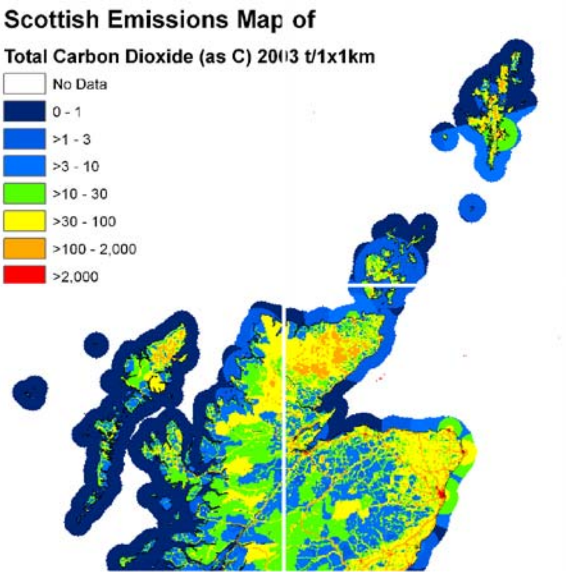

Mitigating Against Climate Change in Scotland: Identification and Initial Assessment of Policy Options

Report to the Scottish Government

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Issue V 1.0
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Date: October 2008

Executive summary

This is the final report under the Scottish Government contract CR/2007/53, *"Mitigating Against Climate Change in Scotland: Identification and Initial Assessment of Policy Options"*. This project has been undertaken for the Scottish Government's Rural and Environment Research and Analysis Directorate by AEA, with support from the Centre for Ecology and Hydrology (CEH).

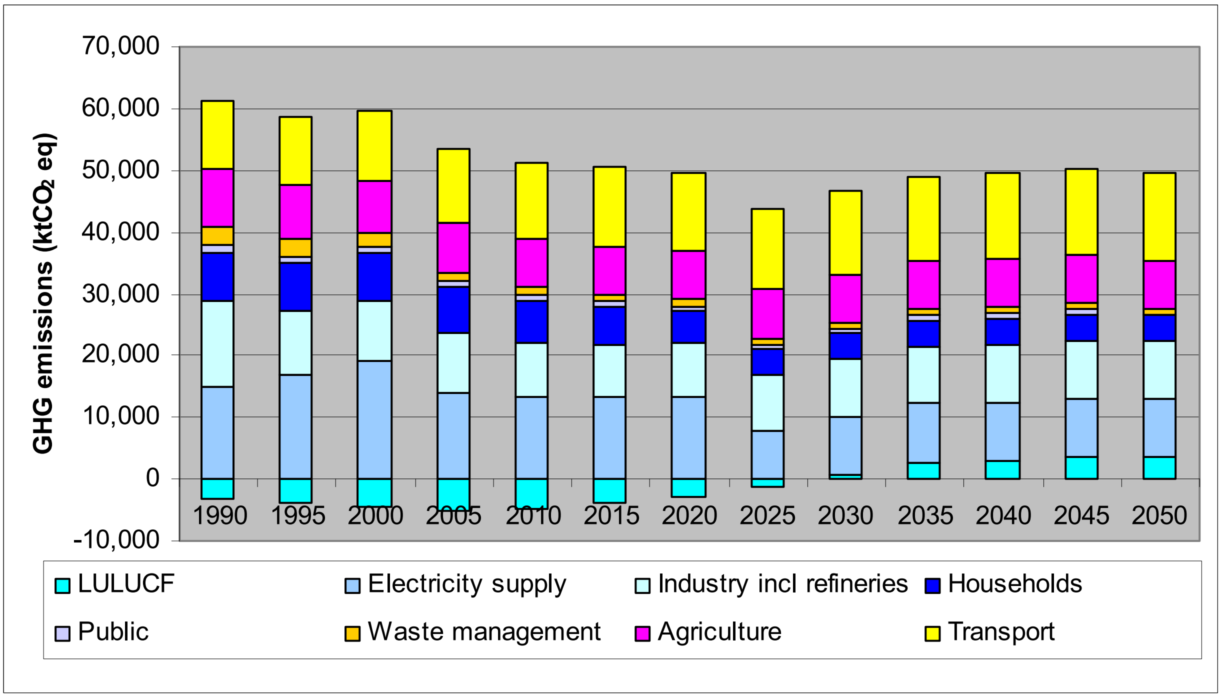
The Scottish Government has announced its intention for Scotland to take a leadership role in tackling Climate Change. The Government recently consulted on the details of the Scottish Climate Change Bill, which is likely to set a mandatory long-term target to achieve an 80% reduction in emissions by 2050 against 1990 levels. In the shorter term the Government has also committed to reducing emissions in the period to 2011. Both these targets were set out in the Scottish Government's Economic Strategy in November 2007.

This study provides key evidence on the policy options for delivering Scotland's climate change objectives, including the 80% target. The objectives of the study were:

- To generate a range of policy options aimed at achieving reductions in net greenhouse gas (GHG) emissions in Scotland;
- To conduct an initial assessment of the impacts of policy options in terms of costs and effects in Scotland;
- To conduct an initial assessment of the feasibility, affordability and likely public acceptability of each option in Scotland.

This study has addressed carbon dioxide (CO_2) emissions from electricity generation, business, public sector buildings, housing, transport and land use, land use change and forestry (LULUCF), methane (CH_4) emissions from waste and agriculture, and nitrous oxide (N_2O) emissions from agriculture. Together these sources represent nearly 90% of current Scottish GHG emissions. Emissions from sources not addressed by this study – mainly offshore emissions and emissions of hydrofluorocarbons – are expected to fall significantly over the period due to industry trends and the effects of policies in the baseline. However these other emissions sources may not fall by as much as 80% by 2050 – in which case the emissions considered by this study would need to fall by over 80%.

Historic and projected baseline GHG emissions from these sources in Scotland are shown overleaf. These baseline projections were developed for this study using information from the Scottish Greenhouse Gas Inventory (NAEI 2007), the Scottish Energy Study, BERR's projections in the 2007 Energy White Paper and other sources. These projections include the impact of a wide range of existing policy measures. They suggest an overall reduction in GHG emissions from these sources of about 13% from 1990 to 2050, largely driven by anticipated changes in electricity generation, changes in waste management practice and energy efficiency improvements in industry and households. Emissions from transport and net emissions from (LULUCF) are expected to rise over the period in the absence of further policies.



Baseline projections of GHG emissions in Scotland[1 2]

The study has identified and assessed a wide range of emissions reduction options for 2050 using information from literature review, consultation with key stakeholders and the authors' own expert knowledge. Many of the more familiar measures that are in place at present, do not feature in the list of options for 2050. This is because many of these measures are assumed to have already been fully implemented by 2050. Hence measures such as grants for cavity wall insulation in homes are not included. Furthermore, over the coming decades to 2050 there are likely to be significant technical developments that will offer additional potential for emission reduction. Hence there will be further policy measures associated with these new opportunities.

The policy options identified in this study have been assessed using a common framework and grouped into Very High, High, Medium, Low and Very Low priority according to their likely abatement potential and likely cost-effectiveness in 2050. This assessment also takes some account of uncertainty, likely public acceptability and other factors such as impacts on fuel poverty. Some of the policies with higher impacts in each group are shown in the table below, along with their estimated emissions abatement potential if implemented in isolation from other policies.

Priority Group	Policy Ref No	Some examples of higher impact policies in each group	GHG reduction in 2050 ($ktCO_2$ eq)
Very High	E1	Carbon capture and storage (CCS) for electricity generation	8,577
	T11	Package of measures based on improved vehicle technologies	1,017
High	B1	Grant Support – Biomass	925
	L1	Increase forest area	810
	W1	Ban biodegradable waste from landfills	583
Medium	D9	Biomass boilers in domestic homes	507
	PS3	Extending CEEF	214
Low	A7	Use of nitrification inhibitor with N fertilizers	391
	D10	Solar water heating for domestic use	299
Very Low	T14	Scotland-wide road pricing scheme, with incentive to encourage uptake of low emissions vehicles	886
	L17	Manage field margins to increase carbon storage	96

[1] This chart shows the 88% of Scottish GHG emissions that are the focus of this study
[2] All emissions data are in annual terms, in CO_2 equivalent designated as CO_2eq

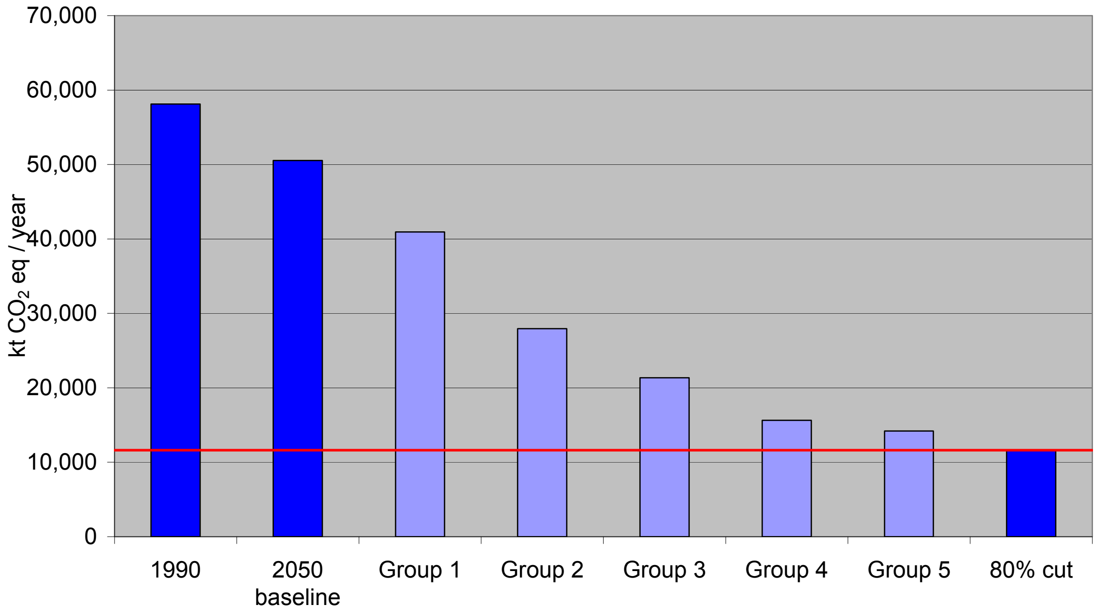
This process leads to definition of a set of scenarios for the assessment of abatement potential and costs:

- 2050 Business as usual / baseline / reference
- Adoption of 'Very High priority measures' (Group 1)
- Adoption of 'Very High' (Group 1) and 'High' priority measures (Group 2)
- Adoption of 'Very High', (Group1) through to 'Medium' priority measures (Group 3)
- Adoption of 'Very High', (Group1) through to 'Low' priority measures (Group 4)
- Adoption of 'Very High', (Group1) through to 'Very Low' priority measures (Group 5)

The policies allocated to each group are set out in Section 5. Having allotted policy options to these different groups, the emission savings can be summed, starting with Group 1, as these are generally the measures that make the most difference to total emissions and are the most cost-effective. Emission savings for each measure are recalculated as they are brought in to avoid double counting emission cuts already accounted for.

To reiterate, this is an initial assessment of possible options and the analysis that follows should be seen in this light. The costs are broad orders of magnitude, not precise estimates. All of these findings will need further work to assess feasibility and firm up the cost estimates.

As shown in the figure below, a very significant cut in emissions by 2050 from 1990 levels appears to be possible, if all the practicable measures identified are introduced and are effective. For the emissions sources considered in this study[3] these policy options have the potential to deliver by 2050 a reduction of over 75% on 1990 levels. Further reductions may be possible from the emergence of additional new technologies or from additional demand reduction measures.



Cumulative effect of measures in each group compared to 1990 emissions, the 2050 baseline and an 80% cut in 1990 emissions

The cost in 2050 of achieving an emissions reduction of 63% by implementing Group 1-3 measures is estimated to be about £1.7 billion[4] expressed in 2005 prices. This impact covers just the cost of implementing the identified measures and does not taken into account the wider economic and societal costs and the wider potential benefits. It is not possible to give a reliable estimate of the additional costs of measures to achieve a reduction of more than 63% as many of the measures in Groups 4 and 5 are very uncertain at this stage. These costs need to be set against the benefits of reducing not just GHG emissions, but also emissions of other air pollutants such as fine particles, SO_2 and NO_x that will also fall as a result of decarbonisation. Research for the European Commission has demonstrated that these co-benefits of climate policy can be very significant.

[3] This study considers a basket of GHG emissions that are 88% of total current Scottish GHG emissions, see Section 3.4
[4] Costs in the years up to 2050 will vary and are not covered in this report

Emissions savings and costs are subject to increasing uncertainty over time, particularly for emerging technologies. It is expected that costs will reduce as new technologies become more available and mass-produced, and this has been factored in where the information is available. The assessment does not include costs to develop and demonstrate the new technologies that underlie some of the policy options – these are difficult to assess and in any case these will not all be borne in Scotland. We have not taken account of all costs that may be significant, for example those associated with electricity grid upgrades linked to a widespread expansion of renewable electricity generation and with plant decommissioning. These are complex matters that are linked to the combination of generation and demand in a specific grid zone. In addition these costs are not included in BERR's assessments that accompanied the Energy White Paper. Hence the assessment does not account for all of the potential costs.

It has not been possible to fully account for inter-linkages, interactions and trade-offs between sectors, e.g. decarbonised electricity and the implications for choice of measures in end use sectors. Further analysis would be needed to address these issues, perhaps using an energy model such as the IEA's MARKAL model.

The result provides details of one way in which Scotland could achieve a very significant GHG reduction by 2050. This is not the only way by which this could be achieved, but the result serves to illustrate that a wide range of measures will be required and that the cost will progressively rise as more measures are put in place. Alternative ways by which a significant GHG reduction could be met, may feature different technologies and hence different policy measures, or may feature different views of feasibility or public acceptability.

This study has given a flavour of the sort of major emissions reductions that could be possible and the policies that might play a part in achieving them. Further work will be needed to develop and implement policies in each sector, to understand the likely implications of different choices at different times and to explore interactions between different sectors. Priorities for research are likely to include:

- Technical research to reduce the uncertainties associated with promising emissions reduction options and mapping out when and how they might best be introduced. Research topics might include:
    - Further assessment of the potential for Carbon Capture & Storage, including power stations and major industrial installations in collaborative schemes, e.g. sharing storage and pipeline facilities.
    - Assessment of the prospects for new vehicle technologies including plug-in hybrids and battery-electric vehicles, including their suitability for Scotland's rural population.
    - Assessment of the future demand for biomass (for housing, business, public sector and transport), and identification and prioritisation of sources of supply.
    - Mapping of opportunities for District Heating and Combined Heat and Power (CHP), to assess the additional potential for GHG reductions by providing low carbon heat and power from local sources.
    - Assessment of the constraints and costs associated with expansion of the electricity grid to accommodate distributed (low carbon) electricity generation.

- Improvements to the Scottish Greenhouse Gas inventory so it can be used more effectively as a basis for Scottish emissions projections and the analysis of Scotland-specific policies. For example, the development of more rigorous energy balance data for Scotland, including more fuel-specific and more end-user consumption data by commercial, domestic and industrial sub-sectors, perhaps even to include fuel consumption by technology.

- Behavioural research, e.g. to assess how individuals can be encouraged to adopt efficiency measures or to change their lifestyles. Behavioural change programmes will be key to the successful introduction of new technologies and may lead to additional emissions reduction opportunities not quantified in this study. Behavioural research could also be used to explore how Scottish citizens are likely to respond to different scenarios of economic growth and climate change awareness/action, e.g. would a move to greener electricity make people more likely to leave the lights on or buy a bigger television.

- Further analysis of the long-term emissions reduction potential across all sectors with particular emphasis on the emissions reduction trajectory, i.e. which technologies should be introduced when, and how will this affect costs. A Scotland-specific GHG projection model building on the UK MARKAL model would be a possible starting point for this.

- Analysis of the emissions and abatement options associated with the minor emitting sources not addressed in this study, such as emissions from offshore oil & gas activity, CH_4 emissions from natural gas distribution, and N_2O emissions from transport.

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Glossary

AD	Anaerobic Digestion
AEA	AEA
BAU	Business as Usual
BERR [5]	Department for Business, Enterprise and Regulatory Reform – formally the DTI
C&D	Construction and Demolition (waste)
C&I	Commercial and Industrial (waste)
CCS	Carbon Capture and Storage
CEEF	Central Energy Efficiency Fund
CERT	Carbon Emission Reduction Commitment
CHP	Combined Heat and Power
CH_4	Methane
CO_2	Carbon Dioxide
CO_2eq	Carbon dioxide equivalent
Defra [5]	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
DH	District Heating
DTI	Department of Trade and Industry
EEC	Energy Efficiency Commitment
EfW	Energy from Waste
EPC	Energy Performance Certificate
EU ETS	European Union Emissions Trading Scheme
F Gas regulations	EC Regulation No 842/2006 on Certain Fluorinated Greenhouse Gases
GSHP	Ground Source Heat Pump
GWP	Global Warming Potential
HECA	Home Energy Conservation Act
HFCs	Hydrofluorocarbons
HMRC	Her Majesty's Revenue and Customs
IEA	International Energy Agency
$ktCO_2eq$	Thousand tonnes of carbon dioxide equivalent
LED	Light Emitting Diode
LESA	Landlord's Energy Saving Allowance
LULUCF	Land Use, Land Use Change and Forestry
MACC	Marginal Abatement Cost Curve
MARKAL	The IEA Market Allocation model
MBT	Mechanical Biological Treatment
MoD	Ministry of Defence
$MtCO_2$	Million tonnes of CO_2
MSW	Municipal Solid Waste
MVHR	Mechanical Ventilation with Heat Recovery
NAEI	National Atmospheric Emissions Inventory
NO_x	A term for mono-nitrogen oxides, Nitric Oxide and Nitrogen Dioxide.
N_2O	Nitrous Oxide
OSPAR	Oslo Treaty and Paris Treaty regarding prevention of marine pollution
PFCs	Perfluorocarbons
PV	Photovoltaic
RO	Renewables Obligation
ROS	Renewables Obligation (Scotland)
SCHRI	Scottish Communities and Householder Renewables Initiative
SF_6	Sulphur hexafluoride
SKM	Smith Knight Merz
SMEs	Small and Medium Enterprises
SO_2	Sulphur Dioxide
SPP6	Scottish Planning Policy 6
SWH	Solar Water Heating
SWI	Solid Wall Insulation
UEP30	BERR's Updated Energy Projections

[5] This report refers throughout to BERR/Defra, changes to these departments has resulted in many of the responsibilities previously assigned to these Departments now being the responsibility of the Department of Energy and Climate Change (DECC).

1 Introduction

1.1 Background to the Study

In recent years Climate Change has moved to the centre stage of environmental, economic and transport policy in Scotland:

"This government wants Scotland to show leadership in tackling climate change…

> *… Our planned Scottish Climate Change Bill will set a mandatory long-term target to achieve an 80% reduction in our emissions by 2050*
>
> *…To meet the 2050 target - and to move us along the trajectory towards that target - new policies will be needed*
>
> *…We want Scotland to become a global leader in developing solutions to the challenge of climate change."*

John Swinney, Cabinet Secretary for Finance and Sustainable Growth - June 2007[6]

The Scottish Government's commitment to leading was confirmed in the Government Economic Strategy, published in November 2007[7]. This set two targets:

- To reduce emissions by 80 per cent by 2050.
- To reduce emissions over the period to 2011.

It is essential, therefore, to identify the policy options that will deliver this profound change, particularly in areas of the economy that to date have not been greatly affected by existing climate change policies. This will require identification of new policy options and also require consideration of the practical issues and public acceptability of policy implementation in areas where there may be significant resistance to change.

The Scottish Climate Change Bill public consultation closed on 23 April 2008, attracting over 21, 000 responses, the Bill will be introduced to Parliament before the end of 2008. This study will provide key evidence in development of the policy options for delivering climate change objectives, including the 80% target.

1.2 Objectives

This research addresses the following objectives:

- To generate a range of policy options aimed at achieving reductions in net greenhouse gas emissions in Scotland.
- To conduct an initial assessment of the impacts of policy options in terms of costs and effects in Scotland.
- To conduct an initial assessment of the feasibility, affordability and likely public acceptability of each option in Scotland.

Future work will be able to focus on the most promising options identified here once this initial assessment is complete.

[6] Speech by John Swinney on 21 June 2007: http://www.scotland.gov.uk/News/This-Week/Speeches/Greener/climatechangejun21
[7] Government Economic Strategy http://www.scotland.gov.uk/Publications/2007/11/12115041/0

1.3 Structure of this report

The remainder of this report is presented in the following sections:

Section 2 – Methodology – this section provides a summary of the methodology used to identify and assess the policy options.

Section 3 – GHG Emissions – this section reviews the scale, breakdown and trends in GHG emissions in Scotland.

Section 4 – Sector Profiles – for each of the 8 sectors. These provide:

- A definition of the sector.
- A baseline emissions trend.
- A list of policy options.
- An assessment of abatement potential and cost.
- A summary of acceptability and feasibility.

Section 5 – Cross Sector Analysis – where the sector measures are classified and the acceptability and feasibly is taken into account. These are then grouped into tranches of measures.

Section 6 – Conclusions – which presents the conclusions from this study including areas requiring further research.

Appendix 1 – Lists key data sources

Appendix 2 – Lists the key stakeholders contacted during the research

Appendix 3 to 10 – Lists in detail each policy measure for each sector

2 Methodology

2.1 Data sources

Data has been collected for this work through a review of relevant literature and consultation with key stakeholders. The key literature in this area includes:

- Plans issued by Scottish and UK Government.
- Information on emissions and trends in emissions.
- Foresighting studies carried out for UK Government and internationally.
- International datasets, for example on energy efficiency and renewable policies.
- Studies on energy policy, e.g. relating to the use of biomass and hydrogen fuel cells.
- Specific sectoral studies, for example on housing and waste management, and
- The results of public attitude surveys.

A list of these studies is presented in Appendix 1.

Prominent stakeholders include representatives of the Scottish Government and its Agencies, and other bodies such as the Sustainable Development Commission and the Policy Studies Institute. A listing is provided in Appendix 2.

2.2 Sectors and options considered

The analysis has considered options for each of the following 8 sectors:

- Electricity generation
- Business and Industry
- Public
- Waste management
- Housing
- Land-use change and forestry
- Agriculture
- Transport[8]

In the interest of reaching an 80% cut in emissions it is necessary to push current abatement policy (evolutionary change) and identify further, more radical measures (revolutionary change). Consideration is also given to cross-cutting policies and those that have an influence on other sectors. For example, switching from fossil fuel for vehicles will reduce the impact of other policies aimed at changing emissions from the transport sector.

Consideration is given to reduction of the three main greenhouse gases with emissions presented in terms of carbon dioxide equivalent (CO_2 eq). Whilst policies to reduce carbon dioxide (CO_2) emissions are considered for all sectors, the options for significant non-CO_2 GHG reduction focus on:

- Methane (CH_4): energy supply, waste management, land-use change, agriculture.
- Nitrous Oxide (N_2O): electricity generation; business and industry; agriculture, transport.

The other greenhouse gases account for 1.6% of total Scottish GHG emissions in 2005 on a CO_2 equivalent basis, i.e. taking account of the differences in Global Warming Potential. These emissions are already being dealt with by European legislation e.g. the F Gas regulations. Hence they have not been considered further in this study.

[8] These are based upon the NAEI sectors and their definitions.

When considering further options it is recognised that different circumstances will cause some policy options, in use elsewhere, to work better or worse in Scotland. For example:

- The location of power stations on the East coast of Scotland, along with the extensive oil and gas reservoirs offshore, creates a potential opportunity to exploit Carbon Capture and Storage.
- Scotland has some of the best resources in wave and tidal energy in Europe and the world[9]. Hence policies that support their exploitation will be found in the relatively small number of countries with similar resources (e.g. Portugal, Canada, USA, Norway, Australia).
- In many European countries recycling rates are much higher than in Scotland and the residual waste provides heat and/or power. Hence there are opportunities to reduce GHG emissions from the transport and landfilling of waste, although the entire emissions impact of these measures will need to be taken into account, including local air quality impacts.

Direct extrapolation of experience elsewhere is thus not always appropriate. Particular consideration needs to be given to the policy levers that could be used to transform GHG emissions in Scotland – and how these can be used to implement new policy options. In the interests of efficiency it is important that the review of policy options should not preclude ideas that may require joint action by the Scottish and UK Governments.

2.3 Generation and assessment of policy options

The research methodology followed 3 steps;
- Option generation.
- Assessment of Impacts.
- Assessment of feasibility, affordability and public acceptability.

Option Generation

When considering the impacts of policy measures in the time frame up to 2050 there is considerable uncertainty over many of the key variables such as future development of carbon saving technologies and hence the role for policy options that may support these technologies. To cast the net as widely as possible the option generation commenced with a literature search and consultation with a small number of individuals in the Scotland, the UK and in Europe. The aims of the search was to base the generation of options on the widest possible set, with the options being appraised having been identified after considering all realistic alternatives. The search aimed to capture evolutionary options (development of existing measures) and revolutionary options (completely new measures with more profound impacts).

The policy options were identified for each of the eight key sectors in Scotland listed in Section 2.2.

For each possible policy option the rationale, classification of type of policy lever (investment, subsidy etc) was undertaken. The current trend in emissions in each of these sectors was assessed, based on the Scottish Greenhouse Gases Inventory published in May 2007[10]. The trend and the drivers behind the trend were used to derive a Business as Usual projection of emissions.

A wide range of policy options for all sectors and all GHGs has been generated drawing on the sources listed in Appendix 1 and other sources. For each policy, information is presented either in the summaries in Section 4 or in the Appendices. Initial emphasis has gone to describing:
- Effectiveness at reducing GHG emissions relative to the baseline defined for 2050.
- Costs and cost-effectiveness.
- Associated uncertainties.

[9] "We have a vast potential in renewable energy - that is unrivalled in Europe" – Alex Salmond- http://www.scotland.gov.uk/News/This-Week/Speeches/First-Minister/renewables/Q/EditMode/on/ForceUpdate/on
[10] See http://www.airquality.co.uk/archive/reports/cat07/0709180935_DA_GHGi_1990-2005_v2.xls - Since this analysis was completed a revised report was published.

To the extent possible, this has been performed drawing on published sources, though the nature of this work, with assessment out to 2050, has made it necessary in some areas to rely on the expert judgement of the project team and those we have consulted.

The study takes a high level approach to the definition of policy measures, i.e. the focus is on measures that will have a material and lasting impact. There will be many more specific policy measures with a finer level of granularity that will also make a contribution to the 2050 target. However, given that this study includes all sectors, the focus is necessarily on the larger opportunities.

Similarly there are many supporting policy measures that will play an important role, including information and advice, procurement and training. While these play an important practical role the focus of the analysis has been on the core policy measures.

Assessment of impacts

For each policy option an assessment of costs and effectiveness was undertaken. Given the uncertainties associated with assessing costs and impacts in 2050, this included expert judgement as well as the results of the literature review. This is particularly true for the revolutionary measures, where less published material is available. Given these constraints the aim was to indicate the 'likely' scale of each option rather than a precise estimate.

The assessment of impacts was undertaken at sector level, including a wide range of policy measures. These were then considered again as part of a cross sector assessment. The cost effectiveness and abatement potential of each policy measure was classified as High, Medium, Low or Very Low. From this the policy measures were grouped to help identify those measures with the best potential and to differentiate them from the progressively less attractive.

Some measures result in a step change in emissions (e.g. new power stations), some measures result in a gradual change in emissions (change to new vehicle technology) while some measures result in very slow changes in emissions (changes to buildings). Hence some policy changes made early in the timeframe may take many years to result in a significant impact on emissions.

The sector profiles in Section 4 consider policies in isolation from each other rather than the cumulative effects of combinations of policies for a particular sector. These options are then brought together in the cross-sectoral analysis section (Section 5). Here account is taken of the fact that some measures are alternatives to others (e.g. carbon capture and storage or renewables) and some measures influence the impacts of others (e.g. heating efficiency improvements have less of an effect on emissions if buildings have already had their insulation improved).

Assessment of feasibility, affordability and public acceptability

As part of the assessment, the feasibility, affordability and public acceptability of each policy measure in each sector has been assessed. These are taken into account in the cross sector analysis of measures, where these factors are incorporated in the final assessment of abatement potential and cost effectiveness. In other words, if a measure has significant associated issues regarding feasibility and public acceptability, then the cost effectiveness assessment may be adjusted to reflect these wider issues. This assessment includes consideration of the policy levers that would be needed to implement each measure, which may include relevant EU, UK and Scottish powers. Some of the measures proposed will require state aids clearance. As a result the competency for decisions regarding some policy measures may lie between several of the key bodies.

3 Current and future estimates of greenhouse gas emissions in Scotland

3.1 Emissions to 2005

The pattern of greenhouse gas (GHG) emissions in Scotland differs from the pattern found in the rest of the UK. Notable features include:

- Lower industry emissions since the closure of the Ravenscraig integrated steel works.
- Higher emissions from space heating as a result of the cooler climate, more exposed buildings and a higher proportion of buildings with traditional solid walls.
- A lower level of car ownership in urban areas and a corresponding higher use of public transport, along with a high annual mileage for vehicles in rural areas.
- A more significant carbon sink from land use change.

Figure 1 shows the observed trends in Scottish GHG emissions from 1990 to 2005. It is clear that the Scottish GHG inventory is dominated by CO_2, with significant contributions also from CH_4 and N_2O. The contributions of PFCs, HFCs and SF_6 are small, though emissions of both HFCs and SF_6 have both increased in recent years. These three gases are not considered further – changes in their emissions are well within the uncertainties of emission estimates and abatement potentials for the three main GHGs. The red line in Figure 1 shows the effect of an 80% reduction in Scottish GHG emissions (relative to 1990 emission levels).

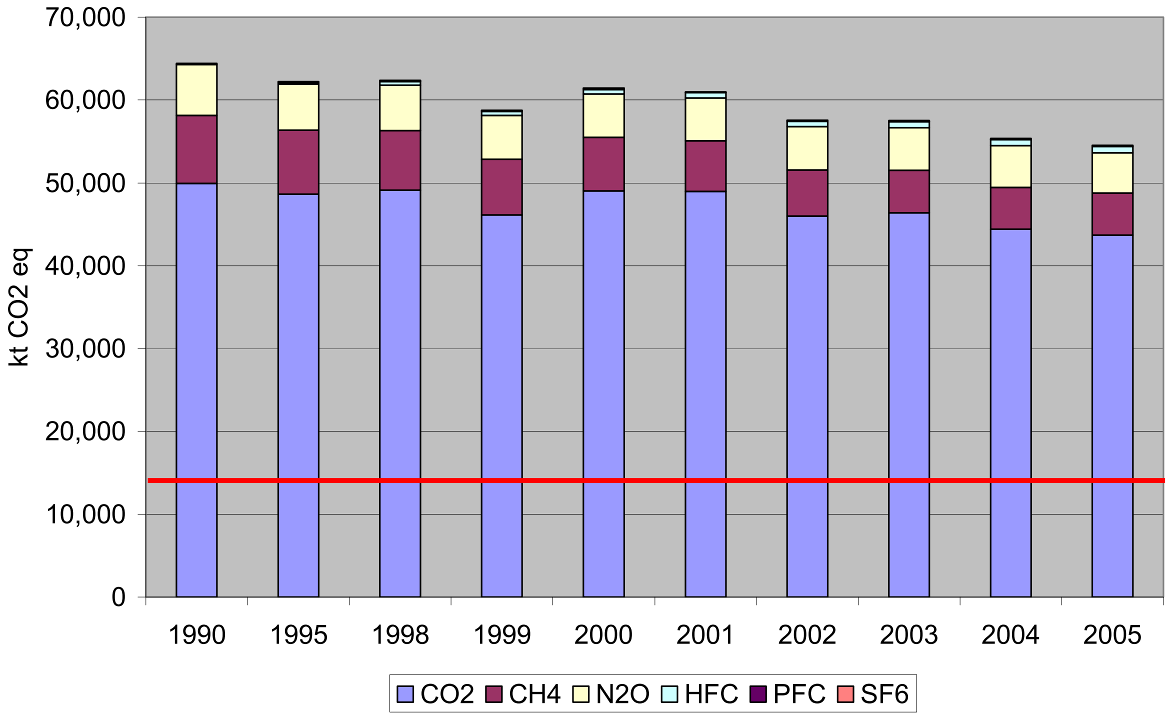

Figure 1 Net Scottish GHG Emissions 1990 to 2005[11]. The red line corresponds to an 80% reduction in emissions from 1990 levels

[11] National Atmospheric Emissions Inventory AEA – August 2007. While emissions data for 2006 is now available this analysis was undertaken prior to the publication of the 2006 data.

Figure 2 shows the same data, but disaggregated by end use sector. Significant contributions are made by electricity generation, industry, residential, agriculture and transport sectors. A negative contribution is made by land use, land use change and forestry (LULUCF) through its net absorption of carbon from the atmosphere over the years shown.

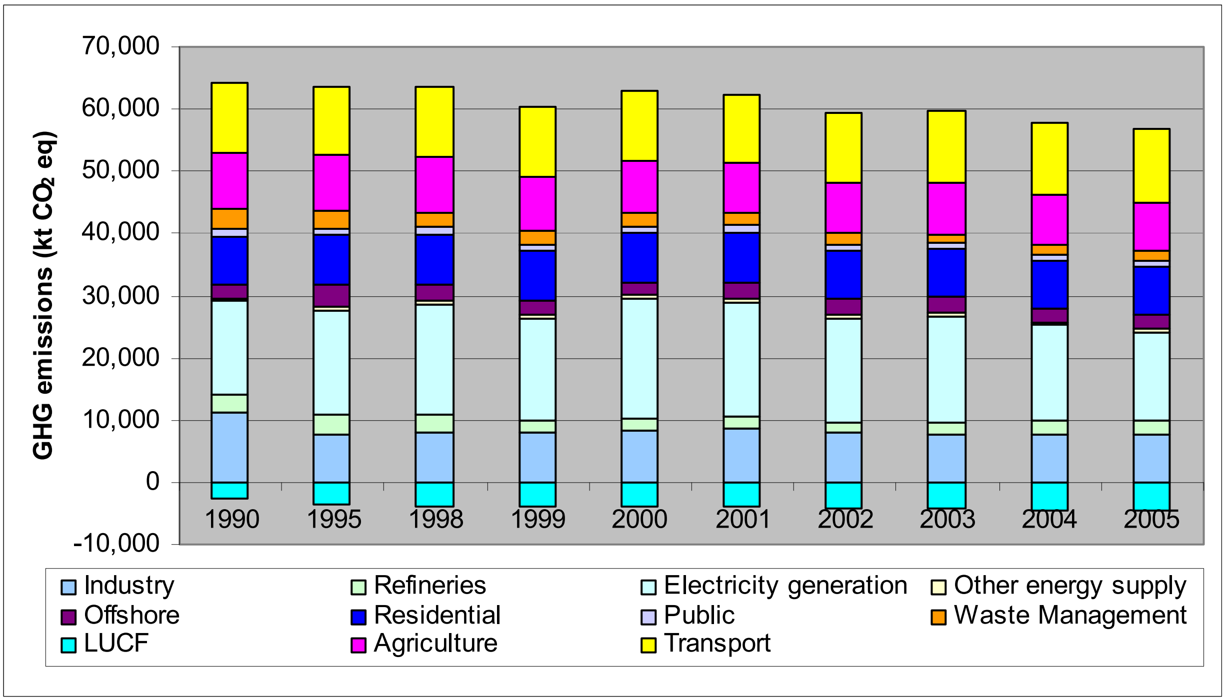

Figure 2 Scottish GHG Emissions 1990 to 2005 by sector[12 13]

The two figures show that Scottish GHG emissions have fallen by 10 $MtCO_2$ eq. (16%) since 1990. Hence good progress has been made against the objectives of the Scottish Climate Change Programme and the Scottish contribution to UK Kyoto targets.

It is clear from Figure 2 that no sector is dominant. Achieving an 80% cut therefore requires action to be taken in most, if not all sectors, but the precise distribution of cuts will depend on a more detailed assessment of costs and effectiveness of options.

The following table describes the factors behind the changes in Scottish GHG emissions from 1990 to 2005 in more detail and sets out some of the factors that have led to increases (shown as **+**) or decreases (shown as **-**) in emissions.

Table 1 GHG trends and drivers

NAEI Sector	Factors behind the Trends
Energy supply	– Increasing renewable generation + More use of coal and less nuclear due to technical difficulties at nuclear plant and relatively low wholesale coal price.
Agriculture, business, industrial processes and waste management	– Significant closures in steel, paper and electronics sectors. + Increasing use of electricity – Controls on landfill – Reductions in livestock numbers
Public and residential	– More stringent building standards + Increasing electricity use for appliances, IT and air conditioning
Transport	– Improved vehicle fuel efficiency + Increasing car mileage
Net land use change & forestry	– Carbon sequestration by existing forests, increasing net removals

[12] National Atmospheric Emissions Inventory AEA – August 2007
[13] “Other” emissions in this chart are primarily methane emissions from the distribution of natural gas

3.2 Scotland's Future Policy Direction

Before considering the baseline projections for emissions in Scotland to 2050, this section briefly reviews the broader policy context.

With a new Government in place, a number of broad policy initiatives have been launched in the past year. These are presented in the Government Economic Strategy, published in November 2007. This states that:

> *"Sustainable economic growth is the one central Purpose to which all else in government is directed and contributes."*

This purpose has a direct bearing on GHG emissions, as economic growth has in the past been closely associated with growth in emissions. The strategy recognises this tension, hence one of the 5 strategic objectives[14] set out in the strategy is to deliver a Greener Scotland, with specific targets to:

- Reduce emissions by 80% by 2050 and
- Reduce emissions over the period to 2011.

The strategy notes the initiatives taken in some economies to break the link between emissions and economic growth, citing New Zealand as a leader in this area.

A number of policy developments are underway to take forward the 5 objectives, including the core purpose of economic growth.

These broader economic policy objectives are likely to create some tension with policy measures to reduce emissions. At this early stage of policy development these tensions cannot be pinpointed accurately. However, the UK Climate Change Bill, the consultation on proposals for a Scottish Climate Change Bill and this study all fall under the Greener Scotland objective and hence are linked to the overall Economic Strategy. Thus the overall success of the Strategy and achieving the 80% target are linked.

Recognising this wider context, the policy measures considered, and in particular the feasibility and public acceptability assessment, take into account the wider policy context to achieve sustainable economic growth. As a result some of the more revolutionary measures, such as restricting air travel, need to be carefully assessed, as air travel for tourism and business purposes have a strong link to economic growth.

3.3 Policy options currently in place for further reductions in GHG emissions

A number of measures to address climate change are implemented via EU or UK level initiatives, e.g. the EU Emissions Trading Scheme, or the Renewables Obligation. In some cases Scottish Government co-funds UK programmes, and these are tailored to Scotland's needs. In addition there are a range of Scottish policies for reducing GHG emissions, including:

- The Scottish Community and Householder Renewables Initiative (SCHRI) – funding small scale renewable energy installations.
- The Central Energy Efficiency Fund (CEEF) – improving energy efficiency in the pubic sector.
- Stricter building regulations – reducing the GHG footprint of new homes and business premises.
- Scottish Planning Policy 6 (SPP6): Renewable Energy – setting the planning framework for large and small scale renewable energy.
- Safe and Fuel Efficient Driving – training HGV drivers in fuel efficiency.
- INCREASE– supporting local recycling initiatives to divert waste from landfill.

[14] The 5 Strategic Objectives are to map a Scotland that is Wealthier & Fairer, Smarter, Healthier, Safer & Stronger and Greener.

The impact of these and other existing policy measures needs to be recognised in the baseline emissions projections.

3.4 Projections to 2050

The primary sources of GHG emissions projections for the UK are:

- BERR's projections of CO_2 emissions as published in the Energy White Paper[15] and elsewhere, and
- The projections of non-CO_2 GHG emissions that have been updated recently by AEA following earlier work by Entec.

The UK CO_2 projections are not disaggregated by country and only extend to 2020, while the non-CO_2 projections only extend to 2030. It has therefore been necessary to disaggregate the baseline projections of UK emissions to give Scottish emissions, and to extend projections to 2050 using parameters such as economic growth or population, along with AEA's knowledge and judgement over trends and specific issues in each sector. This part of the work draws on recent experience of developing projections gained from the Scottish Energy Study, the SKM/AEA study on "Grid Issues Arising from Potential Changes to the Generation Background in Scotland" and AEA's MARKAL modelling work for BERR and Defra. These studies provide projections to 2020 or in some cases to 2030. For this study these projections have been developed and extended to 2050, giving the baseline scenario are shown in Figure 3.

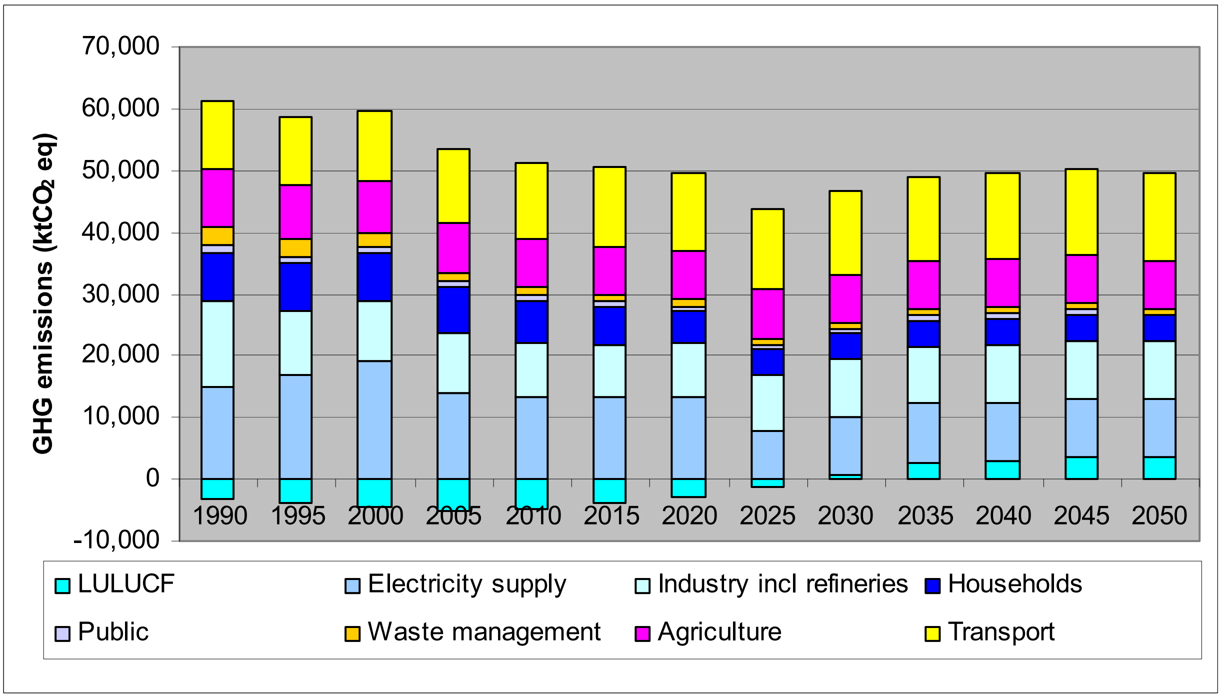

Figure 3 Scottish GHG Emissions 1990 to 2050 by sector

These include CO_2 emissions from electricity generation, industry, public sector buildings, housing, transport and land use, land use change and forestry (LULUCF), methane (CH_4) emissions from waste and agriculture, and N_2O emissions from agriculture. Together these sources represent about 88% of current Scottish GHG emissions. They do not include non-CO_2 emissions from industry, electricity generation, households or transport, or emissions from the offshore industry, as it is not possible to consider every possible source within the timeframe of this sort of study. Therefore the totals do not exactly correspond to those presented in Figure 2.

[15] http://www.berr.gov.uk/energy/whitepaper/page39534.html

The remaining 12% of Scottish GHG emissions from sources not addressed by this study are expected to fall significantly over the period due to industry trends and the effects of policies in the baseline. The main activities that are responsible for these emissions are:

Table 2: Emissions sources not addressed

Source	%	Reduction options
On shore Oil & Gas processing terminals	4.4%	Options similar to the business sector (e.g. CCS) plus declining N Sea activity.
Other energy supply (open cast coal, gas network)	1.8%	Gas network leakage reduction
F gases (refrigeration, industry processes etc.)	1.6%	F-gas legislation requires measurement and reduction of losses
Off road machinery (construction)	1.2%	Engine technology
Transport N_2O	0.9%	Improved catalysts

While the emissions from these sources will fall over the period to 2050, they may not fall to the 80% level. Hence additional reductions below the 80% level may be required for the GHG sources that are considered in this study.

The BERR UK projections for CO_2 incorporate a wide range of existing policy measures. Many are UK level policy measures including:

- Climate Change Levy (CCL)
- Climate Change Agreements (CCAs)
- EU Emissions Trading Scheme (EU-ETS)
- Carbon Reduction Commitment (CRC)
- Carbon Emissions Reduction Target (CERT)
- Supplier Obligation

The impact of these measures is included in the UK projections. Hence these measures are assumed to have a similar impact in Scotland and are therefore accounted for in the baseline projection.

Some measures specific to Scotland are in place. Many of these are broadly similar to UK measures, with specific budgets or technical details to suit the situation in Scotland. Some examples are:

- Building regulations.
- The CEEF for public bodies (similar to the Carbon Trust/Salix fund but implemented in a different way).
- Loan Action Scotland, interest free loans for SMEs (similar to a Carbon Trust scheme).

The BERR projections do not provide a high level of detail on each policy measure. For example all of the Carbon Trust measures are aggregated as one impact. Hence this study was unable to adjust the baseline projection for Scotland to recognise these specific Scottish policy measures. However they would tend to add savings and hence reduce the baseline.

Total emissions from the sectors considered in this study decline through to 2025, increase over the following 10 years and then stabilise. The CO_2 projections are largely based on BERR's UK-level projections for the Energy White Paper in 2007 (EWP 2007[16]) and so incorporate BERR's assumptions. The results by sector show significant reductions from the electricity generation and residential sectors, and growth from transport and the land use sectors. The main reasons for these baseline trends can be summarised as follows, while further information is provided in the sector profiles (Section 4).

[16] http://www.berr.gov.uk/energy/whitepaper/page39534.html

Looking at the baseline emissions for each sector in turn:

Electricity generation – reduced emissions to 2025 due to increased deployment of renewables and potential closure of existing coal fired power stations, followed by a small increase as coal and nuclear stations in the baseline are assumed to be replaced by gas fired stations. This follows BERR's projections, which assume that energy prices favour new gas fired stations.

Business/industry – fairly flat projection reflecting economic growth in some sub-sectors balanced by ongoing improvements in energy intensity.

Waste management – reduction in emissions due to implementation of the EC Landfill Directive, which restricts the amount of biodegradable waste that can be sent to landfill.

Housing – reduced emissions through existing and planned policies, in particular improved Building Standards and successive obligations on suppliers to introduce energy efficiency measures.

Public sector buildings – reduced emissions through existing and planned policies, e.g. improved Building Standards.

Transport – growth in car ownership and use, tempered to some extent by improvements in vehicle efficiency.

Agriculture – flat trend based on the assumptions that there will be no major changes in livestock numbers or fertiliser use.

LULUCF – emissions follow a cyclical pattern, tied in closely with forest rotation cycles. In recent years the net effect has been significant carbon sequestration, this is expected to change to a situation where emissions and sequestration are matched i.e. no net additions or removal of GHG emissions from around 2030.

4 Sector profiles

This section presents the sector level results, for each of the 8 sectors. These results are considered further in Section 5, the Cross Sector Analysis. At sector level the results are presented in $ktCO_2eq$ for ease of reading, the aggregated results across all sectors are presented in $MtCO_2eq$ (1,000 $ktCO_2eq$ = 1 $MtCO_2eq$).

For each sector the following information is provided:

- A short description of the sector.
- Emissions and trends within the sector.
- Identification of policy options for the sector.
- The emissions reductions and costs – prior to consideration of cross sector effects.
- Acceptability and feasibility of the policy options.

As electricity generation is a separate sector, the emissions data for the other sectors is solely the direct emissions, i.e. emissions from combustion of gas, oil coal etc. Many policies that encourage energy efficiency will reduce direct as well as indirect emissions. All emissions data is in annual terms.

For each sector additional information is provided in Appendixes 3 to 10.

4.1 Electricity Generation

This section covers the electricity generation sector; more details of the results are given in Appendix 3. The potential for additional abatement through the use of Combined Heat and Power (CHP) is considered separately in Section 4.9. Microgeneration is considered in this Section and also in the Housing Sector, as this term includes technologies that provide heat as well as electricity. Any potential overlaps are dealt with in the cross sector analysis.

The sector currently includes five large centralised plants – Cockenzie and Longannet (coal), Peterhead (gas/oil) and Hunterston B and Torness (nuclear). Scotland's total generation includes a significant proportion of renewable generation, particularly hydro and onshore wind, as well as a number of emerging technologies which could be important in future years (marine, deep offshore wind). Emissions from refineries, and associated mitigation options, are covered by the chapter on industry.

Complexity arises in that electricity generated in Scotland may be used outside Scotland in other parts of Great Britain, through distribution via the transmission network. Therefore, mitigation in this sector in Scotland has an impact on the carbon intensity of the wider UK generation mix – and therefore on the assumed savings that can be attributed to measures in end use sectors. Given that electricity generation in Scotland is transmitted to and used in other parts of the UK, decisions about operation of current generation capacity, and investment in new build is linked to the UK situation as a whole. This is fundamental to how this sector may develop in future years.

4.1.1 Emissions and trends

The starting point for assessing trends in GHG emissions for the sector to 2050 is the Scottish Greenhouse Gas Inventory[17] (NAEI 2007). This establishes the current level of electricity generation emissions at around 14 Mt CO_2/year. Projecting CO_2 emissions for this sector is not straightforward, particularly in the longer term due to various issues, economic, technical and planning related.

[17] See http://www.airquality.co.uk/archive/reports/cat07/0709180935_DA_GHGi_1990-2005_v2.xls - Since this analysis was completed a revised NAEI report has been published.

However, a report to the Scottish Government (AEA 2007b) provides projections for the electricity generation sector to 2030 and considers changes out to 2050 (though only qualitatively). The projections assume that electricity generation is tied into a supply-demand balance that accounts for domestic Scottish electricity demand, own electricity use by the generation sector, transmission losses and export levels. Based on this information, the following emissions baseline has been developed focussed on use of natural gas and coal – as renewable and nuclear plant do not contribute to emissions. Oil is not included specifically – low usage for electricity generation means that associated emissions will be small, within the uncertainty of the overall estimates. In the period up to 2030 all five of the large centralised plant are due to close. Hence the projection shows significant changes up to 2030. Post 2030 the replacement gas fired plant is assumed to be in place, and no further changes in capacity and output are assumed, hence a business as usual position is assumed, with emissions in the baseline after 2030 not changing year on year. These projections do not account for any significant growth in the use of electricity for heating or for charging electric vehicles.

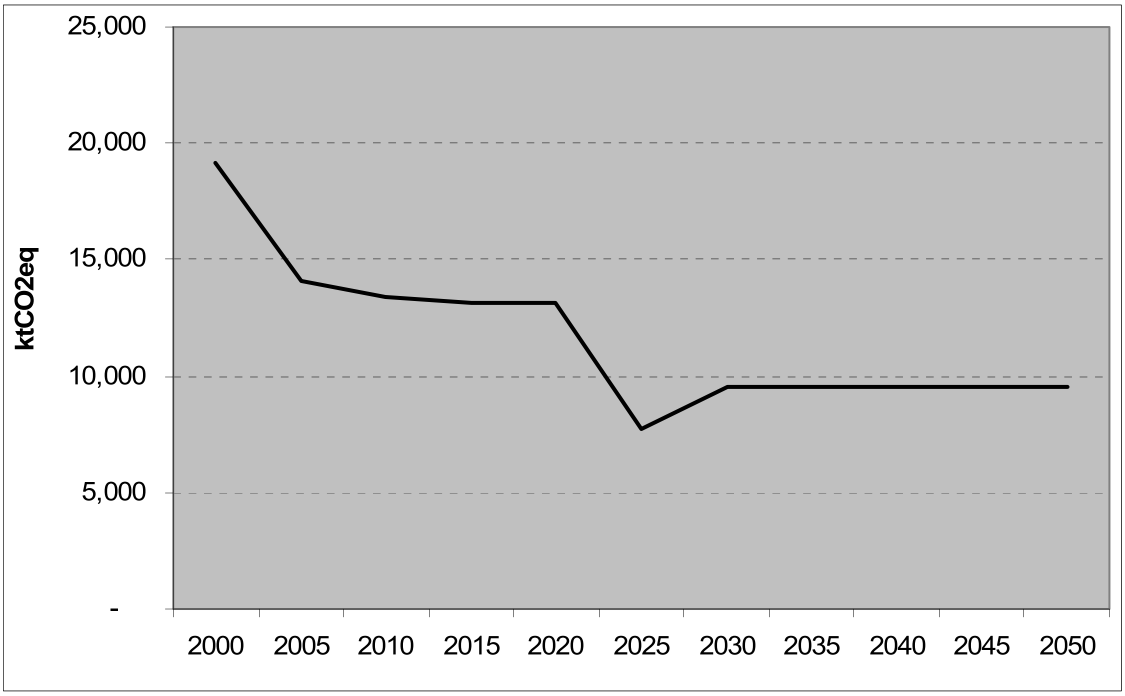

Figure 4 Baseline GHG emissions from electricity generation in Scotland, 1990-2050

4.1.2 Identification of policy options

Emissions from the electricity generation sector can be reduced by:

- Switching from fossil-fuel based generation to lower carbon generation types.
- Carbon capture and storage on fossil generation plant.
- Increased efficiency of generation plant.
- Increased uptake of microgeneration particularly micro-renewables (PV and micro wind).
- Reduced demand for electricity – through efficiency improvements, consumer behavioural responses, fuel switching, structural changes in the economy.

Decarbonised electricity could also have a knock-on effect on:

- Emissions from use of heating if domestic and business users were to switch to electrical heating, away from fossil fuels.
- Uptake of electric vehicles.

These cross sector interactions are dealt with in Section 5.

The baseline takes into account the following Scottish and UK policies that currently exist or are planned, as these will reduce emissions from electricity generation or changes to energy supply. Given the significant renewables resource in Scotland (hydropower, biomass from forestry, wind / marine potential), much of the emphasis is on the development and implementation of renewables policy.

- Scottish programmes and policies:
    - Scottish renewable electricity targets (31% in 2011 and 50% in 2020).
    - Renewables obligation (Scotland).
    - Biomass Action Plan for Scotland (Scottish Executive 2007).
    - Renewable Heat Strategy (proposed).
    - Energy Efficiency and Microgeneration: A Strategy for Scotland (draft).
    - European Marine Energy Centre (EMEC).
    - Wave and Tidal Energy Support (WATES) scheme.
    - SCHRI
    - Scottish Planning Policy 6 (SPP6) – Renewable Energy.
    - Policy on new nuclear generation.

- UK programmes and policies:
    - EU Emissions Trading Scheme Phase II and Phase III.
    - UK Energy Bill.
    - UK CCS demonstration programme.
    - Amendment to the Renewables Obligation.

A wide range of potential new (or extended) policy options for Scotland have been identified here by considering:

- The possible further evolution of existing policy options in Scotland and the UK.
- What is already being done, or considered, elsewhere in Europe.
- What has been proposed by leading researchers in the field.
- Other ideas proposed by the project team and the stakeholders consulted.

At this stage the net has been cast wide and ideas are included irrespective of concerns on cost-effectiveness or likely public acceptability. The aim was to produce a long list of possible options that could then be assessed against a number of criteria.

4.1.3 Emissions reduction potential, and preliminary assessment of costs

This section on emission reduction potential focuses on centralised supply-side electricity generation, as decentralised electricity / heat generation such as microgeneration are covered in end use sector assessments such as the business and domestic sectors.

Table 3 shows the percentage emissions reduction potential that could be achieved by 2030 and 2050 from each of the main policies or types of policy listed in the previous section, Table 4 shows this in absolute terms. It is not possible to derive the total achievable savings from the sector by simply adding up the savings in the final column because there are overlaps and interactions between policies.

Table 3 Emissions reduction potential from future policy options

Ref	Policy name	Reduction potential (as a % of relevant sector baseline)		Comment / Assumption
		2030	**2050**	
E1	Encourage take up of CCS (retrofit) for existing coal / gas generation plant	0%	90%	Policy assumed to be in place in 2035 - and that fossil plant built in 2025 / 2030 are capture ready
E2	Require enhanced efficiency of new stations through Section 36 Consents	5%	5%	Assumes that 5% can be made relative to BAU plant build
E3	Permit new build nuclear	47%	47%	Assumes new nuclear built instead of coal plant in 2025. Gas retained to provide flexible back-up generation
E4	Increase target under the Renewables Obligation (Scotland) (ROS)	3%	3%	Gas plant operates at lower load; hence reduction in emissions. Additional generation exported
E5	Significant support for emerging renewables	100%*	100%	Assumes grid upgrade which enables load balancing from rest of GB; removal of environmental protection / supply chain constraints
E6	Introduction of fusion technology	0%	100%*	Uncertainty over earliest potential date for this technology to be introduced – may be post 2050.
E7	Increase in renewable microgeneration	5%	10%	Information and financial support provided for electricity generation technologies, i.e. micro wind, PV etc.
E8	Promotion of biomass	-	-	Impact of types of measures explored in end-use sector chapters
E9	CHP uptake	-	-	
E10	Grid infrastructure development	-	-	Not possible to specify emission reduction potential. These measures are to enable changes to the sector that lead to greater potentials for emission reductions
E11	Electricity Act/Planning process	-	-	
E12	Hydrogen strategy	-	-	

* Reduction potentials based on 'revolutionary' type policy. Early shutdown of some thermal generation plants would be required to achieve this. By 2050 this is an alternative to CCS as a way of decarbonising the electricity supply system.

Table 4 Electricity Generation Emissions Reduction Potential in 2050

Ref	Policy name	Reduction potential (ktonnes CO_2 eq)	
		2030	2050
E1	Encourage take up of CCS (retrofit) for existing coal / gas generation plant	-	8,577
E2	Require enhanced efficiency of new stations through Section 36 Consents	477	477
E3	Permit new build nuclear	4,451	4,451
E4	Increase target under the Renewables Obligation (Scotland) (ROS)	254	254
E5	Significant support for emerging renewables	9,530	9,530
E6	Introduction of fusion technology	-	9,530
E7	Increase in renewable microgeneration	477	953

The above options can be split into two groups – firstly, those that ensure radical reductions in emissions from fossil plant (either through alternative build or CCS) or secondly, smaller reductions resulting due to the alternative generation technologies that do not replace large generation plant.

Many different cost assessments have been undertaken to assess the abatement costs of electricity generation under various options. DTI[18]'s Energy White Paper (EWP 07) provided costs on different abatement options for electricity generation technologies. For those measures where cost data is available, the following figures on costs have been considered.

Table 5 Potential abatement costs for each option

Ref	Policy name	Indicative costs of abatement in 2050 (£/tCO_2eq)	Assumptions
E1	Encourage take up of CCS (retrofit) for existing coal / gas generation plant	16	EWP 07 estimate is £60/TC
E2	Require enhanced efficiency of new stations through Section 36 Consents	0	Assumption that near zero cost - as only changing planning policy
E3	Permit new build nuclear	0.3	EWP 07
E4	Increase target under the (ROS)	64	EWP 07 (weighted across onshore wind (80%), offshore wind (15%) and wave (5%)
E5	Significant support for emerging renewables	84	EWP 07 (weighted across onshore wind (55%), offshore wind (30%) and wave (15%)
E6	Introduction of fusion technology	Very high	
E7	Increase in renewable microgeneration	404	EWP 07

NB. £ 2005 basis

As an established near-free carbon technology, nuclear generation is amongst the most cost-effective, although much depends on the cost assumptions concerning waste and decommissioning, interest payments during construction, capital investment assumed for class of generation etc. The long term waste and decommissioning costs are the subject of particular debate.

The technical performance and costs of emerging technologies such as wave and tidal are likely to improve post-2020 subject to research and experience that improves technology performance.

[18] Published by the then DTI, now the policy responsibility of BERR

4.1.4 Acceptability and feasibility of policy options

There are a number of issues concerning public acceptability and feasibility of policy options proposed, especially in the following cases:

- Nuclear power.
- Renewable generation (and associated infrastructure) particularly relating to intrusion on natural landscapes and possible effects on wildlife.
- Carbon capture and storage with respect to uncertainties in assessment of effectiveness and costs and the safety implications of transporting CO_2.

These are set out in Table 6:

Table 6 Acceptability and Feasibility of Electricity Generation Sector Policy Options

Ref	Policy name	Acceptability Issues	Feasibility Issues
		Legend: + *is a positive issue*, - *is a negative issue*	
E1	Encourage take up of CCS (retrofit) for existing coal / gas generation plant	- Will require pipelines across land and sea/estuary areas. - Storage in Firth of Forth – close to populated areas + Opportunities for Scottish Industry. + Aligns refinery with low carbon market.	- Technology not yet fully commercially proven, support for pilot/demonstration plant at EU and UK level. - Initial plants will be larger scale power stations, will need scaled to smaller sites. - May be more expensive for smaller sites.
E2	Require enhanced efficiency of new stations through Section 36 Consents	+ New plant will have lower SO_2, NO_x and CO_2 emissions. - May be viewed as building in dependence on fossil fuels.	+ Technology available & proven. + Use Electricity Act Section 36 to implement + Feasibility study underway.
E3	Permit new build nuclear	- Concerns over waste disposal issues, at public and political level. + Large contribution to target at low cost.	- Potential very long Electricity Act process. - Concerns over costs of waste disposal and decommissioning.
E4	Increase target under (ROS)	- Development issues may become greater as more sites are used and cumulative impact increases. - More grid upgrades needed leading to more environmental siting issues. - More expensive than energy efficiency measures.	+ Main technologies (wind, biomass) largely proven. + Support system and powers in place. - Increases requirement for new or upgraded transmission lines.

Ref	Policy name	Acceptability Issues	Feasibility Issues
		Legend: + *is a positive issue*, - *is a negative issue*	
E5	Significant support for emerging renewables	+ Diversifies from dominance of wind energy. + Economic development opportunities.	+ Potential economic benefits from new technology - Uncertainty over timescale and costs.
E6	Introduction of fusion technology	+ No radioactive waste issues. + No security of fuel supply issues.	- Technology at early stage, uncertain if available before 2050. - Very high research & development costs. - No specific factors that would lead to a Scottish investment.
E7	Increase in renewable microgeneration	- Will require a large number of households to adopt. - High costs. - Disruption (e.g. scaffolding, construction work for PV and micro wind). + Visible statement of green credentials. - Visible so possible planning issues. Not as cost effective as energy efficiency	- Current market driven by grants due to high costs. - Technologies often suited to rural dwellings, limiting potential. + May create higher awareness of energy issues and foster acceptance of renewable energy. - Performance issues/reliability on early systems + In future may be in permitted development

4.1.5 Sector Results – Electricity Generation

Based on the:
- abatement potential for the 8 measures discussed above
- costs for these measures
- acceptability and feasibility of these measures

Five policy measures for the electricity generation sector are considered to have a material and practical contribution to make to the 2050 reduction. The following figure shows these five measures plotted in terms of their:
- Abatement potential
- Abatement cost

The amount of carbon dioxide equivalent abated as a result of implementing each policy was assessed. The cost of implementing each policy was also determined. As a result of these considerations, taking into account uncertainties and any secondary impacts, each policy was placed in the abatement effectiveness matrix shown in Figure 5 and assigned a priority. This categorisation was based on the individual policy measure in isolation rather than its impact or cost when implemented alongside other policies. Further details of the categorisation are given in Section 5.

CCS for coal and gas power stations and significant support for emerging renewables are seen to have the highest potential for GHG abatement, effectively decarbonising electricity generation[19], with CCS at lower cost than greater levels of renewables. Enhanced energy efficiency and increasing renewables uptake both offer medium abatement potential at low cost, while renewable microgeneration is expected to be a high cost measure.

The policy levers for electricity generation are complex and held by the EU, UK Government and the Scottish Government. In addition world energy prices strongly influence investment and operation decisions in this sector. The Scottish Government has a number of policy levers at its disposal including planning, revenue support through the RO and capital grant support schemes.

Cost per tonne (£/t CO_2 eq)	**High**		**E7**	
	Medium			**E5**
	Low		**E2** **E4**	**E1**
	Very low (cost saving measures)			
		Low	**Medium**	**High**
		Quantity of GHG Abated (Mt CO_2 eq)		

E1	CCS for Coal/Gas power stations
E2	Enhanced Efficiency – uptake via planning
E4	Increased Renewables via RO target
E5	Significant Support for Emerging Renewables
E7	Increase in renewable microgeneration

Key:

Very High priority measures
High priority measures
Medium priority measures
Low priority measures
Very Low priority measures

Figure 5 Summary – Electricity Generation Sector[20]

[19] CCS would not completely decarbonise electricity generation as it is only likely to be 90-95% effective in removing CO2.
[20] The ranking of policy E5 includes an adjustment for uncertainty – see Section 5.1 for details

4.2 Business

This sector includes emissions from:

- The industrial sector (chemicals, food, paper engineering).
- The commercial sector (offices, hotels, retail etc.)
- Oil refineries (which are considered in this section, as the relevant policies are similar to those that apply to industry more generally).

Emissions from these Sub-Sectors were 17% of Scottish GHG emissions in 2005, falling from 22% in 1990. Emissions from electricity use in the sector are recorded separately under electricity generation. Further information on the policy options for the business sector is given in Appendix 4.

4.2.1 Emissions & Trends

Within the emissions inventory, 98% of emissions from the business sector are CO_2. The remainder is largely N_2O from mobile off road machinery (plant at construction sites, quarries etc). As these are transport related and a very small proportion of the total, they are not considered further. Emissions data are shown in Figure 6. Data to 2000 are taken from the NAEI. Figures from 2005 to 2020 are from the Scottish Energy Study. The projections in the Scottish Energy Study take BERR UK level projections adjusted to take account of the different composition of each business sub-sector. The UK projections take into account energy efficiency measures included in the DTI's 2005 energy projections. Figures post-2020 are estimated here by extrapolation of forecast trends for 2005 to 2020 for each sub-sector. The BERR projections include significant economic growth in sectors such as chemicals.

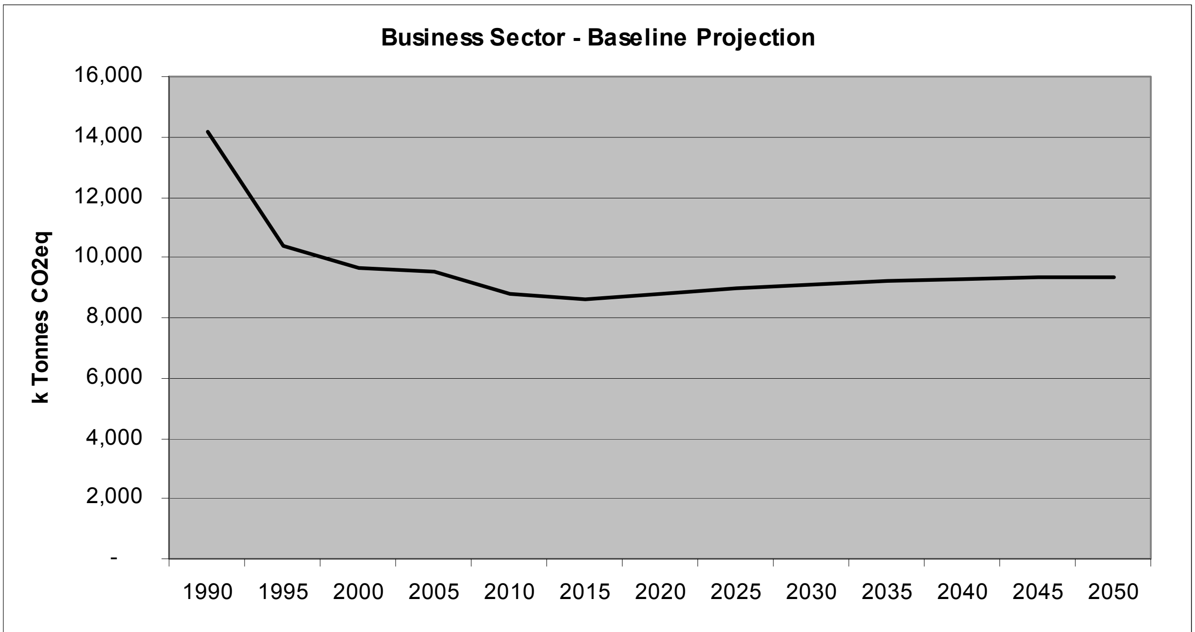

Figure 6 Estimated CO_2 emissions from the Scottish business sector 1990-2050

4.2.2 Identification of policy options

A wide range of policy options have already been developed to reduce energy, and carbon emissions, in business. The impact of these policy options in terms of carbon reduction will be accounted for in the baseline projections of energy and hence carbon emissions. However it is important to consider what these current and planned policy options are. Firstly to avoid any double counting of carbon saving potential and secondly to identify evolutionary improvements to the current policy mix.

Existing and planned policies include:

- Energy Saving Trust and Carbon Trust support for energy efficiency in SMEs
- Energy saving opportunities and microgeneration in SMEs
- UK ETS
- Building Regulations
- Carbon Trust
- Climate Change Agreements
- Climate Change Levy
- Enhanced Capital Allowances
- Carbon Reduction Commitment

The descriptions are broad. For example, the Carbon Trust provides a wide range of support and advice to the business sector, this could result in many different energy saving measures being adopted, from staff training, efficient lighting, heat recovery through to biomass heating etc. As the impact of these measures is included in the baseline projections, no further savings can be assumed from these types of evolutionary measures.

There is a wide range of measures of saving energy, and or carbon, available to the business sector now. New or enhanced measures will be available in the future. A review of a wide range of reports and analysis was undertaken to generate a list of technical measures and the associated policy options. From this a long list of policy & technical measures were identified, ranging from standards for carbon reporting, through grants and advice, to novel approaches such as green chemistry.

4.2.3 Emissions reduction potential, and preliminary assessment of costs

Many of the evolutionary measures appear to be included in the baseline projections, hence they cannot be assumed to offer additional carbon savings. In addition, some of the evolutionary measures offer modest reductions in carbon emissions from the items of plant or machinery that they are deployed upon. Furthermore, the persistence of the savings from behaviour change measures will not be as great as savings from larger capital intensive measures. These reductions are worthwhile, but do not reflect the transformation that is required in Scotland’s business sector to meet the proposed 80% reduction. To avoid double counting and to make the analysis more practical, the focus has been on the capital intensive measures that offer a more profound cut in emissions. There is a possibility that this will increase the costs of emission reduction, e.g. less investment may be required in biomass if the heat demand has been reduced by evolutionary measures.

Hence the assessment in the business sector has been on the large scale, revolutionary measures that have the potential to make deeper cuts in carbon emissions. These policy options and their abatement potential are shown in Table 7 and Table 8.

Table 7 Business Sector Emissions Reduction 2030 & 2050

Ref	Policy name	Reduction potential (as a % of relevant sector baseline)		Comment / Assumption
		2030	2050	
B1	Biomass Boilers – Grant support[21]	10%	10%	Biomass for selected large industrial sites. 70% reduction in CO_2 on these sites.
B2	Electric Furnace – Grant support	0%	2%	Conversion of high temperature melting in the glass and metals sectors to electric furnaces. Relevant when carbon intensity of electricity falls. 62% reduction in CO_2 for these sites.
B3	CCS Refineries - Planning & Regulation	0%	23%	Larger Scale CCS for Grangemouth. 90% reduction in CO_2 for the refinery.
B4	CCS Industry - Planning & Regulation	0%	28%	Smaller scale CCS for cement, chemicals etc. 90% reduction in CO_2 for these sites.
B5	Low Carbon Building Refurbishment – Building Regulations	3%	3 %	Introduce a 25% reduction in carbon emissions when each service sector building is refurbished.
B6	EfW - AD - Grant support	<2%	<2%	Digestion of food sector waste on site to generate heat and/or power from biogas. 10% reduction in CO_2 for these sites.

Table 8 Business Sector Emissions Reduction 2030 & 2050

Ref	Policy name	Reduction potential (ktonnes CO_2 eq)	
		2030	2050
B1	Biomass Boilers - Grant support	925	925
B2	Electric Furnace - Grant support	0	204
B3	CCS Refineries - Planning & Regulation	0	2,161
B4	CCS Industry - Planning & Regulation	0	2,635
B5	Low Carbon Building Refurbishment – Building Regulations	245	279
B6	EfW - AD - Grant support[22]	148	148

In addition to the potential identified above there will be opportunities for additional savings via:

- Biomass boilers in smaller industrial sites[23].
- Biomass CHP – increasing the carbon savings through electricity generation alongside heat.
- Electric Furnaces – conversion of smaller furnaces in the engineering sector.
- Centralised EfW – AD – collecting waste from smaller sites to increase the number of sites served and hence the carbon savings.

As data on the smaller sites is not readily available, the additional potential has not been included in the projections. Emissions reductions beyond those calculated here are therefore likely.

In addition to the emissions reduction potential in refineries & industry, there are opportunities to reduce emissions in the buildings used in the service sub-sector (banks, retail, hotels etc). The measures are similar to those that apply to public sector buildings, see Section 4.5. The most significant of these is use of the building regulations to reduce carbon emissions when refurbishing existing service sector buildings.

[21] Issues on the supply of biomass are discussion in Section 4.9
[22] Abatement potential from AD is the reduction in emissions from heating fuel that would other wise have been used – avoided emissions from electricity generation and landfill are not included in this sector.
[23] Loans are already available in Scotland to SMEs installing biomass boilers.

Table 9 Potential abatement costs

Ref	Policy name	£/t CO_2eq		Comment / Assumption
		2030	2050	
B1	Biomass Boilers - Grant support	£80	£80	EWP 07 MACC
B2	Electric Furnace - Grant support	£88	£88	None found - assume this is higher than CCS for coal - otherwise electricity will not be low enough in carbon to make this measure viable
B3	CCS Refineries - Planning & Regulation	n/a	£120	EWP 07 MACC
B4	CCS Industry - Planning & Regulation	n/a	£144	EWP 07 MACC + 20% for smaller scale
B5	Low Carbon Building Refurbishment – Building Regulations	£50	£50	As for measures PS1 & PS2 in Section 4.5.3
B6	EfW - AD - Grant support	-£1,288	-£1,288	BERR Report URN 07/1468

NB. £ 2005 basis

4.2.4 Acceptability and feasibility of policy options

For measures in the business sector the public acceptability issues will often be indirect, rather than direct, as the changes will not affect the daily lives of most citizens.

Table 10 Acceptability and Feasibility of Business Sector Policy Options

Ref	Policy name	Acceptability Issues	Feasibility Issues
		***Legend**: **+** is a positive issue, **-** is a negative issue*	
B1	Biomass Boilers - Grant support	**-** Local Air Quality issues may need to be addressed. **-** Fuel supply may increase local traffic in certain areas. **-** May encourage import of biomass. **+** Employment in fuel supply.	**-** Local Air Quality issues may need to be addressed. **-** Increasing pressure on supply of biomass, may increase costs or reduce environmental benefits.
B2	Electric Furnace - Grant support	**+** Reduces local emissions.	**-** Only worthwhile when carbon intensity of electricity falls. **-** Infrequent investment opportunity – during process change.

Ref	Policy name	Acceptability Issues	Feasibility Issues
		***Legend*: + is a positive issue, - is a negative issue**	
B3	CCS Refineries - Planning & Regulation	**-** Will require pipelines across land and sea/estuary areas. **-** Storage in Firth of Forth – close to populated areas **+** Opportunities for Scottish Industry. **+** Aligns refinery with low carbon market.	**-** Technology not yet fully proven. **-** Initial plants will be larger scale power stations, will need scaled to smaller sites. **-** May be more expensive for smaller sites. **-** No pipelines in situ – local storage under Firth of Forth
B4	CCS Industry - Planning & Regulation	**-** Will require pipelines across land and sea/estuary areas. **-** Storage in Firth of Forth – close to populated areas **+** Opportunities for Scottish Industry. **+** Aligns industry with low carbon market.	**-** Technology not yet fully proven. **-** Initial plants will be larger scale power stations, will need scaled to smaller sites. **-** May be more expensive for smaller sites. **-** No pipelines in situ – local storage under Firth of Forth
B5	Low Carbon Building Refurbishment – Building Regulations	**+** Employees may value working in green buildings.	**-** Opportunities will be infrequent, as premises vacated.
B6	EfW - AD - Grant support	**+** Reduces transport of waste. **+** Reduces waste costs. **+** Improves competitiveness. **-** Environmental standards may be harder to achieve for sites in urban settings.	**+** Increasing waste disposal costs will improve cost effectiveness.

4.2.5 Sector Results – Business

Based on the:

- abatement potential for the 6 measures discussed above
- costs for these measures
- acceptability and feasibility of these measures

Six policy measures for the business sector are considered to have a material contribution to make to the 2050 reduction. The following figure shows these six measures plotted in terms of their:

- Abatement Potential
- Abatement cost

The amount of carbon dioxide equivalent abated as a result of implementing each policy was assessed. The cost of implementing each policy was also determined. As a result of these considerations, taking into account uncertainties and any secondary impacts, each policy was placed in the abatement effectiveness matrix shown in Figure 7 and assigned a priority. This categorisation was based on the individual policy measure in isolation rather than its impact or cost when implemented alongside other policies. Further details of the categorisation are given in Section 5.

One measure for the business sector is in the Very High priority Group 1.This measure is grant support for biomass boilers. This is relevant to a wide range of sites with low temperature industrial processes at a very low abatement cost. The measure with the largest abatement potential is CCS for Grangemouth, the cost of CCS for these sites is assumed to be higher than that for power station sites. The remaining 4 measures are in the Medium priority group, with the CCS for other industrial sites offering the greatest abatement. There may be some potential to link some industrial CCS schemes, leading to lower costs of abatement.

Cost per tonne (£/t CO_2 eq)	**High**			**B4**
	Medium		**B2 B5**	**B3**
	Low		**B1 B6**	
	Very low (cost saving measures)			
		Low	**Medium**	**High**
		Quantity of GHG Abated (Mt CO_2 eq)		

B1	Grant Support Biomass
B2	Electric Furnaces
B3	CCS for Grangemouth
B4	CCS for Industry
B5	Retrofit low carbon to buildings
B6	EfW AD

Figure 7 Summary – Business Sector[24]

Key:

- Very High priority measures
- High priority measures
- Medium priority measures
- Low priority measures
- Very Low priority measures

[24] The ranking of policies B2, B4, B5 and B6 include an adjustment for uncertainty – see Section 5.1 for details

4.3 Waste

This sector includes Municipal Solid Waste (MSW), Commercial & industrial waste (C&I) and Construction and Demolition waste (C&D). Further information on the waste sector is given in Appendix 5.

4.3.1 Emissions and trends

The main focus for the waste sector is on emissions of methane in landfill gas as a result of biodegradable material from MSW & C&I sources. Legislation on the sector in the last 10 to 15 years, particularly the requirement for recovery of landfill gas has caused a 50% cut in landfill gas emissions.

The requirements of the Landfill Directive, mean that Scotland has to reduce the amount of biodegradable waste it is sending to landfill, to 75% of that produced in 1995 by 2010, to 50% by 2013, and to 35% by 2020. Taking these targets into account, it is forecast that under the baseline scenario emissions will continue to fall, but at a relatively slow rate. By 2050 it is anticipated that landfill gas emissions in Scotland would still be almost 1 Mt CO_2 eq annually, as shown in Figure 8. It should be noted that emissions from waste incineration get included under waste sector but emissions from other types of waste disposal and recycling will be counted under business.

In January 2008, the Scottish Government announced a new vision for a 'zero waste Scotland'[25]. This sets out a number of objectives, including:

- A vision for a zero waste Scotland.
- Increase recycling targets for municipal waste, rising to 70% by 2025.
- Reducing landfill to 5% by 2025.
- Setting high thermal efficacy standards for energy from waste.

The fulfilment of this vision is not reflected in the baseline emissions projection shown in Figure 8.

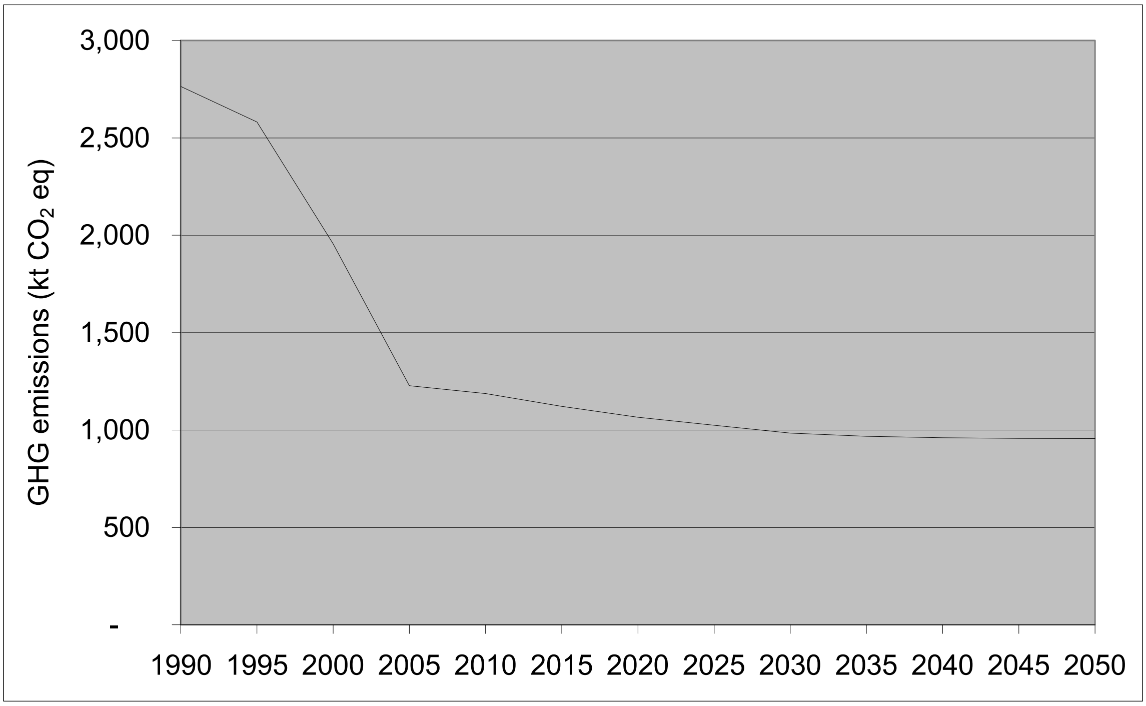

Figure 8 Baseline GHG emissions from the waste sector in Scotland, 1990-2050

[25] See: http://www.scotland.gov.uk/News/This-Week/Speeches/Greener/vision-for-waste/

4.3.2 Identification of policy options

The principal option identified here, for further reduction in landfill gas emissions, is to ban the landfill of biodegradable material. The costs of doing so are contained in the alternative treatment, disposal and other routes that would be needed. These may include:

- Waste minimisation (using less resources).
- Alternative materials allowing reuse (e.g. bottle collection, reverse vending machines)
- Recycling back to the original material (e.g. paper to paper).
- Recycling to other materials (e.g. kitchen waste to compost, or paper and other residual wastes to refuse-derived fuel, now marketed under various names).
- Thermal treatment or digestion with energy recovery.

This policy option goes further that the recent Scottish Government policy announcement in Jan 2008, which would reduce MSW to landfill to 5% by 2025.

4.3.3 Emissions reduction potential, and assessment of costs

We have estimated that a ban on sending biodegradable waste to landfill by 2040 would reduce emissions by 61% by 2050. The costs of alternative waste disposal options such as composting, anaerobic digestion, incineration (energy from waste) and mechanical biological treatment (MBT) vary from <£0/t CO_2eq to between £35/t and £90/t CO_2eq depending partly on the market price of products such as compost which are produced. Whilst it is difficult to say with any certainty how these markets will develop over the next 40 years, at present we assume that costs would be towards the higher end of this - say £50/t for 2030 reductions and £70/t for additional reductions to 2050, as in Table 13. Further work on this could therefore identify opportunities to refine these costs.

One complication for this sector is that biodegradable material already sent to landfill would continue to generate methane for many years to come as landfill gas collection technologies are not 100% effective.

Other complications relate to knock-on consequences, in terms of greenhouse gas emissions, of the alternative routes for waste management. While many recycling options lead to a net reduction in greenhouse gas emissions, other waste management options such as incineration may lead to a net increase. The competing effects are, for the purposes of this report, considered to be roughly in balance. The effect of the ban on sending biodegradable waste to landfill on emissions is shown below in Table 11 and Table 12. The relative effect compared to baseline emissions is shown in Figure 9.

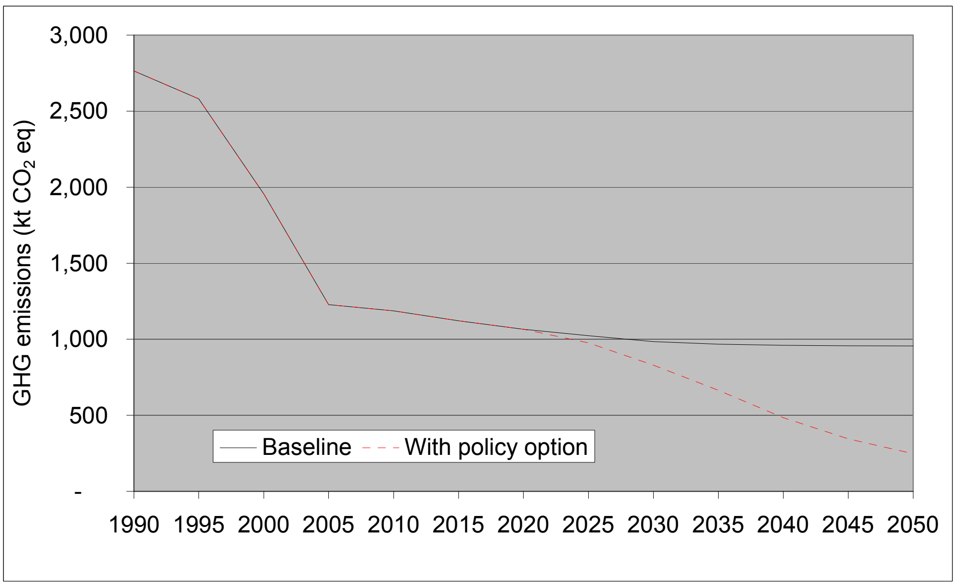

Figure 9 The effects of a ban on the landfill of biodegradable material on GHG emissions

Table 11 Waste Management Emissions Reduction 2030 & 2050

Ref	Policy name	Reduction potential (as a % of relevant sector baseline)	
		2030	2050
W1	Ban biodegradable waste to landfill	16%	74%

Table 12 Waste Management Emissions Reduction 2030 & 2050

Ref	Policy name	Reduction potential (kt CO_2 eq)	
		2030	2050
W1	Ban biodegradable waste to landfill	158	583

Table 13 Waste Management Emissions Reduction Costs 2030 & 2050

Ref	Policy name	£/t CO_2 eq		Comment / Assumption
		2030	2050	
W1	Ban biodegradable waste to landfill	£50	£70	Typical costs – in middle of range

4.3.4 Acceptability and feasibility of policy options

There has been much work in recent years on alternatives to, what might be termed, the traditional waste management options of incineration and landfill. Composting schemes, in particular, provide great potential for avoiding the landfill of organic matter. Several European countries already have a ban on landfill of biodegradable waste, so there is a precedent for the policy.

The measure is likely to be broadly acceptable, provided that it can be achieved at reasonable cost. Concern may be expressed if it leads to greater levels of incineration. This should be offset against the availability of alternative treatment routes for material that enters the waste stream and the legislation that now exists, to reduce harmful incinerator emissions, to levels much lower than in the past.

For the waste sector the main policy drivers are EU Directives and the Waste Strategy in Scotland. The Scottish Government can influence how waste is managed through the Concordat with local authorities and the planning system.

This policy will encompass use of suitable waste as an energy source. This will enhance GHG reductions, through the displacement of fossil fuels. The adoption of standards for high thermal efficiency will increase these additional savings

Table 14 Acceptability & feasibility issues for waste management measures

Ref	Policy name	Acceptability Issues	Feasibility Issues
		***Legend**: **+** is a positive issue, **-** is a negative issue*	
W1	Zero biodegradable waste to landfill	**-** Public concerns over incineration remain. **+/-** May increase transport of waste. **+** Reduces landfill and local environmental risks near landfill sites.	**+** Technologies proven. **+** Policy already used elsewhere in Europe. **-** Emissions will take time to reduce due to legacy of waste already in landfills. **-** Residual materials may be more difficult to use for energy.

4.3.5 Sector Results – Waste

The following figure shows the policy measure for the waste sector plotted in terms of:

- Abatement Potential
- Abatement cost

The amount of carbon dioxide equivalent abated as a result of implementing each policy was assessed. The cost of implementing each policy was also determined. As a result of these considerations, taking into account uncertainties and any secondary impacts, each policy was placed in the abatement effectiveness matrix shown in Figure 5 and assigned a priority. This categorisation was based on the individual policy measure in isolation rather than its impact or cost when implemented alongside other policies. Further details of the categorisation are given in Section 5.

The only policy measure in this sector is judged to offer medium abatement potential at low cost.

Cost per tonne (£/t CO_2eq)	**High**			
	Medium			
	Low		**W1**	
	Very low (cost saving measures)			
		Low	**Medium**	**High**
		Quantity of GHG abated (Mt CO_2 eq)		

W1	Zero biodegradeable waste to landfill

Figure 10 Summary – Waste Sector

Key:

- Very High priority measures
- High priority measures
- Medium priority measures
- Low priority measures
- Very Low priority measures

4.4 Households

This section provides an overview of emission trends, existing policies, future policy options and the costs, benefits and public acceptability issues associated with those options for the Scottish households sector. Further details including references and assumptions are provided in Appendix 6.

4.4.1 Emissions & trends

Figure 11 shows the baseline projection for direct CO_2 emissions from households[26] in Scotland from 1990 to 2050. Historic data are taken from the Scottish Greenhouse Gases Inventory. The projection to 2025 is based on the latest BERR projection (UEP30) of growth rates in UK emissions, adjusted to take account of different population trends for Scotland and the UK and taking out the emissions reduction attributed to the zero carbon homes policy (which does not apply in Scotland[27]). We have derived the baseline for 2025 to 2050 using Scottish population projections alone; this is somewhat conservative as it doesn't allow for any ongoing impact of policies introduced before 2025.

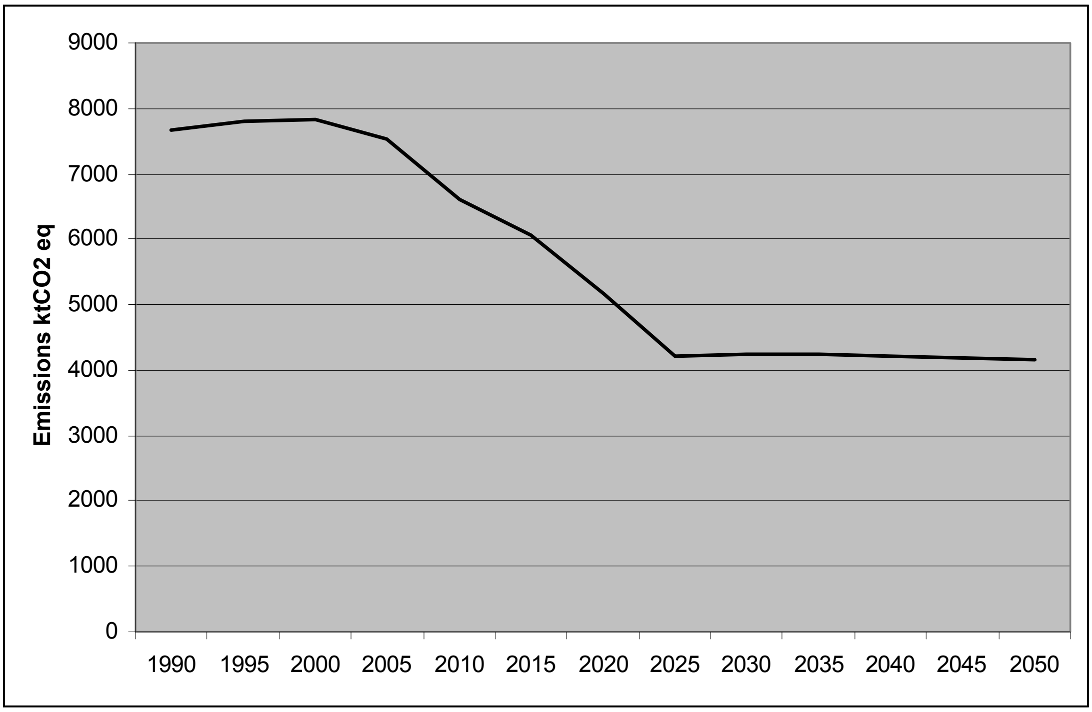

Figure 11 Baseline projection of CO_2 emissions from Scottish households 1990-2050

It has not been possible to base the analysis on specific details of the Scottish housing stock, due to a lack of data, but some of the key differences are discussed below.

- **Housing age**: The Scottish housing stock has fewer older houses than the English stock, which suggests there may be proportionally less potential for solid wall insulation in Scotland. This inference is not backed up by anecdotal evidence from Scottish stakeholders, who believe there are more hard to treat dwellings in Scotland, that are unsuited to cavity wall insulation. It has also been suggested that those dwellings with cavity walls have wider cavities than in England and so the insulation is more expensive to install. Further work would be needed to confirm the potential for cavity wall insulation in Scotland. If it is less than that in England then this means the baseline emissions projection is lower than it should be.

[26] Indirect emissions from electricity use are accounted for in the electricity generation sector.
[27] While the zero carbon homes policy does not apply to Scotland, the 2007 Sullivan Report "A Low Carbon Building Standards Strategy for Scotland" has recommended similar measures for Scotland – see http://www.sbsa.gov.uk/pdfs/Low_Carbon_Building_Standards_Strategy_For_Scotland.pdf .

- **Housing type**: Scotland has a much higher proportion of flats than England. With the exceptions of cavity wall and loft insulation (which are included in the baseline), many energy efficiency measures are equally as applicable to flats as houses. However additional efforts may be required to address the landlord-tenant barrier and the issues around common building areas in multi occupancy tenements. Micro-generation technologies may be less applicable because of the lack of individual roof space to place SWH panels, PV panels or wind turbines. Against this, Scotland has a higher proportion of housing off the natural gas network, where microgeneration (excluding micro-CHP) offers particular advantages.

- **Heating fuel**: 72% of Scottish households use gas as the main heating fuel compared to 81% in England, reflecting the fact that fewer Scottish homes are connected to the mains gas network. This indicates that there may be a proportionally greater potential for ground source heat pumps and biomass boilers in Scotland, as neither technology relies on gas connection. However further research would be needed to confirm this potential, as other factors such as building design and biomass fuel availability will influence potential uptake. In some cases it may be more cost effective to switch fuels, particularly if the property is close to an existing gas network.

- **Climatic differences:** There are a number of climatic parameters, e.g. temperature, wind speeds and solar insolation (direct and diffuse), which differ between Scotland and England. These tend to affect the attractiveness of various technologies between the two countries, although this is not an exact science:
    - PV requires direct sunlight to work well so less hours of direct sunlight in more northern latitudes make this technology less attractive.
    - Higher wind speeds generally make wind more attractive the further North, but localised microclimates and specific site parameters are of greater significance.
    - SWH efficiency will be affected by heat loss from the collector due to lower ambient temperatures and greater effects of 'wind-chill', so this technology may be generally less attractive. However, where the hot water makes a contribution to space heating the longer heating season and greater overall heat load through the winter can make the technology more worthwhile at higher latitudes.

  These climatic parameters are generally considered to have less effect on uptake in Scotland than other factors such as grant availability and the proportion of housing off the gas network (see above).

4.4.2 Identification of policy options

Table 15 below lists Scottish and UK policies that currently exist or are planned to increase energy efficiency and reduce carbon emissions in the Scottish households sector. The list also includes policies that are primarily aimed at addressing fuel poverty, and which also impact energy efficiency in poorer households. All of these policies are described in the Scottish Climate Change Programme and/or the UK Energy Efficiency Action Plan.

Table 15 also shows the estimated carbon savings in 2020[28] from each policy to give a feel for the relative importance of each policy to climate change objectives. These estimated carbon savings take some account of rebound effects at the measure level, e.g. savings from efficient lighting, under Energy Efficiency Commitment (EEC), assume more efficient lighting, will be used more than the lighting it replaces. Even so, it is possible that the full savings from each policy will not be realised because of unanticipated rebound effects.

All of these policies are included in the emissions baseline. The main focus is on improving the energy efficiency of the building stock through tighter building standards for new build housing, applying technical measures such as cavity wall insulation and condensing boilers to existing buildings, through progressively larger scale obligations on energy suppliers, and improving the efficiency of lights and appliances by working with manufacturers. There is also increasing use of behavioural measures such as education, information and advice programmes. Such behavioural measures are seen as important in supporting and enforcing other policy measures, but there is limited information and some doubt about their effectiveness in isolation.

[28] These figures are provided for 2020 rather than 2030 as elsewhere in this report as they are taken from the UK Energy Efficiency Action Plan.

Table 15 Current and planned policies for the Scottish Households sector, including carbon savings in 2020 where data is available

Policy area	Policy	Carbon savings in 2020	
		UK $MtCO_2$ eq	Scotland $MtCO_2$ eq
New buildings	Building Regulations Scotland 2007	N/A	1.5
	Energy Performance of Buildings Directive	2.2	0.2
Existing buildings: heating/insulation	Energy Efficiency Commitment (EEC)	2.9	0.2
	Carbon Emission Reduction Commitment (CERT)	4.0	0.3
	Supplier Obligation	12.8	1.1
	Scottish Housing Quality Standard	1.5 *	0.1
	Warm Deal and Central Heating Programme		
	Reduced VAT on energy saving materials	#	#
	Landlord's Energy Saving Allowance (LESA)	#	#
	Home Energy Conservation Act (HECA)	#	#
Existing buildings: lights/appliances	Market Transformation Programme	4.8	0.4
Existing buildings: microgeneration	Scottish Communities and Householder Renewables Initiative (SCHRI)	#	#
Behavioural measures	Energy Saving Scotland advice network	#	#
	Climate Challenge Fund	#	#
	Climate Change Schools Initiative	#	#
	Smart Metering	0.7	<0.1
	Energy Performance Certificates	#	#

* Total savings from UK fuel poverty programmes.
** Pro-rated from UK savings – no data available on likely Scottish share of Supplier Obligation.
# Figures not available – likely to be less than 0.1 $MtCO_2$ savings in 2020.

We have identified a wide range of potential new policy options for Scotland by considering:

- Possible further evolution of existing policy options in Scotland and the UK
- What is already being done, or considered, elsewhere in Europe
- What has been proposed by leading researchers in the field
- Other ideas proposed by the project team and the stakeholders consulted

At this stage a wide range of ideas were considered, being conscious not to discount ideas too early on, for cost-effectiveness or likely public acceptability reasons. The aim was to produce a long list of possible options that could then be assessed against a number of criteria.

We considered potential new policy options in six main categories:

- Technology based policies to reduce emissions from new buildings
- Technology based policies to reduce the emissions associated with (space and water) heating in existing buildings
- Technology based policies to reduce the emissions associated with lights and appliances in existing buildings
- Technology based policies for micro-CHP and microgeneration
- Behavioural measures to support the introduction of lower carbon technologies or reduce the demand for energy services
- Accelerated replenishment of the housing stock[29]

Table 16 shows a long list of possible policy options for the Scottish households sector, before feasibility and acceptability issues are taken into account. These are grouped into the six categories listed above. They include some options that are alternative scales of the same overall policy, e.g. different levels of building standards.

[29] Note: accelerated demolition would improve the in-use efficiency of the housing stock, but there could be negative impacts on resource efficiency once the embedded carbon of building materials and the environmental impacts of demolition/construction are taken into account.

Table 16 Future policy options for the housing sector

Policy area	Policy
New buildings	Tighter building regs - adapt Section 6, including microgen requirements
	Tighter building regs – adopt proposals by Sullivan panel; net zero carbon homes by 2016/17
	Tighter building regs - net zero carbon homes by 2011
	Tighter building regs - include built-in appliances & cap total emissions
	Introduce EPC sub-banding for lower carbon homes & promote heavily
	Evaluate low carbon buildings & feed results back into building regs
	Lower stamp duty for better performing buildings (not just zero carbon)
	Statutory Guidance on Planning and Sustainable Development
	More R&D into improved buildings
	Compulsory air tightness tests
	Compulsory green roofing on new developments
	Training & capacity building in construction industry
	Implementation of SPP6 policy for on-site low and zero carbon equipment
Existing buildings – heating & insulation	Continue Energy Efficiency Best Practice for Housing programme
	Tighter building regs - progressive phase out of G, F, E rated properties
	Higher standards for social landlords
	Improved & better promoted Landlords Energy Saving Allowance (LESA)
	Further supplier obligations
	Low carbon zones rolled out by Local Authorities
	Mandatory performance assessment when upgrading, remortgaging etc.
	Stamp duty refunds if insulate/improve within a year of purchase
	Low interest loans (green mortgages) for improvements
	More R&D into measures for hard to treat housing
	Legally binding standards on LAs on housing performance
	Renewable heat obligation
	Promote community heat and power
Existing buildings - lights & appliances	Phase out incandescent bulbs by e.g. 2010
	Mandate use of LEDs by e.g. 2030
	Stand-by power reduced to maximum of 1W or lower
	Subsidised replacement of old fridges
	Only A rated equipment to be sold
	Reduced street lighting
	Mandate vacuum insulated panels for refrigeration
	Energy labels showing absolute consumption not e.g. W/litre
Existing buildings – micro CHP & microgeneration	Expand existing support programmes (SCHRI)
	More R&D into micro CHP technologies
	Implement Merton rule - 10% (and rising) generation on-site for LAs
	Feed-in tariff for exported electricity
	Increased permitted development rights for domestic microrenewables
Behavioural measures	Gas and electricity monitors in all homes, e.g. by 2010
	Personal carbon allowances/trading
	Energy advice by third parties, e.g. social workers

In the analysis that follows we have focused on the technical measures listed in Table 16 and simplified and shortened the list to twelve specific options (D1 to D12):

D1 New homes – 20% CO_2 reduction
D2 New homes – 30% CO_2 reduction
D3 New homes – 50% CO_2 reduction
D4 New homes – 75% CO_2 reduction
D5 More efficient lighting
D6 Further insulation measures for existing homes
D7 Ground source heat pumps
D8 Photovoltaics
D9 Biomass boilers
D10 Solar water heating
D11 Micro wind
D12 Micro-CHP

There were three reasons for defining and selecting the options in this way. Firstly, these are the technical measures likely to make the biggest impact on emissions. Secondly, it is impossible to quantify the impact, or cost, of a generic policy option, such as a feed-in tariff or an energy label, without a detailed impact assessment. Finally, there is a dearth of data on the impact of behavioural measures and many of the behavioural measures are aimed at supporting technological change, rather than demand reduction per se. For example, Energy Performance Certificates aid the introduction of low and zero carbon homes and appliance labelling supports market transformation. Further work would be needed, to research the potential for emissions reduction, through reduction in the demand for energy services, e.g. through attitudinal change programmes.

A 2006 report by Oxera, for Defra[30], on policies for energy efficiency in the UK household sector, highlighted the importance of underpinning efforts to introduce technical measures with appropriate information provision. This study found that future energy savings are not currently an important factor in a householder's decision to fit insulation or buy efficient appliances. They also found that householders have a poor knowledge of energy efficient measures and will tend to overestimate the costs, and the installation time, of such measures. This helps to explain why measures such as cavity wall insulation and loft insulation, which are very cost effective, have still not reached their technical potential after many decades.

4.4.3 Emissions reduction potential, and preliminary assessment of costs

New build housing

The policy options listed for new housing in Table 16 represent different options for reducing the carbon impact of housing to be built between now and 2050. Several of the options refer to zero carbon homes by a certain date; 2016/17 in the case of the Sullivan report proposals[31]. It is important to note that this doesn't necessarily mean such housing will have no demand for fossil fuels, but rather that any demand will be balanced by renewable energy generation, whether that be from microgeneration or larger scale renewables deployment on housing developments. The exception to this is the introduction of biomass CHP or district heating, where there may be little or no need for fossil fuel heating.

30 Oxera: Policies for energy efficiency in the UK household sector January 2006
31 Sullivan 2007. A Low Carbon Building Standards Strategy for Scotland, Panel of Scottish Ministers, 2007 http://www.sbsa.gov.uk/pdfs/Low_Carbon_Building_Standards_Strategy_For_Scotland.pdf

Table 17 presents emissions savings and costs, for lower carbon new build housing options in Scotland, based on a recent report by Turner & Townsend, which fed into the Sullivan review[32]. The final column – cost per tonne of CO_2 – is not included in the Turner & Townsend report and has been calculated by assuming a 40 year lifetime of measures, a 3.5% discount rate and recent fuel prices[33]. These assumptions are in line with those used by BRE in its calculation of the cost-effectiveness of measures for existing housing (as presented in Table 18). The Turner & Townsend study considered energy efficiency and microgeneration measures that can be combined to produce housing with 20%, 30%, 50% and 75% lower carbon emissions than that meeting 2007 Building Standards. These costs are much higher than those given in the Regulatory Impact Assessment for Building a Greener Future, perhaps reflecting uncertainty in future costs of solar water heating and other microgeneration technologies. Further work is needed to understand the costs associated with these technologies.

Table 17 Emissions savings and costs for lower carbon new build housing in Scotland

Ref	Emissions Reduction per house (%)	Insulation Measures	Heating Measures	Marginal capital cost per house £ (%)	Cost-effectiveness £/tCO_2eq
D1	20	Improved	Conventional fossil fuelled	4,006 (5%)	367
D2	30	Improved	Solar water heating (SWH)	8,057 (9%)	573
D3	50	Improved	Biomass boiler	13,413 (15%)	583
D4	75	Advanced	Biomass boiler + SWH + MVHR	26,556 (30%)	830

Notes: Efficient lighting also introduced in each scenario; MVHR = Mechanical Ventilation with Heat Recovery; marginal capital costs estimated by Turner & Townsend following consultation with suppliers

These four scenarios are estimated to give 2.2%, 3.3%, 5.6% and 8.4% reduction in overall CO_2 emissions from housing by 2050, respectively. The savings are relatively small because 75% of housing in 2050 has already been built (based on a simple stock model developed by AEA for this study), and because new housing is already significantly more efficient than the average stock. Note, any measure to increase the demolition rate would increase the impact of energy efficient new housing; in this work we have assumed a constant demolition rate of only 0.1% consistent with past trends.

Existing housing

The measures shown in Table 18 have been considered for the existing Scottish housing stock. Cavity wall insulation is not included because it is assumed this cost-effective measure will already be introduced to its full technical potential through successive supplier obligation programmes. This is consistent with information provided in the Call for Evidence on the Household Energy Supplier Obligation published by Defra in June 2007[34]. However, it could be questioned whether the supplier obligations will reach all hard to treat housing, of which there is a higher proportion in Scotland. Similarly all boilers are assumed to be A rated condensing boilers by 2030. This list is not comprehensive and excludes many measures with lower but still significant emissions reduction potential, such as improved heating controls, more efficient cookers, hot water cylinder insulation and more energy efficient televisions. Further information on these measures is included in BRE's report "Reducing Carbon Emissions from the UK Housing Stock", which was the main reference for this section.

The replacement of inefficient incandescent lighting with compact fluorescent lamps (CFLs) is included as an additional measure for 2030 in BRE's analysis and our own. Defra agreed a voluntary agreement with manufacturers to phase out incandescent bulbs by 2011 in September 2007. The impacts of this agreement are therefore not in the Energy White Paper projections upon which our baseline was based.

[32] The impact on costs and construction practice in Scotland of any further limitation of carbon dioxide emissions from new buildings. Turner & Townsend for Scottish Buildings Standards Agency, November 2007.
[33] Figures used were 3p/kWh for gas and 10p/kWh for electricity
[34] http://www.defra.gov.uk/environment/climatechange/uk/household/supplier/pdf/evidence-call.pdf

Table 18 Emissions savings, cost and cost-effectiveness of measures for existing housing

Ref		Capital cost per dwelling [1] £		Technical Potential per dwelling [2] tCO_2eq		Cost effectiveness [3] £/tCO_2eq	
		Low	High	2030	2050	2030	2050
D5	Energy efficient lighting (initially CFLs and later LEDs)	85	200	0.08	0.13	82	-72
D6	Solid Wall Insulation	1,309	3,272	0.54	0.54	-6	-6
	External insulation of cavity walls	As above		-	0.18	-	587
	Loft insulation up to 270mm	138	273	0.25	0.25	-17	-17
	Floor insulation (raised timber)	50	1,000	0.09	0.18	-5	-5
	Single to Low e double glazing	0	4,000	0.12	0.12	198	198
D7	Ground Source Heat Pumps	2,300	5,500	-	1.74	-	208
D8	PV in 2030	6,900	13,300	0.40		1,213	
	PV in 2050	14,225	142,250		3.72		1,167
D9	Biomass boilers	2,500	4,000	-	0.88	-	104
D10	Solar Water Heating (SWH)	1,650	2,475	0.67	0.72	305	335
D11	Micro wind	N/A	N/A	-	0.48	-	606
D12	Micro-CHP	1000	600	0.50	0.50	61	4

[1] Range of costs reflects high & low purchase cost, DIY vs. professional installation and marginal vs. full cost. Costs estimated by BRE based on information from suppliers; costs in 2030 assumed equal to costs in 2020 as no other information available.
[2] Potential reduction in Scottish CO_2 emissions, based on 8% of total UK savings (see comments below).
[3] Cost-effectiveness based on average of low and high costs.

The potential emissions savings and costs in Table 18 are mainly derived from analysis of the UK housing stock. No such analysis is available specifically for Scottish housing but factors discussed in Section 4.4.1 will result in some differences between the impact on UK vs. Scottish housing.

Options for new and existing housing

Table 19 shows the abatement for each measure in 2050. The three most significant measures are: ground source heat pumps, further insulation measures for existing homes and biomass boilers. Measures that reduce electricity use in the home, such as photovoltaics, have zero CO_2 reduction potential in 2050 because we are only dealing with direct emissions here. Indirect emissions from electricity supply are addressed in the electricity generation section (Section 5).

Table 19 Household Sector Potential abatement 2050

Ref	Policy name	Reduction potential (ktonnes CO_2 eq)
		2050
D1	New homes – 20% CO_2 reduction	92
D2	New homes – 30% CO_2 reduction	139
D3	New homes – 50% CO_2 reduction	231
D4	New homes – 75% CO_2 reduction	347
D5	More efficient lighting	55
D6	Further insulation measures for existing homes	526
D7	Ground source heat pumps	1,370
D8	Photovoltaics	1,540
D9	Biomass boilers	507
D10	Solar water heating	299
D11	Micro wind	199
D12	Micro-CHP	102

The cost of abatement in 2050 is shown in Figure 17, showing a wide range, from very low cost measures such as Micro-CHP and insulation for existing homes, through to very high cost measures such as Photovoltaics and 75% CO_2 reduction in new homes. The figures for micro-CHP are based on the assumption that the additional cost of micro-CHP over a condensing boiler will fall from £1500/unit today to £600/unit by 2050, due to technological advances and volume manufacture. They also assume that households with micro-CHP units will be able to sell electricity back to the grid at the price they pay for their electricity. Clearly there are considerable uncertainties on these figures, as would be expected when projecting costs and performance 40+ years ahead for technologies that have yet to emerge fully from the R&D stage.

Table 20 Household potential abatement costs in 2050

Ref	Policy name	£/t CO_2eq	Comment / Assumption
		2050	
D1	New homes – 20% CO_2 reduction	£367	From Turner & Townsend 2007[35]
D2	New homes – 30% CO_2 reduction	£573	From Turner & Townsend 2007
D3	New homes – 50% CO_2 reduction	£583	From Turner & Townsend 2007
D4	New homes – 75% CO_2 reduction	£830	From Turner & Townsend 2007
D5	More efficient lighting	-£72	From BRE 2005[36]
D6	Further insulation measures for existing homes	£95	From BRE 2005
D7	Ground source heat pumps	£208	From BRE 2005
D8	Photovoltaics	£1,167	From BRE 2005
D9	Biomass boilers	£104	From BRE 2005
D10	Solar water heating	£335	From BRE 2005
D11	Micro wind	£606	From BRE 2005
D12	Micro-CHP	£4	From CT Micro-CHP evaluation[37]

NB. £ 2005 basis

4.4.4 Acceptability and feasibility of policy options

Table 21 provides a summary of some of the main public acceptability and feasibility issues for policies in the households sector. Some of these issues relate to the particular technology employed while others relate to the nature of the policy. Public acceptability will also be influenced by the potential of the technology or policy to contribute to policy objectives other than climate change mitigation, e.g. fuel poverty alleviation.

[35] "The impact on costs and construction practice in Scotland of any further limitation of carbon dioxide emissions from new buildings", Turner & Townsend for Scottish Buildings Standards Agency, November 2007.
[36] "Reducing carbon emissions from the UK housing stock", Building Research Establishment, 2005.
[37] "Micro-CHP Accelerator Interim Report", Carbon Trust, November 2007

Table 21 Acceptability & feasibility issues for housing measures

Ref		Acceptability Issues	Feasibility Issues
		Legend: **+** *is a positive issue,* **-** *is a negative issue*	
D1-D4	New Housing	**+** Positive public opinion e.g. 73% believe all new buildings should by law be powered by renewable energy[38] **+** Opportunities for Scottish industry to take a lead & export ideas **-** Excessive additional costs could dampen the housing market & threaten construction targets	**+** Scottish Government has powers to implement and enforce Building Standards **-** Possible supply constraint for biomass (particularly if resource is also needed for industrial biomass heating and/or transport biofuels) **+/-** Suppliers of SWH and biomass boilers already in place, but how quickly could they gear up?
D6, D7, D9, D10	Existing Housing – Heating & Insulation	**+** Measures such as loft insulation are often cheaper than expected **+** Insulation improves comfort **-** Solid Wall Insulation (SWI) reduces internal dimensions or affects external appearance **-** Heat Pump installation typically involves digging up garden or drive **-** Biomass boilers may affect air quality under certain conditions although technologies can mitigate the impact **-** Landlord/tenant barrier particularly in private rented sector, mixed tenure/tenement properties	**+** Most technologies including heat pumps and biomass boilers are already available and proven, although there are some remaining performance and reliability issues **-** Large capital investment required for SWI, heat pumps or biomass boilers; householders unwilling or unable to invest (role for suppliers and/or Government?)
D5	Existing Housing – Lights & Appliances	**+** Awareness/uptake of energy efficient lighting already increasing **-** Perception of energy efficient lighting suffers from poor performance of earlier models **-** Appliances generally selected for other reasons and customers are not willing to pay much extra	**+** Other countries (e.g. Australia) have already announced phase out of inefficient lighting (it is understood that UK/Scotland cannot do this under EC trade rules and has instead initiated a voluntary agreement) **-** LEDs not yet available at reasonable cost **+** Market transformation process for appliances well embedded and working well

[38] From Allegra Project Renew, UK Consumer Perspectives on Renewable Energy, October 2006

Ref		Acceptability Issues	Feasibility Issues
		***Legend**: **+** is a positive issue, **-** is a negative issue*	
D7, D11, D12	Existing Housing – Micro-CHP and micro-generation	**+** Positive public opinion of renewables (see above) **+** Visual microgen technologies, e.g. micro-wind, becoming fashionable **-** Planning constraints in some areas **-** Public unaware of micro-CHP	**+** Likely to be defined as permitted development **-** Higher prices for exported electricity required **-** Grid integration issues if large quantities of variable output microgen such as PV or wind **-** Large upfront capital costs and long payback periods (see above) **-** Performance/retrofit issues

4.4.5 Sector Results – Households

The following figure shows 12 specific measures in the households sector selected from the options described above and plotted in terms of their:

- Abatement potential in 2050
- Abatement cost in 2050

The amount of carbon dioxide equivalent abated as a result of implementing each policy was assessed. The cost of implementing each policy was also determined. As a result of these considerations, taking into account uncertainties and any secondary impacts, each policy was placed in the abatement effectiveness matrix shown in Figure 12 and assigned a priority. This categorisation was based on the individual policy measure in isolation rather than its impact or cost when implemented alongside other policies. Further details of the categorisation are given in Section 5.

In general the measures for new housing are less cost-effective, as are microgeneration technologies. However, as explained in the previous sections, there is considerable uncertainty over the costs associated with these options. The most cost-effective option appears to be more efficient lighting, although this only has a small impact on total emissions. Improved insulation (largely solid wall insulation), micro-CHP and biomass boilers all give significant potential savings at low or medium cost. As stated above, this analysis has been based on the UK housing stock and further work would be required to confirm the potential and costs of these options in Scotland.

Compared with other sectors, Scotland has relatively strong policy levels in the households sector. Planning matters are devolved, as are building standards, and Scotland operates its own grant schemes and social programmes aimed at reducing fuel poverty. On the microgeneration side, again Scotland can influence planning through permitted development and can provide grants and adapt the Renewables Obligation.

Some policy levers are held elsewhere, such as Energy Performance Certificates (EPCs) and the labelling of appliances. Even proven and relatively cost-effective technical measures such as loft, cavity and solid wall insulation face many barriers and it has been suggested by the Environmental Change Institute and others that progressive levels of Supplier Obligation will not be sufficient to tackle these. Instead they recommend a regulatory approach, supported by grants for poorer households, whereby houses have to meet minimum energy efficiency standards before they can be sold or let, with this standard progressively increasing. These standards could be based on the categories in the EPCs, e.g. phasing out F rated housing. A less stringent version of this concept has been considered by UK Government, whereby minimum standards are required for the whole house before planning permission is granted for a modification. It is not clear whether Scotland has the policy levers to implement this sort of minimum standards approach unilaterally.

Cost per tonne (£/t CO_2 eq)	High		D10 D11	D8 D7
	Medium	D1	D2, D3, D4, D6, D9	
	Low	D5	D12	
	Very low (cost saving measures)			
		Low	Medium	High
		Quantity of GHG Abated (Mt CO_2 eq)		

D1	New homes – 20% CO_2 reduction
D2	New homes – 30% CO_2 reduction
D3	New homes – 50% CO_2 reduction
D4	New homes – 75% CO_2 reduction
D5	More efficient lighting
D6	Further insulation measures for existing homes
D7	Ground source heat pumps
D8	Photovoltaics
D9	Biomass boilers
D10	Solar water heating
D11	Micro wind
D12	Micro-CHP

Figure 12 Summary – Households[39]

Key:

Very High priority measures
High priority measures
Medium priority measures
Low priority measures
Very Low priority measures

[39] The ranking of policies D1, D2, D3, D4, D6 and D7 include an adjustment for uncertainty – see Section 5.1 for details

4.5 Public sector

This section addresses the emissions from fuel use in public sector buildings, emissions from electricity and transport are dealt with in the relevant sections of this report. Fuel consumption in the public sector has a small but important impact, generating around 2% of Scotland's CO_2 in 2005. The public sector also has an important leadership role, demonstrating carbon and emission reductions by example.

The Public Sector in itself is a broad and diverse sector that includes a number of different services. For the purposes of this study it is taken to include:

- Central Government both UK (including BERR, MoD, HMCE etc.) and Scottish Devolved Administrations
- Local Authorities – there are 32 Local Authorities in Scotland
- NHS Health Boards
- Police, Fire and other service bodies
- Educational bodies
- Community sites
- Religious sites and historic buildings

As some of these service areas have similarities with those in the commercial sector it is clear that there will be overlaps with the policy suggestions. Therefore the main focus of this section is on the performance of public sector buildings.

Further detail on emissions savings for the public sector is provided in Appendix 7

4.5.1 Emissions & trends

Understanding and predicting the potential in the public sector is not straight forward as each sub-sector has a different baseline, characteristics and energy demand. Only by understanding the specific needs and existing conditions with each of the sectors is it possible to predict the full potential. Fortunately, much work has been done in each of these public sector areas and information relating to each has been broken down in the following sub sectors:

- Central Government both UK (including BERR, MoD, HMCE etc.) and Scottish Devolved Administrations
- Local Authorities
- NHS Health Boards
- Educational bodies

A range of measures are already in place to reduce emissions from public sector buildings. These include: building regulations, loan funds and grant support. Hence there is a gradual downward trend in the baseline emissions, due to the gradual impact of these measures.

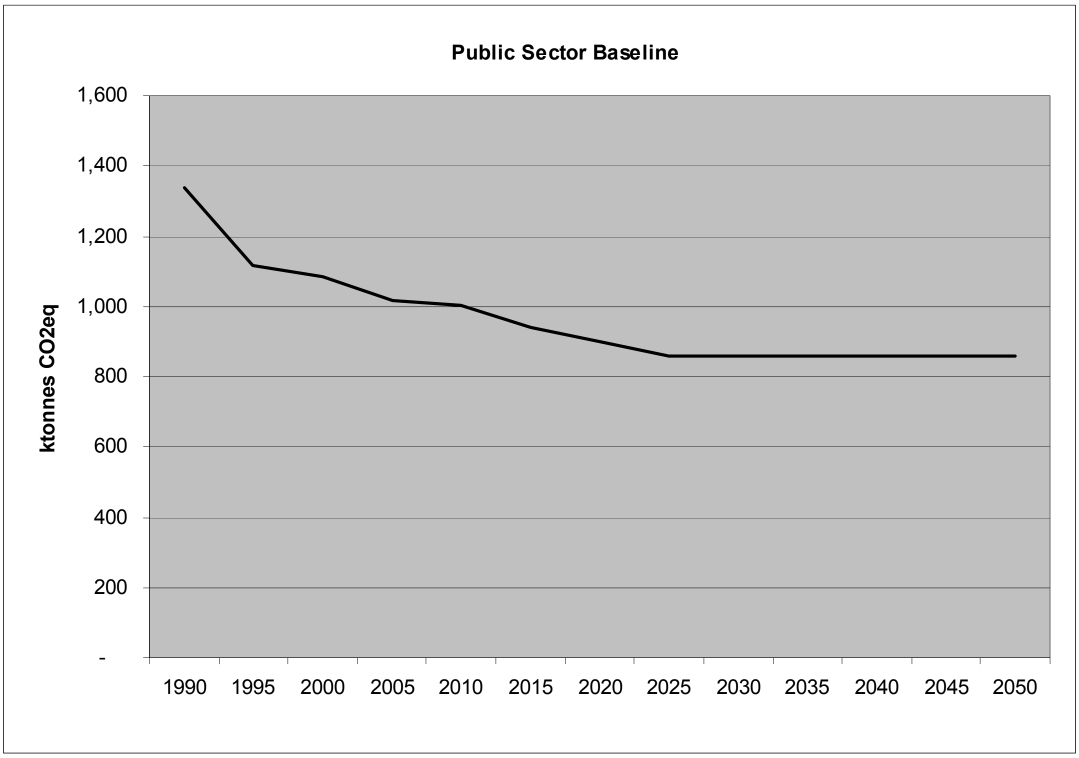

Figure 13 Baseline GHG emissions from the public sector in Scotland, 1990-2050

4.5.2 Identification of policy options

Reduction in carbon emissions in the public sector can be generated in a number of ways by introducing new requirements, new technologies and new processes.

These can be grouped to include:

- Building Standards
- Procurement processes
- Behavioural aspects
- Institutional change

In 2007 the Scottish Government published its proposed environmental policy stating its targets and how, within the public sector, it would reduce its carbon emissions. The proposed targets are:

- Reduce CO_2 emissions caused by energy use in public sector buildings by 12.6%, from 1999/2000 levels, by March 2011.
- Reduce CO_2 emissions caused by energy use in public sector buildings by 30%, from 1999/2000 levels, by March 2020.

To meet these proposed targets a number of routes were set out, including;

- Maintenance of plant and machinery to ensure optimum efficiency.
- Effective management of heating plant.
- Ensure new build and refurbished premises meet appropriate energy efficiency levels.
- Encourage staff to save energy.
- Procure electricity from renewable sources, investigate options for off-setting emissions from other energy use.
- Adopt the Carbon Trust's Carbon Management Programme.
- Investigate options for on site micro-generation using renewable energy technologies.
- Continue to research new products, methods and technologies for conserving energy.
- Develop an energy action plan.
- Display the 'operational ratings' (actual energy performance) at target buildings.

There are a wide range of new policy options available to the public sector. A long list of nearly 50 options were identified. Emphasis is largely on the refurbishment of the existing estate as current construction rates for the sector are low as a proportion of the total estate, and new build is in any case much better addressed through existing mechanisms. A sample of the options, collated under 4 headings, are listed below:

- **New Public Buildings**
    - Tighter Building Standards as recommended by the Sullivan report.
    - Tighter planning controls and use of sustainable energy, including district heating.
- **Existing Public Buildings**
    - Tighter Building Standards as recommended by the Sullivan report for refurbishment etc.
    - Centralised recording of buildings' energy performance, analysis and rankings.
- **Procurement and Finance**
    - Target setting and performance measures sustainability in current .procurement practises.
    - Ring fencing for sustainability funding and measures for LA.
- **Influencing**
    - Training of staff on sustainability and integration into buildings.

Most of these measures would be implemented via the Building Standards, Carbon Management and the CEEF, providing regulatory and fiscal investment incentives to encourage uptake. Hence the focus will be on enhancing or extending these existing measures, to extend their scope, and reach and therefore increase the potential impact.

For example CEEF funding for energy efficiency investments is currently restricted to projects, which have a payback period of less than 5 years. This is restrictive for a number of new technologies that are unable to demonstrate sufficient payback. By extending the payback period to 7-10 years it would allow the CEEF programme to become more flexible and provide greater coverage. Recently this approach has been partially adopted through the extension of CEEF to allow for renewable energy projects with a payback of up to 7.5 years.

The Carbon Management programme provides support for 1 year to a Local Authority, NHS Trust or Education Body to enable development of an implementation plan, which looks to the following 5 years. This provides a good strategic platform for change and uptake of measures applicable under the CEEF funding and other behavioural change aspects. To date no Carbon Management programme has come to the end of its 5 years but there is hope that once a programme and strategy becomes embedded into existing policy it would continue and therefore offer greater savings than initially estimated.

4.5.3 Emissions reduction potential, and assessment of costs

Table 22 shows the emissions reduction potential that could be achieved by 2030 and 2050 from each of the main policies or types of policy listed in the previous section. It is not possible to derive the total achievable savings from the sector by simply adding up the savings in the final column because there are overlaps and interactions between policies.

Table 22 Emissions Reduction potential Public Sector 2030 & 2050

Ref	Policy name	Reduction potential (as a % of relevant sector baseline)		Comment / Assumption
		2030	2050	
PS1	Expand Building Standards	21%	24%	From 2010 Building Standards extended to include higher requirements for refurbishment, reducing emissions in refurbished buildings by 25%.
PS2	Further revision of the Building Standards	N/A	29%	Builds on PS1, from 2035 a further 10% saving required from refurbished buildings.
PS3	Extending CEEF	13%	25%	Further extending the CEEF funding to accept applications that have a higher payback period.
PS4	Enhancing Carbon Management	7%	20%	Continuation to cover all public sector and further phases taking total savings to 20%

Table 23 Emissions Reduction potential Public Sector 2030 & 2050

Ref	Policy name	Reduction potential (ktonnes CO_2 eq)	
		2030	2050
PS1	Expand Building Standards	180	206
PS2	Further revision of the Building Standards	N/A	245
PS3	Extending CEEF	107	214
PS4	Enhancing Carbon Management	57	171

Many of the public sector buildings that are in use now will remain in use in 2050. Hence the focus is on measures to reduce the emissions from these existing buildings. As well as considering the policy mechanism to ensure this reduction, it is worth giving thought to the technical solutions that will provide the basis for such a reduction.

Much has been done in the domestic sector in terms of carbon reduction associated with building fabric through initiatives such as EEC and the forthcoming CERT, however in public sector buildings the same characteristics often apply but are not corrected. Similarly there is little in the current Building Standards requiring improvement of an existing building when refurbished at any level. We would therefore expect the technical solutions reflected in the Standards to include a number of the traditional energy measures, from Cavity Wall Insulation and Double Glazing to Solar Shading.

The CEEF funding goes someway in supporting some of these traditional solutions. However there are to date limited options in some areas, for example there is still a need to understand what the best options are to increase the U-value of an existing solid wall.

Estimated costs are shown in Table 24.

Table 24 Estimated costs of measures for the public sector

Ref	Policy name	£/t CO_2eq		Comment / Assumption
		2030	2050	
PS1	Expand Building Standards	£50	£50	No data – default value used is the typical cost for Group 2 measures
PS2	Further revision of the Building Standards	N/A	£50	No data – default value used is the typical cost for Group 2 measures
PS3	Extending CEEF	£100	£100	Higher than the current level of CEEF funding which is based on £66/tonne of CO_2
PS4	Enhancing Carbon Management	£200	£200	The Carbon Trust currently aim for a minimum cost for carbon of £100/tonne of CO_2

4.5.4 Acceptability and feasibility of policy options

The contribution of public sector buildings to Scottish GHG emissions is small. However, the sector as a whole has a clear role for taking a lead to demonstrate to others what can be achieved. Many outside of the sector with responsibilities for reducing emissions elsewhere are likely to consider it unacceptable for the government not to take proportionate action of its own, including adoption of emerging products and solutions.

For this sector many of the policy levers are directly in the control of the Scottish Government, even areas such as EU legislation may be enacted via regulation that is interpreted and administered in Scotland. Hence all four of the proposed measures for the Public Sector are fully in the competency of the Scottish Government.

Table 25 Acceptability and of Public Sector Measures

Ref	Policy name	Acceptability Issues	Feasibility Issues
		***Legend**: **+** is a positive issue, **-** is a negative issue*	
PS1	Expand Building Standards	**+** Continues the trend to increase the scope and standards required **-** Increased capital cost for new public sector buildings	**+** Continues the trend to increases the scope and standards required
PS2	Further revision of the Building Standards	As above	As above
PS3	Extending CEEF	**+** Proven scheme **+** Reduces energy costs, savings available for front line services	**+** Continues existing scheme with good track record **-** Investments become less cost effective and riskier
PS4	Enhancing Carbon Management	**+** Demonstrates leadership role for the public sector	**+** Continues existing scheme with good track record

4.5.5 Sector Results – Public

Based on the:

- The abatement potential for the 4 measures discussed above
- The costs for these measures
- The acceptability and feasibility of these measures

All four policy measures for the public sector are considered to have a material contribution to make to the 2050 reduction. The following figure shows these four measures plotted in terms of their:

- Abatement potential
- Abatement cost

The amount of carbon dioxide equivalent abated as a result of implementing each policy was assessed. The cost of implementing each policy was also determined. As a result of these considerations, taking into account uncertainties and any secondary impacts, each policy was placed in the abatement effectiveness matrix shown in Figure 14 and assigned a priority. This categorisation was based on the individual policy measure in isolation rather than its impact or cost when implemented alongside other policies. Further details of the categorisation are given in Section 5.

All of the measures considered have Medium abatement potential, with expansions and revisions to building regulations achieved at lower cost than further extension of CEEF or Carbon Management. This assumes that changes to building regulations are implemented in early years so that a larger number of buildings standing in 2050 have been built to these improved standards.

Cost per tonne (£/t CO_2 eq)	**High**			
	Medium		**PS3 PS4**	
	Low		**PS1 PS2**	
	Very low (cost saving measures)			
		Low	**Medium**	**High**
		Quantity of GHG Abated (Mt CO_2 eq)		

PS1	Expand Building Standards
PS2	Further revision of the Building Standards
PS3	CEEF
PS4	Carbon Management

Figure 14 Summary – Public Sector

Key:

Very High priority measures
High priority measures
Medium priority measures
Low priority measures
Very Low priority measures

4.6 Transport

More detailed information on the transport sector is provided in Appendix 8.

4.6.1 Emissions and trends

CO_2 emissions from transport in Scotland have been rising since 1990, and are projected to rise further in future years (see Figure 15). For the years between now and 2025, projected emissions for each mode of transport in Scotland have been based on the emissions projections developed by BERR and estimates for changes in transport activity, split by mode of transport, based on projections from the Department for Transport's (DfT's) National Transport Model. For the years between 2025 and 2050, projected emissions estimates have been developed using transport activity projections data and vehicle efficiency improvement estimates from the UK MARKAL model. Using these datasets, by 2030, emissions are forecast to be 24% higher than in 1990 under the business-as-usual scenario, and 33% higher in 2050. The road transport sector is the dominant source of transport emissions, accounting for over 80% of transport CO_2 emissions in Scotland in 2050. This is a similar contribution to overall emissions seen in 2005. Emissions from aviation have more than doubled since 1990 and are forecast to increase further. This graph does not include indirect emissions from the generation of electricity used for rail transport, which are covered under the electricity generation sector. The main driver for the anticipated increases in emissions is the projected significant growth in demand for all modes of transport, including increases in the number and length of commuting, leisure, and freight journeys. Significant growth in demand is projected at both the UK level and for Scotland – for example, the Scottish Government's Transport Delivery Report estimated that road traffic volumes would rise by 27% by 2021 against 2001 levels.

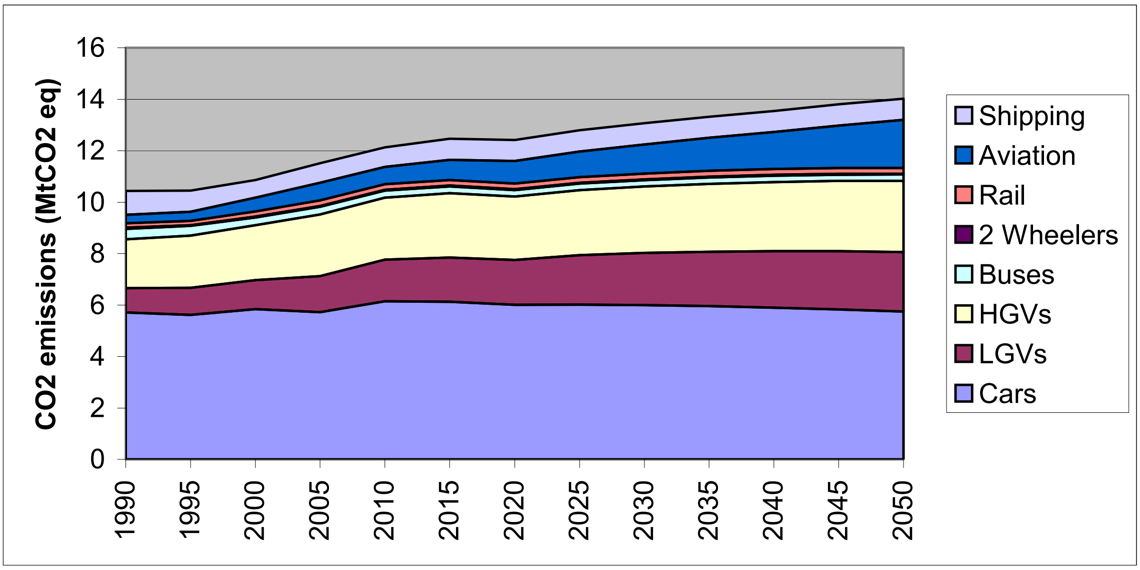

Figure 15 Historic and projected business-as-usual CO_2 emissions for the transport sector in Scotland

The transport sector is also a contributor to emissions of N_2O. N_2O emissions from transport in Scotland were about 0.47 $MtCO_2eq$ in 2005, which represents a rapid increase since 1990 (see Figure 16) but is still less than 4% of total GHG emissions from this sector. Because of the relatively low contribution to overall GHG emissions (less than 1%), we do not consider N_2O emissions from transport further in this report. It is possible that N_2O emissions from transport will increase further in future years, due to technical abatement options being applied to road transport to reduce emissions of NO_x[40]. It is important to note that N_2O emissions are not included in the definition of NO_x emissions.

[40] The term NO_x refers to emissions of nitric oxide (NO) and nitrogen dioxide (NO_2), which together are commonly referred to as oxides of nitrogen. No other types of emissions are included within the definition of NO_x.

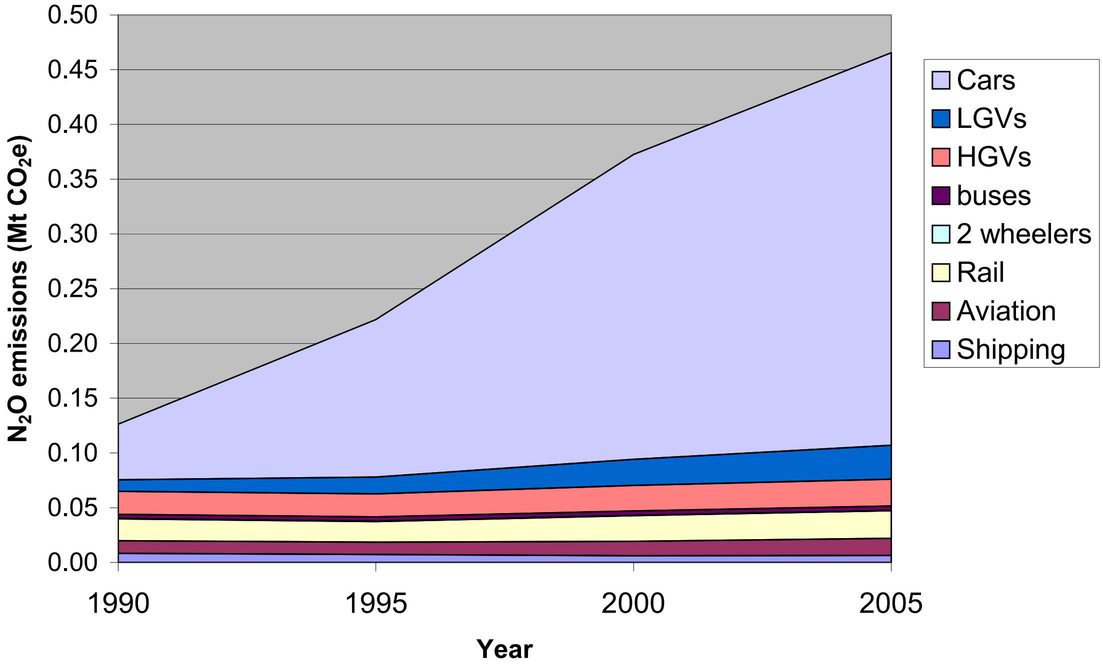

Figure 16 Trends in N_2O emissions for the transport sector in Scotland

4.6.2 Identification of policy options

For the transport sector, there are already a number of policies at the UK or European level that are concerned with reducing emissions of CO_2 – these policies have had, and will continue to contribute towards reducing emissions from the transport sector in Scotland. These policies can be split into supply-side measures (i.e. those that influence the uptake of low-carbon technologies) and demand-side measures (those that influence the demand for travel, or encourage mode-switching to transport modes with lower CO_2 impacts). A list of existing policies, including future planned policies already included in the 2007 Energy White Paper analysis of business as usual emissions projections, is provided below:

Existing policies include:

- Fuel Duty escalator
- Car manufacturers' voluntary agreement on CO_2 emissions from new cars
- European Commission proposed regulatory replacement for the voluntary agreement on new car CO_2 emissions
- Company car taxation system
- Graduated Vehicle Excise Duty
- Emissions reduction policies in Scotland's National Transport Strategy (measures focused on freight)
- Renewable Transport Fuels Obligation
- Inclusion of aviation in the EU ETS from 2011
- Increased uptake of transport biofuels, reflecting the EU's binding target of 10% for the share of biofuels in petrol and diesel for each Member State by 2020. The Gallagher report[41] provides an important source of analysis on the potential indirect impacts of biofuels on carbon emissions via land use change and the impacts on food production.

[41] http://www.dft.gov.uk/rfa/reportsandpublications/reviewoftheindirecteffectsofbiofuels.cfm

A wide range of further new policy options for reducing GHG emissions from the transport sector have been identified, and can broadly be split into supply-side measures (technology measures), and demand reduction measures. The main technologies of interest are:

- Biofuels
- Hybrid-electric technology
- Battery-electric technology
- Hydrogen

Potential demand side measures include, amongst others:

- Encourage uptake of "Smarter Choices" measures[42]
- Restrict growth in aviation sector.
- Road pricing with emissions element e.g. emission-related congestion charging or national road pricing scheme.
- Eco-driving (training drivers to drive more efficiently).

For this study, biofuel options have explicitly been excluded from the analysis because there are currently a number of questions around their global sustainability impacts. In particular, there is evidence to indicate that demand for biofuels is leading to increases in food prices in some countries. Another key issue concerns changing land use patterns whereby forests are being cut down in certain regions of the world so that land can be used for growing biofuel resource feedstocks. Land use change of this nature leads to the release of sequestered greenhouse gas emissions, and also leads to the removal of a CO_2 sink. For these reasons, this study has not considered potential further increases in the uptake of biofuels beyond the levels already agreed for the Renewable Transport Fuels Obligation. The UK Government carried out a high-level review of the indirect impacts of biofuels during 2008, and the findings of which are now available[43].

4.6.3 Emissions reduction potential, and assessment of costs

The full list of the abatement options that have been assessed for the transport sector is shown in Table 26 below, while Table 27 provides initial estimates of the impact of each measure on annual CO_2 emissions along with estimates of cost effectiveness. Data on the costs and cost effectiveness of different measures have been taken from recent research in this area, including (amongst others) the King Review of Low Carbon Cars, and the Commission for Integrated Transport's 2007 study on Transport and Climate Change. Potential CO_2 savings from electric and plug-in hybrid vehicles are based on the assumption that grid electricity will be low carbon by 2030, which is consistent with the analysis of the power generation sector in this study. Where appropriate, we have taken unit cost data and emissions abatement performance data for specific transport sector measures from these previous studies, and used this information to conduct further analysis in order to calculate cost effectiveness values for each measure. More detailed data on costs and emissions (including references) are provided in Appendix 8.

The potential future implementation of technology policies will be driven by the availability and maturity of each specific technology. For the transport sector, this means that advanced petrol engine technologies and hybrid-electric options could be considered over the short-to-medium term (between now and 2020), whilst battery-electric technology is further from maturity and can only be considered as a potential medium term option for widespread introduction (potentially 2020 onwards). Hydrogen is even further from maturity and can only realistically be considered as a long-term option (post 2030 for widespread uptake). It must be stressed that even though many of the technology options are medium-term or long-term options, much pre-policy work can be initiated in the short term to pave the way for the future introduction of these potential low-carbon technologies. In particular, developing national-level strategies for transport technologies such as battery electric or hydrogen vehicles could be carried out over the short term.

[42] Smarter Choices are techniques for influencing people's travel behaviour towards more sustainable options such as encouraging school, workplace and individualised travel planning (see www.dft.gov.uk/pgr/sustainable/smarterchoices/)
[43] http://www.dft.gov.uk/rfa/reportsandpublications/reviewoftheindirecteffectsofbiofuels.cfm

Table 26 Emissions abatement options for the transport sector

Ref	Policy Option	Technical measure	2030 reduction potential for sector[44]	2050 reduction potential for sector
T1	Tightened passenger car CO_2 targets	Stop-start technology for new cars	1%	1%
T2	Tightened passenger car CO_2 targets	Advanced petrol engine technologies	2%	3%
T3	Tightened passenger car CO_2 targets	Micro hybrid technology (Stop-start technology with regenerative braking)	3%	3%
T4	Encourage uptake of hybrid technology	Mild hybrid technology for petrol and diesel cars	6%	6%
T5	Encourage uptake of hybrid technology	Full hybrid technology for petrol and diesel cars	8.5%	11%
T6	Encourage uptake of hybrid technology	Plug-in hybrid technology	15%	28%
T7	Encourage shift battery-electric technology	Battery-electric technology	10%	40%
T8	Encourage shift hydrogen technology	Hydrogen fuel cell technology	0% to 3%	0% to 13%[45]
T9	Eco-driving	Training all drivers to drive with fuel efficiency in mind	2%	3%
T10	Encourage uptake of "Smarter Choices" measures	Packages of soft measures to reduce demand for private transport	2%	4%
T11	Freight measures	Package of measures based on improved vehicle technologies, improvements in operational performance and in purchasing	6%	7%
T12	Restrict growth in aviation sector	No increases in the numbers of flights to and from Scotland's airports from 2020 onwards	3%	8%
T13	Hybrid buses	Buses equipped with hybrid-electric technology to reduce emissions	1%	1%
T14	Road pricing with emissions element	Scotland-wide road pricing scheme, with incentive to encourage uptake of low emissions vehicles	7%	6%

[44] Shown as percentage reduction of transport sector emissions in 2030 (or 2050) not 1990.
[45] The large range of possible values reflects the different fuel options for producing hydrogen.

Table 27: Estimates for 2030 and 2050 of the isolated abatement potential and cost effectiveness of options for the transport sector

Ref	Option	Technical Potential (ktCO_2 eq abated)		Cost effectiveness £/tCO_2 eq	
		2030	2050	2030	2050
T1	Stop-start technology for new cars	140	143	-£190 to -£415	-£211 to -£455
T2	Advanced petrol engine technologies	300	428	-£375 to -£586	-£506 to -£682
T3	Micro hybrid technology (Stop-start technology with regenerative braking)	340	428	-£228 to -£340	-£251 to -£357
T4	Mild hybrid technology for petrol and diesel cars	600	857	-£333 to -£409	-£365 to -£451
T5	Full hybrid technology for petrol and diesel cars	1,200	1,571	£275 to £312	£280 to £322
T6	Plug-in hybrid technology for cars and vans	2,000	4,030	£445 to £715	£625 to £698
T7	Battery-electric technology for cars, vans, buses and HGVs	1,280	5,699	-£35 to +£144	-£39 to +£159
T8	Hydrogen fuel cell technology for cars	190	959	£526 to £943	£422 to £685
T9	Training all drivers to drive with fuel efficiency in mind	290	498	£81	£81
T10	Packages of soft measures to reduce demand for private transport ("Smarter Choices" measures)	290	587	-£22	-£22
T11	Package of measures for road freight based on improved vehicle technologies, improvements in operational performance and in purchasing	0	1,017	-£130	-£130
T12	No increases in the numbers of flights to and from Scotland's airports from 2020 onwards	830	1,180	Unknown	Unknown
T13	Buses equipped with hybrid-electric technology to reduce emissions	30	92	£37	£32
T14	Scotland-wide road pricing scheme, with incentive to encourage uptake of low emissions vehicles	886	886	£2,710	£2,658

Note: negative costs indicate that reductions in operating costs outweigh any increases in capital costs, and hence there may be overall reductions in the costs faced by consumers or vehicle operators.

There are potentially many interactions between these possible measures, e.g. a vehicle can either be battery electric or hydrogen fuelled but not both, and so many of the options fall out when considered in series (see Section 5). The measures with the greatest potential impact are plug-in hybrid and electric vehicle technologies. The technical potential figures are based on the assumption that up to 100% of cars and vans, 50% of buses and 20% of HGVs could conceivably be electrically powered by 2050. These figures implicitly assume major advances in the technology to increase their range and/or cut recharging times. Similarly the maximum deployment of plug-in hybrids is assumed to be 100% for both cars and vans by 2050.

For a number of the options for the transport sector, there may be limited scope for the Scottish Government to act independently of the UK Government, or in some cases independently of the European Commission. For example, options T1, T2, and T3 concern the introduction of low carbon technology options based on a policy driver of stringent CO_2 targets for passenger cars. The European Commission is currently in the process of developing legislation that will regulate CO_2 emissions from new passenger cars. Under the Scotland Act, responsibility for representing the interests of all regions and nations of the UK with regard to potential EU legislation remains with the UK Government, and hence Scotland cannot independently set its own targets for vehicle manufacturers. Additionally, whilst the Scottish Government has devolved powers for a number of areas, including transport, the UK Government retains reserved powers over fiscal and economic policy. This means that the Scottish Government cannot, independently of the UK Government, use the taxation system in new ways to encourage a shift to more sustainable transport options. This may be important with regard to new vehicle technologies (e.g. battery-electric or hydrogen fuel cells), where previous experience in the UK and abroad has shown that either legislative measures or significant fiscal incentives are necessary in order to stimulate significant levels of uptake.

4.6.4 Acceptability and feasibility of policy options

Table 28 provides a summary of some of the main public acceptability and feasibility issues for transport policies.

Table 28 Acceptability & feasibility issues for transport measures

	Acceptability Issues	**Feasibility Issues**
Ref	***Legend**: **+** is a positive issue, **-** is a negative issue*	
Improvements in vehicle efficiency (T1, T2, T3, T4, T5, T11, T13)	**+** Reduced fuel consumption with no discernible change in driving behaviour **-** Some increase in the price of vehicles **-** Possible/perceived safety implications from light weighting of vehicles	**+** Proven technologies already used on some vehicles
Demand side measures (T9, T10, T12, T14)	**+** Measures such as travel plans well received by users **+** Reduced car traffic can be beneficial for pedestrians, cyclists and bus users **+** Positive impacts on air quality **+** Positive impacts on health and tackling obesity **-** Congestion charges and road charging unpopular	**+** London has shown congestion charging can work **-** Will be issues to resolve around larger scale road charging, e.g. dealing with foreign vehicles
Alternative fuels (T8)	**+** Liquid biofuels can be used in a similar way to petrol/diesel **-** Hydrogen would require unfamiliar fuelling methods and slower fill times **-** Hydrogen has perceived (and some real) safety implications	**+** Biofuels can be introduced as blends with petrol or diesel initially, such that engines do not need to be modified for use **-** Biofuels production faces challenges such as competition for land and questions over sustainability in developing countries **-** Hydrogen infrastructure not yet available
New vehicle types (T6, T7, T8)	**+** Public opinion of fuel cell vehicles generally good, though few people have seen one yet **-** Negative connotations with hydrogen (see above) **-** High costs of fuel cell vehicles **-** Electric vehicles tend to have an image problem (reminiscent of milk floats) and too short a range for many uses	**-** Technologies far too expensive for commercial application at present **-** Hydrogen infrastructure required for fuel cell vehicles

4.6.5 Sector Results – Transport

The following figure shows 14 specific measures in the transport sector selected from the options described above and plotted in terms of their:

- Abatement potential in 2050
- Abatement cost in 2050

The amount of carbon dioxide equivalent abated as a result of implementing each policy was assessed. The cost of implementing each policy was also determined. As a result of these considerations, taking into account uncertainties and any secondary impacts, each policy was placed in the abatement effectiveness matrix shown in Figure 17 and assigned a priority. This categorisation was based on the individual policy measure in isolation rather than its impact or cost when implemented alongside other policies. Further details of the categorisation are given in Section 5.

The figure shows that improvements to vehicles, such as start-stop technologies, give medium or high abatement potential at very low cost. Full hybrid and battery electric technologies give higher abatement potential still, but at medium cost. Behavioural measures such as demand reduction and driver training offer medium abatement potential at low to medium cost. The other measures listed are less favourable, offering low or medium abatement potential at medium or high cost.

As with other sectors, the policy levers in the transport sector are controlled at various levels of authority, including EU-level, UK Government level, and Scottish Government level. The Scottish Government cannot independently set the rate of transport fuel duty, vehicle taxation levels, or set Scotland-specific targets for average CO_2 emissions performance of new vehicles, all of which are policy measures that could have a significant impact on reducing emissions from the transport sector. However, the Scottish Government could put in place grant support schemes to encourage the uptake of low CO_2 vehicles - such schemes could be strategically targeted to specific modes of transport, if appropriate. Scottish local authorities can also use planning policies and other demand-based measures such as work-place travel plans and improved public transport services in order to reduce the need for private transport in urban areas.

Cost per tonne (£/t CO_2 eq)	**High**	**T8**	**T5, T6, T14**	
	Medium	**T13**	**T9**	**T7**
	Low		**T10**	
	Very low (cost saving measures)		**T1, T2, T3, T4**	**T11**
		Low	**Medium**	**High**
		Quantity of GHG Abated (Mt CO_2 eq)		

T1	Stop-start technology
T2	Advanced petrol engine technologies
T3	Mild hybrid technology (stop start + regenerative braking)
T4	Mild hybrid technology
T5	Full hybrid technology
T6	Plug in hybrid technology
T7	Battery electric technology for cars
T8	Hydrogen Fuel Cell technology
T9	Driver training
T10	Demand reduction for private transport
T11	Freight vehicle improvements
T12	Restrict growth of aviation (not included above)
T13	Buses with hybrid-electric technology
T14	Road pricing with emissions element

Figure 17 Summary – Transport[46]

Key:

Light green	Very High priority measures
Blue	High priority measures
Orange	Medium priority measures
Yellow	Low priority measures
Pink	Very Low priority measures

[46] The ranking of policies T5 to T10, T13 and T14 include an adjustment for uncertainty – see Section 5.1 for details

4.7 Agriculture

This section presents the results of the assessment for agriculture. More details of the policy options for agriculture are presented in Appendix 9.

4.7.1 Emissions & trends

Figure 18 shows historic and projected GHG emissions from the agricultural sector split by gas. This shows direct emissions from the agriculture sector using the NAEI definitions, i.e. excluding emissions associated with land-use change or transport. Emissions of methane (CH_4) and nitrous oxide (N_2O) are much more significant than CO_2 emissions in this sector. Both CH_4 and N_2O have considerably greater potential to retain radiation and warm the atmosphere than CO_2; the GWP for CH_4 and N_2O are 21 and 310 respectively. Total agricultural emissions of GHG for 2005 were reported as 8,013 kt CO_2 eq, a decrease of 13% since 1990.

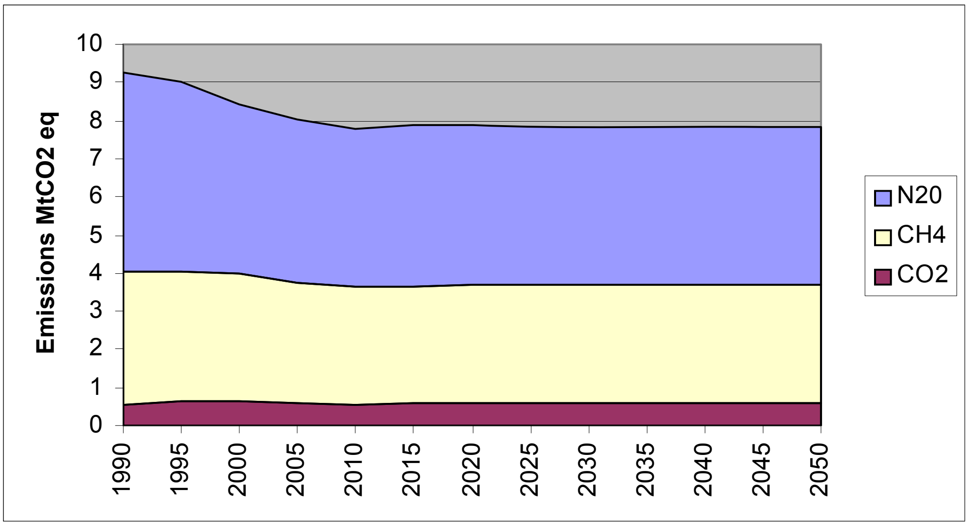

Figure 18 Trends in GHG emissions in Scotland from 1990 to 2050

Although there have been significant reductions in agricultural GHG emissions since 1990, the downward trend is not expected to continue under business as usual projections. The reductions in N_2O emissions reported since 1990 have been due to:

- Decreases in livestock numbers, mainly as a result of poor financial returns. This was exacerbated for beef and sheep by withdrawal of support following CAP reform.
- Decreasing Nitrogen fertiliser use. This has decreased mainly because the price of N fertiliser has gone up while the returns from crops have gone down.
- The need to reduce nitrate leaching to watercourses has also lead to some reductions in fertiliser-N use, mainly as a result of making better allowance for the N supplied by livestock manures and crop residues.
- The decoupling from production of direct support to agriculture following the 2003 CAP reforms.

The reason emission reductions are not expected to continue to decrease is mainly due to the response to Common Agriculture Policy (CAP) reform working its way through the system by about 2015. After that date the surviving livestock industry should be of the size that the market can support. Similarly N fertilizer use is not expected to further decrease as crop prices have increased recently, due to increased global demand, a demand that is likely to be maintained in the foreseeable future. Table 29 shows the main sources of direct emissions.

Table 29 Direct emissions from agriculture as % of total direct emissions from agriculture, 2006

Sector	Enteric CH_4	Manure CH_4	N_2O	Total
Dairy	7.7	1.9	3.3	12.9
Beef	30.8	3.1	14.3	48.2
Sheep	13.9	0.3	5.9	20.1
Pigs	0.3	0.5	0.9	1.7
Poultry	0	0.4	0.8	1.2
N Fertilizer			15.8	15.8

Emissions of N_2O from livestock production are from grazing (14.7% of total) and manure management (10.6%), mainly following application of manures to land.

There are significant uncertainties with respect to the longer-term impacts of CAP reform and changes to World Trade arrangements. Short-term protection from the impacts of CAP reform is assured by use of the Beef National Envelope in Scotland and dairy farmers exiting farming through beef production. However it is likely that these will level off, as the environmental benefits associated with maintaining a minimum stocking density for cattle will be supported through the Rural Development Programme. The expected relative increase in beef prices may offset the costs of any further cross compliance requirements but worldwide competition will lead to a small continual decline in numbers.

While proposals for further reform may be expected in 2008, and were submitted in 2007, the final outcome to the subsequent consultation are still unknown. Furthermore, socio-economic changes under the CAP Health Check (such as phasing out milk quotas) may have an indirect impact on land use and management.

Globally we are entering a new phase where agricultural politics is at the top of the agenda. While this is unlikely to result in short-term legislative changes (at least in the EU) the new emphasis on food security has the potential to shift focus away from environmental management and back to food production which is likely to further affect land use and management.

4.7.2 Policy options

Over half of the direct GHG emissions from agriculture arise from enteric fermentation. Methane is an unavoidable by-product of microbial processes in the rumen, up to 10% of the carbon ingested can be transformed into CH_4. However, methods have been proposed and evaluated to reduce CH_4 emissions from the rumen. Proposed measures may be grouped into:

- Changes to the diet to reduce the intake of substrates for CH_4 emissions.
- Direct manipulation of rumen conditions to reduce the populations of methanogenic microbes.
- Systematic changes within the livestock industry to maintain livestock output with fewer ruminant animals (reduce emissions of CH_4 per kg of product).

Estimated abatement reductions for CH_4 emissions are shown in Table 30. These are shown as percentage reductions in CH_4 and will apply from whatever year they are introduced. The potential measures cited in this table overlap and hence the potential reductions quoted are not cumulative. Costs for these options have not been provided as we are currently uncertain about how current the values provided in the analysis of Jarvis et al. (2001)[47]. Within these tables, those policies that are considered in more detail later in this section are given a reference no, A1, A4, etc.

Table 30 Potential emissions reductions for enteric CH_4

[47] Jarvis SC, Beevor DE, Webb J, ApSimon H and Gibson AI, 2001. *Cost curve assessment of mitigation options in greenhouse gas emissions from agriculture*, Defra project CC0229, 2001. See: http://www2.defra.gov.uk/research/Project_Data/More.asp?I=CC0229&M=KWS&V=Gas

Ref	Description of potential measures to adjust dietary intake by livestock or to manipulate the rumen	% reduction in CH_4 emissions[48]
A1	Continuing and conventional dietary improvement	<10-25
-	Propionate precursors supplied (additives or plant breeding)	<10-25
-	Probiotics to eliminate rumen protozoa	<10-25
A4	Ionophores	10-25
A5	Genetic modification of rumen microflora	10-25
-	Immunogenic approaches	<10
-	Improved genetic potential for dairy cows	<10
-	Bovine somatropin (B.S.T.)	10-15
-	Anabolic steroids	<10
-	Transgenic manipulation of ruminant	<10

Emission of N_2O from the soil is a by-product of the addition of N to soils as mineral-N, manures or excreta deposited during grazing. Bacteria use N compounds as a substrate for energy production. Under anaerobic conditions bacteria obtain energy from nitrate (NO_3) ions (denitrification) while under aerobic conditions other bacteria oxidise ammonium (NH_4) ions to NO_3 (nitrification). In both processes N_2O emissions are only a small proportion of the N applied (1-2%). However, the large GWP of N_2O makes these small emissions significant.

Proposed measures to reduce emissions of N_2O may be grouped into:

- Changes to livestock diets to reduce N excretion and hence N applied to soils.
- Measures to reduce fertilizer-N applications.
- Measures such as nitrification inhibitors to reduce the proportion of N lost as N_2O.

Estimated costs and efficiencies of measures to reduce N_2O emissions from agriculture are shown in Table 31 and Table 32.

Within these tables, those policies that are considered in more detail later in this section are given a reference no, A2, A3, etc.

48 Methane, CH_4, is one of three main GHG arising from the agricultural industry that contribute to the total CO_2 eq emissions, see Figure 18.

Table 31 Potential abatement efficiencies to reduce emissions of N_2O from Jarvis et al. (2001)

Ref	Measures to reduce emissions of N_2O	% reduction in N_2O emissions	Cost (qualitative)[49]
A3	Improve fertilizer efficiency (e.g. make full allowance for manure-N applied)	5	Negative
A3	Impose fertilizer tax	Not known	Large
A3	Improved fertilizer application methods (split dressings: slow release, precision applications: injection/placements: Timing (N effects on N_2O not qualified)	<2-6	Small
A3	Change form of N supplied (reduce NO_3-) (use NH_4+ forms)	10-15	Small to negative
A7	Use chemical inhibitors (nitrification)	10-50	Moderate
-	Switch to organic/clover based management	Not known Likely to be related to reduction in N inputs	Small
A2	Reduce livestock stocking rates	Related to reduction in inputs: overall impact not known	Moderate
-	Use catch crop to reduce NO_3 substrate	Effects on N_2O not known	Small
-	Improved sward management (reseeding procedures, efficient varieties)	Overall effects on N_2O not known	Small
-	Reduce water table (drainage)	N_2O effects not known	Moderate

Table 32 Potential abatement efficiencies to reduce emissions of N_2O from manure management Jarvis et al. (2001) and Moorby et al. (2007)[50]

Ref	Measure	% reduction in N_2O emissions	Cost (qualitative)
	Reduction in dietary N of 10%	6	Small to moderate
A9	Change from litter-based manure to slurry system	15	Large
	Spread manure at appropriate times/conditions	<10	Moderate to large
	Reduce NH_3 emissions (reduced deposition and subsequent 'indirect' effects)	10-25	Moderate to large
A3	Reduce NO_3- runoff: leaching (and indirect effects)	10-25	Small to large
	Reduce grazing period (=more controlled management of N in wastes)	10-25	Large
	Increase aerobic forms applied	10-25	Moderate to large

The use of anaerobic digestion of manures for manure management also has the potential to reduce methane emissions by up to 90%, but at a high cost.

4.7.3 Radical policy options

The following measures are included here to illustrate the extent of change that would be needed to achieve further and significant reductions in emissions from agriculture. The three options would each

[49] The qualitative estimate of cost is the estimated cost of implementing the measure by the farming industry. It does not attempt to take account of the consequent costs or benefits to wider society.

[50] Moorby JM, Chadwick DR, Scholefield D, Chambers, BJ, Williams, JR, (2007), A Review of Research to Identify Best Practice for Reducing Greenhouse Gases from Agriculture and Land Management, Per of Project (CC0206). UK Department of Environment Food and Rural Affairs (DEFRA).

require a major restructuring of Scottish agriculture, with potentially very serious implications for the rural economy. The measures would require profound changes to patterns of personal consumption. Without those changes reducing production within Scotland could merely shift the burden of GHG emissions to other producing countries.

A11: Replace red meat with white: Pig and poultry production emits significantly less GHG per kg of product than the production of meat from sheep and cattle, and dairy production. A simple scenario analysis indicates that if pork and poultry are substituted for beef and lamb, according to the current ratio between pork and poultry production in Scotland, this could lead to a reduction in the direct GHG emissions from agriculture of *c*. 65%. To accurately quantify the potential impacts of such a change, the emissions from changing land use, e.g. tilling grasslands to produce cereals for pig and poultry feeds, need to be estimated. In addition long-term changes to N inputs also need to be taken into account and a proper net GHG budget prepared. For example, while CO_2 emissions from soil will increase following conversion of grassland to arable, the availability of N from soil organic matter will lead to reduced emissions of N_2O from N fertilizer application.

A12: The marginal livestock rearing approach: In this option land would only be made available once land requirements have been met to optimize crop production in Scotland, meet feasible biomass targets and maintain or enhance biodiversity. Ruminants would be fed only on the grass grown on the surplus land, while no crops would be grown solely for consumption by pigs and poultry; those livestock would be raised only on waste. Land currently used directly or indirectly for livestock farming could be freed up for other purposes, such as carbon sequestration. This is a complex scenario and would require a detailed study to elicit an accurate assessment of potential reduction in GHG emissions. However, since under this scenario the emphasis would be on raising livestock on land surplus to other requirements, the most appropriate livestock would be ruminants. Since enteric fermentation is responsible for >50% of agricultural GHG emissions in our opinion it is unlikely that this scenario would achieve an 80% reduction in emissions, although 40-70% might be possible. Such an approach is likely to lead to a substantial reduction in livestock production, including that of milk. As stated above, a detailed study would be required to accurately forecast future production. A likely consequence of reduced domestic production, unless there is a commensurate reduction in demand, would be an increase in imports, with the attendant GHG emissions being produced elsewhere.

A13: Adoption of Vegan diet: From Table 29 it can be seen that 84% of emissions from agriculture result from livestock production, with only 16% associated with fertilizer for crops. Hence adoption of a vegan diet could potentially offer an 84% reduction in GHG emissions. Less meat consumption and production could also mean reduced emissions of GHG from tillage land as more land would be available for crops for human consumption which could then be grown with less fertilizer-N giving further reductions in N_2O emissions. There are two aspects to this.

First, at present much of the arable area is given over to growing crops for livestock, and this is not just relevant to pigs and poultry, cattle are also fed cereal and other arable crops to supplement their diet. The efficiency of conversion of feed protein to animal protein varies. It can be up to 40% for pigs and poultry, but is only 10% for grazed beef and sheep, with c. 25% for dairy produce. The argument is that the land now used to grow cereals and legumes fed to livestock could instead grow crops to feed people and supply their protein requirements, and given that modern bread-making wheats contain >10% protein, and legumes c. 25%, the land needed to supply protein through grain and legumes directly would be less than that currently used to do it via livestock. This may be less so for Scotland, where a greater proportion of livestock production (although not necessarily consumption) is from ruminants, which only graze.

A second argument comes into play that even if some grassland is ploughed out for crops (and it would only need to be a small proportion) that would lead to a short-term spike in CO_2 emissions, but veganism would lead to a permanent cessation of methane emissions from livestock production. It is acknowledged that this is a very drastic approach, but the potential is there. However, the marginal approach to livestock production does seem more reasonable as it would allow meat production from food wastes and on land unsuitable for crops but of little value for wildlife. Hence, with more land available, an increase in the production of cereals and vegetables might be achieved, from more extensive production, and not lead to increases in GHG emissions from those sources. In addition, relinquished grassland could be used to enhance carbon sequestration through afforestation, increasing forest area is a policy in Section 4.8.

Table 33 Agriculture Sector Potential abatement 2050

Ref	Policy name	Reduction potential (ktonnes CO_2 eq)
		2050
A1	Dietary change for livestock	783
A2	Reduce livestock numbers	1,487
A3	Improve fertiliser use efficiency	78
A4	Rumen manipulation - ionophores	391
A5	Rumen manipulation - GM	391
A6	Increase livestock productivity	235
A7	Nitrification inhibitors	391
A8	Reduce grazing	78
A9	Change from farm yard manure to slurry systems	78
A10	Anaerobic digestion	78
A11	White meat instead of red	-
A12	Marginal livestock rearing approach	1,957
A13	Adopt vegan diet	-

4.7.4 Acceptability and feasibility of policy options

Table 34 provides a summary of some of the main public acceptability and feasibility issues for policies in the agriculture sector.

Table 34 Acceptability & feasibility issues for agriculture measures

Ref		Acceptability Issues	Feasibility Issues
		***Legend**: **+** is a positive issue, **-** is a negative issue*	
A1, A4, A5	Measures to reduce enteric methane emissions	**-** Some options may be unacceptable for farmers and/or consumers	**-** Effectiveness is uncertain
A2, A3, A7	Reduced fertiliser use	**+** More efficient use of fertilisers would lead to cost reduction for farmers **+** Amending N fertiliser composition through the use of nitrification inhibitors should be acceptable **-** Any tax on fertilisers likely to be very unpopular	**+** More efficient use is a proven option
A8	Changes to grazing management	**-** While measures such as improved sward management might appear attractive, in that they involve little direct cost, they require time and this is usually at a premium	**-** The impacts of these measures are uncertain
A1	Changes to livestock diets	**+** The use of improved diets should be acceptable and such an approach (phase feeding) has been adopted by pig farmers over the last 10 years	**-** The feasibility will crucially depend on cost. Diets are formulated on a least cost basis to provide energy.

Ref		Acceptability Issues	Feasibility Issues
		***Legend**: **+** is a positive issue, **-** is a negative issue*	
A3, A9, A10	Manure management	**-** Changes to spreading practices are likely to increase costs, through extra storage requirement or new machinery.	
A11, A12, A13	Radical options	**-** Any change to human diet likely to have issues around acceptability, particularly a switch to a vegan diet	**-** Major shifts in diet may be unlikely, as the beneficial health effects of such shifts are currently well known but not taken up

4.7.5 Sector Results – Agriculture

The following figure shows 13 specific measures in the agriculture sector selected from the options described above and plotted (where possible) in terms of their abatement potential and abatement cost in 2050.

The amount of carbon dioxide equivalent abated as a result of implementing each policy was assessed. The cost of implementing each policy was also determined. As a result of these considerations, taking into account uncertainties and any secondary impacts, each policy was placed in the abatement effectiveness matrix shown in Figure 19 and assigned a priority. This categorisation was based on the individual policy measure in isolation rather than its impact or cost when implemented alongside other policies. Further details of the categorisation are given in Section 5.

The potential policy levers for agriculture are held by the EU, the UK Government and the Scottish Government. World food prices will also influence purchasing by the public and investment decisions in this sector. Nevertheless, the Scottish Rural Stewardship scheme provides a potential lever to introduce measures that can reduce emissions directly from farming activities, while public information programmes could be used to encourage changes in diet.

Cost per tonne (£/t CO_2 eq)	High	A3, A8 A9	A1, A2, A4 A5, A6, A7 A12	A2
	Medium	A10		
	Low			
	Very low (cost saving measures)			
		Low	Medium	High
		Quantity of GHG Abated (Mt CO_2 eq)		

A1	Dietary change for livestock (costs not quantified)	A8	Reduce grazing
A2	Reduce livestock numbers	A9	Change from farm yard manure to slurry systems
A3	Improve fertiliser use efficiency	A10	Anaerobic digestion
A4	Rumen manipulation - ionophores (costs not quantified)	A11	White meat instead of red (not shown)
A5	Rumen manipulation - GM (costs not quantified)	A12	Marginal livestock rearing approach (costs not quantified)
A6	Increase livestock productivity (costs not quantified)	A13	Adopt vegan diet (not shown)
A7	Nitrification inhibitors		

Figure 19 Summary – Agriculture[51]

Key:

Very High priority measures
High priority measures
Medium priority measures
Low priority measures
Very Low priority measures

[51] The ranking of policies A1 to A3, and A7 to A9 include an adjustment for uncertainty – see Section 5.1 for details

4.8 Land use, land use change and forestry (LULUCF)

Further information on emissions, policy options and timescales is available in Appendix 10.

This sector is significantly different to the others considered here in that it is capable of removing carbon from the atmosphere and locking it into ecosystems. Most awareness of the importance of this sector is focused on the role of forestry, though other areas are also important, including the way that agricultural land is used and planning policies that address urban spread and derelict land.

4.8.1 Emissions and trends

Emissions and removals of carbon dioxide due to activities in the LULUCF sector are reported in the UK Greenhouse Gas Inventory, as well as emissions of methane and nitrous oxide (although these are not significant compared to the overall emissions of these gases). The LULUCF sector within Scotland is a net sink of carbon dioxide. The size of the sink has increased from around -3,000 to -5,000 kt CO_2, between 1990 and 2005, although this trend is projected to reverse in the future (returning to –3,000 kt CO_2 by 2020). Net emissions/removals in Scotland are dominated by the large forest sink, although emissions from historical land use change to cropland are also significant. These "legacy" emissions will diminish over time, assuming no further land use change. The baseline afforestation rate, used in these projections, is 10 kha/y for 2008-2020, and zero thereafter. This is made up of 5 kha/y conifer, 4 kha/y broadleaf, and 1 kha/y short-rotation coppice willow. This is a different accounting approach to the Kyoto protocol, which accredits all afforestation since 1990, within capped limits.

Projections for the sector are available to 2020, but not beyond.

4.8.2 Policy options

Twenty possible policy options for improving carbon uptake by land were identified and quantified in terms of potential carbon sequestration between 2008 and 2050. For each option, a range for sequestration potential was initially considered, based on best estimate, conservative and maximal assumptions. In each case we have used the best estimate value. The combined effect of policy options is then estimated over the same range, noting that some options are mutually exclusive, or have a multiplicative rather than additive effect. Further information on these options is given in Appendix 10. The forestry cost estimates were based on Mason[52] and other cost estimates were based on Smith[53].

Options 1 to 7: Expand forest area

L1 represents a 'top-down' approach to specifying an increase in forest area. Options 2-7 represent a 'bottom-up' approach, aimed at identifying particular target areas or activities within this sector, and would be components within (rather than additional to) L1.

L1 Increase forest area. In this option, the afforestation rate of 10 kha/y is continued for 2021-2050. Total cost assumed to be £4,700 ha^{-1}, comprising the value of the land, assuming permanent pasture at £3,500 ha^{-1}, plus planting and maintenance costs (£1,200 ha^{-1}). The same costs are assumed in the other forestry options, though land purchase is assumed to be unnecessary in the cases of L2, L3 and L4.
L2 Afforestation of road/rail network. Transport Scotland estimate that there are 3,024 ha available for planting on Scottish road network sites with little or no opportunity cost. A further 2,000 ha is estimated to be available on the Scottish rail network. Cost assumed to be £1,200 ha^{-1}.

[52] Mason, W.L. (2007) Silviculture of Scottish forests at a time of change. Journal of Sustainable Forestry, 24, 41-57.

[53] Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O., Howden, M., McAllister, T., Pan, G., Romanenkov, V., Schneider, U., Towprayoon, S., Wattenbach, M. and Smith, J. (2008) Greenhouse gas mitigation in agriculture. Philosophical Transactions of the Royal Society B-Biological Sciences, 363, 789-813.

L3 Afforestation of derelict land. It is estimated that there are 10,000 ha of derelict land in Scotland, mainly on disused industrial and mining sites. Here, planting is assumed to take place between 2008 and 2017 on 50% of the available area. Cost assumed to be £1,200 ha^{-1}.
L4 Expansion / management of hedgerows. Cost assumed to be £1,200 ha^{-1}.
L5 Prevent further deforestation. Deforestation accounted for emissions of 24 kt C y^{-1} in Scotland in 1990. Here, it is assumed that the deforestation rate could be cut by 50 %. Cost was estimated as a mean value for forested land (£3,212 ha^{-1}).
L6 Expand short rotation coppice (SRC). A recent report (Hardcastle et al, 2006) estimates potential to expand SRC to between 50,000 and 90,000 ha, although only 200 ha were currently in operation. Here it is assumed that SRC could be expanded to 75,000 ha. Cost assumed to be £4,700 ha^{-1}.
L7 Expand short rotation forestry (SRF, 15-y rotation). Using the same procedure as in option 6, it is assumed that SRF could be expanded to 75,000 ha. Cost assumed to be £4,700 ha^{-1}.

Options 8 to 10: Forest management

For these options, modelling assessed the effects of changes to forest management on carbon sequestration. All the simulations used the baseline projections for future forest area (see 4.8.1).

L8 Increase forest rotation length. To give conservative, best, and maximum estimates, rotation length was increased by 30 years from the current default of 59 years. It is assumed that only 30% of the forest area in Scotland is windfirm – hence this measure is applied to this proportion of the forest area. The cost was estimated as the value of the foregone timber production, assuming a standing sale price of £12 m^{-3} for merchantable timber. The foregone timber production was calculated as the reduction in harvested wood products between 2008 and 2050, compared to the default rotation length.
L9 Increase forest productivity. The procedure here was the same as in option 8, except yield class was increased by 2 YC (yield class) units, from the current default of YC 12. The cost estimate was based on the cost of fertiliser addition, estimating that 20 kg N ha^{-1} y^{-1} would be needed to achieve this increase in growth rate.
L10 Switch wood products to long life uses. By switching wood products to longer lifetime products (e.g. construction timber) product lifetime was assumed to increase by 30 years from the current default of 59 years. Costs have not been estimated for this option.

The rotation length measure, L8, and the increased timber market option, L10, interact (as through extended rotations and deferred harvesting, less timber products would be available).

Options 11 to 13: Agricultural land use
L11 Convert cropland to grassland. Modelling assessed the mean annual change in soil carbon stocks over 42 years (2008-2050) for converting crop land to grassland, estimated as 100% of the existing set aside area. Cost assumed to be £5,950 ha^{-1}.
L12 Convert leys to permanent pasture. Again, this conversion shifts agriculture to sequestration through promoting an increase in soil carbon content. The area that could potentially be converted in this way was estimated as 50% of the area currently in <5 year grassland rotations. Cost assumed to be £1,730 ha^{-1}.
L13 Prevent conversion to cropland. Conversion of land to cropland is a significant driver for Scottish emissions. This option considers prescribed reductions 50 %. Cost assumed to be £5,950 ha^{-1}, the estimated difference in the value of cropland and grassland.

Options 14 to 17: Agricultural land management

L14 Improve cropland management. Mitigation potentials for cropland activities were taken from Smith *et al. (*in press). These were applied to the area of arable land with mean values used to estimate the range. The cost was estimated at £82 ha^{-1}.
L15 Improve grassland management. The impact of changes to grassland management were quantified in the same way as for option 14, except annual mitigation potentials for grassland practices were used, and applied to the total grassland area for Scotland. The cost was estimated at £49 ha^{-1}.
L16 Reduce lime application. The effect of reducing lime application was estimated via a prescribed reduction of 50 %. The cost was taken as £200 ha^{-1}.

L17 Manage field margins. The mitigation potential of this option in Scotland is estimated based on its effectiveness and uptake under Environmental Stewardship in England. It is assumed that uptake in Scotland is 100% of that in England, relative to the arable area in the two countries. The cost is estimated as £5,950 ha^{-1}.

Options 18 and 19: Management of organic soils

L18 Prohibit horticultural peat extraction. A prescribed reduction of 50 % was assessed. The cost estimate was based on wholesale price of peat.
L19 Peatland restoration. The effect of peatland restoration on net greenhouse gas balance is potentially very large but highly uncertain (even down to the sign of the net effect). Our conservative estimate was simply zero, whilst the maximum estimate was based on the information from Smith et al[54]. This was applied to an estimate (fairly conservative) of the area of peatland undergoing restoration in Scotland (150,000 ha). The best estimate was based on a typical value for peat accumulation in intact bogs.

Option 20: Urban expansion

L20 Prevent urban expansion. Conversion of land to settlement accounted for 2.9% of emissions in 2005. A prescribed reduction of 50 % was applied. The cost was estimated as the value of the land, assuming a mean for residential land in Scotland of £800,000 ha^{-1}.

4.8.3 Impact on carbon sequestration by the sector

Figure 20 shows the impact of these policy options on carbon sequestration, through land use change, reflecting specific conditions within Scotland. The trend line for policy options in Figure 20 never crosses into net emission, whilst in the baseline scenario, the sector becomes a net source in 2030. A substantial fraction of Scotland's fossil fuel derived emissions could be sequestered in 2050 if all LULUCF options were combined to maximal effect. However, greatly restricting timber harvesting via extended rotation lengths is unlikely to be an acceptable policy when viewed in the wider context. The use of wood as a sustainable building material has wider benefits and great potential for carbon sequestration. By substituting for concrete and steel, which use substantial fossil fuels in their production, emissions are abated whilst simultaneously removing carbon from the atmosphere. Reductions in locally-grown timber may be replaced by increased imports from Scandinavia and the Baltic states, leading to increased transport costs. Given that timber harvesting is likely to continue, the best estimate of the achievable level of sequestration is ~10 % of the 1990 fossil fuel emissions.

[54] Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O., Howden, M., McAllister, T., Pan, G., Romanenkov, V., Schneider, U., Towprayoon, S., Wattenbach, M. and Smith, J. (2008) Greenhouse gas mitigation in agriculture. Philosophical Transactions of the Royal Society B-Biological Sciences, 363, 789-813.

The trend line for policy options, shown in Figure 20, never crosses into net emission, whilst in the baseline scenario, the sector becomes a net source in 2030.

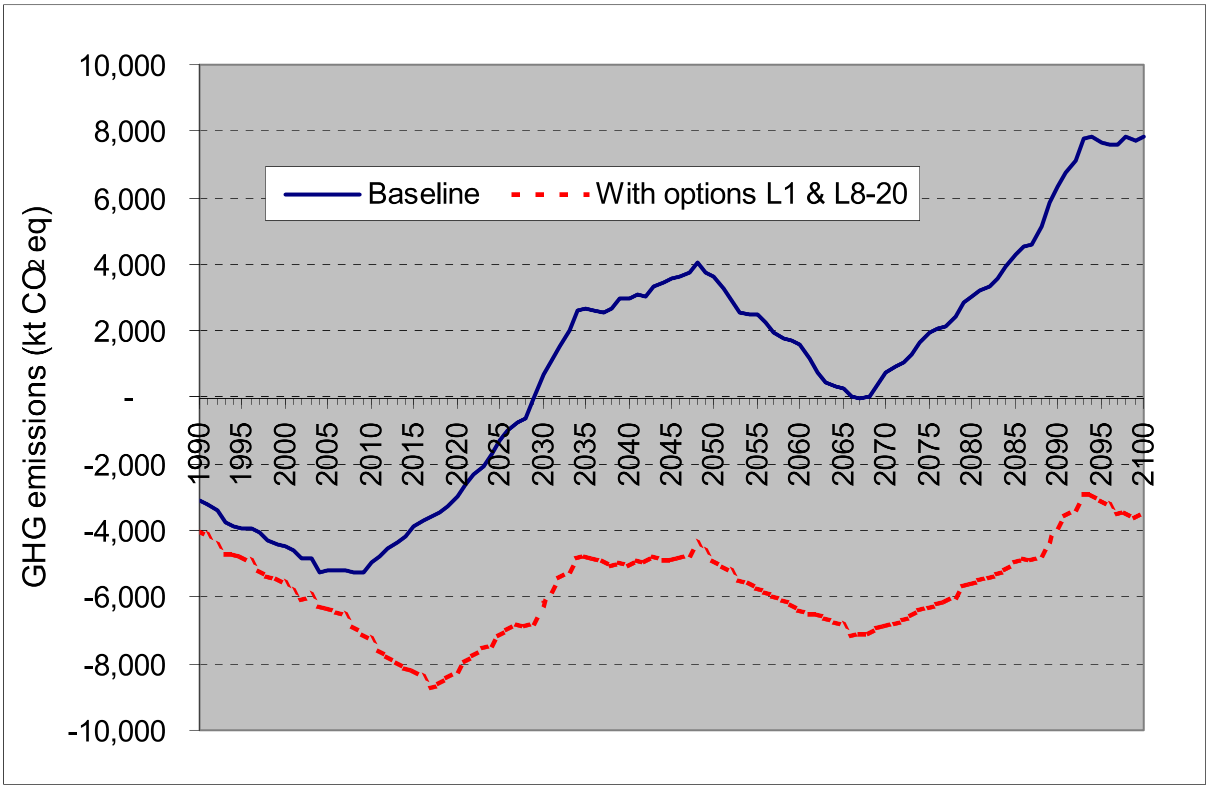

Figure 20 Changes in carbon sequestration through land use under the baseline and policy option scenarios from 1990 to 2100 (negative figures here indicate the take up of carbon by ecosystems).

Table 35 shows the carbon sequestered by these policy options and the estimated costs incurred. The impact of policies L2 through to L7 have been included in the total abatement for policy L1.

The three options with most potential (in terms of absolute saving and cost-effectiveness) are improving grassland management, increasing forest area, increasing forest rotation length.

Of the measures considered, the potential for peatland restoration is particularly uncertain. At its maximum, this could contribute almost 8 % of the 1990 fossil fuel emissions; at worst, the effects of CH_4 emission could cancel out completely or even outweigh the effect on CO_2 sequestration. Compared with others, the basic science underpinning this option is highly uncertain; there are very few UK studies on which to base estimates of the current carbon balance of UK peatlands and even fewer which quantify the effect of restoration work. More research is clearly needed here given the potential magnitude of savings and the cost effectiveness of this carbon sink. Accordingly this measure was deemed too problematic to be carried forward into the overall analysis.

Table 35 Potential abatement and abatement costs for each option

Ref	Sub-sector	Policy option	Abatement (kt CO_2-eq/y, 2008-2050)	Cost per tonne (£/t CO_2eq)
L1[55]	Expand forest area	Increase forest area	810	18
L2	Expand forest area	Afforestation of road/rail network	25	4
L3	Expand forest area	Afforestation of derelict land	42	4
L4	Expand forest area	Expansion/mgmt of hedgerows	76	6
L5	Expand forest area	Prevent further deforestation	44	1
L6	Expand forest area	Expand SRF (5-y rotation)	382	22
L7	Expand forest area	Expand SRF (15-y rotation)	661	13
L8	Forest management	Increase forest rotation length	712	5
L9	Forest management	Increase forest productivity	119	362
L10	Forest management	Switch wood products to long life uses	570	200
L11	Agricultural land use/ management	Convert cropland to grassland	432	22
L12	Agricultural land use/ management	Convert leys to permanent pasture	206	32
L13	Agricultural land use/ management	Prevent conversion to cropland	84	754
L14	Agricultural land use/ management	Improve cropland management	489	101
L15	Agricultural land use/ management	Improve grassland management	995	61
L16	Agricultural land use/ management	Reduce lime application	134	138
L17	Agricultural land use/ management	Manage field margins	96	929
L18	Management of organic soils	Prohibit horticultural peat extraction	30	73
L19	Management of organic soils	Peatland restoration	107	14
L20	Other	Prevent urban expansion	857	1,214

[55] Includes the impact of measures L2 to L7

4.8.4 Acceptability and feasibility of policy options

Table 36 Acceptability and Feasibility of policy options.

Ref		Comment
L1	Increase forest area	High public acceptability particularly if managed to maximise other benefits such as wildlife, recreation & aesthetics, as well as timber. Some flexibility needed e.g. to ensure regeneration of derelict land is done in a way that benefits local communities.
L2	Afforestation of road/rail network	
L3	Afforestation of derelict land	
L4	Expansion / management of hedgerows	
L5	Prevent further deforestation	
L6	Expand short rotation coppice	Provides an alternative income stream so may be welcomed. Also likely to benefit wildlife. SRF more likely as new afforestation.
L7	Expand short rotation forestry	
L8	Increase forest rotation length	Extended rotation lengths unlikely to be acceptable in wider context of restricting harvesting and the impacts of wind throw.
L9	Increase forest productivity	Significant sequestration potential.
L10	Switch wood products to long life uses	Acceptability dependent on application.
L11	Convert cropland to grassland	Acceptability dependent on specific details of such programmes, e.g. compensation payments to farmers.
L12	Convert leys to permanent pasture	
L13	Prevent conversion to cropland	
L14	Improve cropland management.	Acceptability dependent on how these options interact with agricultural production.
L15	Improve grassland management	
L16	Reduce lime application	
L17	Manage field margins	
L18	Prohibit horticultural peat extraction	High public acceptability, but would affect those with peat extraction rights.
L19	Peatland restoration	Probable high public acceptability via benefits to wildlife and potential for significant carbon sequestration. Again, affects those with peat extraction rights.
L20	Prevent urban expansion	Preservation of the green belt is always seen as a popular policy, though this may be dependent on the situation of individuals (e.g. homeowners close to green belt vs. residents in deprived parts of towns).

4.8.5 Sector Results – LULUCF

The following figure shows the measures identified for the LULUCF sector plotted in terms of their:

- Abatement potential in 2050
- Abatement cost in 2050

The amount of carbon dioxide equivalent abated as a result of implementing each policy was assessed. The cost of implementing each policy was also determined. As a result of these considerations, taking into account uncertainties and any secondary impacts, each policy was placed in the abatement effectiveness matrix shown in Figure 21 and assigned a priority. This categorisation was based on the individual policy measure in isolation rather than its impact or cost when implemented alongside other policies. Further details of the categorisation are given in Section 5.

From this analysis the most promising options appear to be afforestation measures and improved grassland management, which offer high potential abatement at low cost. Converting cropland to grassland and converting leys to permanent pasture offer medium abatement potential at high cost, while the other options are either higher cost or offer lower abatement potential.

Cost per tonne (£/t CO_2 eq)	High	L13, L17 L20	L9, L10	
	Medium		L16 L14	
	Low	L18	L1, L8, L11 L12, L15	
	Very low (cost saving measures)			
		Low	Medium	High
		Quantity of GHG Abated (Mt CO_2 eq)		

L1	Increase forest area	L11	Convert cropland to grassland
L2	Afforestation of road/rail network (not shown)	L12	Convert leys to permanent pasture
L3	Afforestation of derelict land (not shown)	L13	Prevent conversion to cropland
L4	Expansion/management of hedgerows (not shown)	L14	Improve cropland management
L5	Prevent further deforestation (not shown)	L15	Improve grassland management
L6	Expand short rotation coppice (not shown)	L16	Reduce lime application
L7	Expand short rotation forestry (not shown)	L17	Manage field margins
L8	Increase forest rotation length	L18	Prohibit horticultural peat extraction
L9	Increase forest productivity	L19	Peatland restoration (not shown)
L10	Switch wood products to long life uses	L20	Prevent urban expansion

Figure 21 Summary – LULUCF

Key:

- Very High priority measures
- High priority measures
- Medium priority measures
- Low priority measures
- Very Low priority measures

4.9 Cross Sector Reduction Opportunities

Some opportunities do not readily fit in one sector alone as they affect several opportunities. The main sources of direct emissions in the end use sectors (business, households & the public sector) are the use of fossil fuels for heating.

District Heating with Combined Heat and Power

The main cross sector example is District Heating (DH) with Combined Heat and Power (CHP). The CHP options considered in the earlier sections were for individual sites where the heat load for the site was sufficient to make CHP a viable option. Many sites have insufficient heat use to be suitable for CHP. District Heating can link up heat loads that are different in scale, duration and profile. This should create a more constant heat load that suits CHP, increasing the potential.

For the reasons set out below these additional savings from DH have not been assessed in this study, however there will be additional potential by combining heat loads.

Combined Heat and Power represents an opportunity to provide heat and power in a highly efficient manner, recovering heat that is normally lost in the production of power.

In 2006 there were 87 good quality CHP schemes in Scotland generating over 3 GWh of electricity and 8 GWh of heat. This represents 6% of power generated and 8% of heat use in Scotland. These CHP schemes mainly serve large process sites in the petrochemicals, chemicals and food sectors, with some smaller installations in the public and service sectors, hospitals, swimming pools, hotels etc.

The development of CHP systems is closely linked to the heat loads that they serve. In Scotland and the UK the main model has been CHP serving individual sites. To achieve attractive investment returns these sites have high levels of heat use throughout the year – e.g. the examples above. These sites are limited in number and this model restricts the potential for CHP development. In many other countries the model has been to develop CHP in conjunction with District Heating systems. The DH system comprises heat mains transporting heat from the CHP to heat consumers in all sectors. In these systems the fuels used include biomass and waste materials, as well as fossil fuels.

There is no existing evaluation of the potential for CHP and DH for Scotland that would inform this assessment of the contribution that could be made in 2050. For DH this is particularly complex, as a spatial analysis of heat use is required. However, there is likely to be a contribution, over and above the assessment that has been made here, at sector level. In 2050 the form of CHP is likely to be biomass or waste fired, combined with a District Heating system with very low heat loss. Hence the heat supply from CHP/DH in 2050 will have zero or low carbon emissions.

The impact of additional savings from CHP will fall in three of the sectors, business, public and households. In qualitative terms the likely impacts are:

Business Sector – The measures considered in the business sector include use of biomass to supply heat and AD to convert waste streams to energy. The AD potential is in the form of CHP, as the most cost effective means of converting biogas to energy is via a CHP system. The biomass potential was considered as a heat only technology. If these schemes were to be developed as CHP, they would provide zero carbon electricity as well as heat. Hence the impact would be on the electricity supply sector, reducing carbon in this sector not the business sector. The cost of biomass CHP may be lower than other forms of zero carbon electricity, reducing the policy cost in the electricity supply sector. Biomass CHP would require significantly higher volumes of fuel, adding to acceptability and feasibility issues regarding supply of biomass.

The analysis considered if use of biomass was suitable for the 44 sites with the highest direct carbon emissions in Scotland, option B1. The sites with more modest heat demands may be suitable for connection to a CHP/DH scheme, providing that they are located close to other suitable heat consumers. This would increase the potential carbon savings in the business sector.

Household Sector – In 2050 the carbon emissions of new homes will be zero, in compliance with existing plans for development of the building standards. Hence the potential for additional saving via CHP & DH will be in existing homes. These may be the older properties of traditional construction. These have a high level of heat use. In tenements with solid wall construction and shared lofts, cavity wall insulation and loft insulation have limited impact. Given the presence of stairs, lack of fuel storage and the urban setting, the opportunity for low carbon heat, via individual biomass boilers or ground source heat pumps, is also limited. With large numbers of these properties in urban areas, DH with CHP may offer an opportunity for low carbon heating that cannot be achieved by other means. Hence the additional benefits will be greater carbon saving potential, at a cost that is lower than individual low carbon microgeneration solutions.

Public Sector – The additional carbon savings from CHP & DH in the public sector will include potential in hospitals, schools, Higher Education Institutes and office buildings. As a heat customer with long term commitment and a leadership role in combating climate change, the public sector is seen as a key stakeholder in the development of CHP & DH. The impact of CHP & DH in the public sector would be to increase carbon savings, by offering more sites zero carbon sources of heat, at a cost that is lower than individual small scale biomass systems.

Fuel Resources for CHP – Currently most CHP schemes use natural gas as the fuel. The high efficiency of CHP means that this offers a carbon reduction compared to separate production of heat and power.

To offer greater carbon savings, the future contribution of CHP will require significant increases in the use of low carbon fuels. Hence increasing biomass CHP or biomass heat may be constrained by the fuel supply chain. Suitable biomass resources include:

- Forestry and related industries (e.g. co-product or round wood)
- Energy crops (e.g. short rotation coppice)
- Waste streams (e.g. waste wood, food waste etc.)

The forestry biomass resource in Scotland is substantial, but there are many other potential uses for forestry biomass that are already commercially viable. As well as diverting the resource from existing end uses, there may be a need to increase the resource. Hence there are cross sector issues with the policy measures on land use, particularly L1 - Increase forest area and L8 - Increased forest rotation.

Energy crops at present are in limited supply and the economic and wider impacts of energy crops are currently being reappraised.

Finally, initial assessments of the energy potential in waste streams show that there is a significant resource, which merits further investigation to establish the economic potential for energy recovery. This has a cross sector link with policy measure W1 – Zero biodegradable waste to landfill.

Suitable biomass resources are also available from outside Scotland and can be imported – through bulk transport. The experience of the market, in co-firing biomass in power stations, shows that the necessary infrastructure can be set up quickly, if the market conditions are attractive.

For all types of biomass resource, the economics and the overall environmental impact of the resource, and its life cycle impact should be carefully assessed.

Centralised Anaerobic Digestion

The analysis includes estimates for the potential for Anaerobic Digestion (AD) to treat liquid effluent in industry (B6) and agriculture (A10). The scale, and hence economics, of AD can be enhanced if Centralised AD (CAD) is used to treat effluent from several sources, at a single centralised site (normally a site that has significant heat and electrical loads). The potential for CAD requires more detailed consideration of the geographical distribution of suitable liquid waste streams (food industry, agriculture & public sector), along with the potential location of the CAD scheme at a suitable energy intensive host site. As a result, CAD would offer greater abatement potential than the separate impact of policies B6 and A10.

5 Cross-sector analysis

In the preceding sections the policy measures that offer additional GHG reductions have been considered at a sector level. These include a wide range of options that build on the many existing measures to contribute to the 2050 target. In this section we draw on the sector level analysis, to rank the measures, to address potential double counting and to assess the total impact and costs.

The most important and objective criteria in this work relate to abatement potential and cost. The overall analysis of measures therefore starts with these. Recognising the inherent uncertainties when considering impacts in 2050, it seems appropriate to group options into broad categories for abatement potential and cost, rather than taking figures as given for an initial prioritisation of options. This is done through inspection of information gathered during the project, as described in Section 4 and the appendices.

As shown below, the highest priority would naturally go to the least expensive measures with the highest abatement potential. Expensive measures of limited potential would be given the lowest priority etc.

Figure 22 Cross Sector Analysis - Concept

Cost per tonne (£/t CO_2 eq)				
	High	Option … Option … Option … etc.	Option … Option … Option … etc.	Option … Option … Option … etc.
	Medium	Option … Option … Option … etc.	Option … Option … Option … etc.	Option … Option … Option … etc.
	Low	Option … Option … Option … etc.	Option … Option … Option … etc.	Option … Option … Option … etc.
	Very low (cost saving measures)	Option … Option … Option … etc.	Option … Option … Option … etc.	Option … Option … Option … etc.
		Low	Medium	High
		Quantity of GHG abated (Mt CO_2 eq) – Relative to Total Scottish emissions in 2050		

Key:

- Group 1 - Very High priority measures
- Group 2 - High priority measures
- Group 3 - Medium priority measures
- Group 4 - Low priority measures
- Group 5 - Very Low priority measures

An alternative view may be that any option that is low cost should be given very high priority. However, this may divert attention by regulators and other stakeholders towards options with limited potential, and away from options with much greater potential.

Following a review of the range of abatement costs and abatement potential, the following broad boundaries were defined – comprising 4 levels of abatement costs and 3 levels of abatement potential. The selection of the boundaries, allowed the long list of policy measures to be grouped into the 5 categories shown in Figure 22.

Table 37 Categorisation of options with respect to cost and abatement potential.

	Cost, £ per tonne CO_2 eq	Abatement potential
Very low	<0	
Low	0 -100	<100 kt CO_2 eq
Medium	101- 300	100 - < 1000 kt CO_2 eq
High	>300	≥1000 kt CO_2 eq

This is, however, only half of the story. The ranking of measures will also be affected by:

- Confidence in data and associated uncertainty
- Ancillary effects (e.g. on air quality or employment)
- Acceptability of measures (e.g. regarding nuclear power)

These need to be factored in at a second stage in the prioritisation process. Where there is major concern it may be appropriate to drop an option down a category in the ranking. Where there are significant additional benefits to an option, or comparatively low uncertainty it may be appropriate to move an option up a category.

In most cases, it would not be recommended to move an option by more than one category through consideration of secondary concerns – the main drivers for the prioritisation process have to be the costs and effectiveness of dealing with GHG emissions. There are some exceptions, where measures are considered completely unacceptable. In these cases sensitivity analysis could be applied. Options where the non-GHG benefits of a measure are so significant that the measure will be adopted irrespective of climate concerns should be included throughout.

The scores associated with emissions savings and costs are shown in Figure 22. Uncertainty scores range from 0 (relatively certain) to 1 (relatively uncertain) and the “other factor” scores range from –1 (positive ancillary impact) to +1 (negative ancillary impact). The ancillary impacts may be beneficial hence strengthening the case for an option and increasing the priority of the option. Alternatively, the option may have undesirable secondary affects, in which case the priority of the option is reduced.

We recognise that there is a degree of subjectivity in assignment of uncertainty and “other factor” ratings, which are based on expert judgement from those responsible for each sector. Further work would be needed to fully assess the ancillary costs and benefits of each policy option.

This prioritisation process is perhaps best explained by an example. Taking policy option D1, improving the building standards for new housing from 2010, to give a 20% reduction in CO_2 emissions from 2007 standards:

- The emissions savings associated with this policy are 92 ktCO_2, which rates as Low abatement potential according to Table 37.
- The abatement costs are £367/tonne, which rates as High cost according to Table 37.
- The Low abatement score and High cost score combine to give an un-adjusted combined score of 5, based on the concept illustrated in Figure 22.
- There is no adjustment for uncertainty as the savings associated with this policy are considered to be relatively certain. The uncertainty score is based on our sector expert’s view of the relative certainty of the emissions savings associated with the measure. This will in turn be influenced by their view of the feasibility and likely acceptability of the measure.

The policy is rated as –1 under the "other factor" rating, to account for the positive ancillary impacts of this policy, particularly the effects on fuel poverty. This moves the final rating for the policy up to 4, and so the policy appears within the list of Low priority measures in Table 40. This "other factor" is also used in connection with renewables support, where the score is +1 to reflect the additional and unaccounted for costs of grid upgrade. This process leads to the definition of a set of scenarios for assessment of abatement potential and costs:

- Business as usual / baseline / reference
- Adoption of 'Very High priority measures' (Group 1)
- Adoption of 'Very High' (Group 1) and 'High' priority measures (Group 2)
- Adoption of 'Very High' (Group 1), through to 'Medium' priority measures (Group 3)
- Adoption of 'Very High' (Group 1), through to 'Low' priority measures (Group 4)
- Adoption of 'Very High' (Group 1), through to 'Very Low' priority measures (Group 5)

5.1 Defining each group of measures

The following tables list the policy options in each priority category for 2050:

	Group 1 - Very High priority measures	Table 38
	Group 2 - High priority measures	Table 39
	Group 3 - Medium priority measures	Table 40
	Group 4 - Low priority measures	Table 41
	Group 5 - Very Low priority measures	Table 42

As described above, the tables show the initial weighting which is based on cost-effectiveness and emissions abated only, for the case where options are introduced in isolation of each other. The weighting is then revised taking account of uncertainty (where it would be sufficiently large to affect the rating according to Table 37 and other factors that may either make the rating better or worse. Within each priority category, measures are then ranked in terms of cost-effectiveness.

Once the final rating is determined, the final abatement potential for each measure is calculated, when in series with the other options being considered. The series abatement calculation is brought in to avoid double counting emission cuts already accounted for. The method used for calculating adjusted emissions savings depends on the nature of the policy and the other measures that have already been taken up. For example:

- Savings from measures that save electricity only, such as high efficiency lighting (policy D5) are assigned a zero emissions saving because the electricity generation sector has already been decarbonised through the introduction of carbon capture and storage (policy E1). Note this is a simplifying assumption since CCS is only 90% effective in emissions reduction and so there will be residual emissions from power generation.
- A policy to introduce nitrogen inhibitors in fertilisers (policy A7) gives lower emissions savings than it would have done in isolation as it is introduced after improved efficiency of fertiliser use (policy A3).
- Emissions savings from powertrain technology measures for road transport have been calculated on the basis that different powertrain technologies are mutually exclusive. This means that the abatement potential from the most cost effective options are included first, and then less cost effective options with greater abatement potential are included in the analysis later, with the important caveat that the earlier, more cost effective powertrain options with lower abatement potential are removed from the analysis to avoid double counting. Hence, battery-electric technology for cars (policy T7) has been chosen in preference to other measures for cars (policies T1-T4) because policy T7 offers a deeper cut albeit at higher abatement costs.

Having allotted options to these different groups, emission savings can be summed, starting with Group 1, as these are generally the measures that make the most difference to total emissions and are most cost-effective. The total impact of implementing each category of options in series can be seen in Figure 23.

The tables also show the policy cost associated with each measure, this is the series abatement potential times the cost of abatement. The policy costs for the more certain policies in Groups 1 to 3 are shown in Figure 25.

Table 38 List of Very High priority measures

Ref	Policy Option	Abatement (kt CO_2 eq) in 2050 as an isolated measure	Cost per tonne (£/t CO_2eq) in 2050 as isolated measure	Abatement rating	Cost rating	Initial weighting	Uncertainty rating	Other factor weighting	Final weighting	Abatement (kt CO_2 eq) in 2050 as a series measure	Cost of Policy (£M)
T2	Advanced petrol engine technologies	428	-506 to -682	Medium	Very low	1	0	0	1	0[56]	0
T4	Mild hybrid technology for petrol and diesel cars	857	-365 to -451	Medium	Very low	1	0	0	1	0[56]	0
T1	Stop-start technology for new cars	143	-211 to -455	Medium	Very low	1	0	0	1	0[56]	0
T3	Micro hybrid technology (Stop-start technology with regenerative braking)	428	-251 to -357	Medium	Very low	1	0	0	1	0[56]	0
T11	Freight Transport - Package of measures based on improved vehicle technologies, improvements in operational performance and in purchasing	1017	-130	High	Very low	1	0	0	1	1017	-132
E1	Encourage take up of CCS for existing coal / gas generation plant	8577	16	High	Low	1	0	0	1	8577	137

[56] Policy T7 is assumed to be adopted in place of this measure – see Section 5.1 for details

Table 39 List of High priority measures

Ref	Policy Option	Abatement (kt CO_2 eq) in 2050 as an isolated measure	Cost per tonne (£/t CO_2eq) in 2050 as isolated measure	Abatement rating	Cost rating	Initial weighting	Uncertainty rating	Other factor weighting	Final weighting	Abatement (kt CO_2 eq) in 2050 as a series measure	Cost of Policy (£M)
B6	EfW-AD	149	-1,288 to +1,351	Medium	Very low	1	1	0	2	149	-192
D5	Regulation or Voluntary Agreement to promote more efficient lighting	55	-72	Low	Very low	1	1	0	2	0	0
T10	Packages of soft measures to reduce demand for private transport	587	-22	Medium	Very low	1	1	0	2	587	-13
E2	Enhanced efficiency of new build through planning system	477	0	Medium	Low	2	0	0	2	0	0
D12	Micro CHP	102	4	Medium	Low	2	0	0	2	60	0
L8	Increase forest rotation length	712	8	Medium	Low	2	0	0	2	712	6
L11	Convert cropland to grassland	432	23	Medium	Low	2	0	0	2	432	10
L12	Convert leys to permanent pasture	206	31	Medium	Low	2	0	0	2	206	6
L1	Increase forest area	810	35	Medium	Low	2	0	0	2	810	29
PS1	Expand Building Standards	206	50 [57]	Medium	Low	2	0	0	2	206	10
PS2	Further revision of the Building Standards	245	50 [57]	Medium	Low	2	0	0	2	245	12

[57] Cost for this measure set at the mid-point of the low cost range (£50/tCO2eq)

Ref	Policy Option	Abatement (kt CO_2 eq) in 2050 as an isolated measure	Cost per tonne (£/t CO_2eq) in 2050 as isolated measure	Abatement rating	Cost rating	Initial weighting	Uncertainty rating	Other factor weighting	Final weighting	Abatement (kt CO_2 eq) in 2050 as a series measure	Cost of Policy (£M)
T7	Battery-electric technology	5699	-39 to +159	High	Low	1	1	0	2	4938	296
L15	Improve grassland management	995	61	Medium	Low	2	0	0	2	995	61
E4	Increase target under the Renewables Obligation (Scotland) (ROS)	254	64	Medium	Low	2	0	0	2	0	0
W1	Ban disposal of biodegradable waste in landfill by 2040	583	70	Medium	Low	2	0	0	2	583	41
B1	Grant support - Biomass	925	80	Medium	Low	2	0	0	2	925	74
E5	Significant support for emerging renewables	9530	84	High	Low	1	0	1	2	0	0
B3	CCS for Grangemouth refinery	2161	120	High	Medium	2	0	0	2	2161	259

Table 40 List of Medium priority measures

Ref	Policy Option	Abatement (kt CO_2 eq) in 2050 as an isolated measure	Cost per tonne (£/t CO_2eq) in 2050 as isolated measure	Abatement rating	Cost rating	Initial weighting	Uncertainty rating	Other factor weighting	Final weighting	Abatement (kt CO_2 eq) in 2050 as a series measure	Cost of Policy (£M)
B5	A wide range of building fabric and building services technologies	279	50 [58]	Medium	Low	2	1	0	3	279	14
L18	Prohibit peat extraction	30	74	Low	Low	3	0	0	3	30	2
T9	Training all drivers to drive with fuel efficiency in mind	498	81	Medium	Low	2	1	0	3	204	17
B2	Grant support - Electric furnaces	205	88	Medium	Low	2	1	0	3	205	18
D6	Further measures to improve insulation of existing buildings	526	95	Medium	Low	2	1	0	3	518	49
PS3	CEEF	214	100	Medium	Medium	3	0	0	3	214	21
L14	Improve cropland management	489	102	Medium	Medium	3	0	0	3	498	51
D9	Biomass boilers	507	104	Medium	Medium	3	0	0	3	436	45
L16	Reduce lime application	134	139	Medium	Medium	3	0	0	3	134	19

[58] Cost for this measure set at the mid-point of the low cost range (£50/tCO2eq)

Ref	Policy Option	Abatement (kt CO_2 eq) in 2050 as an isolated measure	Cost per tonne (£/t CO_2eq) in 2050 as isolated measure	Abatement rating	Cost rating	Initial weighting	Uncertainty rating	Other factor weighting	Final weighting	Abatement (kt CO_2 eq) in 2050 as a series measure	Cost of Policy (£M)
B4	CCS for Industry	2636	144	High	Medium	2	1	0	3	2636	380
PS4	Carbon Management	171	200	Medium	Medium	3	0	0	3	38	8
D7	Ground source heat pumps	1370	208	High	Medium	2	1	0	3	1035	215
D2	Building Standards - 30% reduction in CO_2 emissions from 2007 standards in new housing from 2010	139	573	Medium	High	4	0	-1	3	70	40
D3	Building Standards - 50% reduction in CO_2 emissions from 2007 standards in new housing from 2010	231	583	Medium	High	4	0	-1	3	113	66
D4	Building Standards - 75% reduction in CO_2 emissions from 2007 standards in new housing from 2010	347	830	Medium	High	4	0	-1	3	160	133
D8	Photovoltaics (PV)	1542	1167	High	High	3	0	0	3	0	0

Table 41 List of Low priority measures

Ref	Policy Option	Abatement (kt CO_2 eq) in 2050 as an isolated measure	Cost per tonne (£/t CO_2eq) in 2050 as isolated measure	Abatement rating	Cost rating	Initial weighting	Uncertainty rating	Other factor weighting	Final weighting	Abatement (kt CO_2 eq) in 2050 as a series measure	Cost of Policy (£M)
T13	Buses equipped with hybrid-electric technology to reduce emissions	92	32	Low	Low	3	1	0	4	26	1
A2	Reduce livestock numbers in response to CAP reform	1487	? [59]	High	Medium	2	1	1	4	1487	?
A12	The marginal livestock rearing approach	1957	? [59]	High	Medium	2	1	1	4	1585	?
A4	Rumen manipulation: · ionophores in ruminant diets	391	? [59]	Medium	Medium	3	1	0	4	238	?
A5	Rumen manipulation:· genetic modification of rumen microflora	391	? [59]	Medium	Medium	3	1	0	4	226	?
L10	Switch Products to Long Life Uses	570	? [59]	Medium	Medium	3	1	0	4	399	?
A6	Increase livestock productivity per head	235	? [59]	Medium	Medium	3	1	0	4	136	?
A1	Dietary change for livestock	783	? [59]	Medium	Medium	3	1	0	4	416	?
A7	Use of nitrification inhibitor with N fertilizers	391	? [59]	Medium	Medium	3	1	0	4	187	?
A10	Anaerobic digestion	78	? [59]	Low	Medium	4	0	0	4	78	?

[59] Costs for these measures set at the mid point of medium cost range (200/tCO2eq), this is conservative as costs are very uncertain but likely to be lower

Ref	Policy Option	Abatement (kt CO_2 eq) in 2050 as an isolated measure	Cost per tonne (£/t CO_2eq) in 2050 as isolated measure	Abatement rating	Cost rating	Initial weighting	Uncertainty rating	Other factor weighting	Final weighting	Abatement (kt CO_2 eq) in 2050 as a series measure	Cost of Policy (£M)
T5	Full hybrid technology for petrol and diesel cars	1571	280 to 322	High	High	3	1	0	4	0	0
D10	Solar water heating	299	335	Medium	High	4	0	0	4	127	42
L9	Increase forest productivity	119	352	Medium	High	4	0	0	4	119	42
D1	Building standards - 20% reduction in CO_2 emissions from 2007 standards in new housing from 2010	92	367	Low	High	5	0	-1	4	36	13
E7	Increase in renewable microgeneration	953	404	Medium	High	4	0	0	4	0	0
D11	Micro wind	199	606	Medium	High	4	0	0	4	0	0

Table 42 List of Very Low priority measures

Ref	Policy Option	Abatement (kt CO_2 eq) in 2050 as an isolated measure	Cost per tonne (£/t CO_2eq) in 2050 as isolated measure	Abatement rating	Cost rating	Initial weighting	Uncertainty rating	Other factor weighting	Final weighting	Abatement (kt CO_2 eq) in 2050 as a series measure	Cost of Policy (£M)
A3	Improve fertilizer-N use efficiency	78	? [60]	Low	Medium	4	1	0	5	35	?
A8	Reduce grazing	78	? [60]	Low	Medium	4	1	0	5	34	?
A9	Change from FYM to slurry systems	78	? [60]	Low	Medium	4	1	0	5	34	?
T8	Hydrogen fuel cell technology for cars	959	422 to 685	Medium	High	4	1	0	5	0	0
L13	Prevent conversion to cropland	84	754	Low	High	5	0	0	5	84	63
L17	Manage field margins	96	929	Low	High	5	0	0	5	96	89
L20	Prevent urban expansion	857	1214	Medium	High	4	1	0	5	857	1040
T14	Scotland-wide road pricing scheme, with incentive to encourage uptake of low emissions vehicles	886	2658	Medium	High	4	1	0	5	281	747

[60] Costs for these measures set at the mid point of medium cost range (200/tCO2eq), this is conservative as costs are very uncertain but likely to be lower

5.2 Emission savings and costs

Emission savings and costs are shown in Figure 23 and Figure 25 respectively. It has not been possible to provide costs for Groups 4 and 5 because there are high uncertainties associated with many of the measures in these groups, particularly in the agricultural sector.

There are considerable uncertainties in both costs and emissions savings for measures in Groups 1 to 3 too, which is to be expected given the scope and timeframe of this study and the fact that we are looking ahead over 40 years. Sources of uncertainty include:

- Lack of inclusion of upstream and infrastructure costs for some fuels and technologies, e.g. grid reinforcements required for widespread renewable energy take-up.
- Incomplete accounting for changing costs going forward e.g. learning costs for new technologies. Learning effects have been taken into account where data is available, e.g. for photovoltaics in building applications, but in many cases no information is available after 2020.
- Incomplete accounting for inter-linkages, interactions and trade-offs between sectors, e.g. decarbonised electricity and the implications for choice of measures in end use sectors.
- A degree of in-built optimism about the extent of savings that could be achieved by some measures as they assume maximum effectiveness and/or take-up, including the policy measures in the baseline projection. This optimism has not been borne out historically. For example, many years of energy efficiency programmes in the households sector have not yet achieved full uptake of cost-effective measure such as cavity wall insulation because of a range of non-technical barriers, and improvements in engine technology have mainly led to increased vehicle performance, comfort and safety rather than reduced fuel consumption.

The total reduction for Group 1 through to Group 5 is about 75% of the 1990 emissions considered in this study[61] – hence achieving an 80% reduction would appear to require all of the measures included in Groups 1 to 5 plus new measures that will become available or feasible in the period up to 2050. The measures in Groups 1 to 3 together deliver around 63% emissions reduction on 1990 levels[61].

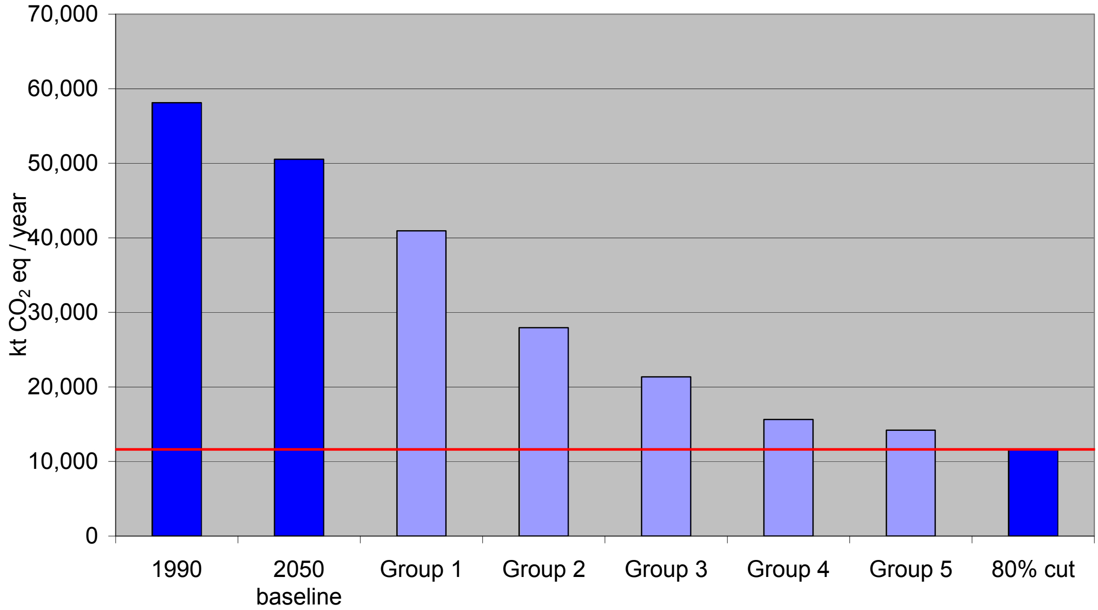

Figure 23 Cumulative effect of measures in each group defined in the main text compared to 1990 emissions, the 2050 baseline and an 80% cut in 1990 emissions

[61] This study considers a basket of GHG emissions that are 88% of total current Scottish GHG emissions, see Section 3.4

The following chart shows the residual emissions after all the measures in Groups 1 through to 5 have been applied to the 2050 baseline.

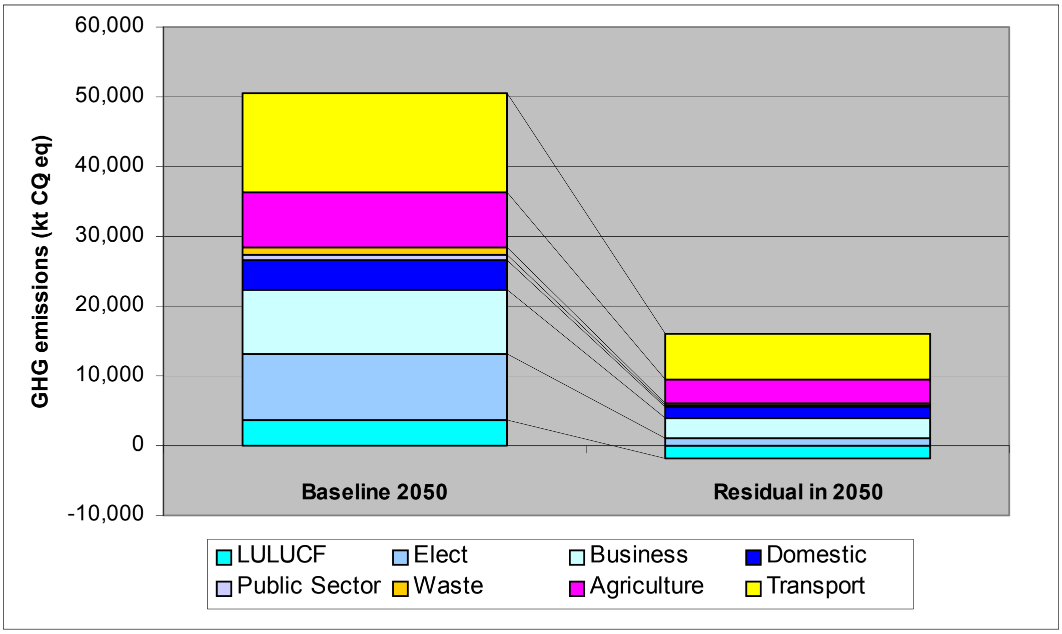

Figure 24 Residual GHG emissions in 2050

This highlights that the sectors with significant residual emissions in 2050 are Transport (mainly aviation and marine sources) and agriculture.

The costs determined for Group 1 measures are £5 million, subsequent measures in Group 2 increase the total cost to £600 million, while the cost in 2050 of achieving an emissions reduction of about 63% by implementing Group 1-3 measures is estimated to be about £1.7 billion[62] expressed in 2005 prices.

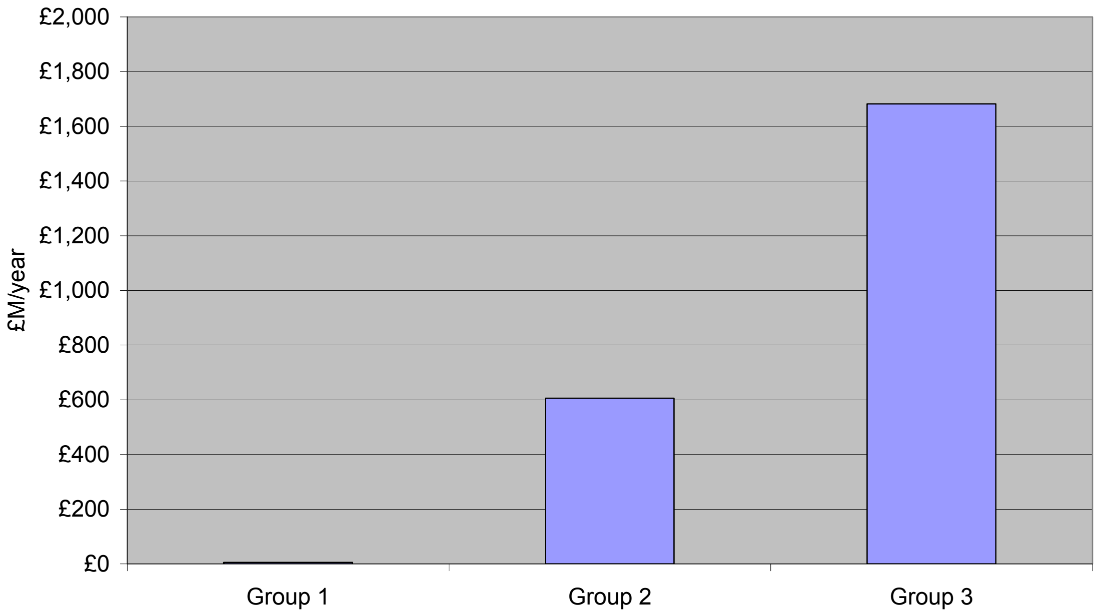

Figure 25 Cumulative costs as each group defined above is brought into the analysis

[62] Costs in the years up to 2050 will vary and are not covered in this report

This impact covers just the cost of implementing the identified measures and does not taken into account the wider economic and societal costs and the wider potential benefits. It is not possible to give a reliable estimate of the additional costs of measures to reduce emissions beyond 63% as many of the measures in Groups 4 and 5 are very uncertain at this stage.

The shape of Figure 23 and Figure 25 are sensitive to the assumptions made about technology choice in the electricity generation sector, although the overall conclusions are less sensitive. Our analysis here implicitly assumes all electricity is generated from coal with CCS at a carbon removal efficiency of 90%. This is because CCS is a Group 1 measure while significant support for emerging renewables falls in Group 2. If we were to make the assumption that all electricity will be generated from renewable sources then the net carbon emissions after implementing Group 2 and subsequent measures would fall, but the costs would increase. In practice, of course, it is much more likely that electricity will be generated in a range of ways in 2050, including both renewables and coal with CCS.

5.3 Problematic measures

A number of measures considered in the sector chapters have not been included in the above listings as a result of specific issues relating to their implementation (see Table 43).

Table 43 List of measures subject to specific problems in implementation

Ref	Policy Option	Issue
T12	No increases in the numbers of flights to and from Scotland's airports from 2020	Significant lifestyle choice. Potential large benefits in terms of emission reduction.
E3	Permit new build nuclear	Acceptability dependent on risk perception and feasibility affected by uncertainty over decommissioning costs. Needs to be judged against the costs, acceptability and feasibility of other large scale measures for electricity sector (e.g. CCS).
L19	Peatland restoration	Great uncertainty in potential for carbon sequestration. Could be significantly greater than best estimate.
A13	Adopt a vegan diet	Significant lifestyle choice but major impact on agricultural emissions.
A11	Consume white meat instead of red	Significant lifestyle choice but major impact on agricultural emissions.
E6	Nuclear fusion technology	Potentially great benefit, but remains a long term technology.

6 Conclusions

This study has identified a large number of measures for reducing GHG emissions in Scotland across eight key sectors. It has determined that significant cuts in emissions can be made in each sector and that a number of these measures, particularly in transport, are cost-effective without reference to emission savings (i.e. they save money, generally through reducing fuel use).

The method developed for this study has allowed policy options across all sectors to be assessed in a common framework. The options are categorised into very high, high, medium, low and very low priority according to their likely cost-effectiveness in 2050, taking some account of uncertainty and other factors such as impacts on fuel poverty.

As shown in the figure below, a very significant cut in emissions by 2050 from 1990 levels appears to be possible, if all the practicable measures identified are introduced and are effective. For the emissions sources considered in this study these policy options have the potential to deliver by 2050 a reduction of over 75% on 1990 levels. Further reductions may be possible from the emergence of additional new technologies or from additional demand reduction measures. This level of reduction does not assume introduction of the most controversial measures identified in the course of this study, ranging from nuclear power to widespread adoption of veganism.

The cost in 2050 of achieving an emissions reduction of 63% by implementing Group 1-3 measures is estimated to be about £1.7 billion[63] expressed in 2005 prices. This impact covers just the cost of implementing the identified measures and does not taken into account the wider economic and societal costs and the wider potential benefits. It is not possible to give a reliable estimate of the additional costs of measures to achieve a greater than 63% reduction as many of the measures in Groups 4 and 5 are very uncertain at this stage. These costs need to be set against the benefits of reducing not just GHG emissions, but also emissions of other air pollutants such as fine particles, SO_2 and NO_x that will also fall as a result of decarbonisation. Research for the European Commission has demonstrated that these co-benefits of climate policy can be very significant.

The results provide details of one way in which Scotland could achieve a very significant share of the 80% GHG reduction by 2050. This is not the only way by which this could be achieved, but the result serves to illustrate that a wide range of measures will be required and that the cost will progressively rise as more measures are put in place. Alternative ways by which a significant GHG reduction could be met, may feature different technologies and hence policy measures, or may feature different views of feasibility or public acceptability. In the period to 2050 it is highly likely that new technologies and hence new policy options will become practical and feasible.

Emissions savings and costs are subject to increasing uncertainty over time, particularly for emerging technologies. It is expected that costs will reduce as new technologies become more available and mass-produced, and this has been factored in where the information is available.

In a high level examination and assessment of the potential policy options, limitations in the data available and limits on the resources available during this study, mean it is not possible to address all of the potential issues associated with each policy option. We have not taken account of all costs that may be significant, for example, those associated with electricity grid upgrades linked to a widespread expansion of renewable electricity generation. These are complex matters that are linked to the combination of generation and demand in a specific grid zone. In addition these costs are not included in BERR's assessments that accompanied the Energy White Paper. Also it has not been possible to fully account for inter-linkages, interactions and trade-offs between sectors, e.g. decarbonised electricity and the implications for choice of measures in end use sectors.

[63] Costs in the years up to 2050 will vary and are not covered in this report

The highest priority measures are in the transport, electricity, LULUCF and business sectors with some of the largest emissions reductions in the high and very high priority group expected to come from:

- Carbon capture & storage for coal- and gas-fired electricity generation plant and for Grangemouth refinery.
- Emerging renewable energy technologies.
- Increasing forest area and rotation length.
- Biomass combustion in industry.
- The introduction of battery electric cars.

Significant reductions are also possible from the agricultural sector but the costs of these measures are very uncertain.

There appears to be less potential for significant savings in the households sector, mainly because many past and planned policies to improve energy efficiency and heating efficiency in the housing stock are already built into the baseline. There is also limited potential for savings from public buildings, although policies in this area can have a positive impact by showing what's possible and setting an example for others to follow.

Application of this level of saving out beyond 2050 may be difficult. Savings through sequestration in LULUCF are cyclical and major savings in the electricity and business sectors are dependent on carbon capture and storage, and storage facilities around Scotland may have finite capacity.

This study has given a flavour of the sort of major emissions reductions that could be possible and the policies that might play a part in achieving them. Further work will be needed to develop and implement policies in each sector, and to understand the likely implications of different choices at different times. Priorities for research are likely to include:

- Technical research to reduce the uncertainties associated with promising emissions reduction options and map out when and how they might best be introduced. Possible topics might include:
  - Further assessment of the potential for Carbon Capture & Storage, including power stations and major industrial installations in collaborative schemes, e.g. sharing storage and pipeline facilities
  - Assessment of the prospects for new vehicle technologies including plug-in hybrids and battery-electric vehicles, including their suitability for Scotland's rural population
  - Further investigation of the costs and practicality of abatement measures in the agriculture sector, in particular measures for reducing methane emissions from livestock
  - More detailed assessment of existing housing stock and the measures that can reduce GHG emissions, focusing on housing types (e.g. sandstone tenements) that are specific to the Scottish housing stock
  - Investigation of the likely infrastructure requirements for moving hydrogen or CO_2
  - Assessment of the future demand for biomass (for housing, business, public sector and transport), and identification and prioritisation of sources of supply
  - Mapping of opportunities for District Heating and CHP, to assess the additional potential for GHG reductions by providing low carbon heat and power from local sources.

- Improvements to the Scottish Greenhouse Gas inventory so it can be used more effectively as a basis for Scottish emissions projections and the analysis of Scotland-specific policies. For example, the development of more rigorous energy balance data for Scotland, including more fuel-specific and more end-user consumption data by commercial, domestic and industrial sub-sectors. Perhaps even to include fuel consumption by technology.

- Behavioural research, e.g. to assess how individuals can be encouraged to adopt efficiency measures or to change their lifestyles. Behavioural change programmes will be key to the successful introduction of new technologies and may lead to additional emissions reduction opportunities not quantified in this study. Behavioural research could also be used to explore how Scottish citizens are likely to respond to different scenarios of economic growth and climate change awareness/action, e.g. would a move to greener electricity make people more likely to leave the lights on or buy a bigger television.

- Further analysis of the long-term emissions reduction potential across all sectors with particular emphasis on the emissions reduction trajectory, i.e. which technologies should be introduced when, and how will this affect costs. A Scotland-specific GHG projection model building on the UK MARKAL model would be a possible starting point for this.

- Analysis of the emissions and abatement options associated with the minor emitting sources not addressed in this study, such as emissions from offshore oil & gas activity, CH_4 emissions from natural gas distribution, and N_2O emissions from transport.

The focus of this work on very major cuts in emissions by 2050, leads to what may at first appear to be some surprising omissions from the list of options. There is, for example, a lack of emphasis on low energy lighting systems. This is because of other measures that decarbonise electricity supply at a low cost by 2050. Before 2050, however, the use of low energy lighting should be considered a priority measure for reducing CO_2 emissions. Given that low-carbon electricity will likely cost more than electricity from current generation, the economic argument for adopting low energy lighting in the short and medium term seems likely to be further strengthened.

The Scottish Government is particularly well placed to take a lead in developing and deploying new electricity generation technologies. This applies to renewable technologies, given Scotland's wind and marine resources, and carbon capture and storage given the presence of large emission sources and potential storage sites. In some other areas, for example the development of new transport technologies, the Scottish government does not appear well placed to take a lead but could lobby for action at UK and European level.

Whilst it is important to be aware of the uncertainties in the analysis presented here, the general conclusions reached in this work are significant. Very major cuts in greenhouse gas emissions are possible, at a price that is in the same range as the costs of other environmental protection measures. The path to substantial emission cuts will no doubt change over time to that defined here, but it is a significant step forward that it is already possible to define a route to such cuts.

Appendix 1. Key data sources

Scottish Government plans, reviews and strategies

- Changing our Ways: Scotland's Climate Change Programme (2006)
- Scottish Climate Change Programme – Annual Report 2007
- Scottish Energy Study (AEA, ongoing)
- The Scottish Climate Change Programme: A Gap Analysis (2006)
- Choosing our future: Scotland's Sustainable Development Strategy (2005)

UK Government plans, reviews and strategies

- Climate Change: the UK Programme (2006)
- Energy White Paper: Meeting the energy challenge (2007)
- UK Energy Efficiency Action Plan (2007)
- UK Climate Change Programme – Annual Report to Parliament (2007)
- Stern Review Report on the Economics of Climate Change (2006)

Emissions and trends

- Scottish Energy Study, Volume 5 (AEA, 2006)
- Scottish Greenhouse Gas Inventory (AEA and CEH, ongoing)
- UK Non-CO_2 emissions projections (AEA, ongoing)

Foresighting studies

- MARKAL modelling analysis for the Energy White Paper (PSI and AEA 2007)
- Additional MARKAL analysis for Defra on >60% CO_2 reduction scenarios (AEA 2007)
- Zero Carbon Britain: An Alternative Energy Strategy (Centre for Alternative Technology, 2007)
- Decarbonising the UK (Tyndall Centre, 2005)
- Pathways to Energy and Climate Change 2050 (World Business Council for Sustainable Development 2005)
- UK Electricity Scenarios for 2050 (Tyndall Centre, 2003)
- World energy, technology and climate policy outlook 2030 (EC, 2003)
- Energy to 2050: Scenarios for a sustainable future (IEA, 2003)

Studies commissioned to support cross-sectoral government reviews

- Synthesis of Climate Change Policy Appraisals (2007)
- Synthesis of Climate Change Policy Evaluations (2006)
- Evaluation of energy efficiency policies and measures under the Climate Change Programme (AEA and PSI, 2005)

International datasets

- EECP database of climate change policies and measures in Europe
- MURE database of energy efficiency policies in Europe
- PROGRESS database of renewable energy policies
- ADAM database of mitigation and adaptation policies
- IEA World Energy Outlook

Energy supply – policies and policy options:

- Grid Issues Arising from Potential Changes to the Generation Background in Scotland (AEA 2007)
- Biomass Action Plan for Scotland (2007)
- Energy Efficiency and Microgeneration: Achieving a Low Carbon Future: A Strategy for Scotland (2007)
- Hydrogen and Fuel Cell Opportunities for Scotland (2006)

Business & industry – policies and policy options:

- A Smart, Successful Scotland (2004)
- Going for green growth: a green jobs strategy for Scotland (2005)

Public sector – policies and policy options:

- Evaluation of the Central Energy Efficiency Fund (AEA, 2007)

Waste management – policies and policy options:

- National Waste Plan (2003)
- Draft Scottish Planning Policy 10: Planning for Waste Management: Analysis of Consultation Responses (2007)
- Business Waste Framework for Scotland (2007)

Housing – policies and policy options:

- Policies for energy efficiency in the household sector (Oxera, 2006)
- Landscape review of household energy demand policies for the National Audit Office (AEA, ongoing)
- A Low Carbon Building Standards Strategy for Scotland (Panel of Scottish Ministers chaired by Lynn Sullivan, 2007)
- The impact on costs and construction practice in Scotland of any further limitation of carbon dioxide emissions from new buildings (Turner & Townsend for Scottish Buildings Standards Agency, 2007)
- Home Truths: A Low Carbon Strategy to Reduce UK Housing Emissions by 80% by 2050 (University of Oxford Environmental Change Institute, 2007)
- Reducing carbon emissions from the UK housing stock (BRE, 2005)
- Delivering cost effective carbon saving measures to existing homes (BRE, 2006)
- Micro-CHP Accelerator Interim Report (Carbon Trust, 2007)
- The Household Energy Supplier Obligation from 2011: A Call for Evidence (Defra, 2007)
- Pathway Beyond Zero Carbon Homes (Energy Saving Trust, 2006)
- Project Renew: UK Consumer Perspectives on Renewable Energy (Allegra Strategies, 2006)

Land use change – policies and policy options:

- ECOSSE: Estimating Carbon in Organic Soils - Sequestration and Emissions (2007)
- Scottish Soil Strategy (forthcoming, 2007)
- CAP Reform: Cross compliance (2005)
- Rural Stewardship scheme

Forestry – policies and policy options:

- Scottish Forestry Strategy (2006)

Agriculture – policies and policy options:

- CAP Reform: Cross compliance (2005)
- Scottish Rural Development Plan (Draft 2007)
- Climate Change and Scottish Agriculture: Changing Our Ways (2006)
- A Forward Strategy for Scottish Agriculture: Next Steps (2006)
- Rural Stewardship scheme

Transport – policies and policy options:

- Scotland’s National transport Strategy (2006)
- Preparing For Tomorrow, Delivering Today: Freight Action Plan For Scotland (2006)
- Scotland’s railways (2006)

Public acceptability of policies:

- Draft Scottish Planning Policy 6: Renewable Energy: Analysis of Consultation Responses (2006)
- Consultation responses on “Scotland's Renewable Energy Potential - Beyond 2010” (2003)
- Managing Radioactive Waste Safely: Public Attitudes in Scotland 2006

Appendix 2: Key stakeholders

Scottish Government and Agencies

Energy supply	– Richard Bellingham
Business and Industry	– Graeme Dickson
Public	– David Robb
Waste management	– Richard Grant
Housing	– Mike Foulis/Angiolina Foster (Communities Scotland)
Land-use change	– Jim McKinnon
Forestry	– Bob Mcintosh (Forestry Commission)
Agriculture	– Philip Wright
Transport	– John Ewing/Malcolm Reid (Transport Scotland)

External Stakeholders

Sustainable Development Commission	- Maf Smith
Industrial & Power Association	- Mike Farley
Policy Studies Institute	- Professor Paul Ekins
Imperial College	- Professor Matt Leach
Energy Saving Trust	- Elaine Watterson
International Energy Agency	- Dr Peter Taylor
Greenpeace	- Dr Doug Parr
Forestry Commission	- Mark Broadmeadow
University of Aberdeen	- Professor Pete Smith

Appendix 3: Electricity generation

Each of these appendices sets out the underlying information for each sector. The format includes:

- A list of existing policy measures already in use.
- Data on the proposed measures – with abatement and cost data for 2030 and 2050.
- The potential abatement is expressed as a % of the sector baseline emissions in that year.
- A range of uncertainty for the abatement potential and costs is included under the +/- columns.

Existing measures

Ref	Option
E8	Scottish renewable electricity targets
E9	Renewables obligation (Scotland)
E10	Biomass Action Plan for Scotland (Scottish Executive 2007)
E11	Renewable Heat Strategy (proposed)
E12	Energy Efficiency and Microgeneration: A Strategy for Scotland (draft)
E13	European Marine Energy Centre (EMEC)
E14	Wave and Tidal Energy Support (WATES) scheme
E15	Scottish Community and Householder Renewables Initiative (SCHRI)
E16	Scottish Planning Policy (SPP) 6
E17	EU Emissions Trading Scheme
E18	UK CCS demonstration programme
E19	Amendment to the Renewables Obligation

Future options

A series of tables are presented for future options:
1. Definition of option, state of deployment
2. Data for 2030
3. Data for 2050
4. Factors influencing deployment, potential, etc.

Ref	Option	Technical measure	State of deployment
E1	Encourage take up of CCS for existing coal / gas generation plant	Retrofit CCS to existing coal and gas plant	Future new policy
E2	Require enhanced efficiency of new stations through Section 36 Consents		Future new policy
E3	Permit new build nuclear	Assumes replace gas generation	Future new policy
E4	Increase target under the Renewables Obligation (Scotland) (ROS)	10% increase in generation from renewables above baseline	Development of existing policy
E5	Significant support for emerging renewables	Renewable generation only	Future new policy - revolutionary option
E6	Introduction of fusion technology	Fusion replacing conventional generation	Future new policy - revolutionary option
E7	Increase in renewable microgeneration	Replacing gas / coal generation	Development of existing policy

		Core data - 2030						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
E1	Encourage take up of CCS for existing coal / gas generation plant	0%		Policy assumed to be in place in 2035 - and that fossil plant built in 2025 / 2030 are capture ready	NA			
E2	Require enhanced efficiency of new stations through Section 36 Consents	5%	30%	Assumes that 5% can be made relative to BAU plant build	Impact on all measures in terms of total abatement - as changes the baseline	0		Assumption that near zero cost - as only changing planning policy
E3	Permit new build nuclear	47%	0%	Assumes new nuclear built instead of coal plant in 2025. Gas retained to provide flexible back-up generation	Impact on E1, reducing savings	0.3	80%	EWP 07 MACC
E4	Increase target under the Renewables Obligation (Scotland) (ROS)	3%	30%	Gas plant operates at lower load; hence reduction in emissions. Additional generation exported		0	30%	EWP 07 MACC (weighted across onshore wind (80%), offshore wind (15%) & wave (5%)
E5	Significant support for emerging renewables	100%	0%	Grid upgrade enables load balancing from rest of GB; removal of environmental / supply chain constraints	Cannot be implemented on top of any fossil generation based measures	0	40%	EWP 07 MACC (weighted across onshore wind (55%), offshore wind (30%) and wave (15%)
E6	Introduction of fusion technology	0%		Earliest technology introduced is 2045	NA			
E7	Increase in renewable microgeneration	5%	20%			£404	40%	EWP 07 MACC

		Core data - 2050						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
E1	Encourage take up of CCS for existing coal / gas generation plant	90%	15%	Fossil plant built in 2025 / 2030 are capture ready	Total abatement potential affected by measure E2	16	50%	EWP 07 estimate is £60/TC
E2	Require enhanced efficiency of new stations through Section 36 Consents	5%	30%	Assumes that 5% can be made relative to BAU plant build	Impact on all measures in terms of total abatement - as changes the baseline	0		Assumption that near zero cost - as only changing planning policy
E3	Permit new build nuclear	47%	0%	Assumes new nuclear built instead of coal plant in 2025. Gas retained to provide flexible back-up generation	Impact on E1, reducing savings	0.3	80%	EWP 07 MACC
E4	Increase target under the Renewables Obligation (Scotland) (ROS)	3%	30%	Gas plant operates at lower load; hence reduction in emissions. Additional generation exported		64	30%	EWP 07 MACC (weighted across onshore wind (80%), offshore wind (15%) and wave (5%)
E5	Significant support for emerging renewables	100%	0%	Grid upgrade enables load balancing from rest of GB; removal of environmental / supply chain constraints	Cannot be implemented on top of any fossil generation measures	84	40%	EWP 07 MACC (weighted across onshore wind (55%), offshore wind (30%) and wave (15%)
E6	Introduction of fusion technology	100%	0%	Plant introduced in 2045; fossil gen. retired early		Very high	Very high	
E7	Increase in renewable microgeneration	10%	20%			£404	40%	EWP 07 MACC

		Influencing factors			
Ref	**Option**	**State of technology**	**Significant other impact**	**Type**	**Other issues**
E1	Encourage take up of CCS for existing coal / gas generation plant	Pilot plant (currently as an integrated technology)	Limited concerns over public acceptability of 'burying CO_2 '	Regulatory / planning	
E2	Require enhanced efficiency of new stations through Section 36 Consents			Regulatory / Electricity Act	
E3	Permit new build nuclear	Newly deployed	Huge public acceptability concerns	Regulatory / planning	
E4	Increase target under the Renewables Obligation (Scotland) (ROS)	Mature, near market and pilot (depending on technology)	As below - except to a much lesser extent	Regulatory / planning	
E5	Significant support for emerging renewables	Mature, near market and pilot (depending on technology)	Large public acceptability concerns over project planning / infrastructure. Concerns on energy security. Employment gains in sector	Regulatory / planning plus grants / subsidies for emerging technologies	No account of costs of removing barriers to mass expansion e.g. grid upgrade
E6	Introduction of fusion technology	Early research / demonstration	Some public concern over cost / technology being in 'nuclear family'	Regulatory / Electricity Act	
E7	Increase in renewable microgeneration	Newly deployed / near market		Information / research / planning	

Appendix 4: Business

Existing measures

Ref	Option
B7	Carbon Trust support for energy efficiency in SMEs
B8	Energy saving opportunities in SMEs
B9	UK ETS
B10	Building regulations
B11	Carbon Trust
B12	Climate Change Agreement

Future options

A series of tables are presented for future options:
1. Definition of option, state of deployment
2. Data for 2030
3. Data for 2050
4. Factors influencing deployment, potential, etc.

Ref	Option	Technical measure	State of deployment
B1	Grant support	Biomass	Proven but not widely economic, update supported by grants
B2	Grant support	Electric furnaces	Future new policy
B3	Planning - strategic projects and CO_2 pipelines	Carbon Capture and Storage for Grangemouth refinery	Future new policy
B4	Planning - strategic projects and CO_2 pipelines	CCS for Industry	Future new policy
B5	Building Regulations to require 25% less carbon in refurbished commercial buildings from 2010	A wide range of building fabric and building services technologies	Future new policy
B6	Grant support	Energy from waste, anaerobic digestion	Future new policy

		Core data - 2030						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
B1	Biomass Grant support	10%	Low	Air Quality issues clarified, sufficient biomass supply available from sustainable sources. Some risk of continuing closures - historic trend, but BERR and S Govt expectations are for growth	Industry - low temp processes	£80	Low	EWP 07 MACC
B2	Electric Furnaces - Grant support	0%	Low	Electricity not low carbon so too early to implement	Industry - high temperature (Glass, metals)	£88	High	None found - assume this is higher than CCS for coal - otherwise electricity will not be low enough in carbon to make this measure viable
B3	CCS for Refineries Planning - strategic projects and CO_2 pipelines	0%	Low	Technology not yet proven at this scale or not cost effective at this scale. Unlikely to happen before 2030.	Refineries	n/a	High	EWP 07 MACC
B4	CCS for Industry Planning - strategic projects and CO_2 pipelines	0%	Low	Technology not yet proven at this scale or not cost effective at this scale. Unlikely to happen before 2030.	Industry - large sites	n/a	High	EWP 07 MACC
B5	Building Regulations to require 25% less carbon in refurbished commercial buildings from 2010	2.7%	Low	Commercial buildings refurbished once every 25 years	Services - new buildings	£50	Mid	Taken from EWP 07 MACC. Should match cost for public sector

		Core data - 2030						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
B6	EfW – AD Grant support	1.6%	Medium	RO Banding in place, landfill tax continues to rise, waste policy favourable	Industry – food	-£1,288	Low	E&Y report to BERR URN 07/1468

		Core data - 2050						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
B1	Biomass Grant support	10%	Low	Air Quality issues resolved, sufficient biomass supply available from sustainable sources	Industry	£80	Low	EWP 07 MACC
B2	Electric Furnaces - Grant support	2%	High	Carbon intensity of electricity << gas	Industry - high temperature (Glass, metals)	£88	Very High	None found - assume this is higher than CCS for coal - otherwise electricity will not be low enough in carbon to make this measure viable
B3	CCS for Refineries Planning - strategic projects and CO_2 pipelines	23%	Medium	1) Technology is proven 2) Economics OK 3) OSPAR/waste issues sorted	Refineries	£120	High	EWP 07 MACC
B4	CCS for Industry Planning - strategic projects and CO_2 pipelines	28%	High	1) Technology is proven 2) Economics OK 3) OSPAR/waste issues sorted	Industry - large sites	£144	High	EWP 07 MACC + 20% for smaller scale
B5	Building Regulations to require 25% less carbon in refurbished commercial buildings from 2010	3%	Low	Commercial buildings refurbished once every 25 years	Services - new buildings	£50	Mid	Taken from EWP 07 MACC. Should match cost for public sector
B6	EfW – AD Grant support	1.6%	Medium	RO Banding in place, landfill tax continues to rise, waste policy favourable	Industry	-£1,288	Low	E&Y report to BERR URN 07/1468

		Influencing factors			
Ref	**Option**	**State of technology**	**Significant other impact**	**Type**	**Other issues**
B1	Biomass Grant support	Newly Deployed	+Employment +Security of Supply	Fiscal	May be shortage of biomass Could be CHP increasing savings but requiring more fuel
B2	Electric Furnaces - Grant support	Mature		Fiscal	Will have result in a modest increase in electricity demand
B3	CCS for Refineries Planning - strategic projects and CO_2 pipelines	Pilot Plant	+Air Quality	Regulatory / planning	CCS focus will be power stations - assume that technology scales down to smaller sites. Some opportunities for multi site schemes - around Grangemouth
B4	CCS for Industry Planning - strategic projects and CO_2 pipelines	Pilot Plant	+Air Quality	Regulatory / planning	CCS focus will be power stations - assume that technology scales down to smaller sites. Some opportunities for multi site schemes - around Grangemouth
B5	Building Regulations to require 25% less carbon in refurbished commercial buildings from 2010	Near market		Regulatory /	
B6	EfW – AD Grant support	Pilot Plant	+Reduction of biomass to landfill	Fiscal	Savings include electricity generation Savings do not include avoided methane emissions in landfills

Appendix 5: Waste

Existing measures

Ref	Option
W2	Increasing recycling rates

Future options

A series of tables are presented for future options:
1. Definition of option, state of deployment
2. Data for 2030
3. Data for 2050
4. Factors influencing deployment, potential, etc.

Ref	Option	Technical measure	State of deployment
W1	Ban disposal of biodegradable waste in landfill by 2040		Future but links to zero waste vision for Scotland

		Core data - 2030						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
W1	Ban disposal of biodegradable waste in landfill by 2040	- 70% from 1990 levels; -16% from BAU	30%	Biodegradable waste to landfill declines in anticipation of the total ban in 2040/ a series of gradually reducing limits for amount of biodegradable waste which can go to landfill	disposal to landfill	From <£0/t to £90/t £50 used	50%	Sectoral Objectives Study 2000 for costs. Costs of alternative waste disposal options vary from cost effective<0 t to between £35 and 90/t depending partly of market price of products such as compost which are produced. Suggest that costs might be towards the higher end of this - say £50/t for 2030 reductions and £70 for additional reductions to 2050

		Core data - 2050						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
W1	Ban disposal of biodegradable waste in landfill by 2040	-91% from 1990; -74% from BAU	30%	Complete ban on biodegradable waste from landfill from 2040 on.	Disposal to landfill	From <£0/t to £90/t £70 used	50%	Costs of alternative waste disposal options vary from cost effiective/0 t to between £35 and 90/t depending partly of market price of products such as compost which are produced. Suggest that costs might be towards the higher end of this - say £50/t for 2030 reductions and £70 for additional reductions to 2050

		Influencing factors			
Ref	**Option**	**State of technology**	**Significant other impact**	**Type**	**Other issues**
W1	Ban disposal of biodegradable waste in landfill by 2040	Some matures/other Newly deployed	Could be some increase in CO_2 emissions from waste sector particularly if mass burn incineration is the alternative route for waste disposal - but should be relatively small net increase due to energy recovery from plant	Regulatory / planning	Several European countries already have a ban on landfill of biodegradable waste, so there is a precedent of the policy

Appendix 6: Households

Existing measures

Ref	Option
-	Building Regulations Scotland 2007
-	Energy Performance of Buildings Directive
-	Energy Efficiency Commitment (EEC)
-	Carbon Emission Reduction Commitment (CERT)
-	Supplier Obligation
-	Scottish Housing Quality Standard
-	Warm Deal and Central Heating Programme
-	Reduced VAT on energy saving materials
-	Landlord's Energy Saving Allowance (LESA)
-	Home Energy Conservation Act (HECA)
-	Market Transformation Programme
-	Scottish Communities and Householder Renewables Initiative (SCHRI)
-	Sustainable Energy Networks (ex EEACs)
-	Climate Challenge Fund
-	Climate Change Schools Initiative
-	Smart Metering
-	Energy Performance Certificates

Note: these measures are all included in the baseline and so their emissions savings and associated costs do not appear in the analysis for this report.

Future options

A series of tables are presented for future options:
1. Definition of option, state of deployment
2. Data for 2030
3. Data for 2050
4. Factors influencing deployment, potential, etc.

Ref	Option	Technical measure	State of deployment
D1	Building standards - 20% reduction in CO_2 emissions from 2007 standards in new housing from 2010	Improved insulation; 100% low energy lamps	Future new policy
D2	Building Standards - 30% reduction in CO_2 emissions from 2007 standards in new housing from 2010	Improved insulation; 100% low energy lamps; solar water heating	Future new policy
D3	Building Standards - 50% reduction in CO_2 emissions from 2007 standards in new housing from 2010	Improved insulation; 100% low energy lamps; biomass boiler	Future new policy

Ref	Option	Technical measure	State of deployment
D4	Building Standards - 75% reduction in CO_2 emissions from 2007 standards in new housing from 2010	Improved insulation; 100% low energy lamps; biomass boiler; solar water heating	Future new policy
D5	Regulation or Voluntary Agreement to promote more efficient lighting	Full replacement of conventional lamps with CFLs by 2030 and LEDs by 2050	VA now in place on conventional lights but not included in baseline
D6	Improved insulation for existing homes	50% of all solid walls insulated; all loft insulation up to 270mm; double glazing; some floor insulation (2030) + extra insulation options in 2050	Future new policy; planned Supplier Obligation post 2011 will include some SWI
D7	Ground source heat pumps	Ground source heat pumps introduced to all possible homes (equivalent to 25m in UK by 2050)	Future new policy
D8	Photovoltaics (PV)	PV introduced to half of housing excluding flats	Future new policy (also assumes PV costs fall significantly by 2050)
D9	Biomass boilers	Biomass boilers installed in equivalent of 5m UK homes (pro-rata for Scotland)	Future new policy
D10	Solar water heating	80% of suitable homes have solar water heating	Future new policy (or major extension of SCHRI)
D11	Micro wind	1-5kW wind turbines	Future new policy
D12	Micro CHP	Fuel cell or Stirling Engine CHP in homes over 100m2	Future new policy

		Core data – 2030						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
D1	Building standards - 20% reduction in CO_2 emissions from 2007 standards in new housing from 2010	2%	0%	15% of total 2030 housing affected (based on modelled build rate)	New housing	£367	20%	Based upon Turner & Townsend 2007
D2	Building Standards - 30% reduction in CO_2 emissions from 2007 standards in new housing from 2010	2%	0%	15% of total 2030 housing affected (based on modelled build rate)	New housing	£573	20%	Based upon Turner & Townsend 2007
D3	Building Standards - 50% reduction in CO_2 emissions from 2007 standards in new housing from 2010	4%	0%	15% of total 2030 housing affected (based on modelled build rate)	New housing	£583	20%	Based upon Turner & Townsend 2007
D4	Building Standards - 75% reduction in CO_2 emissions from 2007 standards in new housing from 2010	6%	0%	15% of total 2030 housing affected (based on modelled build rate)	New housing	£830	20%	Based upon Turner & Townsend 2007
D5	Regulation or Voluntary Agreement to promote more efficient lighting	1%	20%	Conventional lighting fully replaced with CFLs	Existing housing - lighting	£82	200%	BRE 2005
D6	Improved insulation for existing homes	10%	20%	50% of all solid walls insulated; all loft insulation up to 270mm; double glazing; some floor insulation	Existing housing - space heating	£16	600%	BRE 2005

		Core data – 2030						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
D7	Ground source heat pumps	-	-	Assumed not feasible to install many GSHPs by 2030	-	-	-	-
D8	Photovoltaics (PV)	4%	50%	Half of housing excluding flats	Existing housing - electricity	£1,213	50%	BRE 2005
D9	Biomass boilers	-	-	Assumed not an option for 2030	-	-	-	-
D10	Solar water heating	7%	50%	80% of all homes less the number which already have SWI	Existing housing - water heating	£305	20%	BRE 2005
D11	Micro wind	-	-	Assumed not an option for 2030	-	-	-	-
D12	Micro CHP	2%	20%	Just detached housing (proxy for large housing)	Existing housing - water heating	£61	50%	CT MicroCHP

		Core data - 2050						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
D1	Building standards - 20% reduction in CO_2 emissions from 2007 standards in new housing from 2010	2%	0%	21% of total 2030 housing affected (based on modelled build rate)	New housing	£367	20%	Turner & Townsend 2007 (no further cost reductions assumed)
D2	Building Standards - 30% reduction in CO_2 emissions from 2007 standards in new housing from 2010	3%	0%	21% of total 2030 housing affected (based on modelled build rate)	New housing	£573	40%	Turner & Townsend 2007 (no further cost reductions assumed)
D3	Building Standards - 50% reduction in CO_2 emissions from 2007 standards in new housing from 2010	6%	0%	21% of total 2030 housing affected (based on modelled build rate)	New housing	£583	20%	Turner & Townsend 2007 (no further cost reductions assumed)
D4	Building Standards - 75% reduction in CO_2 emissions from 2007 standards in new housing from 2010	8%	0%	21% of total 2030 housing affected (based on modelled build rate)	New housing	£830	40%	Turner & Townsend 2007 (no further cost reductions assumed)
D5	Regulation or Voluntary Agreement to promote more efficient lighting	1%	20%	CFLs fully replaced with LEDs	Existing housing - lighting	-£72	50%	BRE 2005

		Core data - 2050						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
D6	Improved insulation for existing homes	13%	20%	50% of all solid walls insulated; all loft insulation up to 270mm; double glazing; half of floors insulated when replaced/repaired	Existing housing - space heating	£95	100%	BRE 2005
D7	Ground source heat pumps	33%	50%	25 million homes in UK; pro rata for Scotland	Existing housing - space heating	£208	100%	BRE 2005
D8	Photovoltaics (PV)	37%	50%	Half of housing excluding flats; larger area per house than in 2030.	Existing housing - electricity	£1,167	100%	BRE 2005
D9	Biomass boilers	12%	10%	5 million homes in UK; pro rata for Scotland	Existing housing - space and water heating	£104	20%	BRE 2005
D10	Solar water heating	7%	50%	80% of all homes less the number which already have SWI	Existing housing - water heating	£335	30%	BRE 2005
D11	Micro wind	5%	0%	1m x 5kW and 5m x 1kW	Existing housing - electricity	£606	100%	BRE 2006
D12	Micro CHP	2%	20%	Just detached housing (proxy for large housing)	Existing housing - water heating	£4	50%	CT MicroCHP

		Influencing factors			
Option reference	**Option**	**State of technology**	**Significant other impact**	**Type**	**Other issues**
D1	Building standards - 20% reduction in CO_2 emissions from 2007 standards in new housing from 2010[64]	Mature	Fuel poverty +	Regulatory	
D2	Building Standards - 30% reduction in CO_2 emissions from 2007 standards in new housing from 2010	Mature	Fuel poverty +	Regulatory	
D3	Building Standards - 50% reduction in CO_2 emissions from 2007 standards in new housing from 2010	Newly deployed	Fuel poverty +	Regulatory	
D4	Building Standards - 75% reduction in CO_2 emissions from 2007 standards in new housing from 2010	Newly deployed	Fuel poverty +	Regulatory	
D5	Regulation or Voluntary Agreement to promote more efficient lighting	CFLs mature; LEDs under development	None	Regulatory or Voluntary	
D6	Improved insulation for existing homes	Mature; except for external cladding of cavity walls	Fuel poverty +	Regulatory (e.g. linked to house sales) or Supplier Obligation	

[64] The Sullivan report recommends 30% reduction by 2011, 60% for 2013 and net zero carbon for 2016/17 if practical. We have assumed D1 (and D2-D4) is implemented from 2010 as a single step rather than a phased introduction for simplicity of modelling. Clearly if the measure is introduced later then fewer houses will have been built to these standards by 2030 or 2050 and so the emissions savings (and costs) will be lower.

		Influencing factors			
Option reference	**Option**	**State of technology**	**Significant other impact**	**Type**	**Other issues**
D7	Ground source heat pumps	Deployed in other countries; needs further development	Fuel poverty +	Regulatory (in practice difficult to regulate full take-up as major barriers)	Note: effectiveness would be reduced by insulation
D8	Photovoltaics (PV)	Considerable improvement needed to meet cost targets	Energy security advantages	Regulatory or Supplier Obligation	
D9	Biomass boilers	Deployed in small numbers	Energy security advantages	Regulatory or Supplier Obligation	Note: effectiveness would be reduced by insulation
D10	Solar water heating	Deployed in small numbers	Energy security advantages	Regulatory, grants or Supplier Obligation	
D11	Micro wind	Newly deployed	Energy security advantages	Regulatory or Supplier Obligation	
D12	Micro CHP	Demonstration stage	None	Regulatory or Supplier Obligation	Takes account of improved insulation

Appendix 7: Public sector

Existing measures

Ref	Option
-	Energy Performance of Buildings Directive
-	Scottish Climate Change Declaration
-	Carbon Neutral Government
-	Changes to the Renewables Obligation
-	Carbon Reduction Commitment

Future options

A series of tables are presented for future options:
1. Definition of option, state of deployment
2. Data for 2030
3. Data for 2050
4. Factors influencing deployment, potential, etc.

Ref	Option	Technical measure	State of deployment
PS1	Expand Building Standards	The Building Standards set the standards for the construction industry in Scotland. In recent years the standards have been expanded to look at more sustainable measures. It is suggested that it is considered what other carbon reducing factors could be included in the standards. Technical measures include: Greater use of low energy loss materials, passive ventilation techniques, direct use of renewable energy	Future policy For non-domestic buildings –the Sullivan Report recommended reductions if 50% for 2010, 75% for 2013, and net zero carbon for 2016/17 if practical
PS2	Further revision of the Building Standards	As PS1 plus more innovative measures to increase potential savings.	As PS1
PS3	Central Energy Efficiency Fund	Measures with a payback under 5 years. Typically: - Building Controls - Cavity Wall Insulation - Change of Fuel - Draught Proofing - Improving Boiler Plant - Low Energy Lighting - Motors and Drives - Pipe Insulation - Roof Insulation	Future policy

PS4	Carbon Management	The Carbon Trust run a number of different initiatives throughout the UK, In the public sector there are 3 main programmes currently running for LA's HEI's and NHS Trusts. These programmes provide support to develop a carbon reduction plan Carbon Management sets in place targets and plans that will deliver: Behaviour Change Investment in carbon savings in buildings, appliances etc.	Future policy

		Core data – 2030						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
PS1	Expand Building Standards	21%		Assumes the expansion of the Building Standards to include construction waste and higher requirements for refurbishment by 25% by 2010	Overlap with PS2	£50		Mid range of measures in group 2
PS2	Further revision of the Building Standards	0%		Building Standards revised by 2035 for a further 10% reduction in carbon through refurbishment.	Overlap with PS1	N/A		Mid range of measures in group 2
PS3	CEEF	13%		Extending the CEEF funding to accept applications which have a higher payback period.		£100		Higher than existing CEEF costs
PS4	Carbon Management	7%		Continuation and further phases		£200		Higher than existing CT costs

		Core data - 2050						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
PS1	Expand Building Standards	24%		Assumes the expansion of the Building Standards to include construction waste and higher requirements for refurbishment by 25% by 2010	Overlap with PS2	£50		Mid range of measures in group 2
PS2	Further revision of the Building Standards	29%		Building Standards revised by 2035 for a further 10% reduction in carbon through refurbishment.	Overlap with PS1	£50		Mid range of measures in group 2
PS3	CEEF	25%		Extending the CEEF funding to accept applications which have a higher payback period.		£100		Higher than existing CEEF costs
PS4	Carbon Management	20%		Continuation and further phases		£200		Higher than existing CT costs

		Influencing factors			
Option reference	**Option**	**State of technology**	**Significant other impact**	**Type**	**Other issues**
PS1	Expand Building Standards	Continues the trend of recent years. Will include technologies such as additional insulation, low energy passive design	Energy security advantages	Regulatory	
PS2	Further revision of the Building Standards	As PS1, plus may need some innovative technologies.	As PS1	Regulatory	
PS3	CEEF	Targets proven technologies	Creates path for invest to save projects	Grant	
PS4	Carbon Management	NA	Alerts senior managers to wider climate change issues in transport, waste, planning etc	Behaviour Change,	Includes senior management

Appendix 8: Transport

Existing measures

Ref	Option
-	Fuel Duty Escalator
-	ACEA Voluntary Agreement to reduce fleet-weighted average new car CO_2 emissions to 140 gCO_2/km by 2008
-	Graduated Vehicle Excise Duty
-	Company car tax system
-	Renewable Transport Fuel Obligation (RTFO)
-	Safe and Fuel Efficient Driving programme
-	Low Carbon Vehicle Innovation Platform
-	Low Carbon Vehicle Procurement Programme (from April 2008)
-	Emissions reduction policies in Scotland's National Transport Strategy (measures focused on freight
-	European Commission proposed regulatory replacement for the voluntary agreement on new car CO_2 emissions
-	Inclusion of aviation in the EU ETS from 2011

Note: these measures are all included in the baseline and so their emissions savings and associated costs do not appear in the analysis for this report.

Future options

A series of tables are presented for future options:
1. Definition of option, state of deployment
2. Data for 2030
3. Data for 2050
4. Factors influencing deployment, potential, etc.

Ref	Option	Technical measure	State of deployment
T1	Tightened passenger car CO_2 targets	Stop-start technology for new cars	Future new policy
T2	Tightened passenger car CO_2 targets	Advanced petrol engine technologies	Future new policy
T3	Tightened passenger car CO_2 targets	Micro hybrid technology (Stop-start technology with regenerative braking)	Future new policy
T4	Encourage uptake of hybrid technology	Mild hybrid technology for petrol and diesel cars	Future new policy
T5	Encourage uptake of hybrid technology	Full hybrid technology for petrol and diesel cars	Future new policy
T6	Encourage uptake of hybrid technology	Plug-in hybrid technology for cars and vans	Future new policy
T7	Encourage shift battery-electric technology	Battery-electric technology for cars, vans, buses & HGVs	Future new policy
T8	Encourage shift hydrogen technology	Hydrogen fuel cell technology for cars	Future new policy
T9	Eco-driving	Training all drivers to drive with fuel efficiency in mind	Extension of current (limited deployment) policy

Ref	Option	Technical measure	State of deployment
T10	Encourage uptake of "Smarter Choices" measures	Packages of soft measures to reduce demand for private transport	Extension of current (limited deployment) policy
T11	Freight measures	Package of measures based on improved vehicle technologies, improvements in operational performance and in purchasing	Future new policy
T12	Restrict growth in aviation sector	No increases in the numbers of flights to and from Scotland's airports from 2020 onwards	Future new policy
T13	Hybrid buses	Buses equipped with hybrid-electric technology to reduce emissions	Future new policy
T14	Road pricing with emissions element	Scotland-wide road pricing scheme, with incentive to encourage uptake of low emissions vehicles	Future new policy

		Core data – 2030						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
T1	Tightened passenger car CO_2 targets	1%	+20% / -100%	80% of all cars fitted with stop/start technology	Passenger cars	-£190 to -£415	10%	King Review of Low Carbon Cars (cost data and unit emissions abatement)
T2	Tightened passenger car CO_2 targets	2%	+50% /-100%	100% of petrol cars fitted with direct injection technology or downsize engine with boost technology	Passenger cars	-£375 to -£586	10%	King Review of Low Carbon Cars (cost data and unit emissions abatement)
T3	Tightened passenger car CO_2 targets	3%	+20% / -100%	80% of all cars fitted with this technology	Passenger cars	-£228 to -£340	10%	King Review of Low Carbon Cars (cost data and unit emissions abatement)
T4	Encourage uptake of hybrid technology	6%	+100% / -100%	50% of all cars fitted with this technology	Passenger cars	-£333 to -£409	10%	King Review of Low Carbon Cars; and MARKAL Macro Long-run costs of mitigation targets (AEA report for Defra)
T5	Encourage uptake of hybrid technology	8.5%	+100% / -100%	50% of all cars fitted with this technology	Passenger cars	£275 to £312	10%	King Review of Low Carbon Cars; and MARKAL Macro Long-run costs of mitigation targets (AEA report for Defra)

		Core data – 2030						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
T6	Encourage uptake of plug-in hybrid technology	15%	+166% /-100%	50% of all cars and vans fitted with this technology	Passenger cars Vans	£445 to £715	+50% / -50%	King Review of Low Carbon Cars; and MARKAL Macro Long-run costs of mitigation targets (AEA report for Defra)
T7	Encourage shift battery-electric technology	10%	+100% /-100%	20% of all cars and vans fitted with this technology	Passenger cars Vans	-£35 to +£144	+50% / -50%	King Review of Low Carbon Cars; and MARKAL Macro Long-run costs of mitigation targets (AEA report for Defra)
T8	Encourage shift hydrogen technology	0% to 3%	+100% /-100%	10% of all cars fitted with this technology	Passenger cars	£526 to £943	+100% / -50%	King Review of Low Carbon Cars; and MARKAL Macro Long-run costs of mitigation targets (AEA report for Defra)
T9	Eco-driving	2%	+100% /-100%	60% of drivers using eco-driving, achieving 4.5% reduction in CO_2 emissions per vehicle	All road transport modes	£81	+50% / -50%	Extrapolation from CfIT "Transport and Climate Change"
T10	Encourage uptake of "Smarter Choices" measures	2%	+100% /-100%		All modes	-£22	+50% / -50%	CfIT "Transport and Climate Change"

		Core data – 2030						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
T11	Freight measures	6%	+20% / -20%		Light commercial vehicles and Large Goods Vehicles	-£130	+50% / -50%	CfIT "Transport and Climate Change", Page 74-77
T12	Restrict growth in aviation sector	3%	+20% / -20%	Assumes that demand for aviation does not increase beyond 2020 levels	Aviation sector	?	?	Assumption
T13	Hybrid buses	1%	+20% /-100%	100% of buses equipped with hybrid-electric technology from 2015 onwards	Buses	£37	+200% / -50%	MARKAL Macro Long-run costs of mitigation targets (AEA report for Defra)
T14	Road pricing with emissions element	7%	+100% /-100%	Assumes that emissions-related road pricing would give an 8% CO_2 benefits (half the amount achieved in London with current Congestion Charging scheme	All road transport modes	£2,710	+100% / -50%	"Feasibility Study of Road Pricing in the UK" (DfT); "Central London Congestion Charging - Fifth Annual Report" (TfL)

		Core data - 2050						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
T1	Tightened passenger car CO_2 targets	1%	+20% / -100%	100% of all cars fitted with stop/start technology	Passenger cars	-£211 to -£455	10%	King Review of Low Carbon Cars (cost data and unit emissions abatement)
T2	Tightened passenger car CO_2 targets	3%	+50% /-100%	100% of petrol cars fitted with direct injection technology or downsize engine with boost technology	Passenger cars	-£506 to -£682	10%	King Review of Low Carbon Cars (cost data and unit emissions abatement)
T3	Tightened passenger car CO_2 targets	3%	+20% /-100%	100% of all cars fitted with this technology	Passenger cars	-£251 to -£357	10%	King Review of Low Carbon Cars (cost data and unit emissions abatement)
T4	Encourage uptake of hybrid technology	6%	+100% /-100%	70% of all cars fitted with this technology	Passenger cars	-£365 to -£451	10%	King Review of Low Carbon Cars; and MARKAL Macro Long-run costs of mitigation targets (AEA report for Defra)
T5	Encourage uptake of hybrid technology	11%	+100% /-100%	70% of all cars fitted with this technology	Passenger cars	£280 to £322	10%	King Review of Low Carbon Cars; and MARKAL Macro Long-run costs of mitigation targets (AEA report for Defra)

		Core data - 2050						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
T6	Encourage uptake of plug-in hybrid technology	28%	+166% /-100%	100% of all cars and vans fitted with this technology	Passenger cars Vans	£625 to £698	+50% / -50%	King Review of Low Carbon Cars; and MARKAL Macro Long-run costs of mitigation targets (AEA report for Defra)
T7	Encourage shift battery-electric technology	40%	+100% /-100%	100% of all cars, 100% of all vans, 50% of all buses and 20% of all HGVs fitted with this technology	All road transport modes	-£39 to +£159	+50% / -50%	King Review of Low Carbon Cars; and MARKAL Macro Long-run costs of mitigation targets (AEA report for Defra)
T8	Encourage shift hydrogen technology	0% to 13%	+100% /-100%	50% of all cars fitted with this technology	Passenger cars	£422 to £685	+100% / -50%	King Review of Low Carbon Cars; and MARKAL Macro Long-run costs of mitigation targets (AEA report for Defra)
T9	Eco-driving	3%	+100% /-100%	90% of drivers using eco-driving, achieving 4.5% reduction in CO_2 emissions per vehicle	All road transport modes	£81	+50% / -50%	Extrapolation from CfIT "Transport and Climate Change"
T10	Encourage uptake of "Smarter Choices" measures	4%	+100% /-100%	Assumes that by 2050, emissions benefits are 100% greater than in 2030, due to further rollout	All modes	-£22	+50% / -50%	CfIT "Transport and Climate Change"

		Core data - 2050						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
T11	Freight measures	7%		Assumed 20% further improvements over what was achieved in 2050	Light commercial vehicles and Large Goods Vehicles	-£130	+50% / -50%	CfIT "Transport and Climate Change", Page 74-77
T12	Restrict growth in aviation sector	8%		No increases in the numbers of flights to and from Scotland's airports from 2020 onwards	Aviation sector	?	?	Assumption
T13	Hybrid buses	1%	+20% /-100%	Buses equipped with hybrid-electric technology to reduce emissions	Buses	£32	+200% / -50%	MARKAL Macro Long-run costs of mitigation targets (AEA report for Defra)
T14	Road pricing with emissions element	6%	+100% /-100%	Scotland-wide road pricing scheme, with incentive to encourage uptake of low emissions vehicles	All road transport modes	£2,658	+100% / -50%	"Feasibility Study of Road Pricing in the UK" (DfT); "Central London Congestion Charging - Fifth Annual Report" (TfL)

		Influencing factors			
Ref	**Option**	**State of technology**	**Significant other impact**	**Type**	**Other issues**
T1	Tightened passenger car CO_2 targets	Mature		Regulatory	
T2	Tightened passenger car CO_2 targets	Newly deployed / near market		Regulatory	
T3	Tightened passenger car CO_2 targets	Newly deployed		Regulatory	
T4	Encourage uptake of hybrid technology	Newly deployed		Economic	
T5	Encourage uptake of hybrid technology	Newly deployed	Public acceptability/consumer resistance (-)	Economic	
T6	Encourage uptake of hybrid technology	Near market	Public acceptability/consumer resistance (-)	Economic	
T7	Encourage shift battery-electric technology	Near market	Public acceptability/consumer resistance (-)	Economic	
T8	Encourage shift hydrogen technology	Pilot plant	Public acceptability /consumer resistance (-)	Economic	
T9	Eco-driving	Mature	Public acceptability /consumer resistance (-)	Voluntary	
T10	Encourage uptake of "Smarter Choices" measures	Newly deployed		Voluntary	
T11	Freight measures	Newly deployed		Voluntary	
T12	Restrict growth in aviation sector	N/A	Public acceptability/consumer resistance (-)	Regulatory	
T13	Hybrid buses	Newly deployed		Economic	
T14	Road pricing with emissions element	N/A	Public acceptability/consumer resistance (-)	Fiscal	

Appendix 9: Agriculture

There are no existing policy measures for the agriculture sector that aim to reduce emissions of GHGs. Legislation targeting gaseous emissions from agriculture, the Integrated Pollution Prevention and Control (IPPC) Directive, aims to reduce emissions of gases such as ammonia that impact on air quality.

Future options

A series of tables are presented for future options:
1. Definition of option, state of deployment
2. Data for 2030
3. Data for 2050
4. Factors influencing deployment, potential, etc.

Ref	Option	Technical measure	State of deployment
A1	Dietary change for livestock	Protein intake reduced to better match animal requirements. Proportion of reduced-fibre concentrate or high-sugar grass in diet increases.	This approach is being encouraged to reduce concentrations of N in livestock manure in order to reduce NO_3 leaching.
A2	Reduce livestock numbers in response to CAP reform	Numbers of cattle and sheep are expected to decrease as a result of CAP reform	These reductions are already taking place.
A3	Improve fertilizer-N use efficiency	Better matching of application to crop uptake and taking better account of N available from crop residues and organic manure application.	This approach is being encouraged to reduce NO_3 leaching.
A4	Rumen manipulation: · ionophores in ruminant diets	The addition of ionophores to ruminant diets to decrease protein degradation in the rumen and also decrease CH_4 output	Future new policy
A5	Rumen manipulation:· genetic modification of rumen microflora	Manipulation of rumen digestion to change the composition of the rumen microflora so that methanogenic species are less dominant.	Future new policy
A6	Increase livestock productivity per head	Increase the number of lactations by dairy cows so that the number of replacements and their GHG emissions are reduced.	Future new policy
A7	Use of nitrification inhibitor with N fertilizers	Nitrification of N fertilizers containing ammonium (NH_4) is a major source of N_2O emissions. The addition of compounds to NH_4-based fertilizers which inhibit nitrification can reduce N_2O emissions.	Future new policy

Ref	Option	Technical measure	State of deployment
A8	Reduce grazing	The IPCC default EF for N deposited during grazing is 2.0% but only 1.0% for manure-N applied to land. On this basis reducing cattle grazing can reduce emissions of N_2O since the excreta that would have been deposited to directly to land will be handled as manure.	Future new policy
A9	Change from litter-based farmyard manure (FYM) to slurry systems	Solid manures contain both aerobic and anaerobic microsites where NH_4-N can be nitrified to NO_3, providing a source of N_2O emission by denitrification. Slurry, on the other hand, is anaerobic (until the time it is spread onto land) and there is little or no N_2O emission from slurry-based buildings or slurry stores.	Future new policy
A10	Anaerobic digestion	Anaerobic digestion captures CH_4 emissions during manure storage and the gas may be used as a fuel	Future new policy
A11	Consume white meat instead of red	Life cycle analyses report pig and poultry products to emit significantly less GHG during their production, per kg of final product, than sheep meat, beef or dairy products, primarily due to the very much smaller emissions of CH_4 from the digestive system.	Future new policy
A12	The marginal livestock rearing approach	Resources would only be made available for livestock production once land requirements have been meet to optimize crop production in Scotland, meet feasible biomass targets and maintain or enhance biodiversity.	Future new policy
A 13	Adopt a Vegan diet	Human protein requirements can be met without the consumption of livestock products, hence eliminating all GHG from livestock production. Crop land used to produce livestock feeds could be used to produce human food. The greater area of land available could lead to reduced fertilizer-N inputs and less N_2O emission.	Future new policy

		Core data - 2030						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+ /-**	**Source / Key assumptions**
A1	Dietary change for livestock	10% of total, both CH_4 and N_2O		Protein intake reduction would continue, encouragement would be given to increase the proportion of reduced-fibre concentrate or high-sugar grass in diets.	All livestock sub-sectors			IGER (2001) [Ref 40]
A2	Reduce livestock numbers in response to CAP reform	19% of total, both CH_4 and N_2O		Assumes 40% reduction in sheep numbers, 20% in beef and 10% in dairy	Sheep, beef and dairy	0		IGER (2001) [Diff to attribute costs of CAP reform, but can be regarded as zero since changes are taking place]
A3	Improve fertilizer-N use efficiency	1% of total, N_2O only		Better matching of application to crop uptake and taking better account of N available from crop residues and organic manure application would continue.	All crops and grass	0		IGER (2001) zero cost since should reduce fertilizer use and costs
A4	Rumen manipulation: · ionophores in ruminant diets	5% of total, CH_4 only		Since effects occur via influence on micro-organisms, the relationships are not simple and other factors are involved. The effectiveness of such measures has yet to be fully demonstrated on commercial farms.	Ruminants only (Dairy, beef and sheep)			IGER (2001)

		Core data - 2030						
Ref	Option	Potential	+/-	Key assumptions	Sub-sector	£/t CO_2eq	+ /-	Source / Key assumptions
A5	Rumen manipulation:· genetic modification of rumen microflora	5% of total, CH_4 only		Since effects occur via influence on micro-organisms, the relationships are not simple and other factors are involved. The effectiveness of such measures has yet to be fully demonstrated on commercial farms.	Ruminants only (Dairy, beef and sheep)			IGER (2001)
A6	Increase livestock productivity per head	3% of total, both CH_4 and N_2O		Increase the number of lactations by dairy cows so that the number of replacements is reduced.	Dairy			IGER (2001)
A7	Use of nitrification inhibitor with N fertilizers	5% of total, N_2O only		This approach appears to offer the greatest potential for reducing N_2O emissions from fertilizer-N applications as their use will not lead to the drastic reductions in yield possible under some scenarios.	All crops and grass			IGER (2001)
A8	Reduce grazing	35% of total, N_2O only		This reduction very uncertain	Ruminants only (Dairy, beef and sheep)			IGER (2001)
A9	Change from farm yard manure (FYM) to slurry systems	6% of total, N_2O only		This reduction also very uncertain	Dairy, beef and pigs			IGER (2001)
A10	Anaerobic digestion	3% of total, CH_4 only		Direct reductions of emissions may be small, but CH_4 generated may be used as a renewable fuel to further reduce GHG emissions	Dairy, beef and pigs			IGER (2001)

		Core data - 2030						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+ /-**	**Source / Key assumptions**
A11	Consume white meat instead of red	25% of total, both CH_4 and N_2O		This estimate does not take into account possible increase in tillage land needed to supply cereal feeds.	All livestock sub-sectors	Probably high, investment needed		Garnett (2007)
A12	The marginal livestock rearing approach	10% of total, both CH_4 and N_2O		The impacts on GHG emissions from such are complex scenario are difficult to estimate,	All livestock sub-sectors	Probably medium		Garnett (2007)
A 13	Adopt a Vegan diet	30% of total, both CH_4 and N_2O		The demand reduction scenario, however, would lead to an absolute (global) reduction in GHG emissions if, and only if, levels of consumption declined to match reduced production.	All livestock sub-sectors, and arable farming	Probably high		Garnett (2007)

NB. Quantitative cost estimates have not been included due to uncertainties over published estimates.

		Core data – 2050						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
A1	Dietary change for livestock	10%	100%	Protein intake reduction would continue, encouragement would be given to increase the proportion of reduced-fibre concentrate or high-sugar grass in diets.	All livestock sub-sectors			IGER (2001)
A2	Reduce livestock numbers in response to CAP reform	19%	400%	Assumes 40% reduction in sheep numbers, 20% in beef and 10% in dairy	Sheep, beef and dairy	[Diff to attribute costs of CAP reform]		IGER (2001)
A3	Improve fertilizer-N use efficiency	1%	200%	Better matching of application to crop uptake and taking better account of N available from crop residues and organic manure application would continue.	All crops and grass			IGER (2001)
A4	Rumen manipulation: · ionophores in ruminant diets	5%	250%	Since effects occur via influence on micro-organisms, the relationships are not simple and other factors are involved. The effectiveness of such measures has yet to be fully demonstrated on commercial farms.	Ruminants only (Dairy, beef and sheep)			IGER (2001)

		Core data – 2050						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
A5	Rumen manipulation:· genetic modification of rumen microflora	5%	250%	Since effects occur via influence on micro-organisms, the relationships are not simple and other factors are involved. The effectiveness of such measures has yet to be fully demonstrated on commercial farms.	Ruminants only (Dairy, beef and sheep)			IGER (2001)
A6	Increase livestock productivity per head	3%	50%	Increase the number of lactations by dairy cows so that the number of replacements is reduced.	Dairy	Difficult to cost, probably low		IGER (2001)
A7	Use of nitrification inhibitor with N fertilizers	5%	60%	This approach appears to offer the greatest potential for reducing N_2O emissions from fertilizer-N applications as their use will not lead to the drastic reductions in yield possible under some scenarios.	All crops and grass			IGER (2001)
A8	Reduce grazing	35%	100%	This reduction very uncertain	Ruminants only (Dairy, beef and sheep)			IGER (2001)

		Core data – 2050						
Ref	**Option**	**Potential**	**+/-**	**Key assumptions**	**Sub-sector**	**£/t CO_2eq**	**+/-**	**Source / Key assumptions**
A9	Change from farm yard manure (FYM) to slurry systems	6%	100%	This reduction also very uncertain	Dairy, beef and pigs			IGER (2001)
A10	Anaerobic digestion	3%	20%	Direct reductions of emissions may be small, but CH_4 generated may be used as a renewable fuel to further reduce GHG emissions	Dairy, beef and pigs			IGER (2001)
A11	Consume white meat instead of red	65%	20%	This estimate does not take into account possible increase in tillage land needed to supply cereal feeds.	All livestock sub-sectors	Probably high, investment needed		Garnett (2007)
A12	The marginal livestock rearing approach	25%	100%	The impacts on GHG emissions from such are complex scenario are difficult to estimate,	All livestock sub-sectors	Probably medium		Garnett (2007)
A 13	Adopt a Vegan diet	84%	10%	The demand reduction scenario, however, would lead to an absolute (global) reduction in GHG emissions if, and only if, levels of consumption declined to match reduced production.	All livestock sub-sectors, and arable farming	Probably high		Garnett (2007)

NB. Quantitative cost estimates have not been included due to uncertainties over published estimates. Garnett T. (2007). Meat and dairy production & consumption. Exploring the livestock sector's contribution to the UK's greenhouse gas emissions and assessing what less greenhouse gas intensive systems of production and consumption might look like. Working paper produced a part of the work of the Food Climate Research Network. Centre for Environmental Strategy, University of Surrey, November 2007.

		Influencing factors			
Ref	**Option**	**State of technology**	**Significant other impact**	**Type**	**Other issues**
A1	Dietary change for livestock	Principles understood, barriers costs and/or changes to farming practice	Would reduce emissions of ammonia to air and nitrate to water	This approach is being encouraged to reduce concentrations of N in livestock manure in order to reduce NO_3 leaching.	
A2	Reduce livestock numbers in response to CAP reform	NA	Would reduce emissions of ammonia to air and nitrate to water	These reductions are already taking place.	
A3	Improve fertilizer-N use efficiency	Principles understood, being implemented	Would reduce emissions of nitrate to water	This approach is being encouraged to reduce NO_3 leaching.	
A4	Rumen manipulation: · ionophores in ruminant diets	Yet to be demonstrated on commercial farms		Future new policy	
A5	Rumen manipulation:· genetic modification of rumen microflora	Yet to be demonstrated on commercial farms		Future new policy	
A6	Increase livestock productivity per head	Principles understood	Would reduce emissions of ammonia to air and nitrate to water	Future new policy	Might seem a backward step
A7	Use of nitrification inhibitor with N fertilizers	Effectiveness demonstrated		Future new policy	Effectiveness would vary according to site and season
A8	Reduce grazing	Some farmers adopting this practice	Likely to increase emissions of ammonia but could decrease those of nitrate	Future new policy	

A9	Change from farm yard manure (FYM) to slurry systems	Some farmers are doing this to reduce labour costs	Likely to increase emissions of ammonia but could decrease those of nitrate	Future new policy	May be considered by public to have an adverse impact on animal welfare
A10	Anaerobic digestion	Well established, capital cost a barrier	Would further reduce GHG emissions by providing a source of renewable energy (methane)	Future new policy	
A11	Consume white meat instead of red	Between 1945 and 2000 this was the trend in meat consumption	Would require conversion of grassland to crop land with releases of CO_2.	Future new policy	
A12	The marginal livestock rearing approach	Approach understood		Future new policy	Might be considered to be at variance with free market
A 13	Adopt a Vegan diet	Principles well understood	Would reduce emissions of ammonia to air and nitrate to water	Future new policy	Might be extremely difficult to persuade consumers

Appendix 10: Land use, land use change and forestry (LULUCF)

Ref	Sub-sector	Option	Rationale	% of Scottish emissions addressed	Timeframe (short-term / long-term application)	Potential delivery mechanisms	Interactions with other sectors and options	Source / references
L1	Expand forest area	Increase forest area	Increase carbon sequestration and supply of timber for bio energy and material substitution	Currently offsets 17.6% of Scottish emissions (117% of LULUCF emissions)	Immediate application but impacts are long-term	Afforestation grant schemes. Regulated market for carbon offsets. Planning regulations	Increased local timber supply for material substitution; fuel supply for bio energy	The Scottish Forestry Strategy 2006, Possible opportunities for future forest development in Scotland: a scoping study (Macaulay Institute, 2006). National Planning Framework for Scotland 2004.
L2	Expand forest area	Afforestation of road/rail network	Increase carbon storage on otherwise unproductive land (3024 ha available on current trunk road network, potential area on rail network unknown but will be less).	Currently 0.1% of Scottish woodland cover	Immediate application but impacts are long-term	As L1		Transport Scotland report 2007 "Opportunities for offsetting carbon emissions on the Scottish trunk road network."
L3	Expand forest area	Afforestation of derelict land	Increase carbon storage	1.2% of emissions offset by conversion of Settlement land to other uses in 2005 (8% of LULUCF emissions)	Immediate	Grants, agreement to restore land once industrial use has passed		Scottish Forestry Strategy- provision of community woodlands

Ref	Sub-sector	Option	Rationale	% of Scottish emissions addressed	Timeframe (short-term / long-term application)	Potential delivery mechanisms	Interactions with other sectors and options	Source / references
L4	Expand forest area	Expansion/ mgmt of hedgerows	Increase carbon storage					
L5	Expand forest area	Prevent further deforestation	Reduce carbon emissions and retain existing carbon stores.	0.2% of Scottish emissions are from deforestation (1.3% of LULUCF emissions)	Immediate impact	As L1		Suggested by Mark Broadmeadow, FC.
L6	Expand forest area	Expand SRF (5-y rotation)	Reduce emissions through substitution for fossil fuels	Not estimated in current inventory	Short/medium term	Grant schemes. Information on economics, species selection and management. Research/demonstration programme to select most suitable sites/species/management plans.	Energy sector-biomass	http://www.forestry.gov.uk/src; Biomass Action Plan for Scotland.

Ref	Sub-sector	Option	Rationale	% of Scottish emissions addressed	Timeframe (short-term / long-term application)	Potential delivery mechanisms	Interactions with other sectors and options	Source / references
L7	Expand forest area	Expand SRF (15-y rotation)	Increase average carbon storage (compared with SRC) and reduce emissions through substitution for fossil fuels	Not estimated in current inventory	Immediate application but impacts are medium term	Grant schemes. Information on economics, species selection and management. Research/demonstration programme to select most suitable sites/species/management plans.	Energy sector-biomass	Hardcastle et al. (2006). A review of the potential impacts of Short Rotation Forestry. LTS for FC and Defra. Biomass Action Plan for Scotland. Scottish Forestry Strategy.
L8	Forest management	Increase forest rotation length	Increase carbon storage	Currently offsets 17.6% of Scottish emissions (117% of LULUCF emissions)	Immediate application but impacts are long-term	Forest management grant schemes. Agreements with timber companies and Forestry Commission.		The Scottish Forestry Strategy 2006
L9	Forest management	Increase forest productivity	Increase carbon storage	Currently offsets 17.6% of Scottish emissions (117% of LULUCF emissions)	Immediate application but impacts are long-term	Afforestation grant schemes. Research and development into most beneficial strategies.		The Scottish Forestry Strategy 2006

Ref	Sub-sector	Option	Rationale	% of Scottish emissions addressed	Timeframe (short-term / long-term application)	Potential delivery mechanisms	Interactions with other sectors and options	Source / references
L10	Forest management	Switch wood products to long life uses	Reduce carbon emissions from reduced transport emissions,. Increase carbon storage in long-lived harvested wood products and hardwood plantations.	HWP offset 0.1% of Scottish emissions in 2005 but predicted to increase to 3.5% offset over next 5 years (0.8% to 22% of LULUCF emissions offset)	Long-term	Grant schemes, information campaigns. Research and development investment.	Transport sector, Public sector	The Scottish Forestry Strategy 2006
L11	Agricultural land use/ management	Convert cropland to grassland	Reduce emissions from land conversion to cropland and reduced cultivation and energy-intensive inputs. Increase soil carbon storage through increased biomass inputs.	11.4% of emission in 2005 are from Land converted to Cropland (74% of LULUCF emissions)	Short-term	Voluntary agreement schemes- e.g. Rural Stewardship		Rural Stewardship Scheme, Environmental Stewardship Scheme
L12	Agricultural land use/ management	Convert leys to permanent pasture	Reduced emissions through reduced cultivation and energy-intensive inputs	Not estimated in current inventory	Short-term	Voluntary agreement schemes- e.g. Rural Stewardship		Rural Stewardship Scheme, Environmental Stewardship Scheme
L13	Agricultural land use/ management	Prevent conversion to cropland	Reduce carbon emissions/ Maintain existing carbon stocks					

Ref	Sub-sector	Option	Rationale	% of Scottish emissions addressed	Timeframe (short-term / long-term application)	Potential delivery mechanisms	Interactions with other sectors and options	Source / references
L14	Agricultural land use/ management	Improve cropland management	Increased carbon storage in mineral soils through improved tillage, biosolid management and improved agronomy / rotations and reducing N_2O emissions through improved fertilizer practice	0.02% from N_2O emissions (agriculture sector). Offset from cropland/grassland management not estimated.	Short-term	Voluntary agreement schemes	Agriculture sector- reducing N2O emissions from N fertilisers	Unpublished paper from Pete Smith, University of Aberdeen (incorporates ideas from many different sources)
L15	Agricultural land use/ management	Improve grassland management	Increased carbon storage in mineral soils through improved fertilizer and biosolid management	0.02% from N_2O emissions (agriculture sector). Offset from cropland/grassland management not estimated.	Short-term	Voluntary agreement schemes	Agriculture sector- reducing N2O emissions from N fertilisers	Unpublished paper from Pete Smith, University of Aberdeen (incorporates ideas from many different sources)
L16	Agricultural land use/ management	Reduce lime application	Reduce emissions	0.2% of emissions in 2005 (1.6% of LULUCF emissions)	Long term	Voluntary agreement schemes- e.g. Rural Stewardship. Regulation.		
L17	Agricultural land use/ management	Manage field margins	Increase carbon storage					CAP reform proposed guidelines 2008

Ref	Sub-sector	Option	Rationale	% of Scottish emissions addressed	Timeframe (short-term / long-term application)	Potential delivery mechanisms	Interactions with other sectors and options	Source / references
L18	Management of organic soils	Prohibit horticultural peat extraction	Reduce carbon emissions/ Maintain existing carbon stocks	0.2% of emissions in 2005 (1.3% of LULUCF emissions)	Immediate	Regulation by statutory body	Energy sector (peat fuel), Agriculture sector (horticulture?)	
L19	Management of organic soils	Peatland restoration	Increase carbon storage/ Maintain existing carbon stocks					
L20	Other	Prevent urban expansion	Reduce carbon emissions	2.9% of emissions in 2005 from conversion to Settlement (18% of LULUCF emissions)	Immediate	Development Plans	Housing, public	National Planning Framework 2004

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