SCOTLAND'S PATH TO A LOW-CARBON ECONOMY

TECHNICAL APPENDIX

Authors: Katherine Kinninmonth and Mike Thompson (Committee on Climate Change Secretariat)

Date: February 2010

CONTENTS

EXECUTIVE SUMMARY

Scotland has adopted ambitious targets to reduce emissions, which the Committee advised on in our report "Scotland's path to a low-carbon economy". This technical appendix sets out some of the detailed analysis that inputted to that advice.

The key points in this paper are:

- The historic emissions and future caps calculated for the Scottish traded sector are based on the detailed set of data available from the EU ETS, including from firms that opted out early on in the scheme, and emissions from domestic aviation.
- Our emissions projections for the non-traded sector are based on a new model commissioned specifically for this project and on various existing disaggregated government projections. In both cases the robustness of the modelling is constrained by the availability of reliable detailed disaggregated data, and reliant on the robustness of models and assumptions used at the UK level.
- We identify a total 6-7.5 $MtCO_2e$ of abatement potential in the Scottish non-traded sector, which is the sum of a large number of specific measures across the sectors of residential buildings, non-residential buildings and industry, renewable heat, transport, agriculture, waste and land use. The estimates for each measure attempt to build in Scottish-specific circumstances as far as practical given data constraints.
- Recommendations for economy-wide emissions targets are built up from our analysis of the future caps for the traded sector, expected emissions from international aviation and shipping and our proposed trajectory for non-traded sector emissions. The non-traded trajectory builds in flat business-as-usual projections to 2012, which reflect the offsetting trends in the various sub-sectors.
- Different interpretations of the limit on credit use in the Climate Change (Scotland) Act would imply that some of the options discussed in "Scotland's path to a low-carbon economy" would be ruled out or limited.

INTRODUCTION

The Scottish Climate Change Act, passed in August 2009, sets out a comprehensive framework for emissions reduction in Scotland. In particular, the Act sets a long-term target to reduce emissions of Scottish greenhouse gases[1] by 80% in 2050 relative to 1990, with an interim target to reduce emissions by 42% in 2020 relative to 1990. The Act also provides for setting of annual emissions reduction targets and a cumulative emissions budget covering the period to 2050.

In August 2009, the Scottish Government requested advice from the Committee on Climate Change primarily relating to interim targets under the Act. Specifically, the Committee was asked to advise on:

- The highest achievable interim target for 2020,
- The first batch of annual targets from 2010-2022,
- A cumulative emissions budget for Scotland,
- The proposed methodology for inclusion of Scotland's share of international aviation and international shipping emissions and use of non-CO_2 multipliers,
- Limits on the use of offset credits to meet Scottish targets.

The CCC's advice on these issues is contained in the report "Scotland's path to a low-carbon economy". This technical annex sets out the detail of the analytical approach in five key areas:

1. Setting the traded sector cap for Scotland
2. Reference emissions projections for the Scottish non-traded sector
3. Emissions reduction potential in the Scottish non-traded sector
4. Annual emissions targets
5. Use of credits

Note: For maximum transparency the figures in this technical annex are presented in their unrounded form. This implies a degree of spurious accuracy since there will inevitably be significant error margins around all the figures presented, and in use it is recommended that figures are rounded to a suitable level – e.g. to the nearest 0.1 $MtCO_2e$.

[1] The target relates to the basket of 6 Kyoto greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)

1. SETTING THE TRADED SECTOR CAP FOR SCOTLAND

The traded sector is defined as those firms that will be covered by the EU ETS. It comprises power generation, energy-intensive industry and aviation. In each year of its operation, firms within the EU ETS have to surrender sufficient emissions allowances to cover their actual emissions. These allowances are in some cases freely allocated directly to participating installations, and otherwise are auctioned. All participants can purchase emissions allowances at auctions and buy from and sell to other participants (or other traders in the market).

At the Scottish level we are not able to adjust for expansion of the EU ETS to include more combustion sites in Phases II and III. Our definition of the traded sector is therefore based on the Phase I coverage of combustion sites, plus domestic aviation. We exclude international aviation to avoid double-counting as it is treated separately in our analysis along with international shipping.

As in the UK framework, Scotland's emissions targets are on a net carbon account basis – that is net of any purchase of emissions allowances and credits. Emissions in the traded sector will therefore be equal to actual emissions less any net purchase of emissions allowances by Scottish installations. At the UK level, this corresponds to the national-level cap, which can be derived from free allowances distributed to UK firms and UK rights to auction revenues. This section outlines how we have derived a traded sector cap for Scotland.

1.1 TRADED SECTOR EMISSIONS FOR PHASE I – 2005-07

The first step is to estimate the outturn level of emissions from Scottish firms in the traded sector for the years 2005-2007 – Phase I of the EU ETS. To do this we use data on verified emissions from the EU ETS.

Table 1.1: Verified emissions from Scottish installations included in the EU ETS (tCO_2)

Industry Sub-sector	2005 Emissions	2006 Emissions	2007 Emissions
Combustion < 250Kt	2,508,495	2,347,009	3,139,008
Refineries	1,637,432	1,479,351	1,599,731
Cement	-	-	402,718
Glass	-	-	-
Ceramics	21,002	17,652	14,708
Pulp and Paper	176,010	92,863	90,553
Combustion >250Kt	15,456,184	20,260,798	17,021,466
TOTAL	**19,799,123**	**24,197,673**	**22,268,184**

Some installations were able to opt-out from participation in Phase I, but will be covered by the Scheme in later Phases – we therefore add their emissions to the verified emissions in table 2.1. We assume that their emissions in years where they opted-out were the same as in the first year for which verified emissions are available. There are two relevant classifications here:

- 'decision 1' opt-outs, which are not included in 2005 and 2006 figures, but which are included in 2007 emissions – we add these to the figures for 2005 and 2006
- 'decision 2' opt-outs, which are not included at all in the table 1.1. figures, but for which verified emissions are available for 2008 – we add these to the figures for 2005, 2006 and 2007.

Table 1.2: Emissions from installations choosing to opt-out in Phase I (tCO_2)

Industry Sub-sector	2007 emissions from 'decision 1' opt-outs	2008 emissions from 'decision 2' opt-outs
Combustion < 250Kt	993,531	325,575
Refineries	-	-
Cement	402,718	-
Glass	-	243,809
Ceramics	-	6,038
Pulp and Paper	-	480,183
Combustion >250Kt	-	-
TOTAL	**1,396,249**	**1,055,605**

As well as adding in the opt-outs we also add in domestic aviation emissions taken from the NAEI to reach our estimate of total traded sector emissions for 2005-07.

Table 1.3: Scottish traded sector emissions including opt-outs and domestic aviation (tCO_2)

Industry Sub-sector	2005	2006	2007
Combustion < 250Kt	3,827,601	3,666,115	3,464,583
Refineries	1,637,432	1,479,351	1,599,731
Cement	402,718	402,718	402,718
Glass	243,809	243,809	243,809
Ceramics	27,040	23,690	20,746
Pulp and Paper	656,193	573,046	570,736
Combustion >250Kt	15,456,184	20,260,798	17,021,466
TOTAL COMBUSTION	**22,250,977**	**26,649,527**	**23,323,789**
Domestic Aviation	675,302	649,953	614,260
TOTAL TRADED	**22,926,279**	**27,299,480**	**23,938,049**

1.2 TRADED SECTOR EMISSIONS FOR PHASE II – 2008-2012

For Phase II, the UK cap is made up of:

- Primarily allowances freely allocated directly to installations,
- Some allowances from the New Entrant Reserve – held back to allocate to any new entrants, so they are not disadvantaged compared to incumbent installations receiving free allocations,
- A small amount of auctioned allowances.

For Scotland we only have data for freely allocated allowances, since the New Entrant Reserve and the auction pot are held at the UK level. We therefore scale up the allocated allowances in Scotland by factors reflecting the importance of the New Entrant Reserve and auctioning in each EU ETS sector at the UK level – this is equivalent to an assumption that Scotland's share of the New Entrant Reserve and the auctioned allowances is the same as its share of allocated allowances. The cap is held constant for each of the years 2008-2012 covered by Phase II.

Table 1.4: Emissions allocations for the UK and Scotland in Phase II (tCO_2)

EU ETS Sector	UK Allocated Allowances	UK Total Allowances	Scale-up Factor	Scotland Allocated Allowances	Scotland Total Allowances
Aluminium	2,794,952	2,854,101	2.1%	0	0
Cement	10,948,558	11,247,643	2.7%	713,911	733,413
Ceramics	1,598,018	1,653,481	3.5%	40,075	41,466
Chemicals	10,537,384	10,755,850	2.1%	2,232,160	2,278,438
Downstream Gas	1,398,822	2,157,404	54.2%	565,148	871,628
Food and Drink	3,762,970	3,815,854	1.4%	307,488	311,809
Glass	2,201,556	2,262,496	2.8%	248,673	255,556
Iron & Steel	23,727,929	24,380,992	2.8%	0	0
Large Electricity Producers [a]	104,733,780	129,853,452	24.0%	9,554,722	11,846,356
Lime	2,702,870	2,760,070	2.1%	0	0
Offshore	18,133,145	20,444,052	12.7%	1,988,467	2,241,879
Other Electricity Producers	1,390,638	1,417,923	2.0%	105,645	107,718
Others A	854,843	950,549	11.2%	45,962	51,108
Others B	1,493,488	1,522,426	1.9%	120,726	123,065
Others C	417,412	423,425	1.4%	22,419	22,742
Pulp & Paper	3,642,545	3,664,391	0.6%	576,010	579,465
Refineries	19,603,249	19,922,767	1.6%	3,340,205	3,394,648
Services	1,761,309	1,886,209	7.1%	154,766	165,741
TOTAL	**211,703,468**	**245,256,038**		**20,016,377**	**23,025,032**

[a] The extra allowances for the power sector are 7.9 $MtCO_2$ from the New Entrant Reserve and 17.2 $MtCO_2$ from auctioning. For all other sectors the difference is completely dominated by the New Entrant Reserve.

Domestic aviation will enter the EU ETS in 2012, with net emissions capped at 97% of 2004-06 average emissions. Allowances will be partly allocated and partly auctioned, with auction rights based on each Member State's share of EU aviation emissions. We therefore add in domestic aviation based on our business-as-usual projection for 2008-2011, and as 97% of 2004-06 emissions in 2012.

Table 1.5: Scotland's traded sector emissions in Phase II ($ktCO_2$)

	2008	2009	2010	2011	2012
Traded sector - combustion	23,025	23,025	23,025	23,025	23,025
Domestic aviation	588	620	633	647	631
Traded sector TOTAL	**23,613**	**23,645**	**23,659**	**23,672**	**23,656**

1.3 TRADED SECTOR EMISSIONS FOR PHASE III – 2013-2020

In calculating a Phase III cap for Scotland it is important to recognise the increasing importance of auctioning:

- The majority of allowances in Phase III will be auctioned rather than freely allocated,
- The level of auctioning will differ between sectors (e.g. allowances for large combustion will be fully auctioned, whilst allowances for refineries will be fully allocated),
- Member States' shares of auction rights will differ from their share of historical emissions as some rights are retained at the EU level (e.g. to support financing of CCS demonstrations) and as auction rights are redistributed based on national income and past emissions reductions.

To estimate the Scottish cap we apply the following steps:

- Estimate the share of Scottish and UK traded sector emissions for 2005-07 that will in future be auctioned, based on sectoral composition and shares subject to auctioning in 2020.
- Calculate the proportion that Scottish emissions make up of UK 2005-07 emissions that will in future be subject to auctioning.
- Hold that proportion constant going forward, and apply it to estimates of future UK auction rights, to reach an assumed share of auctioned allowances for Scotland.
- For allocated emissions, assume that allocations to Scottish installations fall from 2005-07 emissions in line with the EU-level cap,
- Add domestic aviation emissions at 95% of their 2004-06 average.

Table 1.6: Scottish 2005-07 emissions to be subject to auctioning ($ktCO_2$)

	Share of allowances auctioned in 2020	UK 2005-07 emissions subject to auctioning	Scottish 2005-07 emissions subject to auctioning	Scottish proportion
Refineries	0%	-	-	-
Metal	70%	-	-	-
Cement	0%	-	-	-
Iron and Steel	1%	81	-	-
Ceramics	70%	1,216	17	1.4%
Glass	20%	392	49	12.6%
Pulp and Paper	20%	820	122	14.9%
Coke	1%	164	-	-
Other	70%	-	-	-
Combustion over 250Kt	100%	183,882	17,579	9.6%
Combustion under 250kt	22%	8,819	821	9.3%
Total	**68% UK / 77% Scotland**	**195,374**	**18,588**	**9.5%**

Note: figures for 2005-07 are annual averages

Table 1.7: Scottish emissions cap for 2013-2022 ($MtCO_2$)

	UK Auction pot	Scottish share (9.5%) of UK auction pot	Scottish allocated allowances	Scottish domestic aviation cap	Scottish traded sector cap
2013	131.52	12.51	5.52	0.62	**18.65**
2014	126.95	12.08	5.20	0.62	**17.90**
2015	122.30	11.64	4.89	0.62	**17.15**
2016	117.54	11.18	4.59	0.62	**16.39**
2017	112.69	10.72	4.29	0.62	**15.63**
2018	107.73	10.25	4.01	0.62	**14.87**
2019	102.69	9.77	3.73	0.62	**14.11**
2020	97.54	9.28	3.45	0.62	**13.35**
2021[a]	96.20	9.15	3.21	0.62	**12.98**
2022[a]	90.58	8.62	2.98	0.62	**12.21**

[a] Phase III only runs to 2020. We have used the indicative path proposed by the EU to calculate figures for 2021 and 2022 as required for our advice.

In "Scotland's path to a low-carbon economy" we refer to reductions in traded sector emissions against 1990. We define 1990 traded sector emissions by applying constant proportions to industrial emissions at the sectoral levels. Specifically we assume that:

- All CO_2 emissions from power generation, refineries, offshore oil and gas, iron and steel, and domestic aviation are always part of the traded sector.
- Constant proportions of energy industry (31%), other industry (62%) and services (12%) are traded. As the sectoral composition changes from 1990 to 2005 (e.g. there were 3 $MtCO_2$ emissions from iron and steel in 1990, and less than 0.1 $MtCO_2$ by 2005) this means that the aggregate traded share of 'Industry and commerce' is 54.0% in 1990, compared to 42.5% in 2005[2].

[2] Note that this proportion is slightly higher than the 35.6% quoted in Cambridge Econometrics report (see below), due to the treatment of opt-outs, as described above, which differs slightly from Cambridge Econometrics' treatment.

2. REFERENCE EMISSIONS PROJECTIONS FOR THE SCOTTISH NON-TRADED SECTOR

To formulate UK carbon budgets, the CCC developed, in collaboration with the Department for Energy and Climate Change (DECC) using their Energy and Emissions Model[3], a set of 'reference projections' of energy demand and CO_2 emissions[4]. Reference projections establish the likely scale of the challenge of meeting carbon reduction targets in the future.

In assessing the scope for meeting the required reduction in the non-traded sector (i.e. emissions not covered by the EU ETS) in Scotland, we need to have a set of reference emissions projections designed to reflect possible outcomes in the absence of new policies to reduce emissions.

2.1 CO_2 EMISSIONS PROJECTIONS FOR SCOTLAND

The DECC model does not provide regional CO_2 emissions projections, therefore, in 2008 the CCC devised an approach to disaggregate UK-wide emissions projections for Scotland, Wales and Northern Ireland[5]. In doing so, the CCC recognised that there were a number of limitations to our approach and therefore in building the evidence base for the advice to Scottish Ministers we commissioned Cambridge Econometrics to build upon our previous work and develop an emissions projections tool for Scotland – the Scenario Tool for Emissions Projections in Scotland (STEPS).[6]

The method in STEPS is similar to the CCC's approach in 2008 and is predominantly a top-down disaggregation of UK-wide projections. The model takes the UK projections as given and makes assumptions about how UK emissions trends apply to energy demand in Scotland – as such these projections may be subject to more uncertainty than those for the UK.

The CCC's reference emissions projections used in our analysis of Scottish targets are based upon the results of the STEPS model. The model structure is detailed in the Cambridge Econometrics report to the CCC. In using the model we have made a number of choices over the precise assumptions used. The main changes from the assumptions set out in the Cambridge Econometrics report are:

- Updating the model with the latest DECC regional energy consumption statistics (for 2007), published in December 2009[7] – these data are used to adjust the breakdown from UK energy demand to better-reflect current fuel demand in Scotland. Future years are adjusted by the same rate.

[3] Hereafter the DECC model.

[4] These projections are detailed in a technical annex for Chapter 3, *The Committee on Climate Change reference emissions projections.* Available at: www.theccc.org.uk/reports/technical-appendices

[5] For more information of this approach, see technical annex for Chapter 14, *Differences in national circumstances*. Available at: www.theccc.org.uk/reports/technical-appendices

[6] The full report of Cambridge Econometrics' work is available at: www.theccc.org.uk/reports/supporting-research/

[7] Available at: http://www.decc.gov.uk/en/content/cms/statistics/regional/regional.aspx

- Incorporating a more detailed breakdown of industrial energy consumption by sector and by fuel to improve the breakdown of emissions between traded and non-traded sectors - this has been supplied by AEA Technology and is consistent with the published data (as above). The result of this has been a slight increase in the estimate of non-traded sector emissions in the model.

- Calibrating the non-traded sector share of industrial emissions to the 2005-07 estimates for traded sector emissions outlined in section 1 above. This resulted in a slight decrease in non-traded sector emissions.

- Incorporating projections data from Transport Scotland using the Transport Model for Scotland (TMfS). Cambridge Econometrics suggested that the National Transport Model (NTM) would be a suitable tool for modelling Scottish emissions from road transport but that further investigation was required to understand the differences between the NTM and the TMfS. The CCC commissioned additional runs of TMfS to reflect updated economic assumptions used in the NTM and found that the level and trends in energy demand were very similar between the two models. On balance, the TMfS outputs were chosen for use in the Scottish targets advice as they include more up to date assumptions about land use planning decisions in Scotland than the NTM. We have adjusted the reference projections in line with assumptions that biofuels use for road transport increases to 5% by energy (5% by volume) by 2012 for biodiesel and 3% by energy (5% by volume) for bioethanol, remaining fixed at these levels for future years.

Table 2.1 below shows the key set of scenarios produced by STEPS following the adjustments, the results of which have been used in the CCC's advice.

Table 2.1: Non-traded CO_2 emissions projections for Scotland [a] ($MtCO_2e$)

	2005[b]	2010	2015	2020
Central	26.1	23.6	23.1	23.6
High ff prices	26.1	23.3	22.5	22.8
Low ff prices	26.1	24.3	23.7	24.3

a. Excludes domestic civil and international aviation (traded) but includes international shipping.

b. Non-traded sector emissions in 2005 are adjusted to reflect the coverage of the traded sector in Phase 3, i.e. including opt-outs from phase 1. Coverage of the traded sector is estimated by Cambridge Econometrics and is subject to uncertainty (see Chapter x of the CE report for more detail).

Under the central scenario, the contribution made by each of the key non-traded sectors is shown in Table 2.2.

Table 2.2 Emissions projections for key sectors in Scotland ($MtCO_2e$)

	2005	2010	2015	2020
Residential	7.6	7.3	6.5	6.4
Industry and commerce	7.7	5.7	5.6	5.6
Road transport	9.9	9.6	9.5	9.9
International shipping	1.1	0.8	1.0	1.2

Our reference CO_2 emissions are based on a number of assumptions, consistent with the DECC model:

- **Fossil fuel prices:** We have used the latest set of fossil fuel prices, as forecast by DECC.[8] Our central scenario is scenario 2 where oil prices rise to $80/bbl by 2020, compared with up to $120/bbl in the high and $60/bbl in the low price scenario.

- **Economic growth**: The central economic growth scenarios for the UK are from HM Treasury, consistent with Budget 2009 forecasts, and are consistent with those used by DECC and the CCC for the central economic growth reference scenarios. For our December 2008 report, a set of forecasts of Scottish GVA was commissioned from Oxford Economics in 2008, consistent with 2008 official growth forecasts. To determine the central Scottish GVA variant from the Budget 2009 growth forecasts, the 2008 economic estimates provided to the CCC for the UK and for Scotland were used to calculate growth differentials. The growth differentials between Scotland and the UK are then applied to the latest UK central projections to give Scottish central projections of GVA by sector. This assumes that the impact of the recession will affect Scottish industry in the same way as the UK aggregate.
- **Demographics**: Growth in the number of households in Scotland used in the model to determine Scotland's share of domestic energy demand are consistent with the latest (2006-based) General Register for Scotland projections of household growth.[9] The high and low household growth variants adjust the assumption of the level of net migration in Scotland.

[8] The latest DECC price assumptions are available at:
http://www.decc.gov.uk/en/content/cms/statistics/projections/projections.aspx

[9] Available at: http://www.gro-scotland.gov.uk/statistics/publications-and-data/household-projections-statistics/household-projections-for-scotland-2006-based/list-of-tables.html

Use of the DECC Model

The robustness of the Scottish emissions projections produced by the STEPS model is reliant on the robustness of the UK projections that are used as an input. There is therefore a question in relation to the confidence we can have in those projections.

As part of our analysis to advise the UK government on the first three carbon budgets we commissioned Oxford Economics to undertake a review of the DECC model[10]. That review found that the model is broadly fit for purpose and firmly based on observed past relationships between the drivers of energy demand and resulting energy use. We also commissioned an independent UK forecast from Cambridge Econometrics to provide a benchmark to the DECC projections, which produced similar projections for the non-traded sector except for road transport (i.e. in those parts of the economy for which we have relied on the DECC model in forming our Scottish emissions projections). We can therefore have some comfort that the projections detailed above have a robust foundation, and are based on UK-level projections in line with alternative views.

As part of their review Oxford Economics questioned the ability of the DECC model to project residential emissions when GDP growth was off-trend (e.g. as in a recession). We suggested therefore in our October 2009 progress report that at the UK level emissions in the near-term may turn out to be lower than suggested by the DECC model. The same would therefore apply at the Scottish level, implying a risk that our proposed emissions path could incorporate an overestimate of business-as-usual emissions in the near term.

2.2 NON-ENERGY CO_2 AND NON-CO_2 PROJECTIONS FOR SCOTLAND

Emissions from sources not covered by STEPS are those producing non-CO_2 gases (methane, nitrous oxide and F-gases) and CO_2 emissions arising from land use change and forestry activities. For these emissions, we have used the official projection sources:

1. **LULUCF**: projections are produced annually by the Centre for Ecology and Hydrology (CEH)[11]. Projections are modelled separately for each of the Devolved Administrations and England. The Mid emissions scenario has been used in the advice.

2. **Non-CO_2**: projections are produced by AEA under contract to DECC, these have been disaggregated from UK projections for England, Wales, Scotland and Northern Ireland.[12] There is a single scenario of reference emissions projections.

We have not assessed the robustness of the non-CO_2 regional projections in detail, but we note that there are generally more uncertainties for these sources, both in the understanding of the processes that lead to emissions and in the analysis around drivers and future trends.

[10] Oxford Economics (2008) *Review of the BERR Energy Demand Model*. Available at http://www.theccc.org.uk/reports/building-a-low-carbon-economy/supporting-research

[11] The latest projections are available at: http://www.edinburgh.ceh.ac.uk/ukcarbon/reports.htm

[12] Full report of non-CO_2 projections available at: http://www.naei.org.uk/reports.php

2.3 SCOTTISH GHG NON-TRADED EMISSIONS PROJECTIONS – TRENDS

Combining the CO_2 and non-CO_2 emissions projection, we can compile a greenhouse gas emissions projection for Scotland's non-traded sector.

Table 2.3: Non-traded emissions projection summary for Scotland ($MtCO_2e$)

	1990	2005	2010	2015	2020	% change 1990 - 2020
CO_2 (excluding LULUCF)	27.7	26.1	23.6	23.1	23.6	-15%
Non-CO_2 [a, b]	16.0	10.8	10.6	10.3	9.9	-38%
LULUCF	-2.5	-4.6	-4.0	-2.6	-1.5	-40%
GHG TOTAL	**41.2**	**32.3**	**30.2**	**30.8**	**32.0**	**-22%**

a Includes non-CO_2 emissions from international aviation and shipping.
b Base-year for F-gases is 1995.

3. EMISSIONS REDUCTION POTENTIAL IN THE SCOTTISH NON-TRADED SECTOR

For its advice to the UK government on carbon budgets, the CCC identified cost-effective abatement potential primarily by using the results of marginal abatement cost curve (MACC) modelling. MACCs provide an assessment of emissions reduction potential across a range of measures at a given point in time. They show the level of abatement potential for each measure, and the associated cost per tonne of CO_2. The CCC has developed an economy-wide MACC for the UK which draws together sectoral MACCs for residential buildings, non-residential buildings, industry, transport and power generation[13]. The sectoral and economy-wide MACCs relate to 2020. The starting point for our MACC analysis is to identify technical potential that would be available if there were no emissions reduction constraints. These results have subsequently been adjusted to take into account that there are likely to be constraints to implementing the maximum technical potential of a given measure, due to inertia, lack of information, hidden costs, etc. This adjustment has in part been informed by the CCC's assessment of the social research evidence base.

In constructing the bottom-up MACC models, the CCC has established a range of methodologies for disaggregating emissions reductions between the three devolved nations and England. The disaggregation methodologies do not constitute nation-specific MACCs in their own right, but are a way of estimating the distribution of total UK abatement between the devolved nations and England. This approach was the basis of our analysis in Chapter 14 of *Building a low-carbon economy – the UK's contribution to tackling climate change*, and it has been drawn upon for our analysis of Scottish emissions reduction potential.

This section outlines the approach to estimating abatement potential under each scenario. Results from MACC analysis in buildings, industry, road transport, agriculture, land use and forestry, and waste sectors have been disaggregated to estimate likely savings in Scotland in 2020. As with reference emissions projections, power sector abatement potential has not been disaggregated as this would require assumptions to be made about the location of new plant and renewables, which would be an inherently uncertain exercise given current resources and information and unnecessary in the context of the EU traded sector cap as laid out in section 1.

In our UK analysis, we have set out scenarios for non-traded sector emissions under alternative assumptions about policy. More recently, in our October 2009 report to the UK Parliament, we have focused on two scenarios:

- The **Extended Ambition** scenario is broadly in line with policies to which the UK Government is committed in principle, but where precise definition and implementation of policies is required. It includes, for example, ambitious targets for energy efficiency improvement (including some solid wall insulation), significant penetration of renewable heat, deep cuts in emissions from cars, and some lifestyle changes in homes and transport.

[13] The detail behind these developments are discussed in the technical annexes and supporting research to our December 2008 and October 2009 reports.

- The **Stretch Ambition** scenario adds further abatement opportunities for which no policy commitment is in place, including large numbers of solid wall insulation, road pricing and more significant lifestyle adjustments.

We have applied these definitions to the analysis in advice on Scottish targets and developed Extended and Stretch Ambition scenarios for Scotland.

Our approach in estimating abatement potential for Scotland has been to focus on those issues most likely to imply different levels of achievability in Scotland versus the rest of the UK. We have not attempted to calibrate in all cases to existing Scottish policy ambition and targets. As such our estimates should give a good indication of what abatement is likely to be feasible at the Scottish level, but that will require new and strengthened policies to drive take-up, from both the Scottish and the UK government.

3.1 RESIDENTIAL BUILDINGS

We estimate that UK residential sector direct emissions could be reduced by up to 10 $MtCO_2$ in 2020, which we identify could be delivered by a range of measures, including:

- Improved insulation (e.g. cavity walls, lofts, solid walls),
- More efficient appliances and lighting to reduce electricity demand[14],
- Lifestyle and behavioural measures.

Disaggregating this analysis for Scotland, using the methods described below, suggests that there may be scope for direct (i.e. non-electricity) emissions reductions of up to 1.1 $MtCO_2$ in 2020.

Improved insulation

In order to estimate the savings available in Scotland in 2020, we have used analysis of take-up of energy efficiency measures from the UK's domestic MACC and applied these to the Scottish Government's residential energy efficiency model, DEMScot.[15] This approach assumes that the rate of take-up in Scotland follows a similar trajectory to that of the UK in 2020 whilst allowing for the particular characteristics of the housing stock in Scotland.

Under this approach, the estimated technical potential available for application of certain measures differs significantly between Scotland and the UK as a whole. In particular, the share of the current

[14] Measures relating to electricity demand will not affect emissions in the non-traded sector, since electricity generation is covered by the EU ETS. However, pursuing these measures is still important to ensure overall targets can be met and to contain the costs of doing so. There is also an important role for all energy efficiency measures in combating fuel poverty.

[15] For more information on the DEMScot tool see *Modelling greenhouse gas emissions from Scottish housing: final report*, available at: http://www.scotland.gov.uk/Publications/2009/10/08143041/0

stock that can realistically/practicably be insulated (both loft and cavity insulation) is lower in Scotland:

- **Cavity walls**: DEMScot assumes that 49% of the housing stock currently has unfilled cavity walls but of that 49%, only 60% is judged to be realistically available for insulation. This is due to either homes having timber frames or houses being exposed to driving rain, which both make insulation impractical and prohibitively expensive. By contrast in the UK, 40% of homes are estimated to have unfilled cavity walls and we assume that up to 90% of these can practically be filled.
- **Lofts**: The scope for loft insulation is lower in Scotland, with only 44% of Scottish households having lofts without insulation of a suitable depth to be filled or topped-up under our scenarios, compared to 66% for the UK as a whole. This is due in part to the high proportion of flats and tenements in the Scottish housing stock (40% v. 17% in England).

We have used the DEMScot scenario outputs to estimate the energy savings in our Extended and Stretch Ambition scenarios, in addition to the reference emissions projection for the residential sector. The DEMScot results were adjusted in two ways:

1. In our MACC analysis for the UK, we assumed that 15% of the savings are not realised due to householders choosing to increase 'comfort-taking' due to improved efficiency and therefore cheaper energy. The DEMScot model does not make any account of the rebound effect so we have adjusted savings identified in DEMScot by the same proportion as for the UK MACC. This is a simplified approach and further analysis of the rebound effect in Scotland and how DEMScot might account for this would improve the estimates.
2. We have also made a downward adjustment to DEMScot savings associated with coal demand to account for the reference case (as produced by STEPS, see above) containing substantially more savings from current policies than predicted by DEMScot baseline scenario.

Total savings from improved insulation measures are estimated to be 0.5 $MtCO_2$ in the Extended Ambition scenario and 0.7$MtCO_2$ in Stretch.

Lifestyle and behavioural measures

Consumer behaviour is modelled by DEMScot in a different way to the UK residential MACC model. DEMScot groups households in different user categories – high, medium and low energy users – and assigns a proportion of the population to each category. Each category has a range of behaviours associated with it, such as level of thermostat temperature, energy used in lighting and cooking. In the baseline DEMScot assumes that 30% of households are 'low' energy users, 40% are 'medium' and 30% are 'high'. By contrast in the UK MACC abatement scenario analysis, households are not allocated to consumption groups, instead we directly assume that a proportion (54%) adopt specific measures such as reducing the thermostat and using a cooler washing cycle.

The potential for households to adopt lower energy demand behaviours is uncertain, and there is no direct read-across from the UK MACC measures to the levels of energy use modelled in DEMScot. For the Scottish targets analysis, we have assumed that a proportion of mid and high energy users

might move down a category so that 40% are low users, 40% medium and 20% high in the emissions reduction scenario. Although this implies a smaller number of households making changes (20% rather than 54%) this results in a significant saving of 0.33 $MtCO_2$ in 2020 in the Extended Ambition scenario. Achieving these savings will be reliant on policies being put in place to encourage them and on consumers responding to these signals.

More efficient appliances and lighting to reduce electricity demand

We have not modelled the impact of electrical appliances on energy demand in Scotland as this measure will only affect demand for electricity and therefore not contribute to meeting the emissions reduction target directly, since emissions from electricity generation will be covered within the EU ETS cap. Just as at the UK level, it will still be important for Scotland to pursue cost effective measures to improve efficiency to minimise the cost of meeting emissions targets and to address fuel poverty in the context of increasing electricity prices as the power sector moves towards low-carbon generation sources.

Savings associated with improved efficiency of electrical appliances in the UK as a whole are estimated to save up to 6 $MtCO_2$ of indirect emissions in 2020. As an indication, estimates from the Market Transformation Programme show that savings in Scotland could be up to 800GWh (around 6%) in 2020.

Savings from new-build homes

The baseline emissions projection allows for growth in the housing stock in Scotland as UK energy demand is disaggregated by the share of UK households in Scotland, taking into account expected future growth. Savings associated with improvements in the energy efficiency of new homes is not factored into the baseline emissions projections.

For the UK, we have not done our own analysis on the potential to reduce emissions from new homes, instead we have assumed that direct savings estimated by government for the Zero Carbon Homes policy will be realised in the Extended and Stretch Ambition scenarios, of up to 0.4$MtCO_2$ in 2020. We follow the same approach for Scotland, and use the Scottish Buildings Standards Agency[16] estimates for the impact of improved energy efficiency of new homes resulting from changes to Scottish building standards as recommended by the Sullivan Report[17], which suggests that the savings could be between 0.01 $MtCO_2$ and 0.04 $MtCO_2$ in 2020 to achieve between 25% and 60% carbon emissions reduction from new homes. We have adopted this range as the savings under the Extended and Stretch Ambition scenarios.

[16] Full report available at: http://www.sbsa.gov.uk/research/summ_dom_energ_2010.htm. Table 23 shows national CO_2 savings from emissions reduction scenarios .

[17] http://www.sbsa.gov.uk/sullivanreport.htm

Table 3.1: Extended and Stretch Ambition emissions reductions in 2020, residential sector, Scotland ($MtCO_2$)

	Extended Ambition	Stretch Ambition
Energy Efficiency	0.54	0.74
Behaviour change	0.33	0.31
Building standards	0.01	0.04
TOTAL	**0.88**	**1.11**

The savings estimated using DEMScot for energy efficiency and behaviour change produce larger emissions reductions than a pro-rata share of UK savings (i.e. around 12% of UK savings, which is greater than Scotland's share of UK households of around 9%), even though the characteristics of the Scottish housing stock are more challenging in some ways (e.g. fewer cavity walls and lofts suitable for cost-effective insulation). This in part reflects differences in modelling approaches between DEMScot and the CCC's Residential MACC, e.g. on modelling behaviour change, and also the different carbon intensities of fuel use (e.g. Scotland has more households off the main gas grid).

3.2 NON-RESIDENTIAL BUILDINGS AND INDUSTRY

In our December 2008 report our analysis suggested that there is feasible potential for direct emissions reduction through energy efficiency improvement in UK non-residential buildings (including public buildings) and industry of up to 7 $MtCO_2$ in 2020, through:

- Improving the efficiency of heating and cooling buildings,
- Better management of energy (from motion sensitive lights to optimising heating temperatures and timing),
- Use of more efficient lights and appliances,
- Improving the efficiency of electrical machinery,
- Improving the efficiency of heat generation, insulation and heat recovery.

Scotland's share of the emissions reduction potential in non-residential buildings was established by disaggregating the UK savings (calculated using the non-residential MACC) by energy demand in Scotland by fuel; different shares are used depending on which fuel the measure relates to. This approach does not account for how the distribution of energy demand might change over time. Future work by the Committee relating to the Carbon Reduction Commitment, to be published later in 2010, may provide improved analysis of abatement potential in non-residential buildings. Under the current method, direct emissions reductions in Scotland are estimated to be 0.6 $MtCO_2$ in 2020 under both the Extended and Stretch Ambition scenarios.

In coming to a view on the level of UK industrial abatement potential, the CCC used DECC's ENUSIM model, which AEA updated for the CCC requirements. The model considers in excess of 1000 measures for reducing emissions from industrial energy use in broad industrial sectors and generates an industry-wide MACC[18].

Disaggregating the savings in industry and commercial sectors in the Enusim model has been done using GVA shares using the latest regional GVA data, which assumes that the potential for abatement is related to the relative size of each sector in Scotland. This does not take into account differences in the current efficiency of plant or the number and size of plant in Scotland (e.g. measures may be more cost-effective when applied to one large plant rather than several small plant).

Table 3.2: Direct emissions reduction potentials in non-residential buildings and industry[19] in 2020 ($MtCO_2$) – UK and Scotland, Extended Ambition scenario

	Scotland	UK
Commerce	0.44	3.7
Public sector	0.16	1.4
Industry	0.17	2.2
TOTAL	**0.77**	**7.25**

3.3 RENEWABLE HEAT

In our October 2009 progress report to the UK government, we identified up to 13 $MtCO_2$ of direct emissions reductions in 2020 from the deployment of renewable heat technologies (e.g. biogas, biomass boilers, and biomass CHP) across residential and non-residential buildings, and industry. The savings in our Extended and Stretch Ambition scenarios are consistent with the Scottish renewable heat target of 11% by 2020.

The estimate of emissions reduction from renewable heat in the UK is based upon modelling by NERA[20]. We have not undertaken a bottom-up analysis of the potential for emissions reduction from

[18] For more detail on CCC's use of the Enusim model, please refer to supporting research for Chapter 6. Available at: www.theccc.org.uk/reports/supporting-research/

[19] The results include emissions savings associated with combined heat and power (CHP) installations in industrial sectors. The emissions savings associated with CHP have been allocated on the same basis as for other industrial measures because CHP has been allocated to individual sectors. CHP tends to increase direct emissions yet it reduces demand for electricity; on a net basis, the impact is a reduction in emissions. In the absence of CHP, direct emissions savings from industry would be greater.

[20] Full report available at: http://www.theccc.org.uk/reports/progress-reports/supporting-research-

renewable heat in Scotland but we have estimated Scotland's share based on analysis published under the Renewable Heat Action Plan[21], which suggests that Scotland's target for renewable heat of 11% by 2020 (6.4 TWh of renewable heat used by 2020 or 2 GW installed capacity) represents 9% of the UK renewable heat target in 2020 (72 TWh of renewable heat). We have therefore assumed that 9% of the UK direct emissions reduction occurs in Scotland – just over 1.2 $MtCO_2$ in 2020.

Emissions savings from renewable heat will be determined by the amount of non-renewable heat supply that is displaced and the emissions intensity of that supply. We have not undertaken our own bottom-up analysis of these factors at a Scottish level, but they may well be offsetting:

- There may be less potential to roll-out renewable heat in Scotland. For example the Sustainable Development Commission[22] estimated that Scotland could reach 9.7% of heat consumption being supplied by renewable sources by 2020 (i.e. less than the UK's 12% target).
- A greater proportion of off-grid homes in Scotland could suggest that the homes that are moved to renewable heat could currently have a higher average emissions-intensity of their heat supply than the UK as a whole, which would imply a greater emissions reduction.

No emissions saving is currently estimated for delivering the Scottish 11% target, and further analysis, including the sources of heat that would be displaced, would be needed to determine if it would be enough to deliver the savings we have assumed in our Extended Ambition scenario.

3.4 TRANSPORT

The CCC Extended Ambition scenario comprises a range of measures to achieve an emissions reduction from surface transport of 23 $MtCO_2$ in the UK in 2020. In the Stretch Ambition scenario, emissions reduction increases to 33 $MtCO_2$.

Emissions reduction opportunities are dominated by the scope for improving fuel efficiency of cars (both due to technology innovation and changing car purchase behaviour), but there are also opportunities for improving fuel efficiency of vans and HGVs based on conventional technologies. There is additional abatement potential from more far-reaching measures including widespread introduction of electric and plug-in hybrid technologies to vans. On the demand side, there is significant emissions reduction potential from a range of measures including Smarter Choices measures, eco-driving (e.g. smoother acceleration and braking), and effective enforcement of the speed limit. In the Stretch Ambition scenario, we include emissions reduction from the introduction of national road pricing and lowering the speed limit on motorways to 60mph.

For assessing emissions reduction opportunities in the road transport sector, the CCC developed a model in conjunction with a consortium of consultancies including AEA, Ricardo, Metronomica,

[21] *Renewable Heat Action Plan for Scotland* – available at: http://www.scotland.gov.uk/Publications/2009/11/04154534/0

[22] Report available at: http://www.sd-commission.org.uk/news.php/288/scotland/developing-scotlands-renewable-heat-potential

E4Tech, IEEP and CE Delft[23]. The model produces MACCs relating emissions reductions and associated costs for a range of technology options, and for cars, vans and HGVs.

The emissions reduction that each measure would achieve in Scotland has been estimated as a share of the total emissions reduction in Great Britain based on the proportion of vehicle kilometres travelled in Scotland for the relevant modes. This effectively assumes that the average emissions-intensity of vehicle kilometres falls by the same amount in Scotland as the UK average.

Using current vehicle kilometres as the disaggregating factor reflects only current demand for road transport and not how demand may change over time. It also does not consider how the fleet of vehicles differs between Scotland and the UK and whether the stock changes at a different rate (i.e. if new cars were bought to replace larger, less fuel-efficient cars at a faster rate in Scotland then emissions would fall faster). Initial investigation of these factors suggests that there is not a significant difference between the Scottish vehicle fleet and the UK average, however, these are areas that could be explored in greater detail to improve the approach.

The abatement scenarios include a significant increase in the number of electric and plug-in hybrid cars – up to 1.7million in the UK by 2020. There are measures which the Scottish Government could adopt that might influence the level of penetration in Scotland, in particular by supporting pilot projects, investing in public charging infrastructure (e.g. at strategic points on major routes such as between Glasgow and Edinburgh) and implementing network measures which incentivise the use of low-carbon vehicles (e.g. preferential parking charges or use of bus lanes).

Speed limiting

The UK estimate of emissions reductions as a result of stricter enforcement of the national speed limit is based on share of GB driving which takes place on Scottish motorways, which is lower than the share of total vehicle kilometres driven in Scotland. This reflects the fact that there are fewer motorways in Scotland and more driving is done on roads with lower speed limits. There may be other factors that will influence the impact of speed limiting, such as the level of speeding over and above the limit and the proportion of vehicles that break the speed limit, if these are significantly different in Scotland to the UK average then the emissions savings could be different from our estimate.

Road pricing

Our estimates of road pricing are from modelling work produced by the Department for Transport's National Transport Model. The results are available on a regional basis and the estimate for Scotland is up to 0.3 $MtCO_2$ in 2020. This measure is only included in the Stretch Ambition scenario.

[23] For more information, please refer to supporting research and technical appendices for Chapter 7 of *Building a low-carbon economy – the UK's contribution to tackling climate change*. Available on the CCC's website.

Smarter Choices and Eco-driving

We identified in our October 2009 report that there is likely to be significant emissions reduction potential from demand-side measures aimed, for example, at changing driving behaviours, encouraging modal shift towards public transport and improving journey-planning.

In order to estimate the impact of these measures in Scotland, we have again assumed that savings will be distributed according to transport demand (as measured by vehicle kilometres).

The Scottish Government are pursuing a range of projects which reflect the Smarter Choices approach, under *Smarter Choices, Smarter Places*, which are designed to increase active travel and public transport use and tackle transport emissions. The projects being funded under this programme will involve: better public transport services and residential improvements; upgrades in walking and cycling infrastructures; studies into travel patterns and access; intensive marketing and awareness campaigns; and workshops and information packs. Communities involved range from between approximately 10,000 in Kirkwall to 37,000 in Dumfries. These activities may result in a different range of emissions reductions than those identified in our analysis. Information gathered from the monitoring and evaluation of these projects will enhance the evidence base supporting emissions reduction in transport demand, particularly given their application in smaller communities than those of Smarter Choices in England.

Table 3.3: Abatement potential from transport measures in 2020 ($MtCO_2$) –Scotland, Extended and Stretch Ambition scenarios

	Extended Ambition	Stretch Ambition
Biofuels	0.40	0.40
Car technology	0.83	0.83
Van technology	0.13	0.23
HGV technology	0.07	0.07
Rail efficiency measures	0.03	0.04
Demand - Smarter Choices	0.24	0.24
Demand – Eco-driving cars	0.02	0.08
Demand – Eco-driving vans and HGVs	0.09	0.11
Road pricing	-	0.33
Speed limiting (at 70 mph in Extended, 60 mph in Stretch)	0.02	0.04
TOTAL	**1.83**	**2.36**

Rail

The CCC's estimates of emissions reductions from rail are based upon evidence submitted by the Rail Carbon Trajectory Working Group.[24] This suggests that there is the potential to reduce emissions by 10-14% through a combination of efficiency and network management measures. This includes a reduction of diesel train passenger emissions by 9-13% and freight emissions by 17-21%. These reductions have been applied to Scotland's emissions projections for rail in 2020 and suggest that there is up to 40ktCO_2 of abatement potential from rail. Converting existing track from diesel to electric is not included in this analysis but it should be noted that there are plans to electrify track in various parts of the Scottish rail network, which could result in a reduction in direct emissions from rail.

3.5 NON-ENERGY SECTORS

In our advice to the UK government in December 2008, we recognised that there may be significant scope for emissions reduction from the non-energy sectors of agriculture, land use and waste management. However, we did not include any abatement potential in our Extended Ambition scenario given uncertainties over the precise order of magnitude of potential and the absence at the time of a policy framework. We proposed that these measures should be investigated further with a view to pursuing them as part of prudent budget management.

The policy framework has moved forward since our December 2008 report:

- In 2009, the UK government included emissions reductions from waste management and agriculture in its scenarios set out in the Low Carbon Transition Plan and committed to introduce a policy framework to unlock emissions reduction potential. We therefore included these savings, which relate to England only, in the UK Extended Ambition scenario presented in our progress report of October 2009.
- The Scottish Government in partnership with Forestry Commission Scotland have committed to a target to increase forest cover to 25% of Scottish land area.

In constructing the Extended Ambition scenario for Scotland we have therefore included savings from waste and agriculture in line with the commitments made at the UK level and savings from forestry in line with the Scottish commitment. Our previous analysis suggested that there were likely to be still greater emissions reductions available, and so we include the option to increase effort in agriculture, waste and forestry in our Stretch Ambition scenario.

The Scottish Government has a range of powers to influence emissions in these policy areas and there are already commitments for action in place.

[24] Available at: http://www.theccc.org.uk/pdfs/080521%20CCC%20rail%20submission.pdf

Agriculture

In our analysis for the December 2008 report we commissioned the Scottish Agricultural College (SAC) to construct a MACC for agriculture, land use, land use change and forestry (ALULUCF) [25]. The MACC provides an assessment of potential emissions reduction and associated costs across a wide range of options for the sector. Based on this MACC we suggested that for the UK there was up to 11 $MtCO_2e$ of cost-effective abatement potential feasibly available from agriculture in a high feasible scenario, or 6 $MtCO_2e$ in a central feasible scenario.

In our report we noted that this work was among the first MACCs developed for the agriculture sector and suggested that as such the results should be considered as tentative. We also noted the various sensitivities and multiple policy objectives relating to the sector, but suggested that government should still aim for a significant contribution from the sector towards emissions reduction.

The UK government subsequently included an ambition to deliver 3 $MtCO_2e$ of emissions reduction from agriculture in their Low Carbon Transition Plan, following a review of the CCC MACC[26], discussions with industry groups and consideration of the available policy instruments. Given the balance of reserved and devolved powers, this figure relates only to England. The Committee have not yet assessed the commitment proposed by the UK government (this will form part of our work programme going forward for our second progress report in June 2010), but included the proposed 3 $MtCO_2e$ saving in our Extended Ambition in the October 2009 progress report.

In setting the scenarios for the Scottish advice we have assumed that an Extended Ambition for agriculture would deliver savings proportionate to those proposed for England[27]. This is still less than the central feasible potential identified by our previous analysis, and for the Stretch Ambition we have uprated the Extended Ambition saving in line with the increase in abatement potential in moving from the central feasible to the high feasible potential that we previously identified. Our analysis relating to agriculture for the June 2010 progress report is likely to suggest new assumptions in this area as we better characterise the uncertainties around available abatement potential.

[25] Scottish Agricultural College (2008) *UK Marginal Abatement Cost Curves for the Agriculture and Land Use, Land-Use Change and Forestry Sectors out to 2022, with Qualitative Analysis of Options to 2050.* Available on the CCC's website: www.theccc.org.uk/reports/supportingresearch

[26] Defra (2009), *RMP/5142 Analysis of Policy Instruments for Reducing Greenhouse Gas Emissions from Agriculture, Forestry and Land Management*

[27] Particular concerns have been raised as regards the applicability in Scotland of the specific measure to improve drainage. However, similar concerns have been raised at the UK level – we therefore do not further adjust the disaggregated abatement potential on these grounds. Our further work in 2010 should help establish more robust estimates of abatement potential, both for the UK and for Scotland.

CCC's MACC model disaggregates abatement potential in livestock and crops and soils activities based on the number and type of livestock and the area of land under various uses[28]. As agriculture is a larger proportion of economic activity (and emissions) in Scotland relative to the UK as a whole, the share of abatement potential identified (15%) is relatively greater than is proportionate to Scotland's population share (8.4%). The abatement potential identified is 0.7 $MtCO_2e$ in the Extended Ambition, rising to 1.3 $MtCO_2e$ in the Stretch Ambition.

Forestry and land use

For the forestry sector, in our December 2008 report we identified savings potential of up to 2 $MtCO_2$ (or around 1 $MtCO_2$ in a central feasible scenario) in 2020 from increased forest cover for the UK, and we also noted the role for forestry in providing an increased biomass supply. These savings are based on the 'Mid' and 'Low' emissions scenarios produced by CEH[29] in their forestry emissions projections[30], which are also available at a national level.

The Scottish Government/Forestry Commission Scotland commitment to increase forest cover to 25% of Scottish land area will require additional planting levels of up to 15 kha/yr. This is in line with levels assumed in the CEH 'Low' emissions scenario, which requires a planting rate of 14.6 kha/yr. However, the emissions saving will depend not just on the level of planting but on the type of trees planted and their management regime. We have therefore used the CEH 'Low' scenario as the Stretch Ambition scenario, and our previous central feasible estimate as the Extended Ambition scenario. Further analysis, allowing more formally for tree types and management regime, would be required to establish whether the Scottish commitment would deliver the emissions savings in our scenarios.

Recent analysis published by the Forestry Commission, *Combating Climate Change – a role for UK forests,*[31] has produced analysis of afforestation and forestry management scenarios for the UK, with results available for Scotland. We have not drawn on the detail of this work in our analysis, but it may be useful in refining the estimate of emissions reduction from forestry in Scotland.

We have not included further emissions reduction potential from land use other than forestry, but we note that any potential from restoration of peatland is likely to be concentrated in Scotland. There remain considerable scientific and analytical uncertainties over the potential in this area and over soil carbon sequestration more generally. Further work would be required to establish if this is an area where Scotland can reduce its emissions. It will be important that any further work does not double-count emissions savings already assumed in the inventory projections. Equally, processes that lead to degradation and significant release of stored carbon must be avoided.

[28] The SAC study does not provide a methodology for disaggregating abatement potential relating to anaerobic digestion technologies in these sectors because there are not enough data available to apportion the savings by farm type/size in each nation. For the Scottish targets advice, we have disaggregated these savings based on the share of relevant livestock numbers in Scotland. However, this method may not accurately reflect the opportunities for anaerobic digestion in Scotland and further research would be required to establish more accurate savings.

[29] The latest projections are available at: http://www.edinburgh.ceh.ac.uk/ukcarbon/reports.htm

[30] In calculating savings we apply a lag to the difference, since accelerated planting cannot begin in the past (e.g. 2010 abatement is based on figures for the first year of accelerated planting – 2008)

[31] Available at: http://www.forestry.gov.uk/forestry/infd-7y4gn9

Table 3.4: Abatement potential in Scottish agriculture, land use, land use change and forestry in 2020 ($MtCO_2e$)

	Extended Ambition	Stretch Ambition
Agriculture – crops and soils	0.50	0.99
Agriculture – livestock	0.10	0.19
Agriculture – anaerobic digestion	0.06	0.13
Forestry	0.38	0.76
TOTAL	**1.04**	**2.06**

Waste

The CCC commissioned Eunomia to construct a MACC for the Waste sector, which identified technical abatement potential of up to 6 $MtCO_2e$ as a result of directing waste away from landfill to energy-producing processes[32]. This abatement potential included savings directly from the waste sector (primarily avoided methane emissions from landfill), and savings relating to the generation of renewable energy (e.g. from anaerobic digestion of the waste stream replacing fossil fuel energy generation). The MACC calculates the level of abatement from individual measures relative to each devolved nation's baseline waste emissions, which are calculated using statistics published by each national authority on its waste profile, recycling rates, etc. Eunomia's report sets out the approach to formulating each nation's baseline and recognises that some of the information used is not up-to-date and that since new policies and strategies are being/have recently been formulated in Wales and Scotland, the baseline in these nations may not accurately reflect what constitutes 'firm and funded' policies.

The UK government's Low Carbon Transition Plan targeted around 1$MtCO_2e$ savings from waste emissions in 2020. The estimate is approximately 20% of the CCC's central feasible scenario and includes only those savings directly attributable to the waste sector in England. We included this amount in the UK Extended Ambition for our October 2009 progress report.

As for agriculture, for the Extended Ambition scenario for Scotland, we have included emissions reduction potential in line with the UK Government's proposals for England. We have calculated this as the same share (20%) of the central feasible scenario identified in the MACC for Scotland – 0.09 $MtCO_2e$. Again, for the Stretch Ambition scenario we increase this estimate to reflect our high feasible estimate (i.e. 20% of the abatement available in the high feasible scenario) – 0.10 $MtCO_2e$.

There is a strong existing policy framework in place for waste emissions, and Scotland has adopted a goal of zero waste, with a number of relevant domestic targets (e.g. 70% recycling of municipal waste and no more than 5% of municipal waste being landfilled by 2025). Scotland's Zero Waste Plan

[32] Eunomia (2008) *Developing marginal abatement cost curves for the waste sector*. Available on the CCC's website: www.theccc.org.uk/reports/supportingresearch

will be launched later this year. Further analysis would be required to establish whether these targets would be enough to deliver the abatement potential identified in our scenarios, and whether further abatement could be achieved.

Table 3.5: Abatement potential in the waste sector in Scotland, 2020 ($ktCO_2e$)

	Extended Ambition	Stretch Ambition
Waste	94	105

3.6 LIMITATIONS AND FURTHER DEVELOPMENT

As the approach is generally based on disaggregating UK-wide modelling results, the estimated abatement potential identified in Scotland does not capture the full range of factors that influence the scope for cost-effective abatement potential. More detailed study of abatement potential in Scotland could refine the assessment as to the achievability of emissions targets.

The measures chosen for the Extended Ambition in the Committee's UK advice were selected on the basis of three factors: their importance on the path to an 80% 2050 target, their marginal abatement costs, and practical constraints on delivery. It is likely that the marginal abatement costs for specific measures will differ for Scotland as compared to the UK. Whilst this is unlikely to affect the general balance of effort suitable for Scotland it will be important to recognise it in setting the precise mix of policies. Further work to assess the costs of delivering emissions reductions at the margin in Scotland could help to inform the appropriate mix of effort to aim for across the economy.

Moreover, constraints determining the realistic potential may differ in Scotland. The CCC's evidence base used to determine realistic potential in transport and energy end use sectors relies on social research findings for England and it is conceivable that environmental attitudes and barriers to behaviour change differ between areas of the UK. If, for example, there were judged to be greater barriers the implication would be that achieving the level of ambition outlined in the CCC advice would require a stronger policy effort in Scotland than achieving the equivalent ambition at the UK level. Future research being undertaken by the Scottish Government (i.e. the Scottish Environmental Attitudes and Behaviours Survey) should provide a more reliable source of evidence on which to draw on in the future.

4. ANNUAL EMISSIONS TARGETS

In "Scotland's path to a low-carbon economy" we proposed that, reflecting the lead times to policy development and emissions response, annual targets should be set based on business-as-usual emissions projections to 2012, and then a straight-line trajectory through 2020 that achieves the 2020 target. This is the approach we use to define emissions targets for the non-traded sector, which are then added to the traded sector trajectories set out in section 1, above, and to our business-as-usual projections for international aviation and shipping emissions (with international aviation defined on a net basis, following the aviation path of the EU ETS).

The sum of these components narrowly breaches the minimum reductions set out in the Scottish Climate Change Act in 2012 and 2021. We therefore apply small adjustments to ensure that the economy-wide emissions targets fall from 2011 to 2012, and fall at least 3% after 2019. These changes are well within the margins of error in the non-traded sector emissions projections.

Table 4.1: Components of annual emissions targets ($ktCO_2e$)

	Traded sector (incl. domestic aviation)	International aviation and shipping	Non-traded sector	TOTAL	Adjustment to fit rules of CC (S) Act	Annual Emissions Targets
2007 outturn	23,938	2,359	30,609	**56,906**		
2008 projection	23,613	2,156	30,902	**56,671**		
2009 projection	23,645	2,005	30,326	**55,976**		
2010	23,659	2,006	30,248	**55,913**	0	**55,913**
2011	23,672	2,077	30,146	**55,896**	0	**55,896**
2012	23,656	1,939	30,342	**55,937**	-42	**55,895**
2013	18,653	1,969	29,679	**50,301**	0	**50,301**
2014	17,900	1,987	29,016	**48,903**	0	**48,903**
2015	17,146	1,995	28,354	**47,495**	0	**47,495**
2016	16,390	2,036	27,691	**46,117**	0	**46,117**
2017	15,633	2,086	27,028	**44,747**	0	**44,747**
2018	14,873	2,145	26,365	**43,384**	0	**43,384**
2019	14,113	2,196	25,703	**42,012**	0	**42,012**
2020	13,351	2,217	25,040	**40,607**	0	**40,607**
2021	12,982	2,232	24,377	**39,592**	-204	**39,388**
2022	12,212	2,290	23,714	**38,216**	-10	**38,206**

The breakdown in table 4.1 partly demonstrates why the trajectory we have proposed is broadly flat in the period to 2012, rather than continuing the reductions in emissions observed since 1990:

- Going forward, traded sector emissions follow the EU ETS cap, and as such are flat from 2008-2012 – any reductions in Scottish emissions in this period will be offset by sales of emissions permits so that the Scottish net carbon account remains constant. This contrasts to the historic period, which saw falling Scottish industrial activity lead to a reduction in traded sector emissions of 3 $MtCO_2$ (11%) from 1990 to 2007.

- International aviation and shipping emissions are on an upward trajectory, which will be contained somewhat in 2012 and 2013 as international aviation enters the EU ETS. The overall impact on emissions trends is limited, given the size of the sectors.

- Although non-traded sector emissions fell 10.5 $MtCO_2e$ (26%) from 1990 to 2007, they are not expected to fall going forward. This reflects the combination of the trends and projections in the different sub-sectors that make up the non-traded sector, and specifically increasing land use emissions offsetting decreasing residential and transport emissions:

    - The significant increase (2 $MtCO_2e$) in removals from land use since 1990 reverses into the projection period to give a 1 $MtCO_2e$ net emissions increase from 2009 to 2012. This is due to a reduction in planting rates since the 1990s.

    - The significant fall in non-CO_2 emissions (7 $MtCO_2e$) since 1990 has slowed since 2003, with a projection that emissions will be broadly flat going forward. This reflects that historical progress has been the result of changes that cannot or are not expected to continue – livestock numbers were reduced under previous phases of the Common Agricultural Policy, coal mines have closed, fugitive emissions from the energy sector have been reduced to low levels, the amount of waste sent to landfill has already been reduced considerably.

    - The rest of the historic reduction (1.5 $MtCO_2e$ from 1990 to 2007) is from CO_2 excluding land use (i.e. emissions from residential buildings, industry and commerce, and transport). Emissions from these sectors are projected to fall more rapidly than historically (1 $MtCO_2e$ from 2009 to 2012) during the projection period due to the impacts of policies (e.g. the Carbon Emissions Reduction Target, the Renewables Transport Fuel Obligation) included in the reference projections.

It is possible that emissions could fall more than anticipated in the reference projections:

- The impact of the recession could be greater than we have assumed, either because the recession is deeper than envisaged in Budget 2009 (which is now expected) or because the impact on emissions is greater than assumed in the DECC model. This could imply some outperformance in early target years, and should not be mistaken for policy success.

- Additional policy initiatives over and above those assumed in the projections could reduce emissions further. Where there are specific examples of such policies that will be in place in time to influence emissions to 2012 then the Scottish Government could aim to outperform the targets in the near-term.

Within the trajectories above we can separately identify the emissions from aviation and shipping, as estimated on the bases recommended in chapter 2 of "Scotland's path to a low-carbon economy":

Table 4.2: Emissions from aviation and shipping – 2006-2012 ($ktCO_2e$)

	Domestic Aviation		International Aviation		Domestic Shipping		International Shipping	
	CO_2	Non-CO_2	CO_2	Non-CO_2	CO_2	Non-CO_2	CO_2	Non-CO_2
2006 outturn	650	8	1,132	11	1,017	8	1,185	10
2007 outturn	614	9	1,138	11	923	7	1,212	10
2008	588	9	1,089	11	861	7	1,059	9
2009	620	9	1,148	12	774	7	850	7
2010	633	9	1,173	12	764	7	827	7
2011	647	9	1,199	12	784	7	871	7
2012	631*	9	1,003*	12	809	7	928	8

Note: Non-CO_2 refers to emissions measured in the NAEI for methane and nitrous oxide, not for the non-Kyoto impacts discussed in chapter 2 of "Scotland's path to a low-carbon economy".

* Aviation CO_2 figures for 2012 are for net emissions under the EU ETS cap, other figures from 2008 are projections for gross emissions.

5. USE OF CREDITS

The Climate Change (Scotland) Act has a requirement that a minimum of 80% of effort comes from domestic emissions reduction effort. In "Scotland's path to a low-carbon economy" we interpret this to mean 80% of the effort against 1990 – that is purchase of offset credits outside the EU ETS in any target year should be limited to 20% of the emissions reduction from 1990 to that year. This is not a legal opinion however, and we note that other interpretations could apply, for example:

- 80% of emissions reduction effort from the last year without a target (2009),
- 80% of emissions reduction effort from the previous year's emissions.

These alternative interpretations would mean that a lower level of credit use was permissible than we have assumed. Specifically:

- We suggested that under a 20% EU target and with delivery of the Extended Ambition scenario, Scotland's economy-wide target of a 42% emissions reduction could be met by buying credits within the limits set out in the Act. In comparing to a benchmark of 2009, this would no longer be the case, although it would still apply under the Stretch Ambition scenario.
- A lower permissible level of credit purchase would also limit the option to use credits as a mechanism to hold non-traded sector effort constant in the face of a fixed economy-wide target and traded sector effort that will be defined by the changing EU framework.
- If credits are limited to 20% of the emissions reduction against the previous year, then effectively they are ruled out entirely in any practical sense. As well as having implications for the achievability of a given target this could undermine the credibility of annual emissions targets in the absence of other mechanisms to provide flexibility (see Box 5.2 of "Scotland's path to a low-carbon economy").