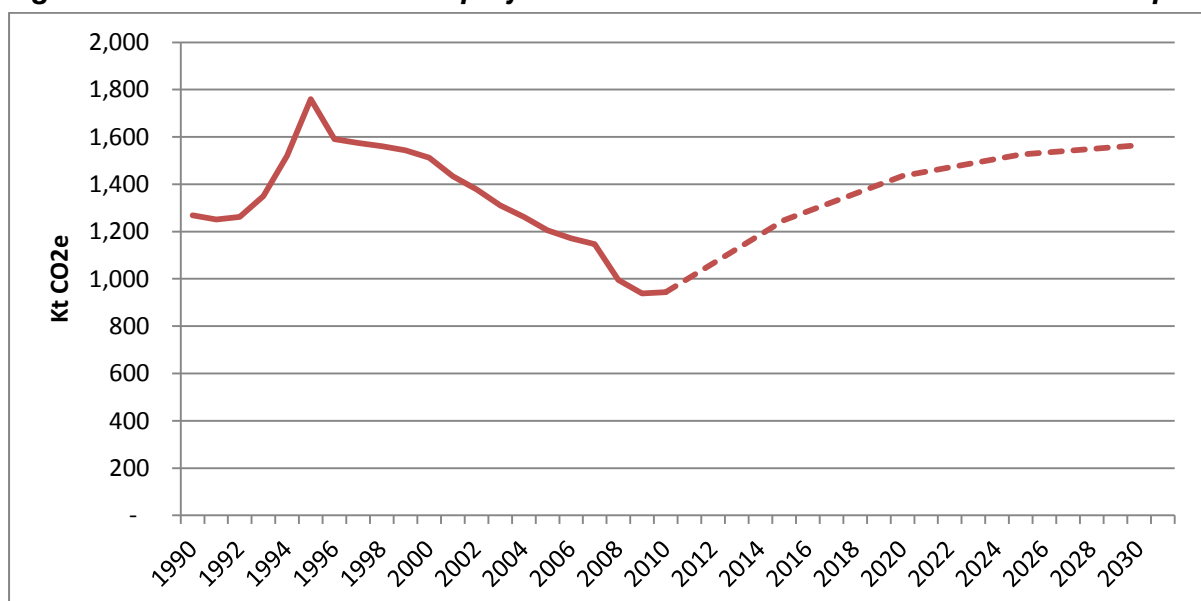
N$_2$O from the transport sector is projected to increase from approximately 1 Mt CO$_2$e in 2010 to approximately 1.6 Mt CO$_2$e in 2030 (see **Figure 4.7.2**). This projected rise is predominantly being driven by changes in the road transport categories.

The trends in projected emissions from road transport cannot be explained by a single factor but are dictated by a combination of factors. These are mainly the rate of traffic growth for each vehicle type, the relative differences in emission factors for each vehicle type and across the Euro classes and the turnover in the vehicle fleet. There can be both combining and competing effects on the trends.

N$_2$O emissions from road vehicles are affected by technologies introduced to control other air pollutant emissions which are regulated, especially NO$_x$. In particular, the Euro standards for petrol cars require the fitting of three-way catalyst systems. Initially, these led to higher N$_2$O emissions as a result of the unintended formation of N$_2$O as a by-product of the NO$_x$ reduction process on the catalyst surface. Improved catalyst formulations are most likely to be the cause of the lower factors for more recent Euro standards, however, other factors may be driving the trend. This is reflected in the fall in emissions in the 2000's.

With respect to HGVs and buses, emissions factors have been increasing since the introduction of new vehicles registered since around 2005. The reason for this is again likely to be due to measures aimed at controlling NO$_x$ and in particular the use of Selective Catalytic Reduction (SCR) which involves injecting urea (a nitrogen compound) into the exhaust stream. This can cause the unintended formation of N$_2$O in the NO$_x$ reduction process.

The steeper rise in projections from 2010 is mainly due to the increased proportion of diesel powered cars in the car fleet and penetration of higher emitting new HGVs in the fleet which eventually levels off causing the rate of increase to slow down.

4.7.1.1 Changes in transport sector nitrous oxide emissions since the previous update

Since the Spring 2012 update new emissions projections for road transport have been produced (**AEA, 2012** - unpublished). This new set of projections utilises 2011 traffic projections produced by the Department for Transport (**DfT, 2011**) and methodology and assumptions developed in 2011 for the latest air pollutant emission projections developed for Defra (**Defra, 2011**).

A number of changes in activity data and emission factors have been made since the previous version of projections and all of these changes are interacting to change the overall trend in future emissions. The changes cannot be assigned to any one specific factor, but among the updated assumptions the changes that are likely to have had the biggest influence on the trend in the projections are as follows:

- Changes in DfT's traffic projections

- Changes in new vehicle sales projections and turnover in the fleet

- Changes in assumptions in diesel car penetration rates in the new car fleet – more rapid diesel penetration initially to 2015 than previously assumed, then declining.

- Use of Automatic Number Plate Recognition (ANPR) data to better characterise the usage of petrol vs diesel cars and vehicles of different ages on the road – in particular the articulated HGV fleet on the road is considerably newer than estimated from the age mix of the overall fleet indicating the much greater usage of newer vehicles than previously thought.

- Changes in N_2O emission factors, in particular those for HGVs showing higher factors for more modern Euro V and VI vehicles compared with earlier Euro standards than previously assumed.

Figure 4.7.3 Spring 2012 and Autumn 2012 transport sector nitrous oxide projections

Figure 4.7.3 above highlights the changes the new road transport projections update has had on total transport N_2O emissions going forward. The updated road transport projections have been re-baselined against the latest GHG Inventory publication following the method explained in **Section 2.1**.

The effect of the new road transport projections has been to increase the projected emissions by approximately 54 kt CO_2e in 2015 and 169 kt CO_2e in 2030. However, the trend for the emissions remains broadly similar to the Spring 2012 update.

4.7.2 Transport sector methane emissions

Methane contributes a marginal proportion of the total non-CO_2 greenhouse gas emissions from the transport sector, representing approximately 7% of emissions from this sector in 2010 and declining to approximately 3% in 2030. As with N_2O from the transport sector, road transport is the most significant contributor to CH_4 emissions, representing approximately 91% of CH_4 emissions from the transport sector in 2030. Air transport, including military, by comparison account for approximately 8%.

Figure 4.7.4 Historical trend and projections of methane emissions from transport
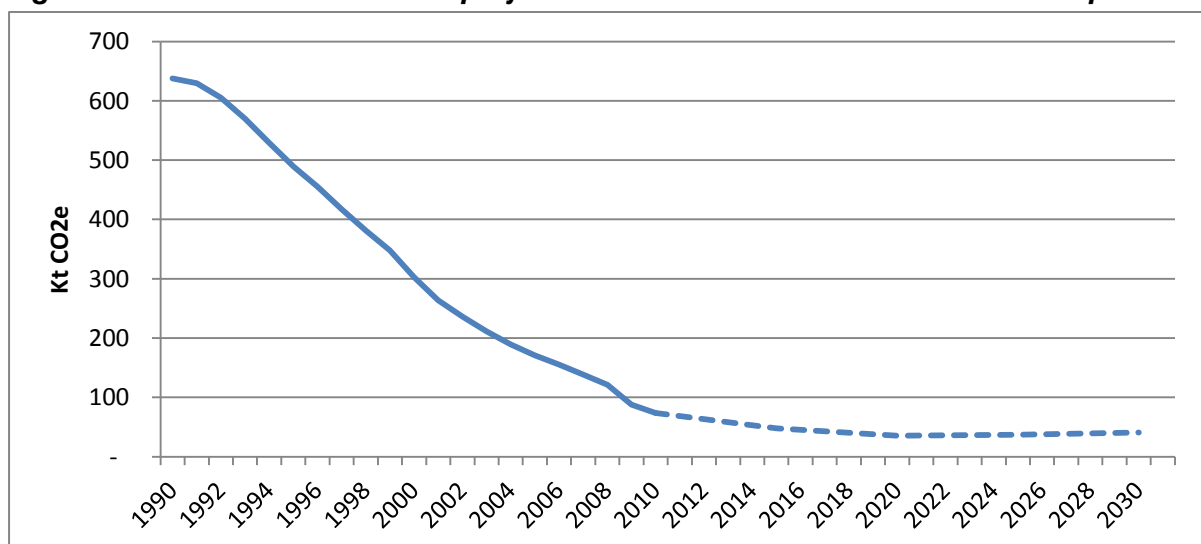
Emissions of CH_4 from the transport sector have declined markedly since 1990, displaying an 88% reduction between 1990 and 2010. The projected trend is for CH_4 emissions to continue to reduce, albeit by a much slower rate, a further 5.5% lower on 1990 levels by 2030. Emissions are therefore projected to be approximately 41 kt CO_2e in 2030.

Methane emissions from road vehicles are not regulated by the Euro emission standards but are affected by technologies introduced to control other air pollutant emissions which are regulated, especially total hydrocarbons. These measures include three-way catalysts for petrol vehicles and oxidation catalysts for diesel vehicles, and general improvements in engine design and management. Thus, CH_4 emission factors broadly fall across the projected time series in line with the reductions in hydrocarbon emissions.

The trends in projected emissions from road transport cannot be explained by a single factor but are dictated by a combination of factors. These are mainly the rate of traffic growth for each vehicle type, the relative differences in emission factors for each vehicle type and across the Euro classes and the turnover in the vehicle fleet. There can be both combining and competing effects on the trends. The combination of these factors leads to the trend displayed in **Figure 4.7.4** above, projecting only a slight further decrease in transport CH_4 emissions going forward.

4.7.2.1   Changes in transport sector methane emissions since the previous update

As detailed in **Section 4.7.1.1** above, a new version of the road transport projections has been incorporated into this update to the non-CO_2 projections. As well as the projected impacts on N_2O, this update has also had effects on the projected emissions of CH_4. A number of changes in activity data and emission factors have been made since the previous

version of projections and all of these changes are interacting to change the overall trend in future emissions.

Figure 4.7.5. Spring 2012 and Autumn 2012 transport sector methane projections
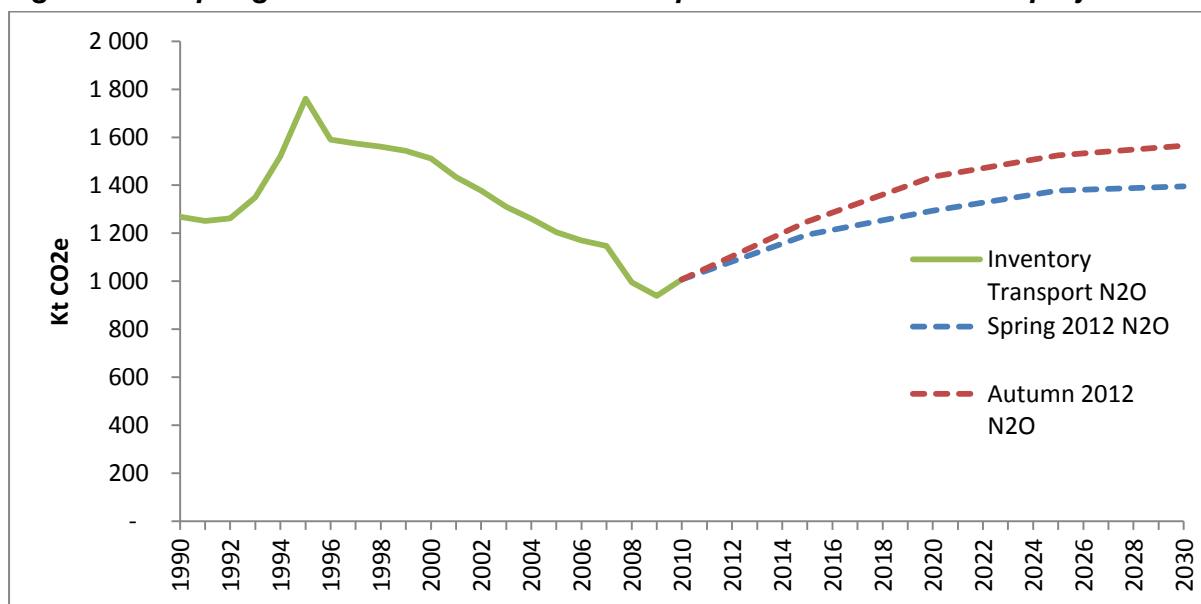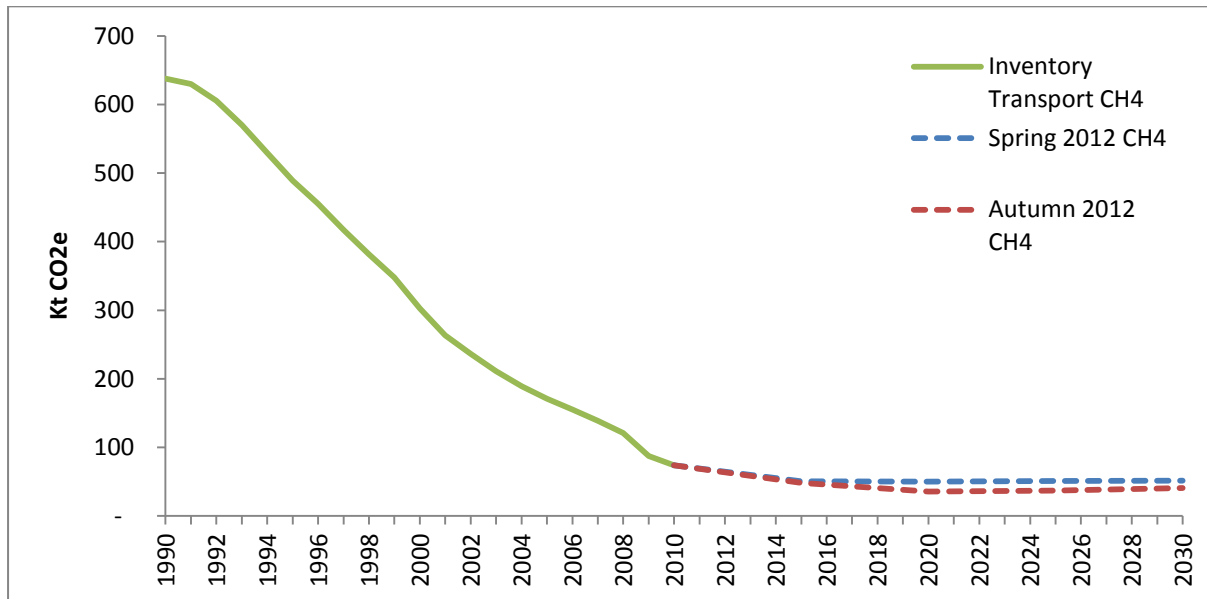

Figure 4.7.5 above highlights the changes the new road transport projections update has had on total transport CH_4 emissions going forward. The updated road transport projections have been re-baselined against the latest GHG Inventory publication following the method explained in **Section 2.1**.

The update to the road transport projections has had the effect of marginally reducing projected CH_4 emissions across the time series, resulting in emissions in 2030 being approximately 10 kt CO_2e lower compared to the Spring 2012 update.

4.8 Waste Management Sector

In 2010 non-CO_2 greenhouse gas (GHG) emissions from the waste management sector were approximately 16.3 $MtCO_2e$, representing around 17% of the UK's total non-CO_2 emissions. Two gases represent the non-CO_2 contribution to emissions from this sector, Nitrous oxide (N_2O) and methane (CH_4). **Figure 4.8.1** below highlights the breakdown in emissions by gases for the waste management sector.

The waste management sector has been updated to correct errors identified in the re-baselining of the previous Spring 2012 projections.

Figure 4.8.1 Non-CO2 GHG emissions projections for the waste management sector
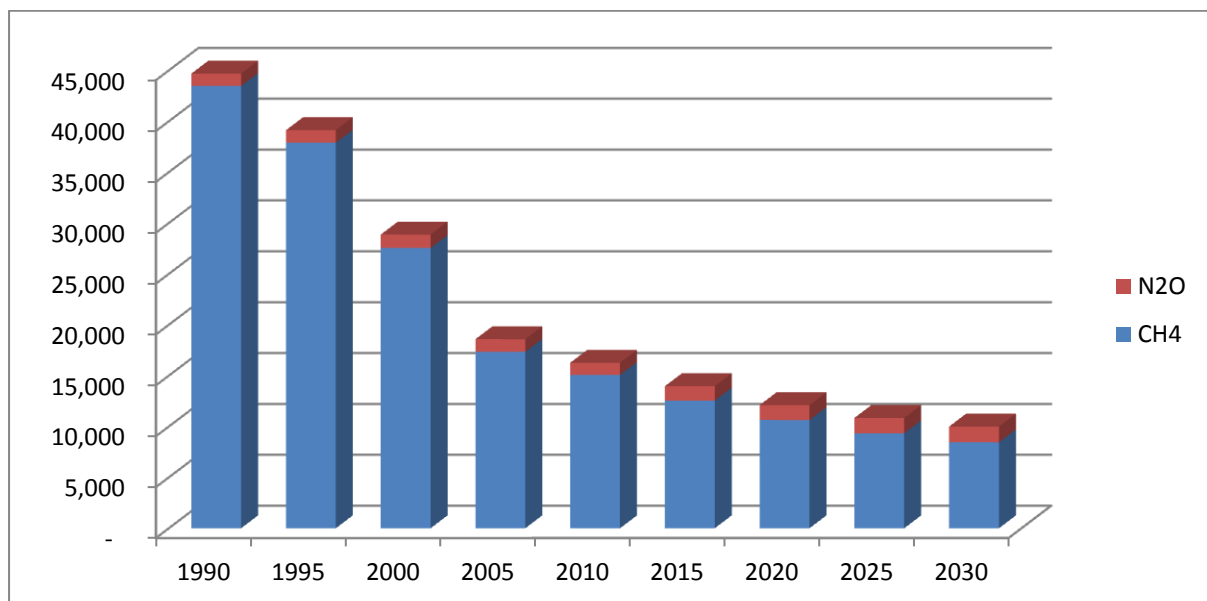
Overall emissions from the waste management sector are projected to be approximately 10 Mt CO_2e in 2030, which corresponds to a decrease in emissions of approximately 39% since 2010 (see Figure 4.8.1). Historically, waste management emissions have decreased 28 $MtCO_2e$ since 1990, which equates to a reduction of approximately 78%. Both historic and projected emissions reductions are dominated by significant reductions in landfill waste emissions.

4.8.1 Waste management methane emissions

Emissions of CH_4 were estimated to be approximately 15.1 $MtCO_2e$ in 2010, representing approximately 93% of non-CO_2 GHG emissions from the waste management sector. Emissions from landfill waste representing 98% of waste management CH_4, with sewage sludge decomposition and incineration also contributing. There has been a significant reduction in the emissions trend since 1990; around 65%. Emissions are projected to decrease by approximately 6.6 $MtCO_2e$, or 44%, between 2010 and 2030 (see **Figure 4.8.4**). This is expected as a result of reductions in the amount of waste sent to landfill.

Figure 4.8.4 Historical trend and projections of methane emissions from waste management
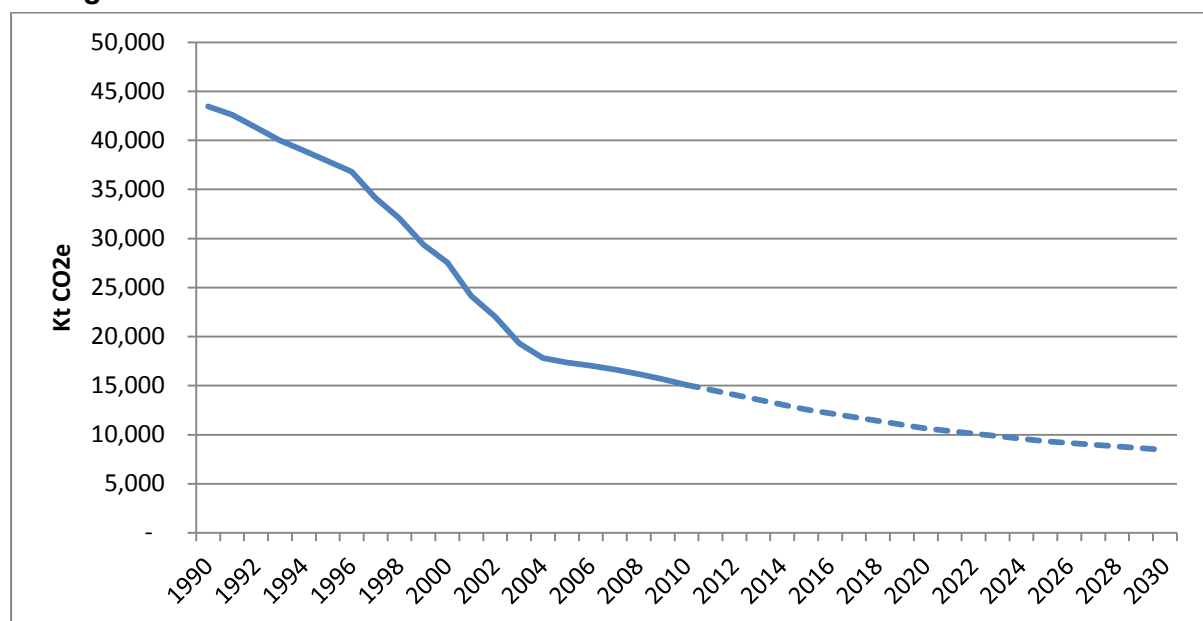
Projected methane emissions from **landfill waste** are estimated using a model, MELMod, which is based on the first-order decay International Panel on Climate Change (IPCC) methodology, and is summarised in the UK's National Inventory Report (NIR).

Emissions from landfill are dominated by emissions from waste already sent to landfill, i.e. historical waste. The decay of this waste drives the observed reduction of approximately 45% in methane emissions from this source. Methane emitted from waste already in landfill will reduce over time, particularly from waste in older landfill sites with little or no methane capture technology. Emissions from old sites represented approximately 6% of methane emissions in 2010, this is projected to reduce to <3% in 2030.

With respect to future waste sent to landfill it is projected that mass of waste sent to landfill will decrease by approximately 15% from 2010 to 2030, based on projections of waste arisings from Local Authority Collected Waste (LACW) to 2019, and Commercial & Industrial (C&I) waste to 2014. As no additional information is available on projected emissions from this category beyond 2019 and 2014, volumes of landfill waste are assumed to remain constant after these respective years.

Projected methane emissions from **waste water treatment** are based on a model used in the historic inventory (**Hobson, 1996**). Projections to 2030 are based on implied emission factors for various disposal routes and projected changes to the amount disposed of to each route (e.g. due to the Landfill Directive), and population growth. The assumptions made on sewage sludge disposal routes in 2020 have been taken from an Entec report (**Entec, 2006a+b**), also used in the Spring 2011 and previous publications.

Projected methane emissions from **waste incineration** (not for power generation, and including the categories of accidental vehicles fires, incineration, incineration of clinical waste, and incineration of sewage sludge) are assumed to remain constant as the future levels of activities in these categories is unknown.

4.8.1.1 Changes in waste management sector methane emissions since the previous update

Following the publication of the Spring 2012 update an error was identified in this sector in relation to re-baselining against the latest UK GHG Inventory. The effect of the correction of this error is seen in **Figure 4.8.4** below. The effect of this change on CH_4 emissions from waste management has been negligible, with new projections being approximately 1% lower consistently across the projected time series than those produced in Spring 2012.

Figure 4.8.4 Spring 2012 and Autumn 2012 waste management sector methane projections
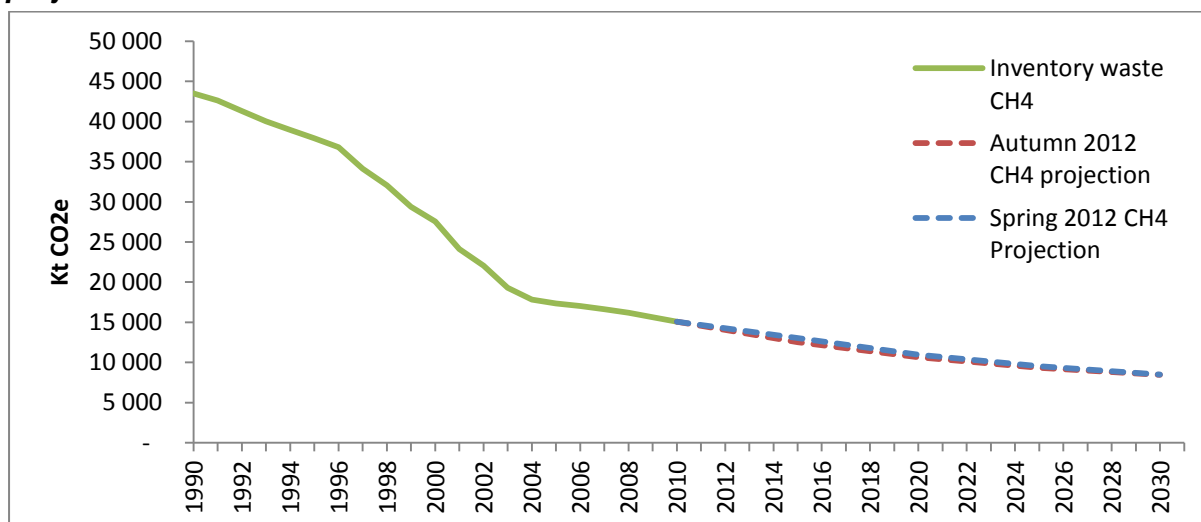
4.8.2 Waste management nitrous oxide emissions

Emissions of N_2O were estimated to be approximately 1.2 $MtCO_2e$ in 2010, representing approximately 7% of non-CO_2 GHG emissions from the waste management sector. These emissions result mainly from sewage sludge decomposition, incineration of sewage sludge, and other incineration. There has been no significant change in the emissions trend since 1990. Emissions are projected to increase by approximately 353 $ktCO_2e$, or 39%, between 2010 and 2030 due to a projected increase in sewage sludge decomposition (see Figure 4.8.2).

Figure 4.8.2 Historical trend and projections of nitrous oxide emissions from waste management
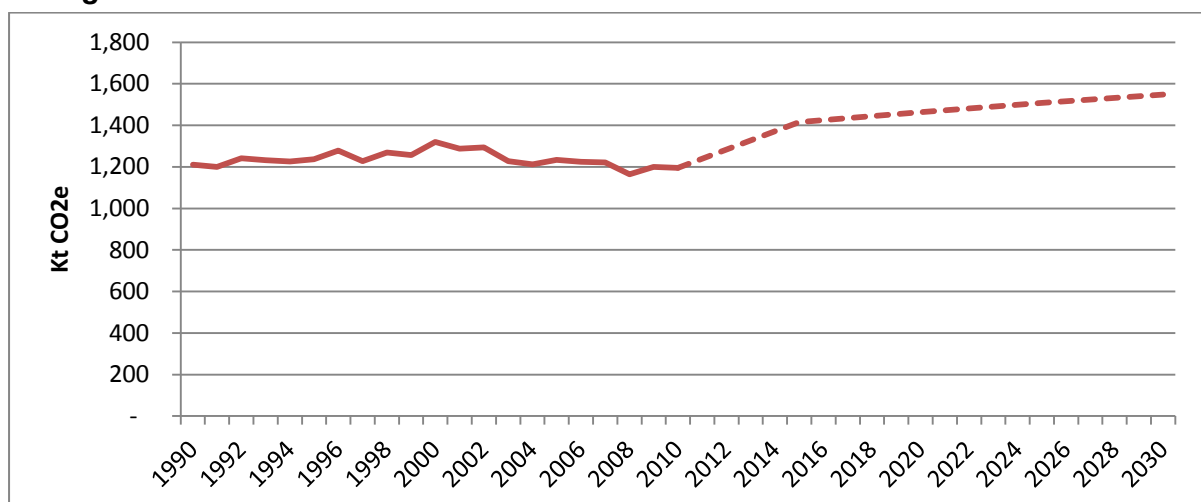
Projections of N$_2$O emissions from **waste water treatment** are based on a constant emission factor per head of population (GAD, 2008). The historic inventory is based on protein consumption and population data. The projections assume that protein consumption will remain unchanged going forwards.

Projected emissions from **waste incineration** (not for power generation, and including the categories of accidental vehicles fires, incineration, incineration of clinical waste, and incineration of sewage sludge) are assumed to remain constant as the future levels of activities in these categories is unknown.

4.8.2.1 Changes in waste management sector nitrous oxide emissions since the previous update

As was the case with CH$_4$ (**Section 4.8.1.1**), an error in the production of the previous set of waste management projections has been corrected in this update. This correction has had the effect of reducing the projected nitrous oxide emissions across the time series. **Figure 4.8.3** highlights the effect this correction has made. Nitrous oxide emissions from the waste management sector are now projected to be approximately 60 kt CO$_2$e lower across the projected rime series than they were in the Spring 2012 update. This is in line with the lower than projected figures reported in the latest UK GHG Inventory.

Figure 4.8.3 Spring 2012 and Autumn 2012 waste management sector nitrous oxide projections
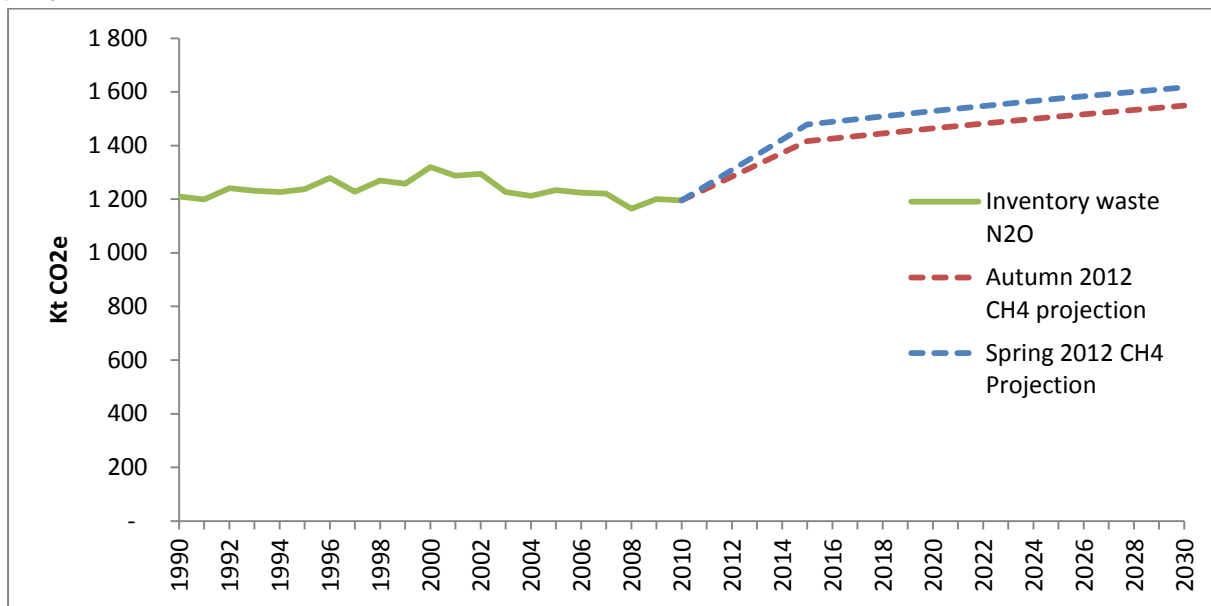
5 Uncertainties

5.1 Uncertainties methodology/approach

The DECC non-CO_2 projections model contains an uncertainties module which comprises a simplified Monte Carlo simulation run at the National Communication level in order to quantify uncertainties in the emissions projections.

This module assumes that the latest inventory year has no associated uncertainty, and the uncertainties in future years relate only to how different the inventory estimate is likely to be to the projected estimate in that year, ignoring the uncertainty associated with the inventory method; see **AEA 2010b** for further detailed explanation of the methodology.

The GHG Inventory uncertainty values are disregarded in this analysis due to the magnitude of the Inventory uncertainties. Including the GHG Inventory uncertainties (specifically N_2O uncertainty: -74% / +263%, see **DECC 2011c**) for the non-CO_2 GHGs would result in these larger uncertainties dominating the Monte Carlo simulation and effectively hiding the much smaller (typically +/- 10 to 30% for most sectors at 2020, up to +/- 50% at 2030) uncertainties in the projected trend.

Since the Autumn 2011 update to the projections, the uncertainty on the growth (positive or negative) of the emissions is used as input for the Monte Carlo simulation rather than the uncertainty around each data point, as was used in prior updates. This conclusion logically follows our stated intention to model uncertainty in the trend without incorporating uncertainty in the historic data which is the basis of the trend.

This methodology is currently under review, with the intention of re-convening a technical sub-committee on uncertainties prior to the publication of the Spring 2013 projections update.

5.2 Uncertainty results

The uncertainty analysis indicated approximately +/- 5% total uncertainty in the emissions for 2010, increasing gradually to around +/- 13% uncertainty at 2020. Beyond 2020 the uncertainty region becomes noticeably asymmetric so at 2030 the lower bound is 27% below the central estimate and the upper bound is approximately 32% above.

This asymmetry is an artefact of analysing the uncertainty in the growth rates rather than on absolute values, and reflects the effect of compounding a percentage increase compared with a percentage decrease: 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. **Figure 5.1** below highlights the uncertainty analysis results around the central projection estimate.

Figure 5.1 Uncertainty analysis for projections used in the Spring 2012 update, as 80% and 95% confidence intervals

Spring 2012 non CO2 projections : Uncertainty analysis
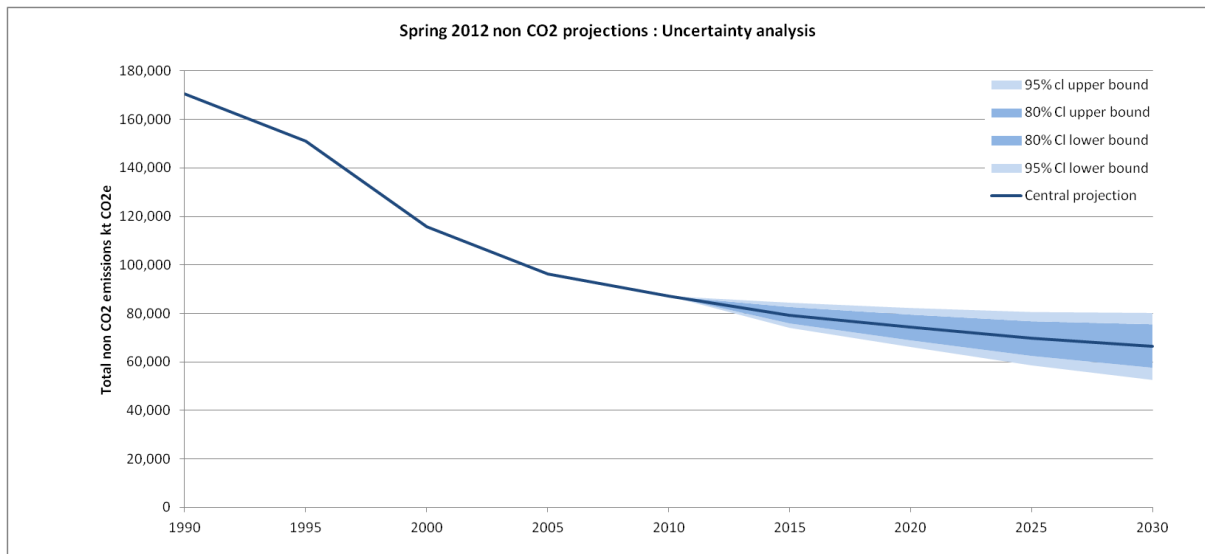
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Annex A: Summary of methods used to estimate emissions projections

6.1 Summary of methods used to estimate emissions projections

Where sectors have been updated the new methodology is described below. Individual sectoral updates are explained more fully in the relevant sector chapters.

6.1.1 Source category 1A1 – Energy Supply

All emissions in these categories are reported in DECC's UEP publications; see **Annex B** for more details.

6.1.2 Source category 1A2 – Business

All emissions in these categories with the exception of 1A2f - Industrial off-road mobile machinery are reported in DECC's UEP publications; see **Annex B** for more details.

1A2f - Industrial off-road mobile machinery

Emissions projections are calculated from a bottom-up approach by the Inventory Agency using machinery- or engine-specific emission factors in g/kWh based on the power of the engine and estimates of the UK population and annual hours of use of each type of machinery. For Industrial machinery, ONS construction statistics and DECC Construction, Industry and Energy growth indexes are used as projections drivers. The methodology follows the Tier 3 methodology described in the latest EMEP/CORINAIR emission inventory guidebook. An update to this model has been provided and used to calculate the projections in this report.

6.1.3 Source category 1A3 – Transport

Domestic aviation – Category 1A3a

Projected emissions from aviation are based on CO_2 forecasts published by the Department for Transport in 2009. The CO_2 emissions forecasts have been used as a proxy for fuel use, and the split between domestic and international emissions is estimated based on DfT passenger demand forecasts. Estimates of emissions from international aviation are not included in national totals.

The emission factors are provided on a mass of fuel basis and have been held constant from the latest inventory year.

Road transport – Category 1A3b

Emissions from road transport have been calculated by AEA's road transport model, based on DfT road traffic projections from 2011 (DfT, 2012). AEA's projected fleet composition has been used to calculate weighted emission factors for each GHG and vehicle type for each year.

Road transport projections have recently been updated and are expected to be included in the Autumn 2012 Non-CO_2 GHG Projections.

Rail – Category 1A3c

All emissions in these categories are reported in DECC's UEP publications; see **Annex B** for more details.

Navigation/Shipping - Category 1A3d (coastal shipping)

All emissions in these categories are reported in DECC's UEP publications; see **Annex B** for more details.

Aviation support vehicles – Category 1A3e

Emissions projections are calculated from a bottom-up approach by the Inventory Agency, using machinery- or engine-specific emission factors in g/kWh based on the power of the engine and estimates of the UK population and annual hours of use of each type of machinery. The emission estimates are calculated using a modification of the methodology given in EMEP/ CORINAIR (1996). For airport machinery, statistics on the number of terminal passengers at UK airports are used (CAA, 2010, and projections taken from DfT 2009)

6.1.4 Source category 1A4 – Other sources

Domestic and commercial sectors - Category 1A4a and 1A4b

All emissions in these categories with the exception of 1A4b – House and Garden Machinery are reported in DECC's UEP publications; see **Annex B** for more details.

1A4b – House and Garden Machinery

Emissions projections are calculated from a bottom-up approach by the Inventory Agency, using machinery- or engine-specific emission factors in g/kWh based on the power of the engine and estimates of the UK population and annual hours of use of each type of machinery. For house and garden machinery, trends in the number of households are used (CLG, 2010 - includes projected household statistics). The methodology follows the Tier 3 methodology described in the latest EMEP/CORINAIR emission inventory guidebook.

Stationary combustion sources in agriculture - Category 1A4c

All emissions in these categories are reported in DECC's UEP publications; see **Annex B** for more details.

6.1.5 Source category 1A5 – Aircraft – Military / Shipping - Naval

This sector includes emissions from military aircraft and shipping. No information is easily available about projected activity from military sources, and it has been assumed that emissions will remain constant.

Emissions from this source are extremely small in relation to total emissions of CH_4 and N_2O (<0.03%).

6.1.6 Source category 1B1 – Solid fuels

Open coal mines - Category 1B1a

Projected emissions from working coal mines utilise the DECC model and have been estimated based on projected coal production data (open cast and deep mined). Up to date emission factors from the GHG inventory have been applied to these activity projections for mining, and coal storage and transport.

Closed coal mines – Category 1B1a

Emissions from closed coal mines are calculated using a newly developed model by WSP Environmental (WSP, 2011), which updates an older model produced by White Young Green (WYG). The updates to the model incorporate refinements and additional data sources as well as upgrades to the assumptions made by WYG. Further details of the model can be found in section 3.4 and the referenced paper.

Solid Smokeless Fuel (SSF) and coke production – Category 1B1b

1B1b – Iron and steel flaring emissions estimates will be reported in DECC's UEP publications; see **Annex B** for more details.

All other 1B1b categories ('coke production' and 'solid smokeless fuel production') categories have been assumed constant in lieu of any appropriate projections data; emissions from these sources are extremely small, <0.01% of total non-CO_2 GHG emissions.

6.1.7 Source category 1B2 – Oil and natural gas

Gas production – Category 1B2b

Methane from leakage from the gas distribution network

Emissions of methane from leakage from the gas distribution network is the largest methane source in the UK inventory outside of the Agriculture and Waste sectors, comprising over 10% of all methane emissions in 2009.

Emissions in this category are projected to decline due to a 30 yr programme (started 2002) to reduce leakage from the gas distribution network by 70%. Projected changes in methane content of natural gas are not considered sufficiently meaningful fluctuations to take account of in the non-CO_2 GHG projections[2].

All other emissions in these categories are reported in DECC's UEP publications; see **Annex B** for more details.

Oil production – Category 1B2a

All emissions in these categories are reported in DECC's UEP publications; see **Annex B** for more details.

Oil and gas production Flaring / Venting – Category 1B2c

All emissions in these categories are reported in DECC's UEP publications; see **Annex B** for more details.

6.1.8 Source category 2A7 – Other

Emissions from fletton brick production are predicted to remain constant from 2010 onwards, having decreased since 2008 due to the closure of one of the two manufacturing plants. Emissions from these sources only contribute a small amount to the inventory totals.

6.1.9 Source category 2B – Chemical industries

Source category 2B5 – Methanol / Ethylene / General

All emissions in these categories will be reported in DECC's UEP publications; see **Annex B** for more details.

Source category 2B2 – Nitric acid production

Nitric acid production is a significant source of N_2O in the UK. Previous consultation with Industry representatives from all operating plants in the UK concluded that nitric acid production is expected to remain constant. Following a DECC consultation (for published documents see **DECC 2011e**) the decision was taken for the UK to choose an early opt-in of emissions from nitric acid production into the EU Emissions Trading Scheme (EU ETS). As a result of this, best available technology (BAT) abatement technology is now fitted at the two remaining UK plants, and this is projected to significantly reduce N_2O from the end of 2012, as stated in the Impact Assessment which accompanies the Consultation document.

New inventory data show a slight increase of approximately 340 Kt CO_2e of N_2O from Nitric acid production in 2010. However, as emissions are stated to reduce from the end of 2012

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[2] As advised by National Grid

onwards, the same projections as were published in the Spring and Autumn 2011 updates have been used for 2012, and the new, lower emissions projection is apparent from that year forwards.

Source category 2B3 – Adipic acid production

In 2009 the last remaining Adipic Acid production plant in the UK closed; emissions from this source are projected to be zero in from 2010 onwards.

6.1.10 Source category 2C – metal production

All emissions in these categories are reported in DECC's UEP publications; see **Annex B** for more details.

6.1.11 Source categories 2E and 2F

Emissions of F-gases occur in these sectors:

- Sector 2C Cover gas for protecting molten Magnesium from oxidation and in primary aluminium production

- Sector 2E Production of halocarbons and sulphur hexafluoride

- Sector 2F Use of F-gases in refrigeration and air conditioning equipment, foam blowing, fire extinguishers, aerosols, solvents, and one component foams

These emissions projections for HFCs, PFCs and SF_6 are produced using a model recently updated by ICF International, which has been produced in order to incorporate revised industry data and improve transparency. The model is also supported by two previous studies conducted by AEA on behalf of DECC(**AEA, 2008c, AEA, 2010b**). Further details of the model can be found in section 3.1 of this report and also in the most recent National Inventory Report (to be published April 2012)

6.1.12 Source category 4 – Agriculture

Agriculture projections used in this update are based on updated DEFRA projections (**DEFRA 2012**), which are in turn based on agricultural activity projections produced by the FAPRI model (**FAPRI 2012**) of UK agriculture.

The FAPRI-UK modelling system was created, and is maintained, by Agri-Food Biosciences Institute (AFBI) at Queen's University Belfast. The model represents the UK agricultural sector via supply and demand equations and is broken down to the Devolved Administration level. Key variables modelled are production, consumption, net-trade and prices for the following commodities: Dairy, Beef, Sheep, Pigs, Poultry, Wheat, Barley, Oats, Rapeseed and Liquid Biofuels. Livestock numbers and crop areas are also modelled. The model is fully incorporated within the EU GOLD (Grain, Oilseeds, Livestock & Dairy) system which is run by FAPRI-Missouri. Consequently, the UK model gives projections to 2020 which are consistent with the equilibrium at EU level.

GHG emissions factors, taken from the National Atmospheric Emissions Inventory (NAEI), are then applied to these activity projections to produce GHG emissions estimates.

DEFRA have used the FAPRI projections to 2020 as the basis of their projections to 2030. Methane and nitrous oxide emissions are projected to decline slowly from 2010 to 2019 and then remain constant from 2020 to 2030 under DEFRA's assumptions.

6.1.13 Sector 5 – Land Use, Land Use Change and Forestry

Estimates of nitrous oxide emissions due to disturbance associated with land use conversion to cropland, nitrous oxide emissions from drained wetlands used for peat extraction and non-CO_2 GHG emissions from biomass burning are calculated using IPCC Tier 1 methodologies. Details of activity data and emission factors are given in Annex 3.7 of the 1990-2009 UK

greenhouse gas inventory. Emissions of methane and nitrous oxide from the LULUCF sector are supplied by the Centre for Ecology and Hydrology (CEH, 2011).

6.1.14 Sector 6 – Waste

Waste disposed to landfill - Category 6A1

The current set of projections are based on a recent update) to the data in the UK model used to estimate emissions from managed waste disposal on land, MELMod 2012 v1.1. The model is based on the first-order decay (FOD) methodology described in the IPCC Good Practice Guidance and IPCC Uncertainty Management in National Greenhouse Gas Inventories, and is summarised in the UK's 2009 National Inventory Report (NIR).

Wastewater treatment - Category 6B2

Emissions of methane from waste water treatment to 2010 have been taken from the Hobson model report (Hobson, 1996). This is the same data source used for the historic inventory. Projections to 2030 are based on implied emission factors for various disposal routes and projected changes to the amount disposed of to each route (e.g. due to the Landfill Directive), and population growth.

The assumptions made on sewage sludge disposal routes in 2020 have been taken from an Entec, also used in the Spring 2012 and previous publications.

Projections of nitrous oxide emissions from waste water treatment are based on a constant emission factor per head of population. The historic inventory is based on protein consumption and population data. The projections assume that protein consumption will remain unchanged going forwards.

Waste incineration – Category 6C

Estimated projected emissions from waste incineration (not for power generation, and including the categories of accidental vehicles fires, incineration, incineration of clinical waste, and incineration of sewage sludge) are assumed to remain constant as the future levels of activities in these categories is unknown.

Annex B: Categories now reported as part of DECC's UEP

Prior to the Autumn 2011 projections update, all non-CO_2 GHG projections publications had reported emissions estimates as given in the most recently published GHG Inventory for all CH_4, N_2O, HFC, PFC and SF_6 sources for all IPCC categories where they occur.

From the Autumn 2011 set of projections forward, new updates exclude a selection of IPCC categories whose projected trend is reliant on information within DECC's UEP publication. These projections will continue to be produced and presented in DECC's UEP publications.

A full list of categories which will no longer be reported in the non-CO_2 GHG projections is presented below.

Categories will be continually reviewed and further additional categories may be added or removed.

Table 7.1 Summary by Gas / IPCC category of non-CO$_2$ GHG emissions to be produced and reported in DECC's UEP

Gas	NC Sector	IPCC Category	Source Name	Gas	NC Sector	IPCC Category	Source Name
CH4				N2O			
	Agriculture	1A4c	Agriculture - mobile machinery		Agriculture	1A4c	Agriculture - mobile machinery
			Agriculture - stationary combustion				Agriculture - stationary combustion
			Miscellaneous industrial/commercial combustion				Miscellaneous industrial/commercial combustion
	Business	1A2a	Blast furnaces		Business	1A2a	Blast furnaces
			Iron and steel - combustion plant				Iron and steel - combustion plant
		1A2f	Ammonia production - combustion			1A2f	Ammonia production - combustion
			Autogenerators				Autogenerators
			Cement production - combustion				Cement production - combustion
			Lime production - non decarbonising				Lime production - non decarbonising
			Other industrial combustion				Other industrial combustion
		1A4a	Miscellaneous industrial/commercial combustion			1A4a	Miscellaneous industrial/commercial combustion
	Energy Supply	1A1a	Power stations		Energy Supply	1A1a	Power stations
		1A1b	Refineries - combustion			1A1b	Refineries - combustion
		1A1c	Coke production			1A1c	Coke production
			Collieries - combustion				Collieries - combustion
			Gas production				Gas production
			Gas Production - combustion at gas separation plant				Gas Production - combustion at gas separation plant
			Gas Production - gas combustion				Gas Production - gas combustion
			Nuclear fuel production				Nuclear fuel production
			Oil Production - gas combustion				Oil Production - gas combustion
			Solid smokeless fuel production				Solid smokeless fuel production
			Town gas manufacture			1B1b	Iron and steel - flaring
		1B1b	Iron and steel - flaring			1B2a	Oil Production - Offshore Well Testing
		1B2a	Oil Production - Offshore Oil Loading			1B2b	Gas Production - Offshore Well Testing
			Oil Production - Offshore Well Testing			1B2c_Flaring	Gas Production - gas flaring
			Oil Production - Oil terminal storage				Oil Production - gas flaring
			Oil Production - Onshore Oil Loading				
			Oil Production - process emissions				
			Petroleum processes				
		1B2b	Gas Production - Gas terminal storage				
			Gas Production - Offshore Well Testing				
			Gas Production - process emissions				
		1B2c_Flaring	Gas Production - gas flaring				
			Oil Production - gas flaring				
		1B2c_Venting	Gas Production - gas venting				
			Oil Production - gas venting				
	Industrial Process	1A2a	Sinter production		Industrial Process	1A2a	Sinter production
		2B5	Chemical industry - ethylene			2C1	Electric arc furnaces
			Chemical industry - general				Iron and steel - flaring
			Chemical industry - methanol				
		2C1	Electric arc furnaces				
			Iron and steel - flaring				
	Public	1A4a	Public sector combustion		Public	1A4a	Public sector combustion
	Residential	1A4b	Domestic combustion		Residential	1A4b	Domestic combustion
	Transport	1A3c	Rail - coal		Transport	1A3c	Rail - coal
			Railways - freight				Railways - freight
			Railways - intercity				Railways - intercity
			Railways - regional				Railways - regional
		1A3d	Shipping - coastal			1A3d	Shipping - coastal
		1A4a	Railways - stationary combustion			1A4a	Railways - stationary combustion
		1A4c	Fishing vessels			1A4c	Fishing vessels

Annex C: Summary of Updated Projections

Table 7.2 below contains a summary of the updated Autumn 2012 projections. 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 and available from the following link (http://www.decc.gov.uk/media/viewfile.ashx?filetype=4&filepath=11/about-us/economics-social-research/4883-nonco2-ghg-emissions-projections-summary-tables-.xlsx&minwidth=true)

Table 7.1 Summary of non-CO$_2$ GHG projections by gas (Kt CO$_2$e)

UK GHG Inventory		1990	2010	2015	2020	2025	2030
Pollutant	NC Sector						
CH4	Agriculture	22382.4	17945.1	17464.4	17097.7	17097.7	17097.7
	Business	21.2	20.4	21.3	22.2	23.6	25.2
	Energy Supply	26251.4	5918.9	5684.1	5246.2	4106.3	2966.6
	Industrial Process	23.6	5.6	5.9	5.9	5.9	5.9
	Land Use Change	18.3	28.6	32.4	27.2	16.5	12.6
	Residential	7.2	3.0	2.1	2.1	2.1	2.2
	Transport	637.8	74.0	48.3	35.7	37.4	41.3
	Waste Management	43470.7	15066.1	12547.3	10643.1	9334.4	8447.3
CH4 Total		92812.7	39061.7	35805.8	33080.1	30624.0	28598.7
N2O	Agriculture	34895.7	28081.0	27100.4	26877.7	26877.7	26877.7
	Business	1082.2	823.6	1030.5	1100.5	1176.5	1260.3
	Industrial Process	24641.2	1316.6	161.2	161.2	161.2	161.2
	Land Use Change	792.5	626.9	481.5	385.1	309.4	250.7
	Residential	4.3	5.1	5.5	5.7	6.0	6.3
	Transport	1268.3	943.7	1248.5	1435.6	1525.0	1564.3
	Waste Management	1210.3	1195.1	1416.1	1463.5	1508.4	1548.6
N2O Total		63894.5	32992.0	31443.7	31429.4	31564.3	31669.2
HFCs	Business	0.0	11498.3	7942.1	5701.1	3530.6	2390.7
	Industrial Process	11373.7	95.2	104.9	106.5	108.3	110.2
	Residential	11.8	2689.8	2746.6	2802.1	2857.3	2908.0
HFCs Total		11385.6	14283.2	10793.6	8609.7	6496.2	5408.9
PFCs	Business	57.9	68.6	86.6	104.8	127.0	127.0
	Industrial Process	1343.6	151.9	56.1	56.1	56.1	56.1
PFCs Total		1401.5	220.5	142.6	160.8	183.0	183.0
SF6	Business	603.9	559.6	524.3	521.6	536.2	536.2
	Industrial Process	426.0	130.1	140.0	143.3	144.9	144.9
SF6 Total		1029.9	689.7	664.4	664.9	681.1	681.1
Grand Total		170524.3	87247.1	78850.2	73944.8	69548.7	66540.9

Table 7.3 Summary of non-CO₂ GHG projections by NC Sector (Kt CO₂e)

NC Sector	Gas	UK GHG Inventory		Projections			
		1990	2010	2015	2020	2025	2030
Agriculture	CH4	22382.4	17945.1	17464.4	17097.7	17097.7	17097.7
	N2O	34895.7	28081.0	27100.4	26877.7	26877.7	26877.7
Agriculture Total		57278.2	46026.1	44564.8	43975.4	43975.4	43975.4
Business	CH4	21.2	20.4	21.3	22.2	23.6	25.2
	HFCs	0.0	11498.3	7942.1	5701.1	3530.6	2390.7
	N2O	1082.2	823.6	1030.5	1100.5	1176.5	1260.3
	PFCs	57.9	68.6	86.6	104.8	127.0	127.0
	SF6	603.9	559.6	524.3	521.6	536.2	536.2
Business Total		1765.2	12970.5	9604.9	7450.2	5393.9	4339.4
Energy Supply	CH4	26251.4	5918.9	5684.1	5246.2	4106.3	2966.6
Energy Supply Total		26251.4	5918.9	5684.1	5246.2	4106.3	2966.6
Industrial Process	CH4	23.6	5.6	5.9	5.9	5.9	5.9
	HFCs	11373.7	95.2	104.9	106.5	108.3	110.2
	N2O	24641.2	1316.6	161.2	161.2	161.2	161.2
	PFCs	1343.6	151.9	56.1	56.1	56.1	56.1
	SF6	426.0	130.1	140.0	143.3	144.9	144.9
Industrial Process Total		37808.2	1699.4	468.1	472.9	476.4	478.3
LULUCF	CH4	18.3	28.6	32.4	27.2	16.5	12.6
	N2O	792.5	626.9	481.5	385.1	309.4	250.7
LULUCF Total		810.8	655.5	514.0	412.3	326.0	263.3
Residential	CH4	7.2	3.0	2.1	2.1	2.1	2.2
	HFCs	11.8	2689.8	2746.6	2802.1	2857.3	2908.0
	N2O	4.3	5.1	5.5	5.7	6.0	6.3
Residential Total		23.3	2697.8	2754.1	2809.9	2865.5	2916.4
Transport	CH4	637.8	74.0	48.3	35.7	37.4	41.3
	N2O	1268.3	943.7	1248.5	1435.6	1525.0	1564.3
Transport Total		1906.1	1017.7	1296.8	1471.3	1562.5	1605.6
Waste Management	CH4	43470.7	15066.1	12547.3	10643.1	9334.4	8447.3
	N2O	1210.3	1195.1	1416.1	1463.5	1508.4	1548.6
Waste Management Total		44681.0	16261.2	13963.4	12106.5	10842.8	9995.9
Grand Total		170524.3	87247.1	78850.2	73944.8	69548.7	66540.9