CHAPTER 9:

NON-CO_2 GREENHOUSE GASES

The Government has asked us to recommend whether the UK's carbon budgets should be stated in terms of greenhouse gases (GHGs), rather than CO_2. Moving from CO_2 to GHG budgets would require adding an amount to reflect expected non-CO_2 emissions[1]. This chapter sets out our analysis of the case for and against setting budgets based on GHGs. It also considers abatement potential across the range of activities that produce non-CO_2 gases in the UK, namely agriculture, waste, industry and energy[2].

The main messages from this analysis are:

- We recommend that budgets should be set in GHGs rather than CO_2. This would control an important driver of climate change, and provide additional opportunities for meeting budgets. Although there would be complexities related to uncertainty over measurement of non-CO_2 emissions, in our view these are manageable. We therefore propose an Intended budget based on a GHG emissions reduction of 42% in 2020 relative to 1990. We also propose an Interim budget based on a 34% emissions reduction in 2020 to apply until a global deal to reduce emissions is agreed.

- Initial analysis suggests that there may be realistically achievable abatement potential of up to 15 $MtCO_2e$ in 2020, with significant opportunity for emissions reduction in agriculture and waste, and some opportunity for emissions reduction in forestry, industry and energy.

- We stress, however, that analysis of abatement options in agriculture is at a far earlier stage than analysis of other sectors, and that some of the abatement opportunities in agriculture raise issues (e.g. relating to animal welfare, or local environmental issues) on which there are a range of opinions. We also note that agriculture is a sector where there is no existing policy framework to deliver emissions reductions. We therefore plan to deepen our analysis of agriculture in subsequent reports and recommend that the Government should focus on developing a policy framework for this sector.

- We suggest that there is considerable uncertainty around realistically achievable non-CO_2 emissions reduction. For this reason, we recommend that non-CO_2 options should be developed as part of prudent budget management, rather than relied on as firm measures that will deliver budgets.

We set out our analysis in 6 sections:

1. Non-CO_2 emissions trends and projections
2. Arguments for and against setting budgets in GHGs rather than CO_2
3. Emissions from agriculture, land use, land use change and forestry
4. Emissions from waste
5. Non-CO_2 emissions from industry and energy
6. Restatement of carbon budgets in GHGs.

1 Where this chapter refers to non-CO_2 gases/emissions it refers specifically to non-CO_2 *greenhouse* gases/emissions as defined in the Kyoto basket. It does not refer to non-CO_2 gases that are not greenhouse gases (e.g. air pollutants such as SO_X and NO_X).

2 This chapter also covers land use, to reflect its close links to agriculture, although most of the associated emissions are actually CO_2.

1. NON-CO_2 EMISSIONS TRENDS AND PROJECTIONS

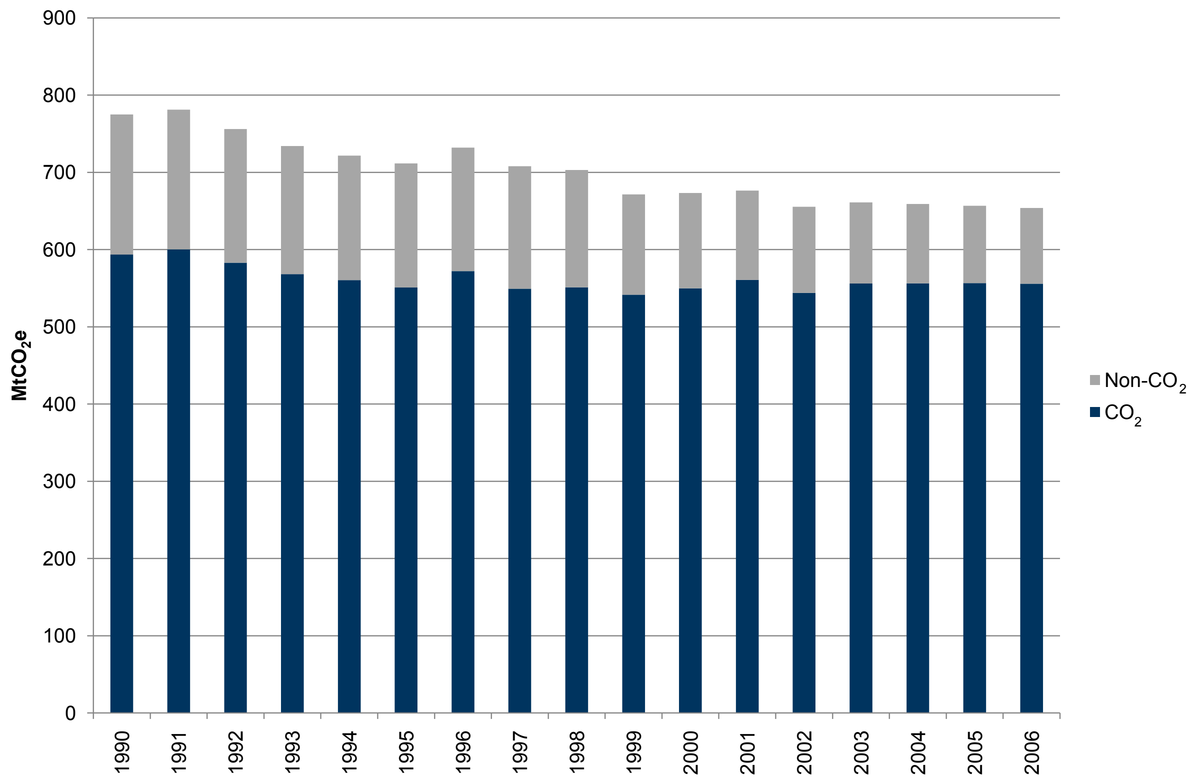
The non-CO_2 emissions that we cover in this chapter are those defined by the Kyoto basket of GHGs: nitrous oxide (N_2O), methane (CH_4) and certain fluorinated gases (F-gases: HFCs, PFCs, SF_6). The main non-CO_2 gases from an emissions perspective are methane and nitrous oxide, which together accounted for 89% of all non-CO_2 emissions in 2006. In turn, non-CO_2 emissions accounted for 15% of total GHG emissions in 2006.

Significant progress has been made in reducing non-CO_2 emissions over the period since 1990. The non-CO_2 emissions reduction achieved between 1990 and 2006 of 46% may be compared to CO_2 emissions reduction of 6% (Figure 9.1). In other words, non-CO_2 gases have contributed disproportionately to the overall GHG emissions reduction of 16% between 1990 and 2006.

The main driver of non-CO_2 emissions reduction has been reduction in methane emissions, which fell by 53% between 1990 and 2006 (Figure 9.2). For the other gases, emissions also decreased over this period, although to a lesser extent than methane.

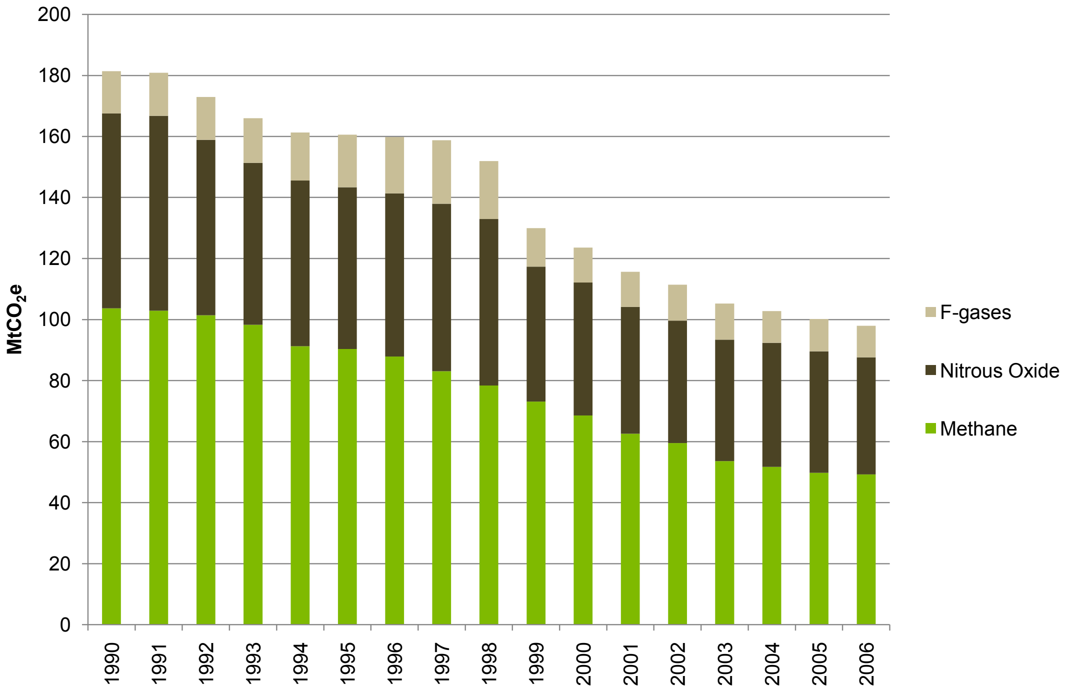
The main driver of methane emissions reduction has been falling emissions from waste in landfill (Figure 9.3). Other areas where emissions have fallen significantly are industrial processes, where reduction of 67% has been achieved through the introduction of low-carbon technologies to abate N_2O emissions, and fugitive emissions from the gas distribution network and coal mines, where emissions reduction of 68% has been achieved. In agriculture, emissions fell by 18% over the period 1990-2006.

Figure 9.1 Non-CO_2 emissions compared to CO_2 emissions, 1990-2006



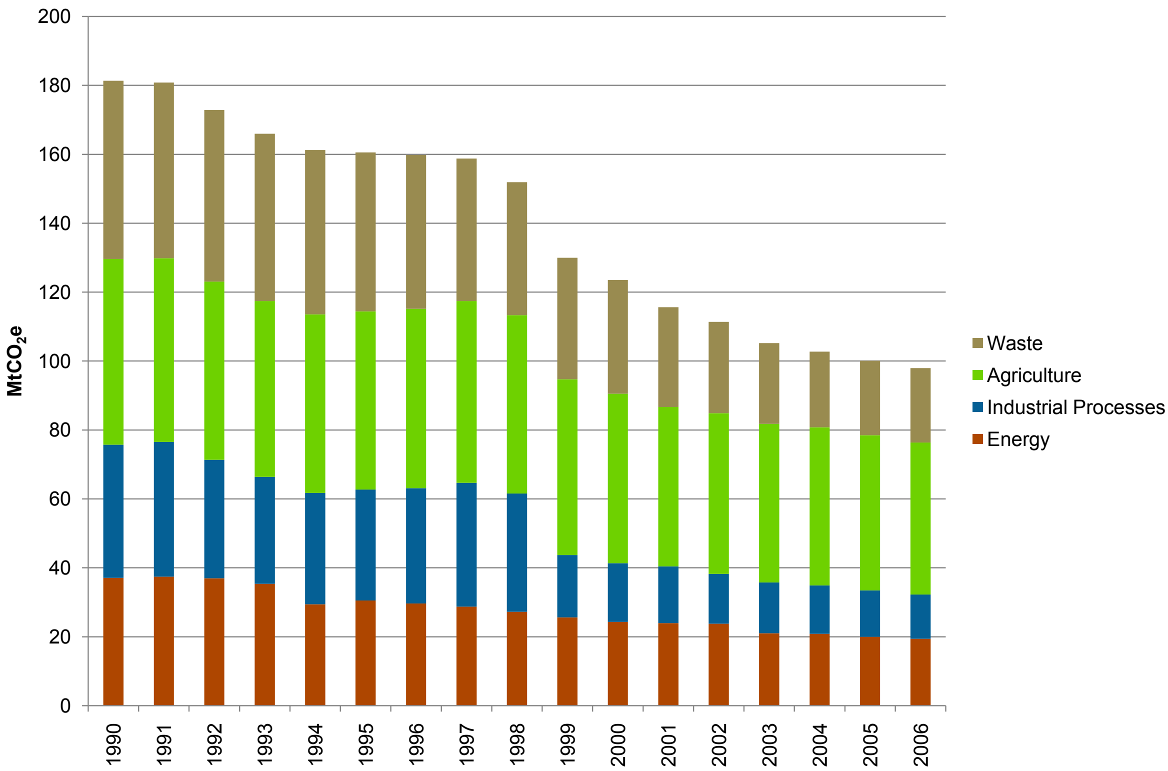
Source: National Atmospheric Emissions Inventory (NAEI) (2008)

Figure 9.2 Non-CO_2 emissions by gas, 1990-2006



Source: NAEI (2008)

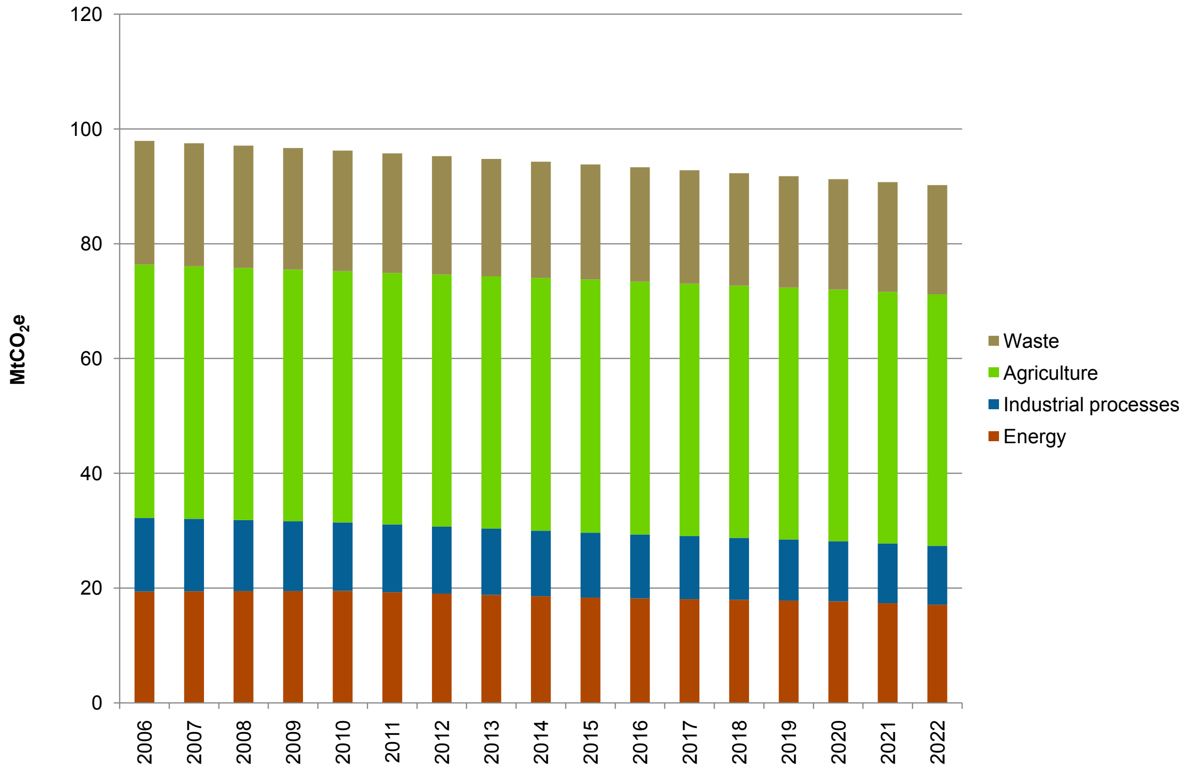
Figure 9.3 Non-CO_2 emissions by sector, 1990-2006



Source: NAEI (2008)

Going forward, Defra has developed scenarios for reference case non-CO_2 emissions projections over the period to 2022[3] (Figure 9.4). The central scenario projects that non-CO_2 emissions reduction over the period 1990-2020 will be 50%, including a 7% reduction projected between 2006-2020. The projections are based on assumptions about policies that are currently in place and emissions reductions that these are expected to deliver.

Figure 9.4 Non-CO_2 emissions projections by sector, 2006-2022



Source: Defra

The projections, however, do not build in the significant additional non-CO_2 abatement potential that our analysis suggests is available. Sections 3-5 set out this analysis in detail. But before moving to these sectoral assessments of abatement potential, we first consider whether the UK's emissions framework should be set in terms of GHGs rather than CO_2.

3 AEA (forthcoming), Projections of non-CO_2 Greenhouse Gases to 2050, *Defra project ED05478*.

2. ARGUMENTS FOR AND AGAINST SETTING BUDGETS IN GHGs RATHER THAN CO_2

Consideration of whether our budgets should be set in terms of GHGs rather than CO_2 involves weighing the benefits of having GHG budgets against complexities that this might involve relating to measurement.

Benefits of having GHG budgets: There are at least three reasons why it would make sense to base the UK budget framework on GHGs rather than CO_2:

- All GHGs, rather than just CO_2, cause climate change. Focusing on CO_2 only without action on non-CO_2 would not limit the relevant set of emissions. This is why our analysis and recommendations in Chapter 1: *Setting a 2050 target* were set out in terms of GHGs rather than CO_2. By extension, it would seem appropriate to set budgets in terms of GHGs.

- The international framework is based on a basket of six GHGs. This is true both of Kyoto, and the EU framework, where EU-wide targets and UK shares are in GHGs (e.g. the non-traded sector target for the UK includes agriculture, waste and other sources of non-CO_2 emissions). The UK's climate change strategy will have to deliver both domestic budgets and international targets, and would be better placed to do this where these share a common metric.

- For a given climate change goal, considering the full range of abatement options across CO_2 and non-CO_2 gases reduces costs and provides flexibility:
  - We will show below that there are cost-effective opportunities to reduce non-CO_2 emissions. Where these are part of the accounting framework, they can be substituted for more expensive CO_2 emissions reduction, thus reducing the cost of meeting a given GHG target/climate change goal.
  - From a risk management perspective, including non-CO_2 emissions provides an additional means for addressing potential shortfalls in CO_2 emissions reduction to meet a given GHG target.

Complexities related to including non-CO_2 gases: The question of whether we should set GHG or CO_2 budgets is complicated by the fact that it is difficult to measure non-CO_2 emissions accurately. Whereas we feel reasonably confident about what the level of CO_2 emissions actually is, there is more uncertainty regarding the level of non-CO_2 emissions.

- In principle, the process of measuring emissions requires measuring the levels of emissions-producing activities, and multiplying these by appropriate emissions factors.

- In the case of CO_2, good data is available on both the level of activity (e.g. consumption of fossil fuels) and related emissions factors (e.g. carbon content of oil, coal, gas, etc.).

- In the case of non-CO_2 gases, however, whilst we feel reasonably confident about the level of activity (e.g. we know how many livestock there are in the UK, and how much waste is landfilled), there is some uncertainty over what emissions factors should be applied to this. This occurs, for example, because we do not have good information about methane emissions from livestock (emissions here depend on specific diet, but we currently use generic emissions factors), or N_2O emissions from the application of fertiliser to soils (where the scientific process is not fully understood and is farm specific, but we do not have farm specific data).

There is an ongoing process to improve measurement of GHGs, which results in periodic updating of the UK's inventory (e.g. to reflect new estimates of emissions factors). Updating of the GHG inventory would have two possible implications if the budget were to be set in GHGs:

- Budget revisions would be required following updating of the inventory.
- More emissions reduction effort could be required to meet a given budget. This would be the case if an inventory update were to leave the budget unchanged but increase the actual level of GHG emissions.

Given that there is a process in place for revising budgets, we do not regard the first of these implications as a good reason not to have GHG budgets.

In principle, the second implication could make budget management more difficult. In practice, however, there are three reasons why this is unlikely to be the case:

- Whilst uncertainty over the level of GHG emissions in any year is considerably more than that for CO_2 emissions, there is less uncertainty over trend emissions.
  - Levels of uncertainty relating to CO_2 and GHG emissions in 2004 are 2% and 14% respectively[4].
  - Ranges for CO_2 and GHG emissions reduction over the period 1990-2004 are 3% to 8% and 11% to 18% respectively.
- The convention for inventory revisions is that any new methodologies are applied consistently over time (i.e. historically and going forward) to the extent possible. If this continues to be the case, the likelihood is that the difference between actual emissions and a budget based on reduction relative to emissions in a base year (e.g. 1990) would be small following any revision.
- To the extent that more emissions reduction effort would be required following a revision, this would be the case anyway in the EU context, since the EU targets are based on GHGs.

On balance, therefore, whilst we recognise that there is a challenging issue regarding measurement, we believe that this could be met through periodic revisions to GHG budgets, the implications of which should not be significant from a budget management perspective.

Recommendation and practicalities: We recommend that budgets are set in terms of GHGs, given the potential benefits that we have outlined, and our view that the complexities are manageable.

In order to operationalise this recommendation, there are issues relating to which GHGs should be included in budgets, and what measurement conventions should be used. In keeping with our analysis in Chapter 1, we propose that GHG budgets should be based on the Kyoto basket of GHGs, and that in converting non-CO_2 emissions to CO_2e it is appropriate to use 100 year Global Warming Potential (GWP), in keeping with the United Nations Framework Convention on Climate Change (UNFCCC) reporting convention[5]; Box 9.1 outlines some of the complexities involved with the choice of this metric. In addition, we propose that GHG budgets should be based on activity data and emissions factors used in the current UK inventory, subject to any future revisions.

4 As reported in the NAEI – 95% confidence interval ranges.

5 Specifically, we recommend that GWP from the Second Annual Report of the Intergovernmental Panel on Climate Change (IPCC) should be used, in keeping with international convention.

Box 9.1 Global Warming Potential as a metric for comparing greenhouse gas emissions

Different greenhouse gases have different characteristics, such as the length of time they reside in the atmosphere and the efficiency with which they trap heat. Various metrics have been proposed which attempt to capture these differences, allowing a comparison between the future climate effects of different GHG emissions. To be consistent with international reporting guidelines we use the 100-year Global Warming Potential (GWP) metric, with values taken from the IPCC's Second Assessment Report (see table below). For emission of an individual GHG, its GWP can be broadly defined as the resulting amount of heat trapped in the atmosphere over a 100-year period, relative to that trapped by the same mass of CO_2 emission. CO_2 equivalent (CO_2e) emissions are defined as the GWP value multiplied by the total mass of GHG emitted, so that 1 tonne of nitrous oxide corresponds to 310 tonnes CO_2e.

Table: 100-year GWPs for gases included in the Kyoto Protocol

Gas	**GWP_{100} (SAR)**	**GWP_{100} (AR4)**
Carbon dioxide (CO_2)	1	1
Methane (CH_4)	21	25
Nitrous oxide (N_2O)	310	298
Hydrofluorocarbons (HFCs)*	140 – 11,700	124 – 14,800
Perfluorocarbons (PFCs)*	6,500 – 9,200	7,390 – 12,200
Sulphur hexafluoride (SF_6)	23,900	22,800

Source: IPCC Second Assessment Report (SAR); IPCC Fourth Assessment Report (AR4)
*HFCs and PFCs are families of gases for which the range of individual GWPs are given.

The change in GWP values since the Second Assessment Report reflects the change in background atmospheric concentrations and increased scientific understanding. It is likely that international reporting guidelines will be updated to reflect these changes in the future. Such changes will have only a small effect on how challenging a given emissions reduction target is, whilst making abatements in certain gases (e.g. methane) slightly more attractive than current analysis suggests.

Whilst the GWP metric is simple and transparent, there has been debate as to whether it is the most appropriate metric for policy use. For example, the choice of a 100-year time horizon is somewhat arbitrary, chosen as a balance to capture both the potency of some short-lived gases and the very long lifetime of CO_2. A shorter time horizon would lend more weight to shorter-lived gases such as methane, and vice versa. Also, GWP focuses on heat trapped (or 'radiative forcing') rather than global temperature increase, and it is now thought that the relationship between radiative forcing and temperature may not be the same across GHGs. As a result other metrics such as the Global Temperature Potential (GTP) metric have been suggested[1], however the IPCC continues to recommend GWP as the best current metric for comparing the future climate effects of emissions of long-lived GHGs.

1 Shine et al, 2005, Alternatives to the global warming potential for comparing climate impacts of emissions of greenhouse gases, *Climatic Change*

At the end of this chapter, we therefore restate our carbon budget proposals (from Chapter 3: *Setting the first three budgets*) in terms of GHGs. Before doing this, however, we consider opportunities for reduction of non-CO_2 emissions that could potentially form important means for meeting and managing GHG budgets.

3. EMISSIONS FROM AGRICULTURE, LAND USE, LAND USE CHANGE AND FORESTRY

Having proposed that budgets be set in GHGs rather than CO_2, it becomes even more important to understand potential for non-CO_2 emissions reduction. We now consider abatement potential in agriculture, and move to a consideration of abatement potential in land use, land use change and forestry, hereinafter referred to as LULUCF.

We set our analysis out in four parts:

(iii) Background: sources of emissions, emissions trends and projections

(iv) Abatement potential

(v) Emissions reduction constraints and the policy framework

(vi) LULUCF.

(i) Background: sources of emissions, emissions trends and projections

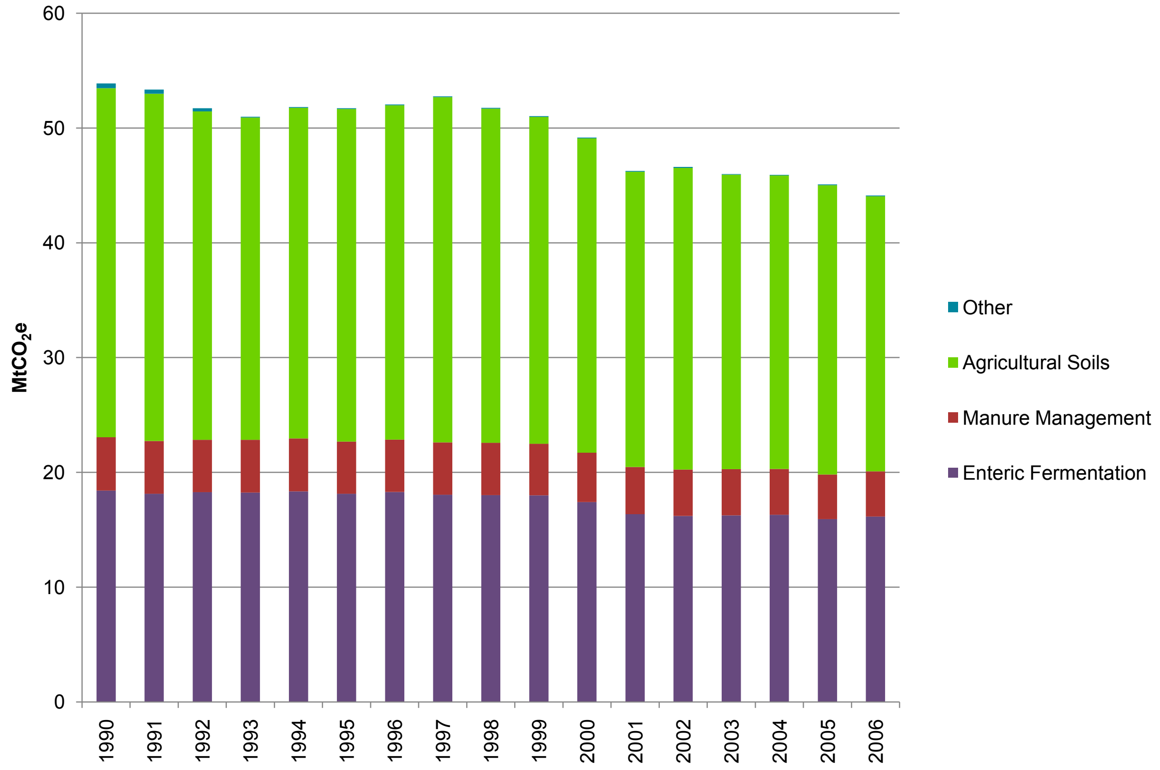
In 2006, non-CO_2 agriculture emissions accounted for 7% of UK GHG emissions, and 45% of all non-CO_2 emissions. They largely comprise emissions from the use of fertiliser on soil (54%), and enteric fermentation (digestive process of livestock) (37%). Remaining agriculture non-CO_2 emissions relate to manure management.

It is important to note that agriculture is also responsible for CO_2 emissions due, for example, to use of machinery, consumption of gas and electricity in buildings, etc. These are not considered further in this chapter, but are an area that we intend to return to in the future.

Emissions trends: Agricultural non-CO_2 emissions have decreased by 18% over the period 1990-2006, from 54 $MtCO_2e$ to 44 $MtCO_2e$ (Figure 9.5). This is a more modest decrease than most other non-CO_2 sectors, but it is more than has been achieved in CO_2 emissions reduction over the same period (6%). Emissions reduction in agriculture is largely attributable to decreasing livestock numbers as a result of Common Agricultural Policy (CAP) reform and reduced use of fertiliser.

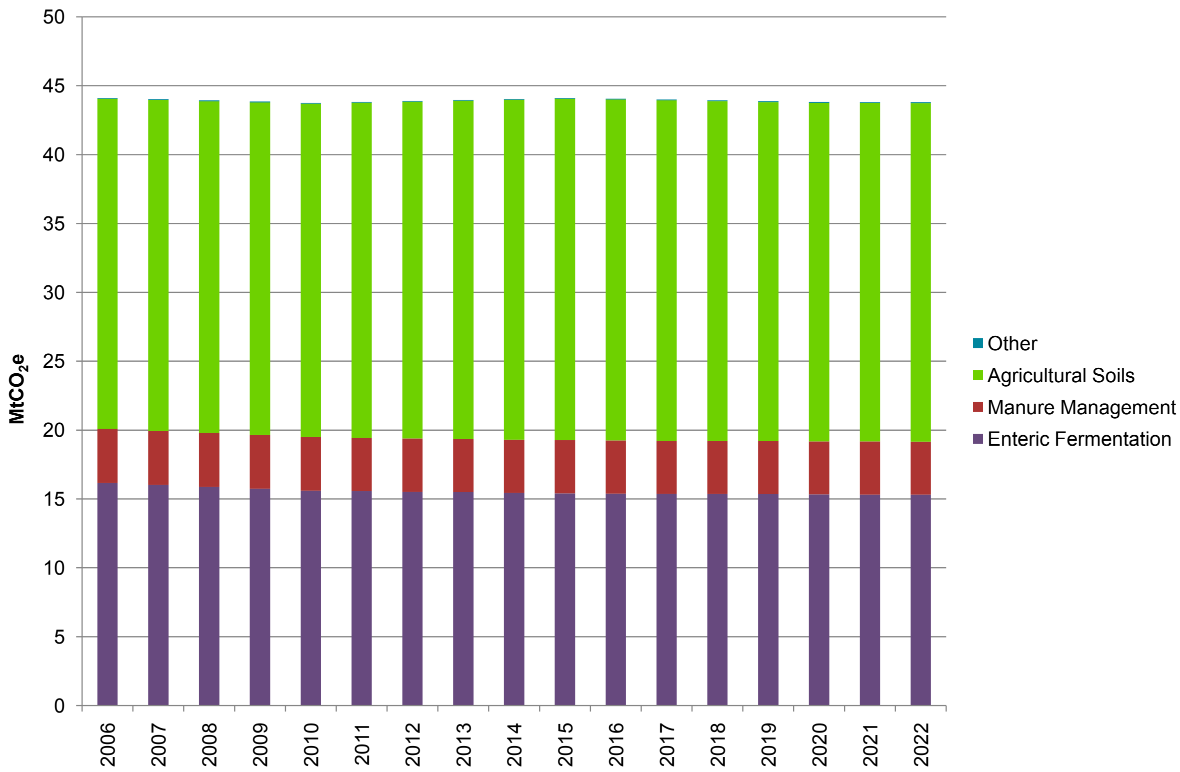
Emissions projections: Going forward, government projections assume that agricultural non-CO_2 emissions will fall by only a further 1%, such that the overall decrease for the period 1990-2020 will be 19% (Figure 9.6). The driver of emissions reduction in the government's projections is a further reduction in the number of livestock resulting from continuing CAP reform.

Figure 9.5 Agricultural non-CO_2 emissions by source, 1990-2006



Source: NAEI (2008)

Figure 9.6 Agricultural non-CO_2 emissions projections by source, 2006-2022



Source: Defra

(ii) Abatement potential

There are three main routes by which emissions can be reduced in the agriculture sector:

- Lifestyle change: less reliance on carbon intensive produce (e.g. beef)
- Changing farming practices
- Using new technology on farms to reduce emissions.

Lifestyle change may offer significant abatement opportunities, for example if diets were to shift towards less carbon intensive food products (see Box 9.2). The analysis that we have carried out, however, does not cover changes in demand. We recognise that this is an important area to consider going forward, and intend that it will form part of our future work programme.

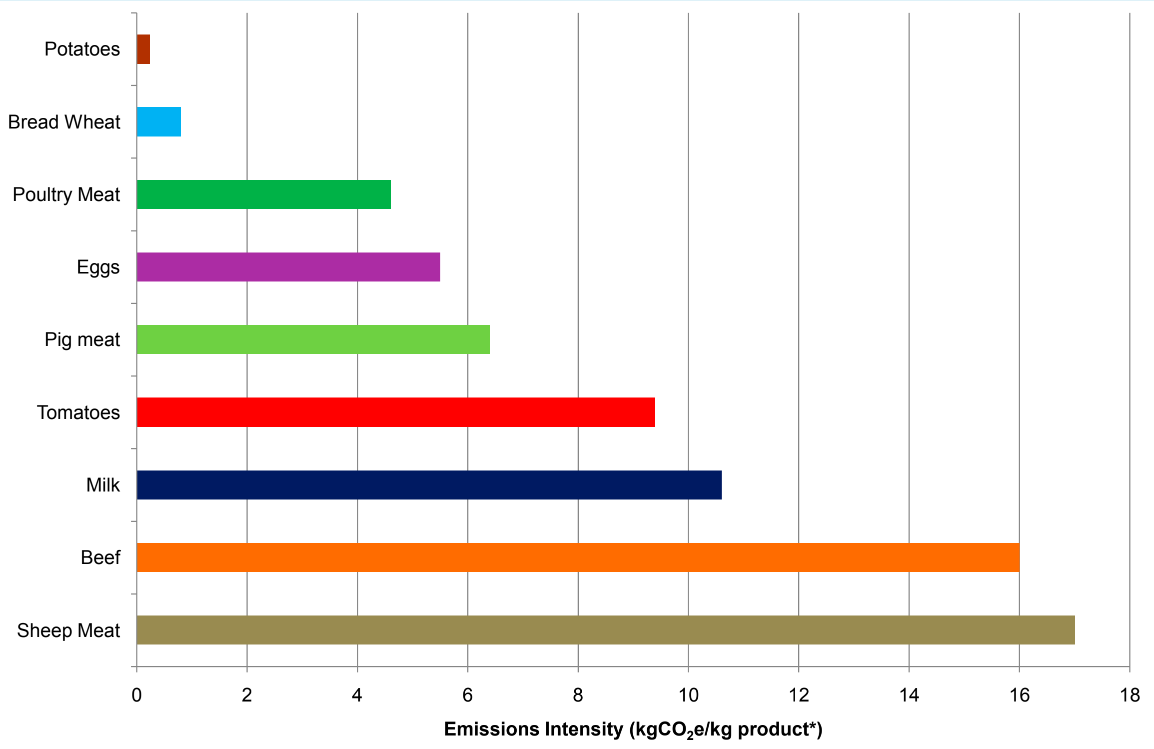
Our analysis focuses on changing farming practices and using new technologies as these relate to crops, soils and livestock. It is based on research that we commissioned from the Scottish Agricultural College. As part of the research, a marginal abatement cost curve (MACC) was constructed, providing assessments of potential emissions reduction and associated costs across a wide range of options. It includes scenarios for *technical* potential (i.e. the level of emissions reduction that would ensue if there were no barriers to unlocking potential) and for *realistic* potential (i.e. a judgement on the level of emissions that might ensue taking into account emissions reduction constraints and ways that these could be addressed). It is among the first MACCs developed for the agriculture sector and the results should be considered as tentative. It also has to be recognised that some of the options identified (e.g. in relation to plant additives and breeding approaches) might raise other issues. The analysis does however illustrate that there is significant potential in agriculture which merits further analysis.

Box 9.2 Abatement opportunity through changing diets

The different foods we eat are responsible for different levels of GHG emissions in their production. The figure below illustrates this based on a life-cycle analysis that accounts for emissions throughout the production stream, for example the emissions intensity for pig meat includes the emissions from fertiliser use in producing crops to feed the pigs.

Cattle and sheep are ruminant animals, able to feed on grass, which results in significant methane emissions from the digestive process. Tomato production entails emissions from energy used for heating and lighting to extend the growing season.

Figure: Estimated emissions intensities for different food products



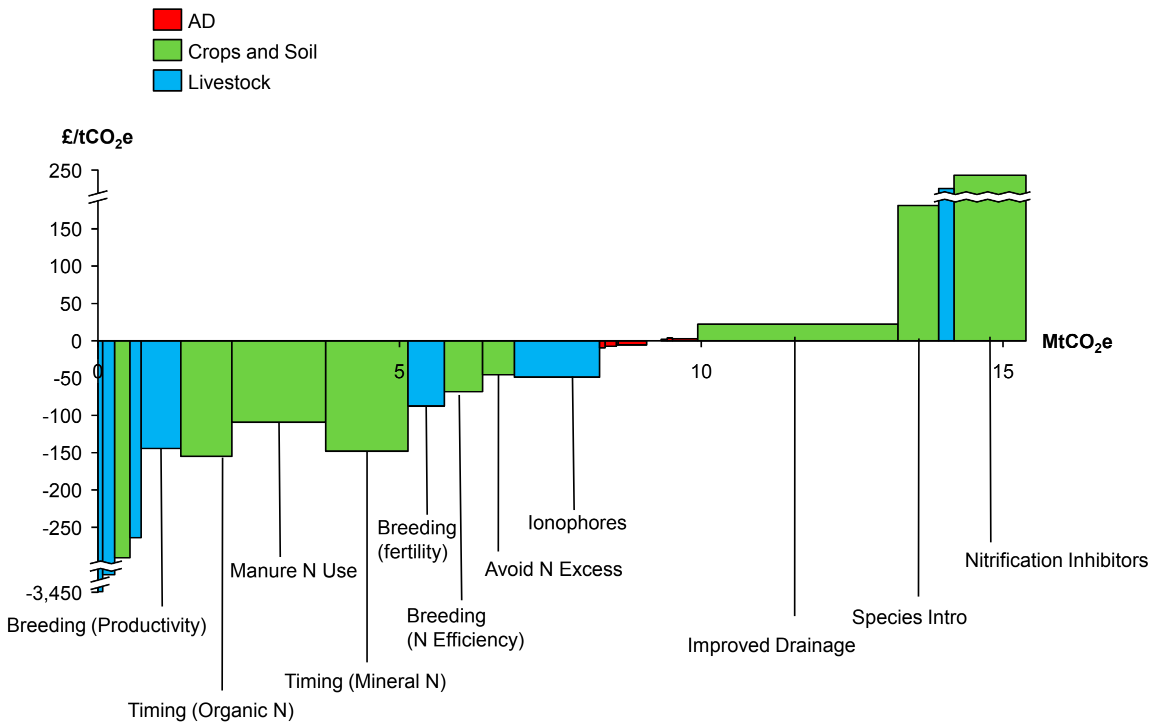
Source: Williams, A.G., Audsley, E. and Sandars, D.L. (2006) Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. *Defra Research Project IS0205.*
Note: * 1kg of product is assumed to be equivalent to 20 eggs or 10l of milk (about 1kg dry matter)

These different emissions intensities imply that there may be an abatement opportunity from shifting diets towards less carbon intensive food products. However, there are a number of complexities, including:

- Food products (and feed inputs) are both imported and exported, so any change in UK food consumption may not impact on UK food production, or therefore UK emissions
- Ruminants (cattle and sheep) have the important advantage of being able to use land unsuitable for arable crops
- Abatement options on the supply side could change these emissions intensities
- Each food product has different nutritional characteristics, so they cannot be treated as direct substitutes
- Consumers are likely to be resistant to changing their diets.

Technical potential: The MACC illustrated in Figure 9.7 suggests that there is around 13 $MtCO_2e$ of abatement potential available at a carbon price of up to £40/tCO_2e (our central carbon price estimate, see Chapter 4: *Carbon markets and carbon prices*), and much of which (around 9 $MtCO_2e$) is available at negative cost (i.e. farmers could potentially save money through implementing these measures).

Figure 9.7 Agriculture non-CO_2 MACC – maximum technical potential, 2020



Source: CCC modelling

Notes: N = Nitrogen, AD = anaerobic digestion
Measures do not appear in exact cost-effectiveness order due to interactions between options. More details and a full measures list is available in the accompanying technical papers.

The technical potential that we have identified at up to £40/tCO_2e comprises:

- 9 $MtCO_2e$ from measures that decrease N_2O emissions from crops and soils, including:
  - reducing fertiliser application where it is applied in excess
  - matching the timing of application with the time when the crop will make most use of it
  - using organic rather than synthetic fertiliser where possible
  - improving drainage of land
  - selectively breeding plants that need less fertiliser.
- 3 $MtCO_2e$ from measures that reduce methane emissions from livestock, including:
  - selecting animals with particular traits for breeding, in order to improve the efficiency of milk and beef production or fertility. The impact of selection both reduces the number of animals required to produce a fixed level of output, and decreases the finishing period of animals, therefore reducing emissions per unit of output.
  - increased use of additives named ionophores that increase productivity and decrease methane production. These are currently banned in the EU but are routinely used as growth promoters in some non-EU countries.
- 1 $MtCO_2e$ from the installation of anaerobic digestion plants (converting agricultural waste to renewable energy) either in a centralised location or on farm.

- **Realistic potential:** Scenarios for realistic potential exclude increased use of ionophores, and constrain remaining technical potential drawing on evidence about current compliance rates for a range of policies:

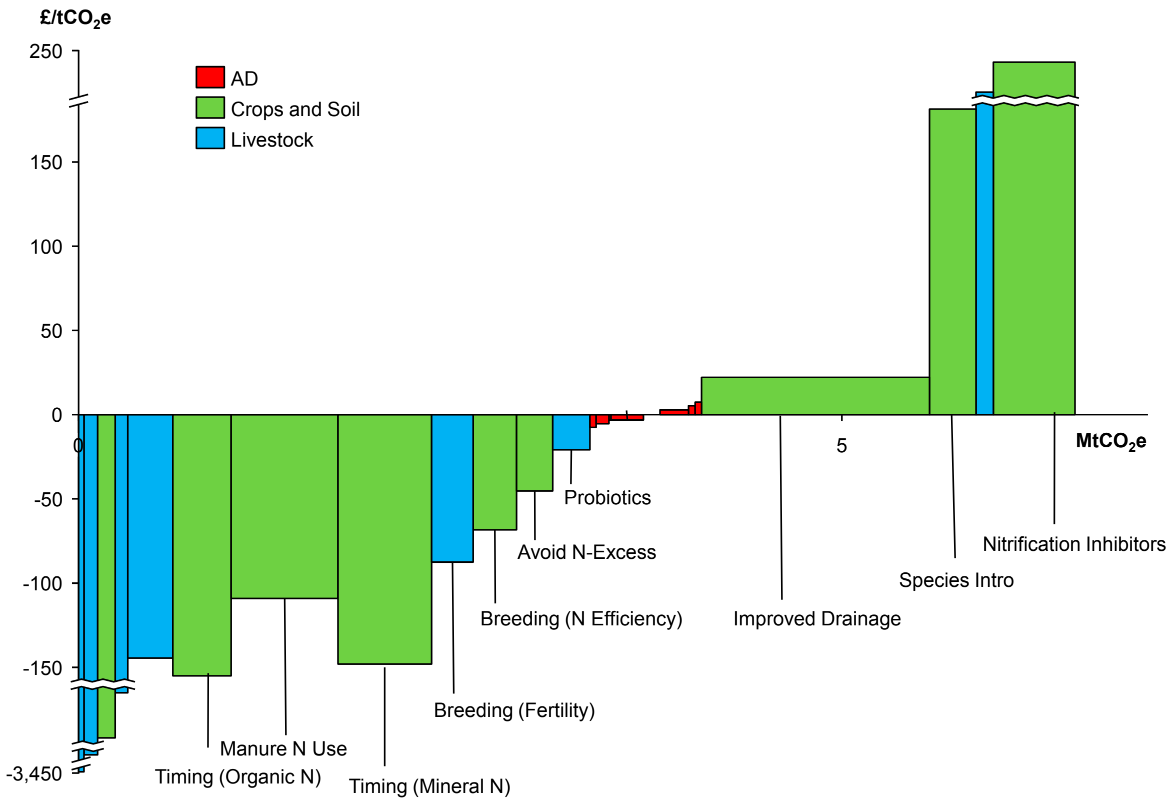
- The central feasible scenario models an incentive-based policy environment, characterised by taxes and subsidies or a cap and trade scheme. Uptake in this scenario is assumed to be 45% of technical potential.

- The low feasible scenario models a policy environment where initiatives are mainly voluntary. In this scenario, measures with negative costs are assumed to have 18% take up, whilst positive cost measures have a lower uptake of 7%.

- The high feasible scenario models a regulation-based policy environment. In this scenario, measures that are defined as easy to enforce are assumed to have an uptake of 92%, whereas measures that are defined to be more difficult to enforce are assumed to have an uptake of 85%.

Under the central feasible scenario, 6 $MtCO_2e$ realistic emissions reduction potential is identified at a cost up to £40/tCO_2e (Figure 9.8). This comprises emissions reduction from crops/soils (70%), livestock (20%), and anaerobic digestion (10%). In the high feasible scenario, estimated realistic emissions reduction potential increases to 11 $MtCO_2e$, driven by higher take up of all three categories of measures.

Figure 9.8 Agriculture non-CO_2 MACC – central feasible potential, 2020



Source: CCC modelling

Note: N = Nitrogen, AD = Anaerobic digestion

Regarding reduction to 2050, there is clear potential from existing options as well as from demand-side changes for agriculture to contribute significant emissions reduction. Further research would be needed to establish if a reduction of 80% on 1990 is possible, but if it is not then other sectors would need to contribute more to the UK's economy-wide target.

(iii) Emissions reduction constraints and the policy framework

Emissions reduction constraints: There are a number of constraints which would have to be addressed through development of the policy framework if agricultural emissions reduction potential is to be unlocked. These are similar to constraints in the context of energy efficiency improvement for households and firms:

- There may be some inertia to changing practices
- Farmers may not be able to invest time in finding out what new practices may be appropriate
- Farmers may lack capital required to invest in new technologies
- The financial benefit of adopting new practices/investing in new technologies may be small at the farm level (notwithstanding that the saving may be large for the sector as a whole).

The policy framework: The agricultural sector does not currently have any policies focused directly on reducing non-CO_2 emissions. We would expect some emissions reduction to occur under the current framework (e.g. due to continuing CAP reform and Environmental Stewardship), but these would not include the bulk of realistic emissions reduction potential that we have identified.

In developing the policy framework to provide more focus on and stronger incentives for emissions reduction, there are at least five options that should be considered:

- **Cap and trade schemes:** farmers or organisations in the agricultural supply chain would have to surrender allowances to cover their emissions. Given a constraint on the number of allowances available, this would result in financial incentives for farmers to reduce emissions.
- **Direct regulation:** practices that have been proven to reduce emissions at reasonable cost would be mandated.
- **Voluntary agreements:** as with direct regulation, but practices would be implemented on a voluntary basis. Incentives for voluntary implementation could be strengthened if emissions reductions were allowed to be sold in carbon markets.
- **Grants, subsidies, charges, levies and taxes:** these would provide financial incentives for emissions reduction.
- **Information provision:** encouraging awareness of best practice could result in emissions reduction.

There are a number of complexities that relate to one or more of these options:

- There is currently limited measurement of emissions at the farm level. This precludes the introduction of systems that provide financial rewards for emissions reductions. Moreover, the use of aggregate factors means that much of the abatement identified in our analysis would not be recognised in the current UK national emissions inventory.
- Introducing a price on emissions (e.g. through cap and trade or taxes) would raise costs. To the extent that agriculture is a globally competitive industry, this could result in displacement of production abroad with no environmental benefit.
- The administrative cost of incentive mechanisms for reducing emissions could be high given the diffuse nature of the farming industry.

- There are multiple policy objectives for agriculture. Policy focused on achieving one objective will often have implications for other objectives. It is not necessarily the case, therefore, that a policy which has positive impacts from a climate change perspective should necessarily be regarded as desirable.

In our view, however, none of these complexities should be seen as prohibitive, and further effort is warranted in resolving them. For example:

- Better measurement of emissions will be available in the future as the UK develops a new smart emissions inventory.
- Whilst competitiveness may be a concern in principle, there is little evidence to say that it should be a concern in practice.
- Regarding administrative costs, there are other areas of the economy where there are diffuse sources of emissions, and where policies have been introduced to reduce emissions (e.g. energy efficiency).
- And it is not clear that policies to support emissions reduction would have sufficiently large adverse impacts for other objectives that they should not be pursued.

The Committee recognises the multiple policy objectives and various sensitivities related to agriculture, but believes that the sector can contribute to tackling climate change whilst achieving other objectives. Given the significant realistic potential that our analysis suggests exists in agriculture, this sector could provide an important means for meeting GHG budgets. Our high level assessment suggests that there are barriers which can potentially be addressed. Our recommendation is that the Government seriously considers developing a policy framework for agriculture focused specifically on climate change and reducing emissions.

(iv) LULUCF

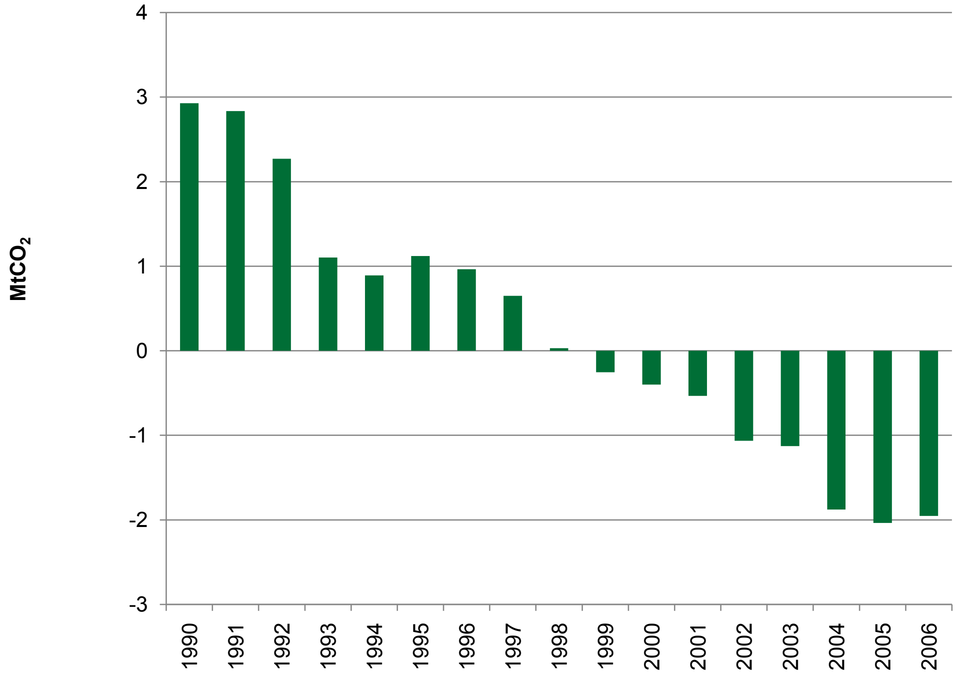
In discussing LULUCF, it is important to start by explaining that most LULUCF emissions relate to CO_2 rather than non-CO_2. It is covered in this chapter, which focuses on non-CO_2 emissions, to reflect close links with agriculture and similarly complex processes. Irrespective of whether the Government accepts our advice in Section 2 above to set budgets in terms of GHGs, LULUCF emissions will be included in budgets, whether these are in CO_2 or GHGs.

Emissions from LULUCF activities are made up almost entirely of emissions from the cultivation of soils and wood harvesting. CO_2 is released from soils due to tillage practices and from forests following harvesting of wood (with possible delay depending on what the wood is used for). Conversely, land management helps to remove CO_2 from the atmosphere through increases in forest and organic matter in soils and avoidance of degradation of those stores.

On a net basis, the LULUCF sector absorbed 2 $MtCO_2$ in 2006, which is less than 0.5% of UK emissions. This relatively small number masks, however, larger figures for emissions and absorptions when these are considered separately. Specifically, LULUCF emissions represent around 4% of the UK's total CO_2 emissions, with absorption representing around 4%-5%.

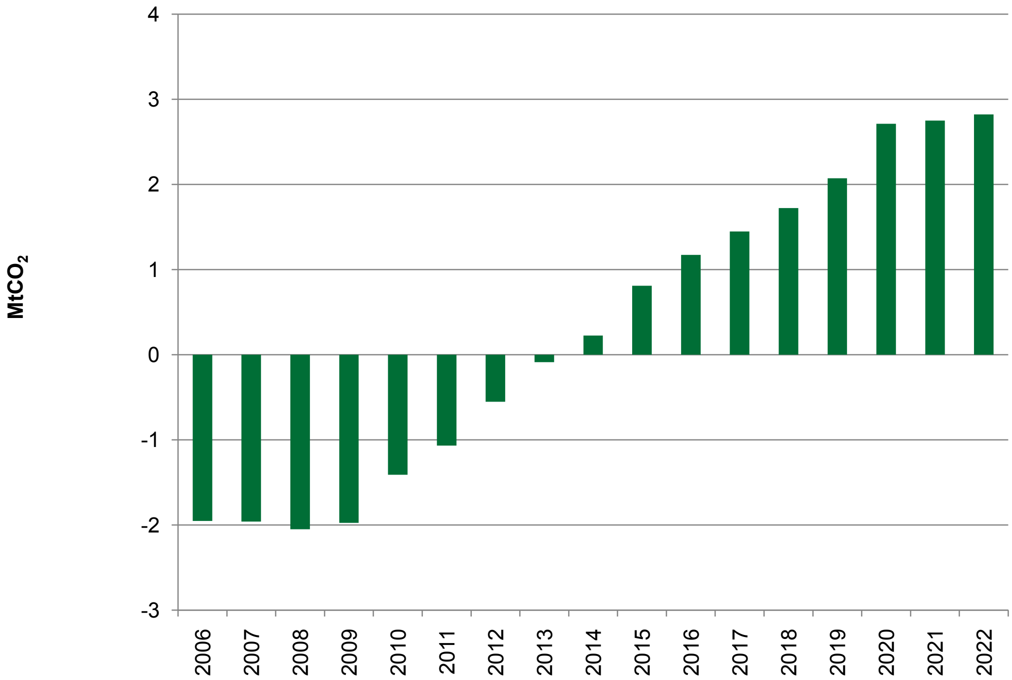
Emissions trends and projections: Net emissions due to LULUCF have moved from adding marginally to reducing marginally the UK's total emissions between 1990 and 2006; this due to changes in land use and forestry practices (Figure 9.9). Going forward, net emissions in 2020 are expected to revert to levels in 1990, with LULUCF becoming a (small) net emitter; this due to the implications of a falling historical tree planting rate (Figure 9.10).

Figure 9.9 LULUCF net emissions, 1990-2006



Source: Centre for Ecology and Hydrology (CEH) (2008) Inventory and projections of UK emissions by sources and removals by sinks due to land use, land use change and forestry, *Defra Contract GA01088*

Figure 9.10 LULUCF net emissions projections, 2006-2022



Source: CEH (2008)

Abatement potential: The analysis that we commissioned from the Scottish Agricultural College to assess scope for emissions reduction in agriculture also covered LULUCF. Within LULUCF, the analysis considered five classes of abatement option:

- Peatland restoration
- Halting liming of organic soils
- Land use transition between grassland and other agricultural uses
- Increasing the number of trees
- More regular harvesting of existing forests.

The analysis suggests that there is not significant abatement potential available from the first three of these measures[6].

The forestry sector, however, can make a potentially significant contribution to emissions reduction. It is possible to increase carbon sequestration[7] by afforesting previously unforested areas, increasing the time a forest is kept standing before it is chopped down, and optimising forest density. Afforestation offers potential to reduce emissions by 2 $MtCO_2$ in 2020 at a small cost saving per tonne of CO_2. This analysis is based on a high planting rate that may be challenging given environmental constraints, licensing regulations and requirements, and limited administrative capacity; we therefore assume realistically achievable potential of 1 $MtCO_2$.

More regular harvesting of existing forests could also increase biomass supply, which would slightly increase net emissions from forestry but reduce emissions elsewhere in the economy through use of biomass in energy supply and substitution for energy-intensive products in construction. In the longer term, increased biomass supply could be achieved through afforestation (i.e. without increased forestry emissions).

As in the case of agriculture, there is no specific policy for LULUCF aimed at meeting a climate change objective. But given the emissions reduction potentially available for this sector, it is our recommendation that the UK Government and national authorities consider how the policy framework might be developed to unlock emissions reduction potential and/or provide additional biomass supply as part of a broader forestry and land use strategy.

6 We note that a range of scientific uncertainties exist in this area and suggest caution is applied to this result.
7 Sequestration refers to CO_2 being removed from the atmosphere, with the carbon being stored instead in biomass and soils.

4. EMISSIONS FROM WASTE

We set out our analysis of waste emissions in two parts:

(i) Background, emissions trends and projections

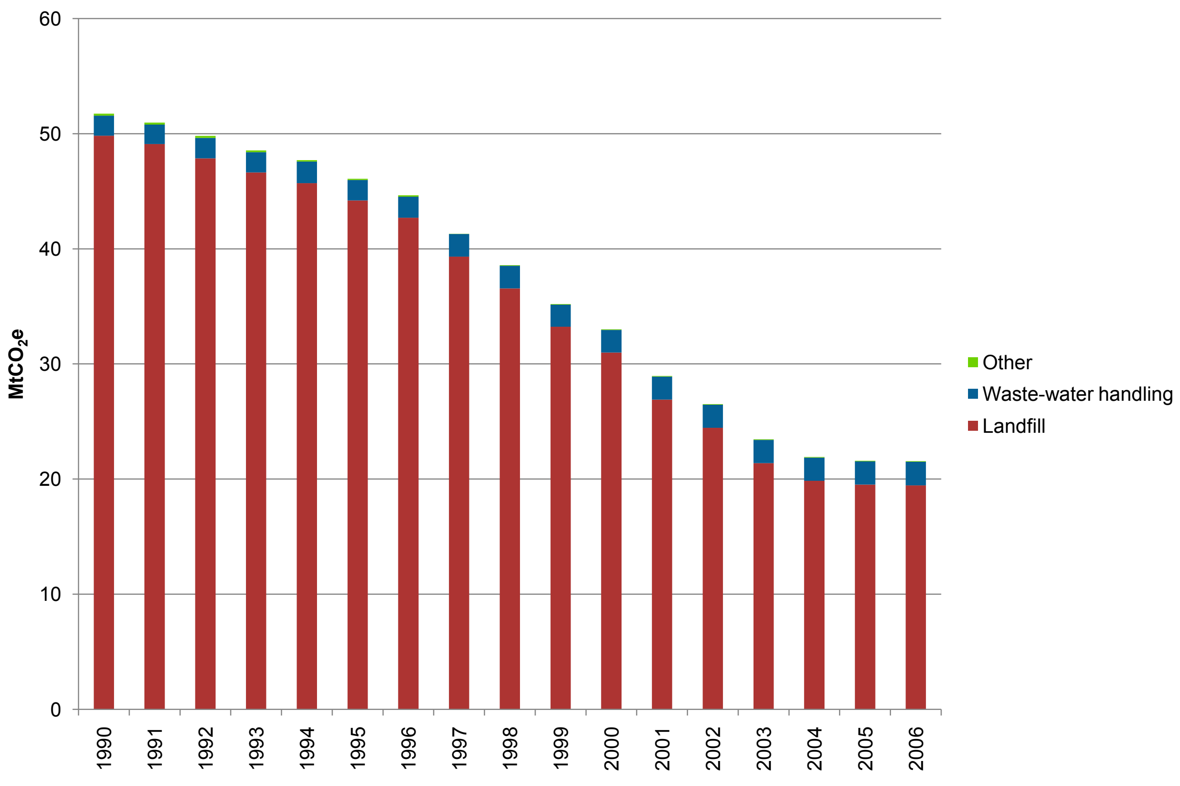
(ii) Abatement potential

(i) Background, emissions trends and projections

Non-CO_2 emissions from waste represented 3% of total UK GHG emissions, and 22% of non-CO_2 emissions in 2006. Waste emissions relate primarily to landfills (89%) and waste-water handling (9%). Landfill emissions result as food, paper and other rotting rubbish biodegrades without oxygen, thus producing methane.

Emissions trends: Emissions from the waste sector have declined 58% over the period 1990-2006, from 52 $MtCO_2e$ to 22 $MtCO_2e$ in 2006. This is due to reduced use of landfills and increased capture of gases from landfill sites, both of which have been driven by a range of EU and UK policies. Other waste emissions have increased slightly over this timeframe but only form a small proportion of emissions from this sector (Figure 9.11).

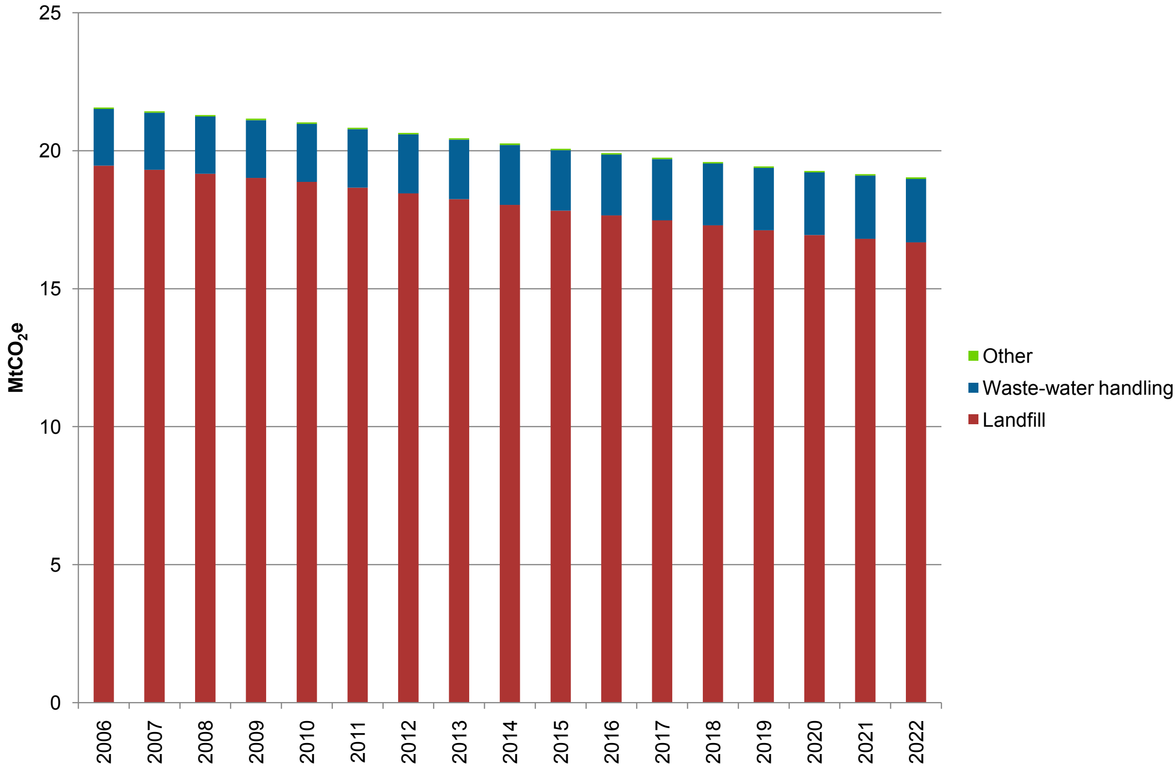
Figure 9.11 Waste non-CO_2 emissions by sub-sector, 1990-2006



Source: NAEI (2008)

Emissions projections: Government projections show waste emissions will fall 11% between 2006 and 2020, by which time they would be 63% below 1990 levels (Figure 9.12). This is due to decreasing emissions from landfill. The driver of emissions reduction in landfill is the EU policy framework, and the assumptions are that the UK meets its commitments in this context.

Figure 9.12 Waste non-CO_2 emissions projections by sub-sector, 2006-2020



Source: Defra

(ii) Abatement potential

There are two main classes of levers for reducing waste sector emissions:

- Downstream, focused on changing the waste management/collection process
- Upstream, focused on changing consumer and producer behaviour either towards producing less waste or disposing of waste in the appropriate manner.

The analysis that we set out in this chapter is focused on the first class of levers (i.e. downstream abatement options), although there is an overlap with the second class of measures given that this will require consumer behaviour change as regards disposing of waste in the appropriate manner. We recognise that changing consumer behaviour as regards producing less waste has an important role to play in reducing emissions from this sector (Box 9.3).

Box 9.3 Importance of behaviour change – reducing emissions from food waste

- It is estimated that we throw away as much as a third of all the food we buy; and at least half of this could have been eaten[1]. A number of reports, primarily by WRAP (Waste and Resources Action Programme), have explored this issue.
- WRAP conclude that the reasons why we waste food are complex, including: buying too much – particularly being tempted by special offers; buying more perishable food; poor storage management; high sensitivity to food hygiene; preparing too much food; not liking the food prepared; and lifestyle factors such as not having the time to plan meals[2].
- The public do not appear to make the connection between the food thrown away and its impact on the environment. The cost factor is more of a consideration, although the public are concerned over packaging waste.
- Recent Defra qualitative research suggests that consumers are open to changing their behaviour in relation to purchasing habits rather than changing diet[3]. However, time, convenience, access, habit, offers and availability remain barriers to consumers adopting more sustainable practices in relation to food.
- Reducing this food waste is the most cost-effective way of avoiding the emissions associated with its disposal. It also offers significant upstream emission and resource savings in production, transport and storage. At the household level reducing waste is cost saving and can help reduce food bills.

1 WRAP (March 2007) *Understanding Food Waste*
2 Brook Lyndhurst (2007) WRAP Food Behaviour Consumer Research (report to WRAP; currently unpublished) quoted in WRAP (March 2007) *Understanding Food Waste*
3 Qualitative research is designed to be illustrative rather than provide statistically representative data. Source: Owen, L., Seaman, H, and Prince, S. (2007). *Public Understanding of Sustainable Consumption of Food: A report to the Department for Environment, Food and Rural Affairs*. Opinion Leader. Defra, London.

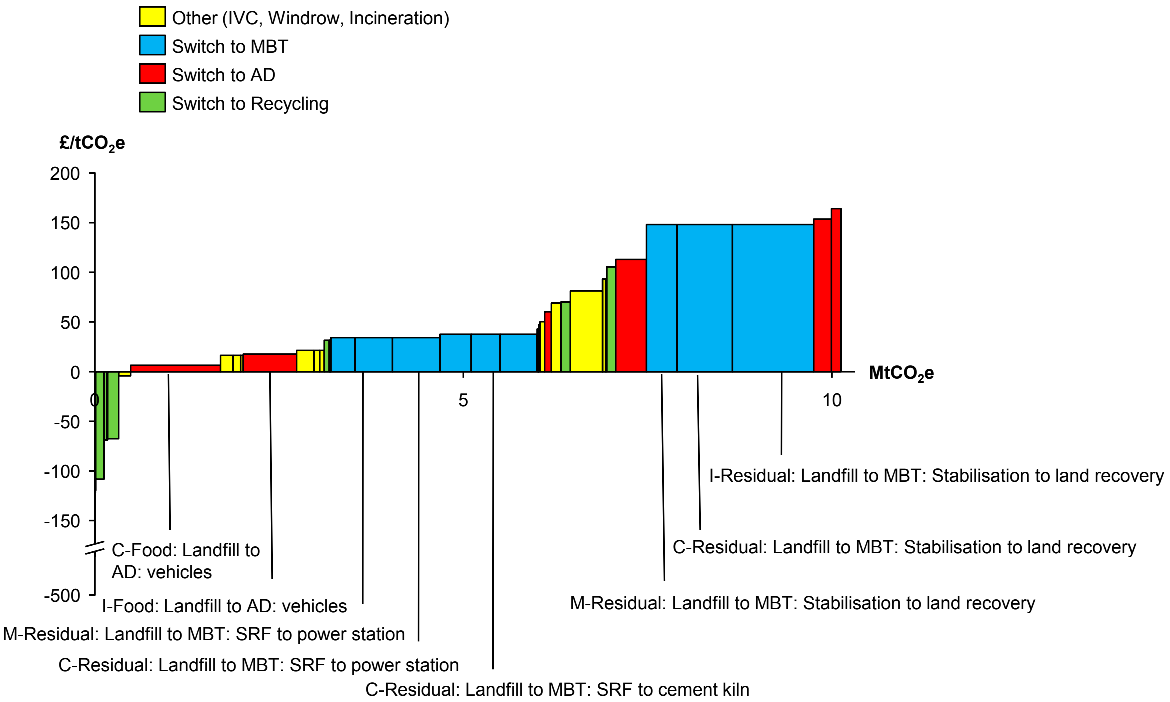
Our analysis is based on a MACC model that we commissioned from Eunomia. The model identifies two key areas – both based around reducing methane emissions from landfill and substituting fossil fuel use in energy production – where there may be significant potential for emissions reduction:

- Processing food waste through anaerobic digestion (AD) to produce biogas, which can for example be compressed for use in vehicles, displacing diesel.
- Processing residual waste through mechanical biological treatment (MBT) to produce either solid recovered fuel (SRF), which can be used in power stations and cement kilns, or an alternative to fertiliser.

A third cost-effective option is increasing recycling. We do not assume significant UK emissions savings from recycling, but the potential to reduce emissions both from UK landfill and from global primary extraction means that the policy framework should cover recycling.

The MACC identifies technical potential to reduce emissions by 6 MtCO_2e in 2020 at a cost of up to £40/tCO_2e; 75% of this potential is accounted for by anaerobic digestion and mechanical biological treatment (Figure 9.13).

Figure 9.13 Waste MACC – maximum technical potential, 2020



Source: CCC modelling
Note: IVC = In-vessel composting, MBT = Mechanical biological treatment, SRF = Solid recovered fuel,
I = Industrial, M = Municipal, C = Commercial

There is a question over the extent to which this emissions reduction may be regarded as realistically achievable. This will ultimately depend on the policy framework for waste, both as it relates to changing consumer behaviour (e.g. as regards recycling food waste) and incentives for moving to alternative treatment options. Our judgement is that 5 $MtCO_2e$ of the potential below £40/tCO_2e can be considered as feasibly achievable.

There is already a policy framework in place in response to EU obligations on waste. New policy is also under development in the context of the wider framework to support investment in renewable energy technologies (see Chapter 5: *Decarbonising electricity generation* and Chapter 6: *Energy use in buildings and industry*); this could, for example, strengthen financial incentives for anaerobic digestion. It is likely therefore that emissions reduction over and above that envisaged in the baseline will occur in practice. But the extent to which this will be the case is uncertain given uncertainty over exactly how the policy framework will develop. Early action is particularly important in this sector due to legacy emissions – once material is landfilled it will continue to emit methane for many decades.

Given the good progress already achieved since 1990, the potential identified to further reduce emissions, and longer-term possibilities in flaring legacy emissions and changing behaviours and materials, a reduction in waste emissions of at least 80% by 2050 appears feasible.

5. NON-CO_2 EMISSIONS FROM INDUSTRY AND ENERGY

We set out our analysis of industrial and energy non-CO_2 emissions in 2 parts:

(i) Background, emissions trends and projections

(ii) Abatement potential and the policy framework

(i) Background, emissions trends and projections

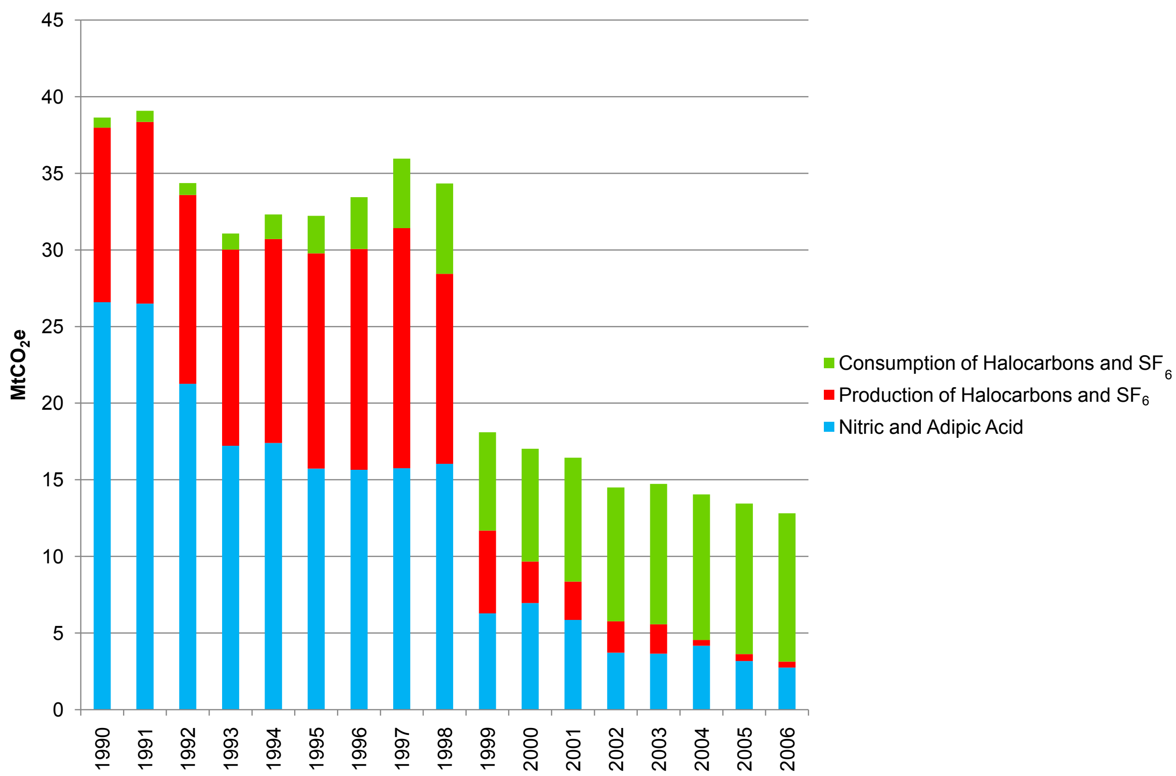
In 2006, non-CO_2 emissions from industrial processes represented 2% of total UK (GHG) emissions, with non-CO_2 emissions from energy accounting for a further 3%:

- Industrial process emissions come primarily from the escape of halocarbons – a type of F-gas – used in applications such as refrigerators, inhalers, fire extinguishers and air conditioning (81%). The majority of the remaining industrial emissions are N_2O and are generated through the production of nitric acid and adipic acid (19%).

- Energy (non-CO_2) emissions come primarily from fugitive emissions from fuels (47%). These emissions mainly come from gas distribution in pipes, methane leaking from coal mines and other leaks that occur during the combustion process. They may also be due to equipment leaks, evaporative processes and windblown disturbances. The other major contributor to emissions in this sector is catalytic converters used in road transport (29% in 2006).

Historic emissions: Non-CO_2 industrial process emissions have declined by 67% over the period from 1990 to 2006, from 39 $MtCO_2e$ to 13 $MtCO_2e$ (Figure 9.14):

Figure 9.14 Industrial process non-CO_2 emissions by sub-sector, 1990-2006

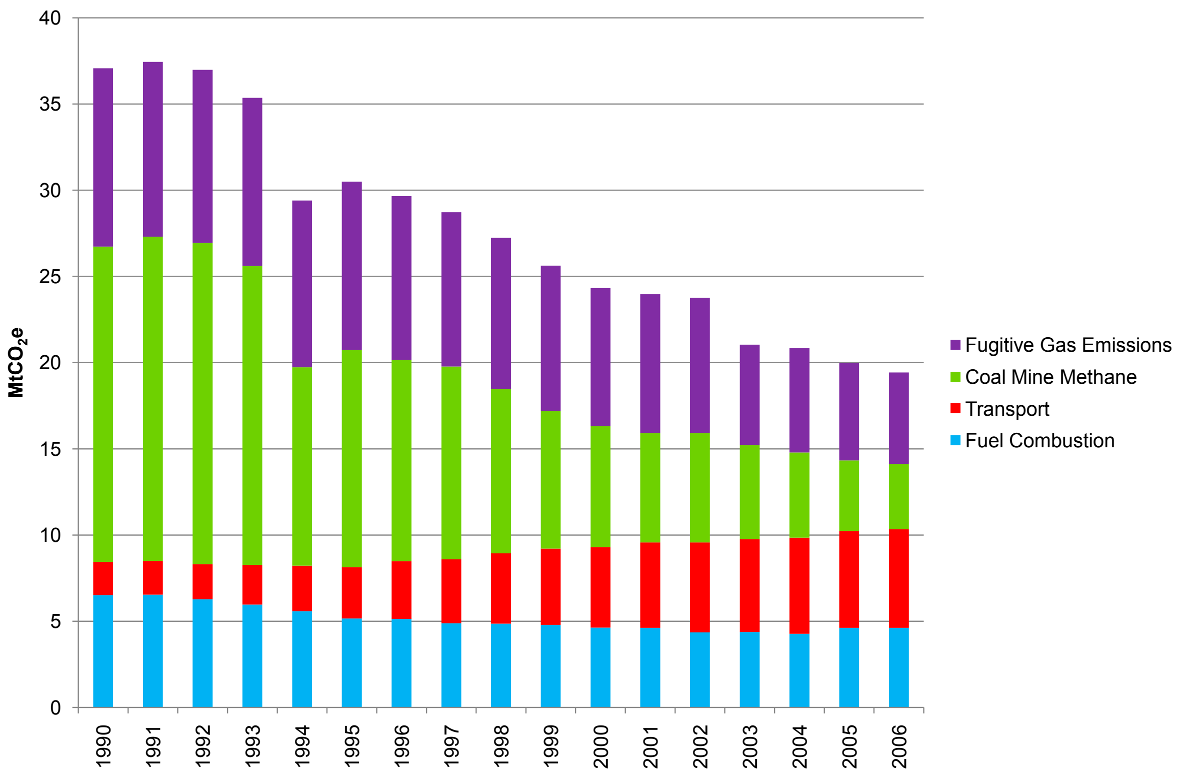


Source: NAEI (2008)

- This is primarily a result of abatement measures introduced to reduce N_2O from adipic and nitric acid manufacture.
- There has also been a sharp decline in the fugitive emissions of F-gases that occur during the manufacture of refrigerants. This change has been driven largely by Integrated Pollution Prevention and Control (IPPC) regulations.
- Offsetting this, the Montreal protocol has phased out the use of ozone gases (with significant climate benefits), but with side effects including their replacement with HFCs resulting in increased F-gas emissions.

Energy (non-CO_2) emissions have declined from 37 $MtCO_2e$ in 1990 to 19 $MtCO_2e$ in 2006, a drop of 48% (Figure 9.15). A fall in coal mine methane emissions (due to industry decline) and a decrease in fugitive emissions from natural gas (due to a health and safety executive enforced gas pipe replacement programme), are the two main contributors.

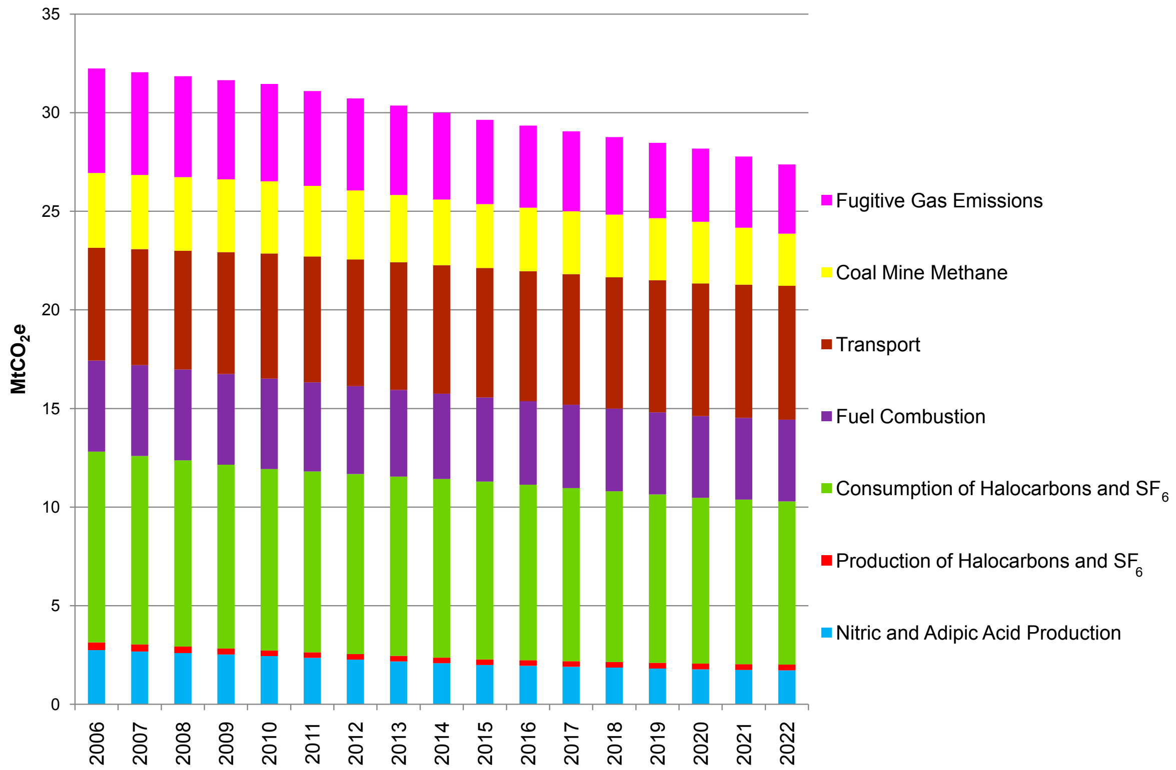
Figure 9.15 Energy non-CO_2 emissions by sub-sector, 1990-2006



Source: NAEI (2008)

Emissions projections: Government projections show industrial process emissions falling by 18% over the period 2006-2020 (Figure 9.16), due to further reductions in adipic/nitric acid emissions, which will be covered by the European Union Emissions Trading Scheme (EU ETS) from 2013, and a decrease in emissions from the use of appliances that emit F gases. Energy non-CO_2 emissions are projected to be 52% below 1990 levels in 2020 based on assumptions that leakage from gas pipes will fall as infrastructure is renewed, with an offsetting increase in N_2O emissions as catalytic convertors are mandated under EU legislation.

Figure 9.16 Industrial process and energy non-CO_2 emissions projections by sub-sector, 2006-2022



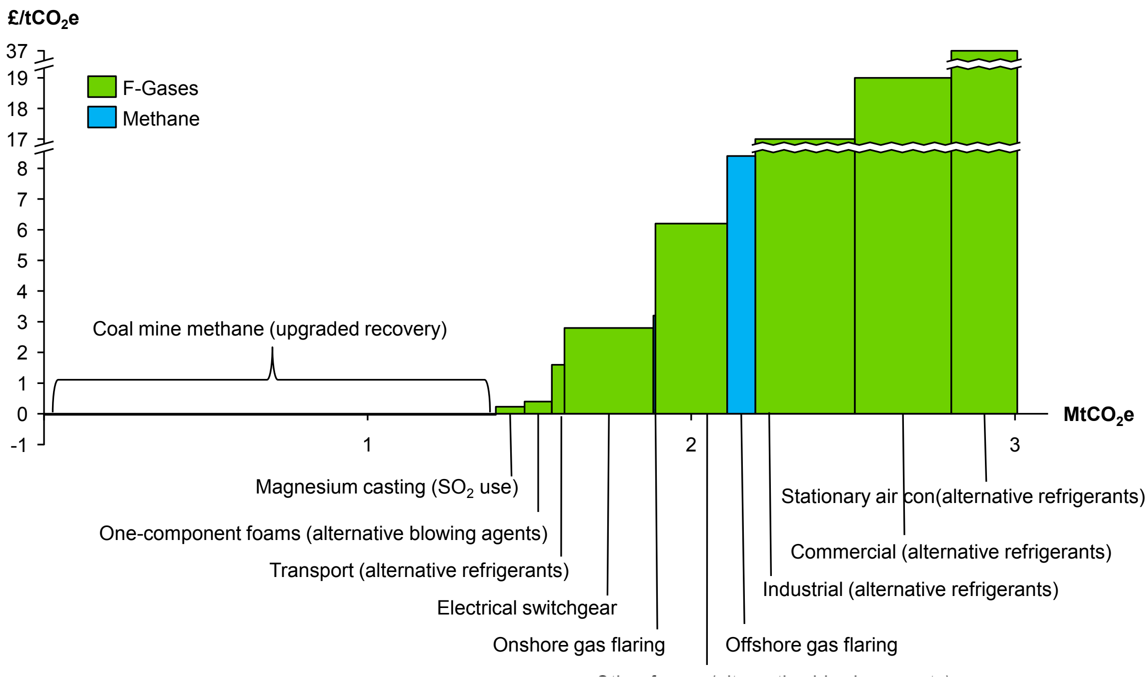
Source: Defra

(ii) Abatement potential and the policy framework

We have not commissioned any new research in the area of industry and energy non-CO_2 emissions. Rather, we have drawn on analysis commissioned by Defra from AEA in this area[8]. AEA have developed a MACC model for non-CO_2 emissions that conservatively suggests there is 3 $MtCO_2e$ abatement potential available at a cost up to £40/tCO_2e (Figure 9.17) from industrial processes and energy:

- Roughly half this saving comes from upgraded recovery and utilisation of methane from coal mines
- The remainder of the saving comes from measures that decrease the leakage of F-gases from appliances or that replace F-gases with less potent gases.

Figure 9.17 MACC for energy and industrial process non-CO_2 emissions, 2020



Source: CCC calculations based Defra project ED05478

Regarding whether this potential is realistically achievable, policy to tackle F-gas emissions is driven at EU level by EC F-Gas regulation and the Mobile Air Conditioning Directive, and it is reasonable to assume that at least some of the emissions reduction potential identified by AEA will ensue. Conversely, there is currently no policy framework in place to encourage reduced methane emissions from coal mines. Whilst this is not a major source of emissions, there is a not insignificant amount of potential available that warrants further consideration of policies that might be introduced here.

8 AEA (forthcoming), Annual Updating of Non-CO_2 Greenhouse Gas Emissions for the UK – Marginal Abatement Cost Curves for Non-CO_2 Greenhouse Gases, *Defra project ED05478*

6. RESTATEMENT OF CARBON BUDGETS IN GHGS

Our CO_2 budget proposals set out in Chapter 3: *The first three budgets* are summarised in Table 9.1. There are two budgets covering the period to 2022: the *Interim budget*, to apply for the period until there is a new global agreement to reduce emissions, and the *Intended budget*, to apply following a global deal. The Interim budget is characterised by an emissions reduction of 29% by 2020 relative to 1990 levels. The Intended budget requires 2020 emissions to be 40% below 1990 levels.

Table 9.1 CO_2 budget proposals, 2008-2022

$MtCO_2$		Budget 1 (2008-12)	Budget 2 (2013-17)	Budget 3 (2018-22)
Interim budget	Traded sector	1233	1114	1011
	Non-traded sector	1304	1235	1103
	Total	**2537**	**2349**	**2114**
Intended budget	Traded sector	1233	1009	800
	Non-traded sector	1304	1201	989
	Total	**2537**	**2210**	**1789**

Source: CCC analysis

We derived our CO_2 budgets based on targets for the UK under the EU's 20%/30% GHG emissions reduction targets for 2020. Specifically, we took these targets, which are expressed in terms of GHGs, and translated them to CO_2 budgets by netting out non-CO_2 emissions under an assumption that these would evolve according to the reference case trajectory (Section 1 above).

To move from CO_2 budgets to GHG budgets, therefore, we simply add back in reference case non-CO_2 emissions[9]. This results in GHG budgets summarised in Table 9.2. The Interim budget is characterised by an emissions reduction of 34% by 2020 relative to 1990 levels; it is this budget that we propose should enter the legislation. The Intended budget requires emissions in 2020 to be 42% below 1990 levels.

9 Note that we have not considered any co-benefits that may result from policies to reduce CO_2. For example, measures reducing road fuel use, such as increased uptake of electric cars, will also tend to reduce N_2O emissions. These are not accounted for in setting budgets, but offer an opportunity to reduce the cost in meeting them.

Table 9.2 GHG budget proposals, 2008-2022

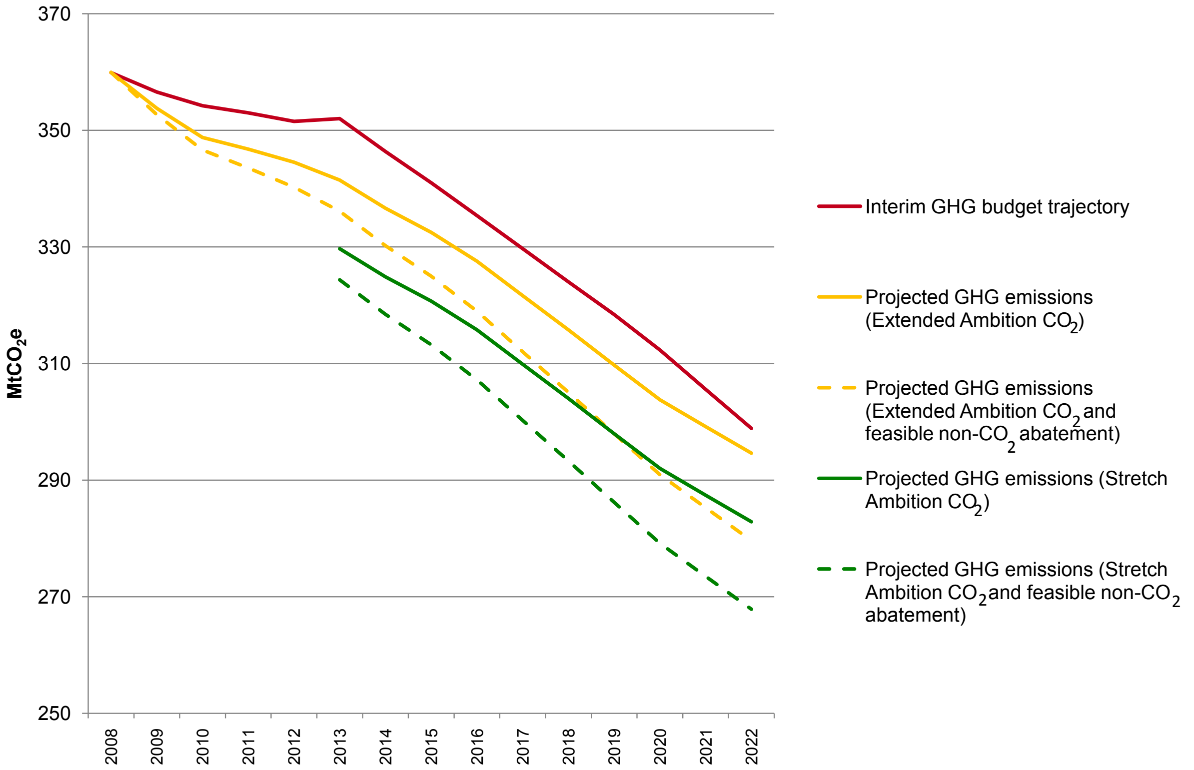
$MtCO_2e$		Budget 1 (2008-12)	Budget 2 (2013-17)	Budget 3 (2018-22)
Interim budget	Traded sector	1233	1114	1011
	Non-traded sector (CO_2)	1304	1235	1103
	Non-traded sector (Non-CO_2)	481	469	456
	Total	**3018**	**2819**	**2570**
Intended budget	Traded sector	1233	1009	800
	Non-traded sector (CO_2)	1304	1201	989
	Non-traded sector (Non-CO_2)	481	469	456
	Total	**3018**	**2679**	**2245**

Source: CCC analysis

We noted in Section 2 above that moving from CO_2 to GHG budgets provides scope for meeting budgets through non-CO_2 emissions reduction, and that this can be attractive from perspectives of cost minimisation and budget risk management.

We illustrate this by comparing emissions in the trajectory under our *Extended Ambition* scenario together with the trajectory under our Interim GHG budget. We do this for the non-traded sector, which is where most of our non-CO_2 emissions occur (Figure 9.18). This comparison shows that whereas feasible CO_2 emissions reduction in 2020 is 9 $MtCO_2e$ more than would be required to meet the budget, this rises to 24 $MtCO_2e$ including non-CO_2 options.

Figure 9.18 Non-traded sector emissions trajectories versus Interim GHG budgets, 2008-2022



Source: CCC analysis
Note: Domestic aviation is excluded throughout for clear comparisons (in reality it will be in the first non-traded budget, but not the second and third, when it will fall in the traded sector)

This has led us to consider the question of whether effort to reduce CO_2 emissions should be relaxed in the context of GHG budgets where there are cost-effective opportunities for non-CO_2 emissions reduction. On balance, however, our view is that given uncertainty over what can realistically be achieved in non-CO_2 emissions reduction and given required CO_2 reduction in the context of progressing towards the 2050 target, CO_2 emissions reduction effort in the period to 2022 should continue at levels proposed in Chapter 3 (i.e. Government should aim to deliver at least the Extended Ambition and consider options in the Stretch Ambition).

This should be complemented by further analysis and development of a policy framework for unlocking non-CO_2 emissions reduction potential. Non-CO_2 emissions reduction would then have an important role to play in mitigating risks related to delivery of CO_2 emissions reduction, allowing budget compliance in the event that some CO_2 emissions reduction is not delivered, and should be regarded similarly to other options in our Chapter 3 *Stretch Ambition* scenario.