Friends of the Earth Scotland

42% BETTER

The feasibility and added value of meeting Scotland's climate change target for 2020

Scotland's champion for our environment.

Contents

This report has been compiled by Duncan McLaren of Friends of the Earth Scotland, drawing on valuable contributions from Evan Williams (EARE) and Ben Murray (Blackwood Environmental). Responsibility for any errors rests with Friends of the Earth Scotland.

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Acronyms reference list

ACE	Association for Conservation of Energy
ADL	Alexander Dennis Ltd
AQMA	Air Quality Management Area
AD	Anaerobic Digestion
CCC	UK Committee on Climate Change
CCS	Carbon Capture and Storage
CO2(e)	Carbon Dioxide equivalents
DECC	UK Department for Energy and Climate Change
ETS	EU Emissions Trading Scheme
EU	European Union
FREDS	Forum for Renewable Energy Development Scotland
GDP	Gross Domestic Product
GDR	Greenhouse Development Rights
GHG	Greenhouse Gas
GVA	Gross Value Added
HEAT	Health Economic Assessment Tool
IUCN	International Union for Conservation of Nature
LPG	Liquid Petroleum Gas
MAC	Marginal Abatement Cost
Mt	Million tonnes
NHS	National Health Service
ppm	parts per million
SG	Scottish Government
RHI	Renewable Heat Incentive
WHO	World Health Organisation

1. Executive summary

Scope

This paper explores the feasibility and implications of achieving a 42% reduction in greenhouse gas emissions in Scotland by 2020. We analyse options for emissions reduction in both the 'traded sector' of electricity generation and major industry, (where net emissions are determined by the functioning of the European emissions trading scheme (ETS)), and in the non-traded sector (including residential use, transport and waste management).

As of 2008, emissions were 21% below 1990 levels. Taking account of committed changes in land use, and projections for 2009 emissions, in order to meet the 2020 target Scotland needs to make further reductions totalling 16.4-17.5 Mt-CO2(e) pa.

Achievable reductions

Achieving a 42% reduction in emissions in Scotland by 2020 is certainly still within reach. There are challenges and there is a need for every sector of Scottish society to play a part in reducing dependence on climate polluting activities.

We find potential for saving 17.3 Mt-CO2(e), even if the ETS remains at its current level of ambition, despite growing political consensus that it can and should be raised. This is largely because the analysis finds greater potential than previous studies in peatland restoration, and in opportunities to lock-in the windfall reductions resulting from economic recession in 2008 and 2009. With these exceptions our figures typically fall within the range of those produced by the Scottish Government and the UK Committee on Climate Change.

We believe these figures are still a conservative estimate of potential. They do not include elevated ETS effort, nor the prospects of using Scotland's renewables potential more directly to cut emissions in the non-traded sector, and they do not directly reflect the value of other social benefits which reduce the net costs of emissions reduction.

Cumulative emissions

Although the absolute emissions target for 2020 is clearly achievable, Scotland is also committed to take account of a 'fair and safe' cumulative emissions budget. Based on the limited research indicative of such a budget for Scotland, the paper compares our likely emissions reduction trajectory with cumulative budgets to 2050 which are compatible with the world achieving long-term CO2(e) atmospheric concentrations in the range of 400 to 550ppm. The analysis suggests that even our most optimistic pathways still fall short of a genuinely fair and safe cumulative budget.

Any windfall gains, such as from an elevation in the EU's ambition should therefore be translated, insofar as possible, into additional reductions over and above 42% by 2020, and in line with earlier delivery of the 2050 target. Scotland should also undertake urgent investigation into appropriate cumulative budgets, and models to help meet fair and safe levels, in particular, an examination of the implications of the Greenhouse Development Rights (GDR) model for Scotland.

Added value

Emissions reductions typically cost money (either as capital investment, or as an ongoing cost). In the analysis presented here we have largely relied on analysis by the Climate Change Committee of levels of mitigation that are economically viable at a specific future carbon price. But mitigation policies also bring other benefits. For instance, investments in energy efficiency typically reduce future energy costs so much that they more than repay the initial investment. Other benefits accrue both directly to individuals and more widely to society as a whole such as improved health, reduced congestion, improved comfort, and significant reductions in the incidence of fuel poverty. The paper presents a series of case studies examining some of these potential benefits.

By helping eliminate fuel poverty, home energy improvements could prevent an estimated 180,000 cases of anxiety and depression each year, and by cutting the incidence of asthma and respiratory problems, they could reduce the number of children and working adults taking time off for illness by 15 and 25% respectively.

A programme of domestic improvements in line with the Scottish Government's proposed Energy Efficiency Action Plan would also result in over 45,000 person-years of employment between now and 2020, with a further 54,000 person years of employment created or safeguarded over the same period in delivery of renewable heating systems.

Air pollution from transport and power stations results in an average reduction in lifespans of around 8 months. In Scotland, that equates to 5,000 deaths and up to £2 billion in health costs annually. A bus scrappage scheme to modernise the bus fleet could cut polluting emissions from buses replaced by 40%, while safeguarding thousands of jobs in plants such as Alexander Dennis in Falkirk.

Increasing cycling rates by improving facilities has particularly positive effect on health. Estimates suggest that a shift from car to cycling to bring about a 40% share of short journeys would save up to 1,672 lives – which translates into annual economic value of up to £2.03 billion. The additional benefits to the economy of higher productivity and less ill health are estimated at £23 million a year, excluding any benefits from reduced traffic congestion.

Increasing the share of journeys undertaken by walking, cycling and public transport to 50% (the same as in the Netherlands) could cut obesity rates in Scotland in half, saving a significant proportion of the £170million a year the NHS in Scotland spends tackling obesity or health problems caused as a direct result. Obesity problems could also be reduced by decreasing dietary intake of meat, which is compatible with lower carbon agricultural systems – especially in terms of reduced dependence on imported feed for animals.

Conclusions

Scotland still has choices in how it achieves the 42% target. Our choices will become much wider if the EU raises its ambition to a 30% reduction by 2020 and sets ETS allocations accordingly.

This study has suggested one pathway which would exceed the target by a small margin without a greater ETS contribution, but the limits to action are only sometimes technical, and more often economic or political. In many cases deeper cuts than envisaged here remain feasible and desirable. But if we choose to limit our options due to political concerns, for example in transport, then the overall costs and difficulties of reaching the target will rise.

On the other hand, programmes for emissions reduction can deliver substantial wider social benefits, which should be taken fully into account - alongside the scientific imperatives relating to climate change - in establishing a desirable level of effort. Focussed effort is needed to improve our understanding of the economic, social and health implications of climate change programmes, so as to ensure we take an optimal pattern of action, with the greatest efforts made where net social benefits are highest.

2. Introduction and background

The Climate Change (Scotland) Act sets out a target to reduce greenhouse gas emissions[1] in Scotland by 42% (compared to a baseline of emissions in 1990). This target however came with caveats, principally the need to take expert advice. Advice has subsequently been provided by the UK Committee on Climate Change (February 2010). Given sufficient strengthening of policy and new measures the target was said to be "*ambitious but still achievable".*

This paper explores the feasibility and implications of achieving 42% emissions reduction using the policy measures set out in the Scottish Government's Climate Change Delivery Plan (June 2009), and other available measures.

The Scottish Government does not directly control all of the policy levers over all of the emissions generated in Scotland. The most significant area where the Scottish Government lacks direct control are those emissions regulated under the EU Emissions Trading Scheme (ETS). This regime governs more than 40% of Scottish emissions from the most energy intense sectors which are collectively referred to as "traded sector emissions"

The targets

Targets are expressed in relation to emissions in the base year (1990) in terms of carbon dioxide equivalent emissions (CO2(e)), this takes account of the differing warming potentials of the basket of 6 gases[2]. Scotland's emissions in 1990 were 70.12 million tonnes CO2 equivalent, made up as follows;

1990 National Communication Categories	Million tonnes of CO_2 equivalent
Energy Supply	22.35
Business and Industrial processes	12.32
Public	1.28
Transport	11.32
International Aviation	0.42
International Shipping	1.56
Residential	7.79
Waste Management	5.78
Agriculture	9.83
Land Use, Land Use Change & Forestry	-2.52
Total	**70.12**

Emissions for these same categories in 2008 (the latest year for which disaggregated data for Scotland is available) were as follows

2008 National Communication Categories	Million tonnes of CO_2 equivalent
Energy Supply	19.43
Business and Industrial processes	7.74
Public	0.99
Transport	12.08
International Aviation	1.09
International Shipping	1.29
Residential	7.57
Waste Management	2.75
Agriculture	7.63
Land Use, Land Use Change & Forestry	-4.47
Total	**56.08**
Total adjusted for ETS trading	**55.33**

1. This report considers Scotland's production of greenhouse gases, within Scotland, that is to say only those emissions which arise in Scotland whether from the production of goods or services or through land use change. It is only those emissions which originate in Scotland that are the subject of these targets.

2. Carbon dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O), Hydrofluorocarbons (HFC), Perfluorocarbons (PFC), and Sulphur hexafluoride (SF6).

This represents a reduction since 1990 of 21%. Estimates of emissions in 2009 based on UK data, also adjusted for trade in ETS permits[3], suggest a level of 53.6 to 54.2Mt-CO2(e) – a reduction of up to 23.5% over 1990 levels[4].

The Climate Change (Scotland) Act 2009 requires that the target for 2010 be set below the level of emissions estimated for 2009, and thus the baseline must reflect the recent reductions resulting primarily from economic recession.

In the years since 1990 transport and international aviation emissions have increased (7% and 157% to 2008) but all other sectors have seen reductions in emissions. These have been achieved as a result of both deliberate action on climate change and shifts in the structure of the economy. This paper considers only those emissions that occur within Scotland, although there are undoubtedly issues around changes in Scotland's relative imports and exports of goods whose production results in carbon emissions.

A target reduction of 42% implies a target of 40.67 million tonnes in 2020. However, for a number of reasons the baseline in 2020 can be expected to rise (notably because the Scottish forest carbon sink is predicted to decline as a result of a decline in planting rates in the 1990s). In absolute terms from 2008 or 2009, this means that to meet the target Scotland should be making reductions totalling 15.8 – 16.4 Mt-CO2(e). The remainder of this report explores how achievable such a target is for Scotland, and illustrates some of the wider implications of delivering such targets.

3. The Climate Change (Scotland) Act 2009 mandates that targets be set and reported against taking account of the average EU wide reduction achieved in the traded sector, rather than the specific territorial emissions in the Scottish part of the traded sector. This is because if Scottish traded sector emissions are higher than those implied by the EU cap, Scottish facilities will need to buy emissions credits from elsewhere, thus reducing emissions elsewhere within the ETS bubble. On the other hand, lower emissions in Scotland imply more credits transferred to other parts of Europe.

4. Assuming traded sector emissions to decline in line with the phase 2 cap, and levels of trading to remain constant, traded sector emissions will fall to 25.87Mt. Non-traded emissions are estimated to fall in line with the sectoral declines from 2008 found in the UK provisional figures form DECC (around 15% for business, 5% for residential, 6.5% in transport, and no decline in waste, agriculture or the public sector). Data downloaded from: http://www.decc.gov.uk/en/content/cms/statistics/climate_change/gg_emissions/uk_emissions/2009_prov/2009_prov.aspx

3. Delivering emissions reduction in the future

Introduction

Projecting forward emissions for sectors and savings achievable through different programmes and measures is fraught with difficulty. Certain changes are predictable and readily quantifiable, such as switching production of electricity from fossil fuel sources to renewables (or even switching between coal and gas). Much more problematic are those measures that depend upon changing behaviours which require estimates of the numbers of people taking them up, the impact they will have on consumption, and their persistence. Such problems can be compounded by difficulties of measurement.

There are nevertheless a number of studies aimed at exploring either the achievability of reduction targets or available routes towards the achievement of targets.

- The Scottish Government published its own Climate Change Delivery Plan[5] in June 2009. This sets out challenges and opportunities for delivering Scottish targets, of 34% and 42% by 2020. Its route to a 42% reduction by 2020 is predicated on the EU ETS providing a sizeable chunk of emissions reduction. Following the passage of the Climate Change (Scotland) Act 2009, the Government is now obligated to produce a further report on proposals and policies (RPP) to deliver the 42% target. A working paper intended to set out options for that report was widely leaked in September 2010[6].

- In February 2010 the UK Committee on Climate Change[7] provided specific advice to the Scottish Government in which it concluded that a 42% target was ambitious but remained achievable. The costs of doing so were expected to be less than 1% of GDP in 2020.

- A report by the Stockholm Environment Institute for Friends of the Earth Europe[8] 'Europe's share of the climate challenge', published in 2009 illustrates how a Europe wide target of 40% by 2020 could be achieved using domestic actions alone (i.e. without recourse to trading of emissions). This analysis sets out the domestic paths to a low carbon future for Europe. The analysis can be readily disaggregated to a UK level which indicates that the UK share of a Europe–wide 40% target would be a little higher at 41% and although it is difficult to further disaggregate this analysis to Scotland it would appear to be entirely consistent with a Scottish 42% target being achievable.

- An analysis by Stop Climate Chaos Scotland "the case for early action, and the achievability of emissions reduction in excess of 40% by 2020" was prepared in response to the Scottish Parliament's Stage 2 vote on interim targets. This paper makes the case that constraints on the contribution of the EU ETS may be overstated because the power sector will contribute a greater share of emissions reduction and this is more heavily weighted to Scotland.

There is therefore considerable reason for confidence that the 42% target is achievable given the appropriate political will.

5. http://www.scotland.gov.uk/Publications/2009/06/18103720/11

6. Available at: http://robedwards.typepad.com/files/draftppreport-1.doc

7. http://downloads.theccc.org.uk/Scottish%20report/CCC-Scottish-Report-web-version.pdf

8. http://sei-international.org/publications?pid=1318

Analysis

In this section we conduct a preliminary analysis of the available Scottish Government (SG) and UK Committee on Climate Change (CCC) figures to illustrate how far they go towards achieving a 42% target. For each of the sectors there are a number of potential policies with associated greenhouse gas savings. Taking these in turn we estimate the following potential (details are shown in Annex 1):

Sector	**Programmes**	**Saving potential** *1000 tonnes $CO_2(e)$*	**Notes**
Traded sector under EU ETS	50% renewables target; Carbon Capture and Storage; Demand reduction; Other renewables	7,300	Using lower estimate by CCC based on only 20% EU target. Includes international aviation.
Business and industry	Renewable heat programme; Efficiency programmes; New building standards; Behaviour change	951	Based on SG estimates, much lower than CCC, allows for significant impact of recession on baseline in this sector.
Transport	Low carbon vehicles; Vehicle and freight efficiency; Traffic management, travel planning; Eco-driving; Biofuels / electric vehicles; Bus and Taxi infrastructure and low carbon vehicle incentive; On street parking control; workplace parking levy; Cycling and walking infrastructure; Car clubs; Speed limit enforcement; Road pricing; Freight modal shift	2,840	Mainly SG estimates. Biofuels potential reduced to address sustainability concerns.
International shipping	Shipping efficiency; modal shift	-184	SG estimate of shipping savings offset by CCC expectation of sector growth vs 2010 baseline
Residential	Efficiency programmes; New building standards; Behaviour change	1406	Mix of SG and CCC estimates: total close to, but below CCC stretch scenario
Waste Management	Zero Waste Scotland measures	605	SG estimates
Agriculture	Livestock; Farming for a better climate; On farm anaerobic digestion; Cross Compliance	1080	Mainly CCC estimates, but reduced to avoid double counting with land-use
Land use change	Soil management; Woodland creation	3160	CCC estimates on forestry, IUCN estimates on peatland restoration
Total		**17,342**[9]	

Our figures are estimates, but we are confident that they are not consistently over-optimistic even though they exceed the target level required. Indeed there are a number of reasons why they may still underestimate potential.

9. Or 17.3Mt-CO2(e), as compared to the required saving outlined earlier of 15.8 –16.4 Mt-CO2(e)

1.Our figures exclude elevated ETS effort

Both the CCC and SG indicate that around 3 Mt-CO2(e) additional savings would be delivered if the EU adopted ETS measures commensurate with a 30% target for emissions reduction by 2020. Although such a shift enjoys significant support amongst EU member states and within the Commission, it has yet to win the necessary level of political consensus.

2.Our figures treat additional renewable capacity as completely within the ETS

Scotland has the potential to increase production of renewable electricity to over 100% of domestic consumption by 2020. It is expected however that a significant level of conventional generation will continue, and any surplus be exported to England and Wales. Insofar as any surplus could be used domestically to substitute for gas in heating or vehicle fuel in transport applications it could reduce emissions against the Scottish target rather than becoming a part of the ETS 'bubble'. The scope is difficult to quantify either in absolute terms, or so as to avoid double counting of other effort in those sectors. But this approach – not included in our figures - could only act to further reduce emissions.

3.CCC estimates of economic potential do not account for all social benefits

Many of the figures we adopt are based directly or indirectly on the CCC's estimates. In turn these are based on econometric estimates of levels of adoption based on a certain notional carbon price. As will be shown in section 5 below, such values do not fully take into account indirect social benefits that may arise such as reduced health service costs, or economic benefits from congestion relief. As a result, elevated effort to deliver additional technically feasible savings can almost certainly be justified.

There are other factors which may act to reduce the potential, but we believe most of these to be substantially smaller in magnitude than the factors set out above:

i. The baseline for technical potential may have changed since initial estimates

Although emissions have fallen in Scotland since 2007, over 85 per cent of these reductions have occurred within the traded sector, so the vast majority of the technical potential of non-traded sector measures remains. We therefore do not believe that our estimates of potential savings need to be reduced significantly to account for any shifts in baseline.

ii. Mixing estimates from different sources may have led to double-counting

An audit of the data sheets suggest that this risk is small – perhaps in the order of 0.25Mt-CO2(e) pa. This has been deliberately offset by selecting figures from the CCC's lower ambition scenario (the Extended package) rather than the higher ambition (Stretch package) where such risks have been identified.

iii. Impacts of economic change on the projected baseline to 2020

Insofar as we have relied on CCC estimates of the potential, we should also take account of their forecast for underlying growth in the non-traded sector to 2020 (of 1.2Mt-CO2(e) pa. This has not been directly incorporated, as many of the estimates we use are derived from the SG which appears to not account for growth in the same way. Also the projection was made based on 2008 data, and takes no account of the risk of a double dip recession. As a result we believe it is unlikely that this factor could exceed the surplus reduction identified below.

The most significant single addition to the work of the CCC is the estimate from the International Union for Conservation of Nature UK Peatland Programme of the potential savings arising from restoration of peatlands, totalling 2.4Mt-CO2e pa from 2015[10]. However to avoid any risk of double counting, the CCC estimate for savings from better management of agricultural crops and soils has been halved to 0.5Mt-CO2(e) pa.

Results of analysis

Applying this analysis to a baseline using the 2008 emissions figures for Scotland, the delivery of the measures we have outlined above would result in total emissions in 2020 of just 39.7 million tonnes of CO2(e), a reduction of 43% (shown on right.)

	Thousand tonnes-CO_2(e)
2008 emissions	55,325
Projected change in 2009 (recession)	-1,145
Land-use sink forecasts to 2020	2,860
Projected 2020 level without mitigation	57,040
Mitigation measures	17,342
2020 emissions after mitigation	39,698
% reduction on 1990 emissions	43%

10. Peatlands and Greenhouse Gas Emissions Reduction Opportunities in Scotland 18/02/10 http://www.iucn-uk-peatlandprogramme.org/GHGOpportunitiesScotland

4.Cumulative emissions

Scotland's Climate Change Act sets targets for reductions in 2020 and 2050, but it also requires ministers to set annual targets for emissions reduction, and critically, to do so while taking account of a fair and safe cumulative budget.

The latter imposes a stiff test.

A safe budget is one commensurate with reductions in global emissions that avoids dangerous anthropogenic impacts on the climate. This has been widely interpreted as a trajectory which avoids temperature rise of more than 2ºC, although there is emerging evidence and political momentum to challenge this, with figures of 1.5ºC and even 1.0ºC being proposed for the long-term safe limit.

The ultimate temperature rise depends primarily on the final concentration of GHGs in the atmosphere, which in turn depends on the cumulative volume of emissions. Scientists can only provide a probabilistic assessment of the likelihood of avoiding a certain temperature rise at a certain concentration. However the maximum safe concentration almost certainly lies in the range of 300-550ppm CO2(e), and most likely in the lower end of this range. Several studies have examined this issue to arrive at estimates of a safe global GHG budget[11].

A fair budget is one commensurate with a fair global distribution of effort, taking account of the disproportionate historical contribution to climate change from emissions by countries in the global North.

Only a few studies have combined safety and equity for individual countries, such as the UK[12]. The UK study by the Tyndall Centre suggested a fair and safe cumulative budget for 2000-2050 of 17.25Gt-CO2, based on achieving atmospheric concentrations of 475-500ppm CO2(e). A Scottish share of this on a population basis would be at most 1.5Gt-CO2. A 550ppm outcome (as considered in the CCC's first report) would allow a larger budget of approximately 20Gt-CO2 for the UK, and almost 1.75Gt-CO2 for Scotland[13].

Assuming emissions reductions until 2022 follow the SG's proposed annual targets, and those after 2022 follow a gradual reduction curve at a rate marginally above 3.5% per year (a path which would just deliver the 2050 target), we can predict when Scotland would exhaust any given cumulative budget. We have compared a central emissions reduction trajectory with alternative estimated fair and safe budgets in Annex 2. A 1.75Gt budget would last until 2044, and a 1.5Gt budget until only 2033.

The size of the budget is fairly sensitive to the outcome concentration, and the analysis undertaken so far is relatively simplistic. For both these reasons further detailed analysis is highly desirable.

Nonetheless, we can conclude that achieving the 42% target is compatible with the estimates given above, but only at the upper end (a 550ppm world). Even then we would have to accelerate action to deliver cuts of over 4.5% per year, and 85% reductions by 2050. The trajectories are only compatible with achieving a 475-500ppm world if subsequent reductions between 2020 and 2035 accelerate to almost 10% per year. Clearly our existing trajectories do not offer a fair or practical contribution to a goal of 450ppm or below.

There are two adequate responses to this analysis. One is to elevate our domestic effort before 2020 (and thereafter) still further. In this context any windfall gain obtained by an elevation of EU effort must be taken as additional reductions, rather than a reason to reduce effort elsewhere.

11. See, for example Meinshausen et al. 2009. Greenhouse-gas emission targets for limiting global warming to 2°C Nature 458, 1158-1162

12. Bows et al 2006. Living within a carbon budget. Tyndall Centre Manchester report for Friends of the Earth and the Cooperative Bank.

13. Based on Bows et al 2006 ibid The report acknowledges confusion in earlier work with respect to CO2 or CO2(e) equivalences. Here it has been assumed that the budgets cited are in CO2(e) and directly comparable with the rest of this report. If this is incorrect the budgets could be around 14% larger to deliver the same atmospheric concentrations. Given subsequent work by Meinshausen, Allen and others that suggests significantly smaller safe carbon budgets, we prefer to use the more conservative figures in the Tyndall report.

Offshore windfarm © laucala.eu

The second would be to dramatically elevate our financial and resource contribution to emissions reductions in developing countries, not as a carbon offset against our existing national or international obligations, but additional to them. This is the model suggested by the Greenhouse Development Rights (GDR) framework[14].

The importance of early action

The timing of different measures can be highly significant in cumulative terms. Early action has a disproportionate positive impact on cumulative emissions. Achieving the full savings available from peatland restoration in the next five years would save over 6Mt-CO2(e) more by 2020 than achieving the same level over ten years, and 12Mt-CO2(e) more cumulatively than delaying action until 2016. However all three approaches would make exactly the same contribution to the annual level of emissions in 2020.

We have analysed the Scottish Government's proposed annual targets regime to 2022 to assess its cumulative effect. Between the targets rejected by Parliament in June, and those now expected to be accepted, there has been a cumulative reduction of 14.29Mt-CO2(e). However, the Government chose to accept lower targets in the early part of the period – based largely on analysis of greater savings resulting from recession, but reduced annual effort in the later part so as to arrive at the same 2020 level. If levels of effort in the later years had been maintained, alongside measures to lock in the early windfall gains, the cumulative benefit would have grown to over 30Mt-CO2(e). By 2050 that could translate into over 100Mt-CO2(e) of cumulative savings (equivalent to over 7 years worth of 2050 emissions). In other words, we could achieve significantly more savings by 2020 and 2050 if we maintain effort in the years from 2014-2020 at the levels previously proposed.

This demonstrates the importance of capturing and maintaining early gains if the Government is to demonstrate compliance with its duty to take account of a fair and safe cumulative emissions budget when setting annual targets.

14. See for example Baer et al 2008 The Greenhouse Development Rights Framework: the right to development in a climate constrained world. Heinrich Boll Stiftung, EcoEquity, Stockholm Environment Institute

5.Costs and benefits

Establishing the detail of the costs and benefits of each programme is a significant exercise for each measure. The Committee on Climate Change estimate costs of acting in the areas they identify to be of the order of 1% of GDP by 2020. This is a not insubstantial sum of money, however, there also significant economic and social benefits available as a result of undertaking these measures.

We provide additional information of the nature of the benefits of low carbon choices in a series of case studies in chapter 6. These benefits include the very real cost savings of associated with reduced energy use. Other benefits accrue both directly to individuals and more widely to society as a whole such as improved health, reduced congestion, improved comfort, and significant reductions in the incidence of fuel poverty.

The real heart of this issue is who bears the cost and how, and who reaps the benefits. It is easy to be very focused on the direct costs of low carbon measures, because these are easier to quantify and will necessarily fall on distinct groups.

Measures associated with behaviour change will very largely require public intervention and therefore costs to the public purse. Benefits may well be quite diffuse; individuals benefiting from lower fuel costs, perhaps as a result of reduced driving or improved insulation, accruing to each individual are likely to be relatively small. Wider benefits to health for example will represent a small but non trivial reduction in pressures on NHS services, improving services for everyone or permitting cost savings to be captured. But taken cumulatively, the overall impact on society would be substantial.

Our preliminary analysis suggests that in many cases these second order benefits alone would justify undertaking many of the measures needed to achieve emissions reduction targets. An illustration of this is provided by marginal abatement cost (MAC) curves, produced by McKinsey and company (and others) demonstrating that there remain a considerable number of measures and opportunities that can be taken at no cost (or indeed negative cost – that is to say there would be a financial benefit in taking the measure).

All of the activities that appear below the zero line in the MAC curve can be undertaken and return a benefit in excess of costs (not considering climate benefits). In short they represent things that should be done, and are beneficial even in the absence of concerns about climate change.

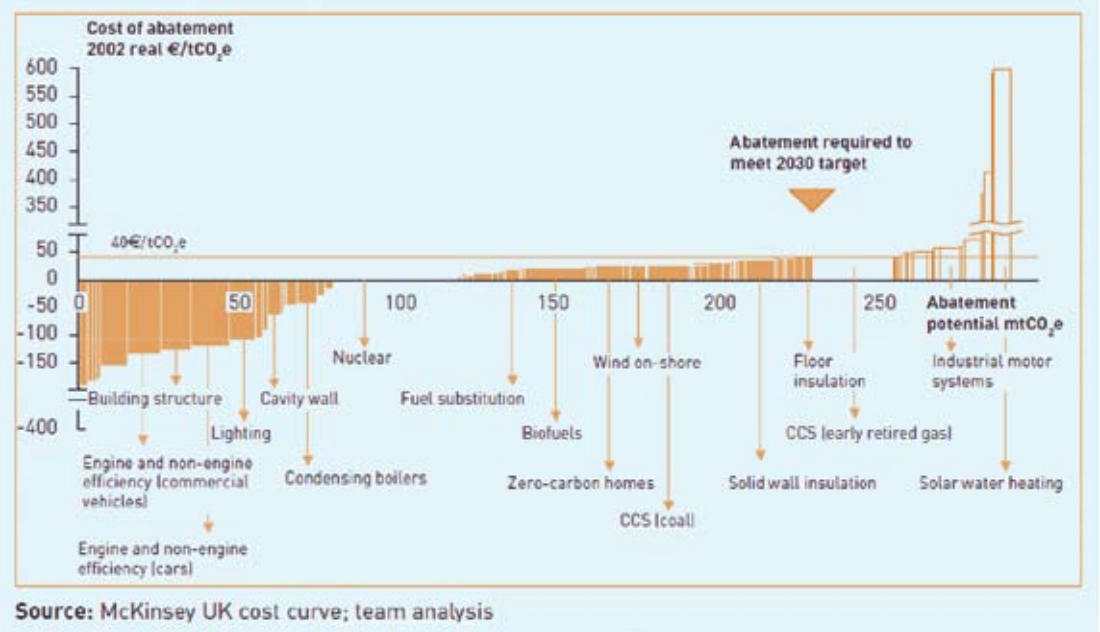
Our analysis suggests there are further financial and social benefits which would move more measures below the zero line, and still others below the ‘cost of carbon’ line equated here with delivery of the 2020 UK target.

The most important benefit, however, remains the avoided harm that climate change would cause in the absence of significant reductions in greenhouse gas emissions. Lord Stern’s analysis of between 5 and 20% loss in GDP globally from climate change demonstrates the scale of the harm that will be suffered if we do not take substantial measures to combat climate change. There will also be not inconsiderable negative social impacts if we fail to address the climate challenge.

It must be noted that the 'cost of carbon' line shown on the chart is derived from the UK target, and lies substantially below the estimates of the social cost of carbon emissions in a 'business as usual world' made by Lord Stern. Moreover Stern's estimates relate only to the impacts of climate change, and do not include valuations of the associated social benefits of mitigation activity.

In other words there are several reasons to argue that greater expenditure on emissions reduction than foreseen by the CCC is justified by the net balance of associated costs and benefits[15].

Example of Marginal Abatement Cost Curve (McKinsey and Company) [16]



Source: McKinsey UK cost curve; team analysis

15. This argument may not apply to the mitigation levels identified by the Scottish Government, as it is not clear that they have been constrained by reference to a cost of carbon limit.

16. Taken from the CBI; Climate Change; Everybody's Business

6. Case studies

This section describes the findings of five representative case studies of emissions reduction measures which have the potential to deliver additional public benefits – to health, equality and the economy.

Home improvements

On average, almost one quarter of an individual's total carbon footprint comes from energy used in the home: for space heating, hot water, lighting and electrical appliances. Within the home, the largest single source of greenhouse gases comes from space heating, accounting for over half of domestic emissions.

Although building standards for new buildings continue to improve, it is estimated that around two-thirds of the housing that will be in use in 2050[17] are already in use now. An urgent programme of retrofit and renovation to boost the energy performance of Scotland's existing house stock is vital to meeting our long term emissions reductions targets. This study suggests that over 0.5Mt-CO2(e) pa will need to be saved through energy efficiency measures in homes.

When it comes to achieving a broad range of environmental, social, health and economic benefits, there are few policies that can rival a programme of domestic energy efficiency improvements. Such a policy can not only deliver the kind of emissions reductions required to meet our climate commitments; it can lift households out of fuel poverty, cut the numbers of excess winter deaths, bring about improvements in both physical and mental health and deliver tangible economic and employment benefits.

Reduced fuel poverty

Within Scotland, hundreds of thousands of households are in "fuel poverty", a situation where over ten percent of household income is needed to maintain a comfortable temperature in the home.[18] Fuel poverty is most common among vulnerable groups such as single parent families, households in receipt of benefits, and those on state pensions.[19] These groups have lower disposable incomes but spend more time at home, and so have to heat their homes for longer. While most fuel poor households are in urban areas, the risk of being fuel poor is very much higher for households living in rural areas.[20] This is largely due to the greatly increased cost of fuel for those without access to mains gas, and the lower thermal efficiency of solid wall housing frequently found in rural areas.

Fuel poverty is a particular problem in Scotland (compared to other parts of the UK) for the following reasons:

- Fuel poverty is strongly linked with low income, and average earnings in Scotland are around 9% lower than in England
- The Scottish climate means that we experience a longer heating season than those living further south; a home in northern Scotland can spend 68% more on heating than a home in southern England
- Scotland has a higher proportion of properties not connected to the mains gas network. This means that they are obliged to use more expensive fuels for heating.
- The Scottish housing stock is also different; homes in Scotland often have wider wall cavities (which are more expensive to insulate) and a lower incidence of loft spaces.[20]

17. Boardman et al. (2005), 40% House. http://www.eci.ox.ac.uk/research/energy/downloads/40house/40house.pdf

18. Energy Action Scotland (2010), About fuel poverty. http://www.eas.org.uk/index.php?page_id=83

19. Faculty of Public Health (2006), Fuel poverty and health – briefing statement.

20. Scottish House Condition Survey, Fuel Poverty Report – 2003/04. http://www.scotland.gov.uk/Resource/Doc/155541/0041758.pdf

Loft Insulation © Simon Williams

The Scottish House Condition Survey report of 2008 found that over one in four Scottish households – 618,000 – were living in fuel poverty. Ongoing increases in fuel prices can only reduce the affordability of heating the home - by 2009 it was estimated that rises in the cost of gas, oil, coal and electricity had resulted in the total number of households in fuel poverty increasing to 800,000[21] – more than one in three Scottish homes. To put this figure into context, the Scottish Government estimates that the incidence of fuel poverty in Scotland is more than three times higher than in England.[22]

Fuel poverty is caused by a combination of three main factors: low household income, high energy prices, and poor home energy efficiency. Of these, improving energy efficiency is the most likely to bring about a permanent reduction in the numbers of households affected by fuel poverty, thus delivering significant social justice benefits.

Health benefits

Living in fuel poverty brings with it significant health consequences, both physical and mental. According to the UK Faculty of Public Health, living in a cold home can increase the likelihood of ill health, including hypertension, heart disease, stroke, influenza and asthma.[23] Mental health can also suffer, largely as a result of difficulty in paying fuel costs. An evaluation into the Warm Front (a scheme set up to tackle fuel poverty through the installation of improved insulation and efficient heating systems) found:

- A reduction in stress, partly from improved living conditions and partly from less difficulty in paying fuel bills
- Those facing great difficulty paying fuel bills were over four times more likely to suffer anxiety or depression than those paying bills easily
- Those expressing dissatisfaction with their heating were 80% more likely to report poor general health than those who were satisfied.
- There was a halving of the incidence of anxiety or depression (also known as “common mental disorder”) from 300 to 150 per 1000 occupants after Warm Front measures were carried out.

21. Energy Action Scotland (2010), About fuel poverty. Op cit.

22. Energy Action Scotland (2010), About fuel poverty.

23. Scottish Government (2008), Review of Fuel Poverty in Scotland. http://www.scotland.gov.uk/Resource/Doc/1125/0060321.doc

On the basis of these figures, eliminating fuel poverty in Scotland could prevent an estimated 180,000 cases of anxiety and depression each year[25], as well as directly reducing material poverty. Within Scotland, it has been estimated that the total cost of mental health problems in 2004-05 was £8.6 billion, equivalent to 9% of the Scottish GDP.[26]

The evaluation concluded that the Warm Front also had a positive impact in reducing the deaths of older people. With regard to preventing the deaths of older people, installing insulation was found to be most cost-effective with an average cost of £12,905 per life-year saved.[27]

A study carried out in Cornwall found that improvements in home energy efficiency resulted in a significant improvement in the incidence of childhood asthma;[28] another study (this time from New Zealand) showed that: *"Insulating existing houses led to a significantly warmer, drier indoor environment and resulted in improved self rated health, self reported wheezing, days off school and work, and visits to general practitioners as well as a trend for fewer hospital admissions for respiratory conditions."*[29] These studies indicate that home improvements can reduce the number of children and working adults taking time off for illness by 15 and 25% respectively.

Cuts in "increased winter mortality"

Each winter, Scotland experiences significantly "increased winter mortality"[30]; this amounted to an additional 3,510 deaths[31] during the winter of 2008/09, (the most recent period for which data are available).[32] Over half of excess winter deaths are from cardiovascular and circulatory disease, with another third from respiratory diseases.[33]

Across the UK, we suffer a higher rate of increased winter mortality than most other parts of Europe and Scandinavia, despite the fact that we have relatively milder winters. The lower quality of British housing stock, which is less thermally efficient than in most other Northern European countries and offers therefore less protection against the cold, has been put forward as one reason for our poor record on winter mortality.[34] A study carried out for the Joseph Rowntree Foundation suggested that: *"people in poorly heated homes are indeed more vulnerable to winter death than those living in well-heated homes. This suggests that substantial public health benefits can be expected from measures that improve the thermal efficiency of dwellings and the affordability of heating them."*

24. *Faculty of Public Health (2006), Fuel poverty and health – briefing statement. Op cit.*
25. *This estimate assumes 50% of fuel poor households are single-person and the remainder comprise just two individuals.*
26. *Scottish Association for Mental Health (SAMH), Cost of mental health problems in Scotland £8.6 billion in 2004-05. http://www.centreformentalhealth.org.uk/news/2006_cost_of_mental_health_in_scotland_billions.aspx*
27. *Green & Gilbertson, Warm Front, better health – health impact evaluation of the Warm Front scheme. http://www.apho.org.uk/resource/view.aspx?RID=53281*
28. *Somerville et al., Housing and health: does installing heating in their homes improve the health of children with asthma? http://www.ncbi.nlm.nih.gov/pubmed/11114752*
29. *Howden-Chapman et al., Effect of insulating existing houses on health inequality: cluster randomised study in the community. http://www.bmj.com/content/334/7591/460.full*
30. *Increased winter mortality is defined as the difference between the number of deaths in the four-month "winter" period (December – March, inclusive) and the average number of deaths in the two four-month periods preceding winter (August – November) and following it (April – July).*
31. *Provisional figure.*
32. *General Register Office for Scotland (2009), Increased Winter Mortality in Scotland 2008/09. http://www.gro-scotland.gov.uk/statistics/publications-and-data/increased-winter-mortality/increased-winter-mortality-in-scotland-2008-09.html*
33. *Faculty of Public Health (2006), Fuel poverty and health – briefing statement. Op Cit.*
34. *Joseph Rowntree Foundation (2001), The impact of housing conditions on excess winter deaths. http://www.jrf.org.uk/sites/files/jrf/n11.pdf*

Employment and economic benefits

Improving the energy efficiency of our homes is also far better for employment than building new fossil fuel power stations. According to the developers, the proposed new coal plant at Hunterston would employ 160 people in the long term. Including construction jobs it might create 25 jobs per terawatt hour (TWh) of electricity generated. Energy conservation would generate 370 jobs per TWh, including indirect effects[35].

An EU study found that there are three main reasons why investment in energy efficiency has such a positive impact in terms of job creation:

- The manufacture and installation of energy efficiency measures is labour intensive compared to energy supply. This accounts for an employment gain of between 10 to 30 person-years per million pounds spent, and nearly 60 person-years if job creation is made a priority.

- Cost effective energy efficiency measures result in consumers spending additional money in the more labour intensive general consumption sector (where a greater share of spending buys services rather than goods or commodities). This effect can generate an additional 70 person-years per million pounds spent over the lifetime of the investment, albeit with some potential rebound effects in terms of carbon emissions.

- Work in the manufacture and installation of energy efficiency measures is accessible to people suffering the highest rates of unemployment given that it is manual labour and distributed around the country. Where programmes are designed to help those in fuel poverty (see above), the work is concentrated in areas where unemployment tends to be highest.[36]

An analysis carried out by the Association for the Conservation of Energy (ACE) determined that a programme of domestic improvements in line with the Scottish Government's proposed Energy Efficiency Action Plan would result in over 45,000 person-years of employment between now and 2020, or an annualised figure of 4,520 installer and support positions either created or safeguarded. Furthermore, the programme of investment would generate £400 million of gross value added to the Scottish economy each year.[37]

The employment and economic benefits to be gained from a massive programme of residential energy efficiency improvements are at the heart of the proposed Green New Deal[38]; domestic energy efficiency installations are so cost-effective that they represent one of the best and most secure ways of investing both public and private money while creating secure employment and making massive cuts in carbon emissions.

35. Wuppertal Institute, Germany. http://www.kas.de/wf/doc/kas_13931-544-1-30.pdf

36. Energy Saving Trust (2007), Sustainable energy and job creation – briefing note. http://www.energysavingtrust.org.uk/business/Publication-Download/?oid=516716&aid=1778737

37. Association for the Conservation of Energy (2009), Warm Homes, Green Jobs. http://www.ukace.org/publications/ACE%20Research%20%282009-10%29%20-%20Warm%20Homes,%20Green%20Jobs%20%5Bbriefing%5D.pdf

38. New Economics Foundation (2008), A Green New Deal. http://www.neweconomics.org/sites/neweconomics.org/files/A_Green_New_Deal_1.pdf

Renewable heat

Within buildings, far more carbon emissions result from space and water heating, most of which is not powered by electricity. In order to maximise the uptake of renewable heat sources, the UK Government has been consulting on a proposed Renewable Heat Incentive (RHI) that would reward households for each kilowatt hour of heat generated from sources such as solar thermal, biomass or heat pump technology. This study suggests almost 0.9Mt-CO2(e) will be saved by the adoption of renewable heat technologies and networks. In this respect renewable heat is a complement to energy efficiency, not a replacement. It can deliver additional emissions reductions by providing residual heat needs, and by providing heat in buildings which are hard to improve through insulation.

Tackling fuel poverty

Improving the energy efficiency of a residential property will always have an important role to play in tackling fuel poverty, but there are many households who can still benefit directly from a reduction in unit energy costs through a switch from fossil fuels to renewable heat sources. This is particularly likely to be the case for households located outside urban and suburban areas.

As well as being more likely to live in traditional solid-walled housing, households in rural locations are less likely to have access to mains gas, forcing them to pay substantially higher prices for propane or kerosene (heating oil) or to use electric heating.[39] And while gas and electricity prices are regulated by Ofgem, LPG and heating oil are not, meaning that consumer protection mechanisms are often minimal.[40, 41] This combination of factors means that extreme fuel poverty (needing to spend 20% or more of household income to maintain a comfortable temperature) is more common in rural than urban areas.[42]

Assisting households – particularly, but not exclusively, in rural areas – to switch from expensive sources of heat to renewable sources that are much cheaper to run has the potential to address fuel poverty across the country, particularly when combined with efforts to improve home energy efficiency. The potential gains are greatest for households in rural areas where fuel bills are highest and extreme fuel poverty is most common.

Health benefits

Households that struggle to heat their homes suffer high levels of poor mental and physical health.[43] Homes with lower internal temperatures are also linked with a higher incidence of excess winter deaths.[44] By cutting the cost of heating a home, and by raising its ambient temperature, a shift towards renewable heat sources can make a substantial contribution to improving health and cutting excess winter deaths.

Economic and employment benefits

But in addition to the social and health benefits to be gained from moving from fossil fuels to renewable heat sources, there are also economic and employment gains to be made. In its study of the economic impacts of the Climate Change (Scotland) Act the Association for the Conservation of Energy (ACE) quantifies the gross value added (GVA) and the numbers of installer and support positions created or safeguarded by measures in the Scottish Government's Energy Efficiency Action Plan. Four of the measures (solar thermal installations, biomass boilers, ground source heat pumps and air source heat pumps) fall within the definition of renewable heat. ACE's analysis indicates that between 2010 and 2020, almost 2.4 million installations in Scotland

39. BBC News (2006), Rural struggle without mains gas. http://news.bbc.co.uk/1/hi/uk/6062716.stm

40. BBC iPM (2008), Rising costs of home heating oil.

41. Centre for Sustainable Energy (2008), Quantifying Rural Fuel Poverty – Final report. http://www.cse.org.uk/downloads/file/FinalRuralFPreport_08_FINAL.pdf

42. Scottish House Condition Survey, Fuel Poverty Report – 2003/04. http://www.scotland.gov.uk/Resource/Doc/155541/0041758.pdf

43. Green & Gilbertson (2008), Warm Front, Better Health – health impact evaluation of the Warm Front scheme. www.apho.org.uk/resource/view.aspx?RID=53281

44. Joseph Rowntree Foundation (2001), The impact of housing conditions on excess winter deaths. http://www.jrf.org.uk/sites/files/jrf/n11.pdf

Snow on roofs
© Sean Wallis

could be carried out, with GVA totalling over two billion pounds accruing to the Scottish economy. Furthermore, ACE estimates that almost 54,000 person years of employment could be created or safeguarded over the same period.[45]

This sector also has an application at a larger scale. To date, Scotland has two power stations burning biomass (one wood and one poultry litter, with a total output of 54MW) but the Forum for Renewable Energy Development in Scotland (FREDS) estimates that there is the potential for a further 450MW of wood fired power supply given current forecasts of indigenous fuel availability.[46] FREDS, and the Scottish Government suggest, wisely, that this resource should be targeted at local heat generation facilities, rather than on production of electricity.

A study prepared by the Sustainable Development Commission found significant potential for increased employment within the wood fuel sector; for each megawatt of wood-fired renewable heating installed, between five and ten times more jobs were created than for other renewable technologies.[47] Balcas operates a wood chip plant in Northern Ireland that supports around 1000 jobs in the timber supply chain; they also have a plant in Scotland that supports between 500-700 positions. Expanding the market for this product could lead to additional employment in this sector.

The use of anaerobic digestion (AD) to convert the organic fraction of municipal solid waste into biogas and a soil improver is another opportunity for renewable heat. The Sustainable Development Commission estimates that over 400,000 tonnes of municipal solid waste (MSW) (almost 12% of Scotland's total) is suitable for anaerobic digestion. Scottish and Southern Energy (SSE) recently announced plans for an AD plant at Barkip in North Ayrshire. The proposed plant is expected to take up to 75,000 tonnes of organic waste each year and have a generation capacity of 2.5MW.[48] Scotland's current output of suitable MSW could support over five such plants (or a larger number of smaller digestors) with associated economic and employment benefits. As well as using AD to process MSW, there is also considerable scope for farm-scale use of anaerobic digestion to deal with agricultural residues and animal wastes; this too would provide valuable employment potential in rural areas.

45. Association for the Conservation of Energy (2009), Warm Homes, Green Jobs. http://www.ukace.org/publications/ACE%20Research%20%282009-10%29%20-%20Warm%20Homes,%20Green%20Jobs%20%5Bbriefing%5D.pdf. The figures given here are additional to those for insulation measures referred to in the previous section.

46. FREDS (2005), Promoting and accelerating the market penetration of biomass technology in Scotland. http://www.scotland.gov.uk/Publications/2005/01/20616/51409

47. Sustainable Development Commission (2005), Wood fuel for warmth – a report on the issues surrounding the use of wood fuel for heat in Scotland. http://www.sd-commission.org.uk/publications.php?id=248

48. Scottish and Southern Energy (2010), SSE announces plan for Scotland's largest biogas plant. http://www.scottish-southern.co.uk/SSEInternet/index.aspx?id=22180&TierSlicer1_TSMenuTargetID=1368&TierSlicer1_TSMenuTargetType=1&TierSlicer1_TSMenuID=6

Bus scrappage scheme

This section examines proposals for a bus scrappage scheme, analogous to the UK Government's car scrappage scheme that ran between April 2009 and March 2010. The Liberal Democrats advocated such a scheme[49], and claimed that investment of £140m[50] would have led to an additional 2000 bus purchases across the UK, with around 200 new buses in Scotland.[51] Such a scheme would bring forward capital investment in new buses, while the scrapped vehicles would be subjected to parts and materials recovery requirements under EU rules as end-of-life vehicles.

Modern buses – particularly hybrid electric vehicles – emit up to 36% less carbon dioxide than older models[52], so bringing the bus fleet up to date would clearly have a positive impact on greenhouse gas emissions, while reducing bus operators' fuel costs. Any stimulus package would also bring direct benefits to the bus manufacturing industry. More comfortable, modern buses should also result in greater passenger numbers, with additional benefits for the economy and social justice, as well as further emissions reductions. Travel by car emits up to 13 times more carbon dioxide than travel by bus[53] (although this depends heavily on occupancy rates), so modal shift has substantial carbon benefits.

Buses © EG Focus

Bus travel in Scotland

- The average Scot travels 478 miles per year by local bus, compared with over 5,000 miles as either the driver or passenger of a car.[54]
- In 1963, there were over 1.5 billion bus journeys made within Scotland; by 2008 that figure had fallen by over two-thirds.[55]
- Across Scotland, 56% of people live within a three minute walk of the nearest bus stop; this figure falls to 38% in remote rural areas.[56]

49. The bus scrappage scheme didn't make it into the Coalition's programme for government, although there remains a pledge to "support sustainable travel initiatives".
50. Liberal Democrats, Manifesto 2010, http://network.libdems.org.uk/manifesto2010/libdem_manifesto_2010.pdf
51. L Wilson, Pers Comm, 12th May 2010
52. B Simpson, Pers Comm, 13th May 2010
53. Mackay, D. Sustainable energy without the hot air p120, http://www.inference.phy.cam.ac.uk/withouthotair/c20/page_120.shtml
54. Scottish Government, High level summary of transport data, http://www.scotland.gov.uk/Topics/Statistics/Browse/Transport-Travel/TrendData
55. Scottish Government, High level summary of transport data Op cit.
56. Scottish Government, High level summary of transport data Op cit.
57. Reuters, Car scrap scheme ends after sales boost, http://uk.reuters.com/article/idUKTRE62T5PQ20100331
58. B Simpson, Pers Comm, 13th May 2010
59. B Simpson, Pers Comm, 13th May 2010
60. L Wilson, Pers Comm, 12th May 2010
61. Environmental Audit Committee, Air Quality. Fifth Report of Session 2009-10. http://www.publications.parliament.uk/pa/cm200910/cmselect/cmenvaud/229/229i.pdf

Economic benefits

The introduction of a bus scrappage scheme would directly benefit the bus industry, just as the car scrappage scheme provided a boost to the car manufacturing industry (the UK Government claimed that car scrappage had contributed to a fifth of all new registrations during the period of the scheme[57]). The UK bus industry is currently suffering a downturn, with order books reportedly down by 40% compared to the same period in 2009.[58]

Alexander Dennis Ltd (ADL) is one of the leading bus manufacturers in the UK, and one of the businesses that would directly benefit from a bus scrappage scheme. Their Bus Body Group is based in Falkirk, and is one of the largest manufacturing employers in Scotland's central belt. Approximately half of the firm's 1800 UK employees are based at the Falkirk plant, and it's estimated that each job at ADL supports another 2.4 jobs within the local community. So altogether, ADL's Falkirk operation keeps over 3000 people in work.[59] A £140 million bus scrappage scheme would safeguard up to 4500 jobs in the bus industry.[60] With plants such as ADL's Bus Body Group in Falkirk accounting for such a high proportion of the company's UK workforce, Scotland could enjoy a disproportionately high share of these secured jobs.

Health benefits

Across the UK, air pollution remains a significant health hazard. Ozone, nitrogen oxides and particulate matter from transport and from power stations are blamed for up to 50,000 deaths annually, with associated health costs of between £8.5 billion and £20.2 billion each year, and an average reduction in lifespans of around 8 months.[61] Assuming just one tenth of these impacts arise in Scotland, that equates to 5000 deaths and up to £2 billion costs annually.

Risks of breaches of European standards for air quality, particularly in urban areas, have led to the establishment of several "air quality management areas" (AQMAs). Within Edinburgh, for instance, the council has established two AQMAs where levels of Nitrous Oxide (NO2)exceed the national standards. Levels of particulate matter have also been found to be approaching national standards.[62] A bus scrappage scheme would lead to the replacement of conventional diesel-engined buses – which are a disproportionate source of NO2 and particulates - with more modern and far less polluting hybrid buses that can cut emissions of NO2 and particulates (as well as CO2) by up to 40%.[63]

This replacement of the bus fleet, stimulated by a bus scrappage scheme, would lead to a very significant potential improvement in urban air quality. In its turn, this would reduce the mortality and health costs known to result from air pollution.

Social justice benefits

Additionally, there is evidence that air pollution (particularly of oxides of nitrogen) has a disproportionate impact on more deprived communities;[64] so policies designed to incentivise the introduction of less polluting vehicles could help to address such inequalities. Moreover, reliable and comfortable buses are disproportionately important for the lower income non-car owning section of the population, in particular as a means to access employment opportunities.[65]

The replacement of buses could also be used as an opportunity to mandate the provision of bicycle carriage facilities on buses (as are standard on or in buses in many other countries). This could facilitate increased bus use on rural and suburban routes.

62. City of Edinburgh Council, Air quality. http://www.edinburgh.gov.uk/internet/Environment/Environmental_health/Pollution/Air_pollution/CEC_air_quality

63. Environmental Audit Committee, Air Quality. Fifth Report of Session 2009-10. Op cit.

64. Defra, Air quality and social deprivation in the UK: an environmental inequalities analysis. http://www.airquality.co.uk/reports/cat09/0701110944_AQinequalitiesFNL_AEAT_0506.pdf

65. Social Exclusion Unit, 2003 Making the Connections: Final Report on Transport and Social Exclusion. http://www.cabinetoffice.gov.uk/media/cabinetoffice/social_exclusion_task_force/assets/publications_1997_to_2006/making_transport_2003.pdf

Improving cycling infrastructure and cycling rates

Road transport accounts for a growing share of Scotland's emissions, and has shown absolute increases in most years since 1990. Reversing this increase in transport emissions must be at the heart of efforts to build a low-carbon Scottish economy. And making a modal shift away from cars in favour of walking and cycling has a key role to play. In this study improved travel planning and improved infrastructure for cycling and walking are estimated to deliver almost 0.6 Mt-CO2(e) of savings per year.

Cycling in Scotland

Cycling rates in Scotland are far lower than those in similar European countries. Denmark and the Netherlands enjoy modal cycling rates[66] of between 18 and 27%, compared to Scotland's one percent. Cycling rates in Denmark and the Netherlands are not simply down to cultural differences (or geography or weather); they have resulted from government policy and investment in cycling infrastructure. Scotland could reach similar levels by increasing cycling's proportion of journeys under five miles to 37 – 40%[67]. 53% of such journeys are currently made by car, and even at distances under two miles the car still accounts for 39% of journeys.

Health benefits

The Health Economic Assessment Tool for Cycling (HEAT for Cycling) has been developed by the World Health Organisation (WHO). The tool is designed to estimate the economic savings resulting from reduced mortality due to cycling.

The Transform Scotland Trust recently applied the HEAT for Cycling tool to Scotland to determine the financial savings that would accrue if the modal share of cycling for journeys of less than 5 miles increased to 20% from current levels; the same exercise was carried out for an increase to a 40% modal share of cycling.

The model indicated that achieving a 20% share of short journeys would result in 815 fewer deaths among 15-64 year olds; a shift from car to cycling to bring about a 40% share of short journeys would save up to 1,672 lives among the same group. Assuming an average number of years saved of 24.5, this gives a value of life years saved of between19,992 (20% share) and 40,964 (40% share). Based upon a UK Government value of life of £1,215,000, the lives saved translate into annual economic savings between £990 million (20% share) and £2.03 billion (40% share).[68]

The tool only calculates savings resulting from reduced mortality (death rates) and ignores savings from reduced morbidity (sickness). Since the UK Government estimates that the savings from reduced morbidity could be at least as great as those from reduced mortality, the overall health benefits could be double those shown above, or as high as £4 billion for a cycling share of 40% for short journeys.

Another study, carried out by Sustrans, performed an analysis of the economic value of actual schemes designed to increase the incidence of walking and cycling. This report looked at three case studies in various parts of the UK and found that all three showed very high ratios of benefit to cost, averaging over 20:1. This is very much higher than for typical road or public transport schemes that rarely deliver a benefit-cost ratio of greater than 10:1 and are usually less than 3:1.

Around half of the monetised benefit of the schemes was in savings to the NHS due to a reduction in the incidence of deaths from coronary heart disease, stroke and colon cancer, all of which are major causes of mortality that can be countered by increased physical activity.

66. Modal share is the proportion of journeys of all distances

67. Transform Scotland Trust, Towards a Healthier Economy, http://www.transformscotland.org.uk/GetFile.aspx?ItemId=108

68. Transform Scotland Trust, Towards a Healthier Economy, Op cit.

69. Sustrans, Economic appraisal of cycling and walking schemes. http://www.sustrans.org.uk/resources/research-and-monitoring/economic-appraisal-of-cycling-and-walking-schemes

Other benefits came from reduced congestion, increased journey ambience (the direct value to the individual of walking or cycling), reduced absenteeism and a lower incidence of accidents. The study did not look at the environmental benefits of the three schemes; including these would have resulted in an even greater benefit-cost ratio.[69]

A third health study examined the relationship between active travel (particularly cycling and walking) and the incidence of health impacts such as obesity and diabetes. The study found that high levels of walking and cycling accounted for as much as half of the difference in obesity levels between countries with high and low rates of active travel. The same effect was seen at a state and city level, reinforcing the existing evidence that higher rates of walking and cycling are consistent with improved health outlooks and greater life expectancy.[70]

On this basis, increasing the share of journeys undertaken by walking, cycling and public transport to 50% (the same as in the Netherlands) could cut obesity rates in Scotland in half, with massive savings to the National Health Service in Scotland, which already spends around £170million a year tackling obesity or health problems – such as heart disease - caused as a direct result.

Economic benefits

A higher incidence of active commuting will lead to higher levels of productivity and fewer working days lost to ill-health; it is possible to calculate these direct economic benefits that would result in more daily commuting being carried out by bike or foot rather than by car.

The Sustrans study cited above[71] derived a value for reduced days lost to work of £8.30 for each commuter user of a new route; applying this value to current figures for Scottish employment and travel behaviour results in a net economic benefit of up to £11.6 million for a 20% shift of daily commuting from car to walking or cycling, and up to £23 million for a 40% shift. These direct economic benefits would be in addition to the health benefits shown above, and are additional to the value of any reduction in congestion achieved.[72]

70. Pucher et al., Walking and cycling to health: A comparison of recent evidence from city, state and international studies. http://www.cfah.org/hbns/archives/viewSupportDoc.cfm?supportingDocID=943

71. Sustrans, Economic appraisal of cycling and walking schemes – methodology. http://www.sustrans.org.uk/assets/files/general/Economic appraisal of local walking and cycling routes - methodology.pdf

72. Transform Scotland Trust, Towards a Healthier Economy, Op cit.

Cyclists © Chris Hill

Road safety benefits

Increased rates of cycling bring health benefits as a result of more physical exercise taking place. But a number of studies indicate that as cycling rates increase, existing cyclists benefit due to a fall in the incidence of road traffic accidents. High rates of cycling (as seen in European countries such as Denmark and the Netherlands) are strongly correlated with low rates of death and injury among cyclists. The USA, which has relatively low cycling rates, has a cycling death rate almost six times higher than Denmark.[73]

The causation relationship probably goes both ways. A safer cycling experience will encourage more people to cycle. And increased numbers of cyclists brings about greater awareness among car drivers and other road users.[74]

Social justice

Increasing the prevalence of transport within Scotland from car to active travel such as walking and cycling can deliver other benefits that are harder to quantify.

Historically low oil prices combined with record high levels of car use have led to many towns and cities being remodelled over time to accommodate universal car ownership. But many of the poorest people in our society do not enjoy, and cannot afford, the benefits of owning and running a car. Government statistics show that 62% of households with an income of below £10,000 a year do not have access to a car.[75] Such households can be excluded from easy access to many facilities and amenities, particularly in an age of ubiquitous out-of-town developments.[76]

Improving cycling infrastructure, and other policies designed to encourage cycling, will help to ensure that nobody is excluded from the benefits of society because of lack of a car.

73. Pucher and Buehler, Why Canadians cycle more than Americans: A comparative analysis of bicycling trends and policies. http://policy.rutgers.edu/faculty/pucher/TransportPolicyArticle.pdf

74. Jacobsen, P.L., Safety in numbers: more walkers and bicyclists, safer walking and bicycling http://injuryprevention.bmj.com/content/9/3/205.abstract

75. Scottish Government, High Level Summary of Statistics Trends. http://www.scotland.gov.uk/Topics/Statistics/Browse/Transport-Travel/TrendData

76. Sustrans, Information Sheet FF46 – Transport and Social Justice. http://www.sustrans.org.uk/assets/files/Info%20sheets/FF46_info%20sheet.pdf

Dietary change (reduced meat consumption)

A European study into the life cycle environmental impacts of final consumption found that food, drink and tobacco were responsible for between 20 and 30% of the environmental impact of total consumption, and that within this sector, meat and meat products had the greatest environmental impact.[77] An analysis of Scotland's carbon footprint showed that our national diet had a significantly higher global footprint than a typical healthy diet, largely due to the high amounts of meat consumed.[78]

A reduction in consumption of meat and dairy products has been identified by the Sustainable Development Commission as one of the changes that will have the most significant and immediate impact on making diets more sustainable, in which health, environmental, economic and social impacts are likely to complement each other.[79]

Meat production on grasslands has a key role to play in minimising greenhouse gas emissions from the agricultural sector; this is because well-managed grasslands can act as important carbon sinks, absorbing CO_2 from the atmosphere. Conversely, when permanent grasslands are converted to arable land, significant quantities of greenhouse gases – amounting to around 12% of the UK's agricultural greenhouse gas emissions – are released into the atmosphere.

The challenge, then, is to move away from imported meat and meat that relies upon imported (and home grown) grains and soya as feedstuffs and instead limit our meat production and consumption to a level that can sustainably be produced on grasslands within Scotland and other parts of the UK. [80]

This study has identified potential to cut emissions in agriculture by over 1Mt-CO_2(e) pa. Reduced meat consumption could contribute significantly to this, although much of the benefit would arise in reduced embodied emissions in imported meat products. Moreover, cutting the existing high levels of meat consumption within the Scottish diet would yield other benefits, particularly in terms of health and food security.

Reduced carbon leakage

Cutting the amount of meat consumed within Scotland and the rest of the UK will have a positive impact on our domestic greenhouse gas emissions. But cutting the amount of meat or animal feed that we import from overseas can also have a major positive impact on other countries' emissions. Moving production overseas results in so-called "carbon leakage", a shift in emissions associated with the transfer of carbon-intensive processes from one country to another.

Britain currently has an annual beef production shortfall of around 300,000 tonnes – to address this, beef from cattle grazed on land that may have been converted from tropical habitats is imported. Likewise, intensive livestock production relies upon imports of soya that may also be linked to the destruction of South American forests.[81] So cutting our meat consumption can help to tackle the problems associated with cattle and animal feed production in other parts of the world. [82]

77. *Tukker et al. (2006), Environmental Impact of Products (EIPRO) - Analysis of the life cycle environmental impacts related to the final consumption of the EU-25. http://ftp.jrc.es/EURdoc/eur22284en.pdf*
78. *Frey & Barrett (2006), The footprint of Scotland's diet – the environmental burden of what we eat. http://www.scotlandsfootprint.org/pdfs/Footprint_Scotland_Diet.pdf*
79. *Sustainable Development Commission (2009), Setting the table – advice to Government on priority elements of sustainable diets. http://www.sd-commission.org.uk/publications/downloads/Setting_the_Table.pdf*
80. *Soil Association (2009), Soil carbon and organic farming. http://www.soilassociation.org/LinkClick.aspx?fileticket=BVTfaXnaQYc%3d&tabid=574*
81. *Soil Association (2009), Soil carbon and organic farming. Op cit.*
82. *Scottish Government (2008), Climate Change and Scottish Agriculture: Report and Recommendations of the Agriculture and Climate Change Stakeholder Group (ACCSG). http://www.scotland.gov.uk/Resource/Doc/223055/0060051.pdf*

Improved food security

The concept of food security means more than simply being able to produce the food that we currently consume. Consumers must have access to sufficient, safe and nutritious food at an affordable price. And the related concept of food sovereignty argues that local food producers should have control over their food production and trading systems. But affordability and reliable access are key parts of the mix.[83] Currently, the United Kingdom produces around 60% of the food it consumes, and around 74% of the types of food that can be produced here. But such figures do not always take into account issues such as imports of energy or animal feed (see previous page).[84]

A number of studies indicate that Britain could produce all the food that would be needed to provide our population with a healthy diet, if not the diet that is presently consumed. A recent study concluded that there were a number of different models (ranging from organic vegan, to conventional with livestock, to permaculture) that could provide the present UK population with a healthy diet of over 2,700 calories per day[85]. Even when meat is included in the diet (admittedly at lower levels than today) the UK can still feed its present population. Such total self-sufficiency would provide a healthy diet (probably considerably healthier than at present) and would undoubtedly protect the UK from global food shortages, but would be lacking in many of the luxuries to which we have become accustomed. The Centre for Alternative Technology has carried out a recent analysis of how Britain could become zero carbon by 2030; under this scenario, our meat consumption is again cut significantly but we can maintain imports of around 15% of our food from Europe and 7.5% from the tropics. The ratio of meat to plant protein in our diet would fall from the current 55:45 to a more sustainable (but by no means austere) 34:66. [86]

Basket of veg © Anguskirk

A symposium recently held by the Policy Foresight Programme[87] questioned whether Britain could – and indeed should – feed itself. It heard that Britain could indeed feed itself (again, provided that our consumption of meat fell), but that meat production was highly appropriate in some parts of the country, particularly in upland areas unsuited to arable cultivation. Livestock in such areas (many of which are located in Scotland) not only provide food on land that would be otherwise unproductive, but also carry out a vital function in maintaining and increasing high levels of soil carbon.[88]

83. Defra (2008), Ensuring the UK's food security in a changing world. http://www.ifr.ac.uk/waste/Reports/DEFRA-Ensuring-UK-Food-Security-in-a-changing-world-170708.pdf

84. Barling et al. (2008), Rethinking Britain's food security. http://www.soilassociation.org/LinkClick.aspx?fileticket=wCYoHYSHsy8%3D&tabid=387

85. Policy Foresight Programme (2008), Can Britain feed itself? Should Britain feed itself?

86. Centre for Alternative Technology (2010), Zero Carbon Britain – a New Energy Strategy. http://www.zcb2030.org/

87. Policy Foresight Programme (2008), Can Britain feed itself? Should Britain feed itself? Op cit.

88. Soil Association (2009), Soil carbon and organic farming. Op cit.

Improved health

Evidence on health and the balance of environmental analysis suggests that a healthy, low-impact diet would contain less meat and fewer dairy products than we typically eat today.[89] Britain's heavily meat-oriented diet is not only environmentally unsustainable, it is also unhealthy. The potential health benefits of eating less meat are likely to be particularly significant in Scotland: *"Much of Scotland's poor health record can be attributed to its unhealthy eating habits … excess consumption of saturated fat, salt, and sugar, and low consumption of fruit and vegetables are all risk factors associated with one or more of cardiovascular disease, cancer, hypertension, type 2 diabetes and obesity"*.[90]

Studies indicate that vegetarians and vegans are significantly less likely to be obese or overweight than meat eaters;[91] this suggests that a reduction in our meat consumption could lead to a significant reduction in obesity levels.

The Scottish Government estimates that obesity and obesity-related illnesses cost the NHS in Scotland around £171 million,[92] when the medical consequences of the merely overweight are included, this figure increases to £312 million.[93] Furthermore, the proportion of the NHS budget spent on obesity and its consequences is likely to double over the coming four decades. It's very hard to quantify how much of this amount could be cut by shifting to a diet containing less meat, but there are clearly cost savings to be achieved.[94]

While the NHS stops short of advocating eating less meat, there is considerable evidence that a shift from a heavily meat-oriented diet towards one containing a higher proportion of vegetable protein could reap considerable health benefits.[95, 96] For instance, there is evidence that the risk of contracting colorectal cancer is higher among adults who eat more red and processed meats, but that this risk is reduced by eating a diet high in fibre, fresh fruit and vegetables. [97]

While a relatively small proportion of meat in the diet can confer valuable health benefits (particularly to vulnerable groups such as breastfeeding mothers), in general there is no need for us to consume as much meat as we currently do. Studies of hunter-gatherers indicate that such groups could quite easily consume much more meat, but choose not to. This indicates that the recent increase in the volume of meat in our diet is not down to innate need, but largely a product of social conditioning and effective marketing.[98]

89. Cabinet Office (2008), Food matters – towards a strategy for the 21st Century. http://www.cabinetoffice.gov.uk/media/cabinetoffice/strategy/assets/food/food_matters1.pdf

90. Scottish Government (2009), The Scottish health survey 2008, Volume 1. http://openscotland.net/Resource/Doc/286063/0087158.pdf

91. Key & Davey (1996), Prevalence of obesity is low in people who do not eat meat. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2352221/

92. Scottish Government (2009), The Scottish health survey 2008, Volume 1. Op cit.

93. Scottish Government (2010), Preventing overweight and obesity in Scotland: A route map towards healthy weight. http://www.scotland.gov.uk/Publications/2010/02/17140721/0

94. Scottish Government (2009), The Scottish health survey 2008, Volume 1. Op cit.

95. Policy Foresight Programme (2008), Can Britain feed itself? Should Britain feed itself? Op cit. 96. Cabinet Office (2008), Food matters – towards a strategy for the 21st Century. Op cit.

97. Cabinet Office (2008), Food matters – towards a strategy for the 21st Century. Op cit.

98. Tudge (2004), So shall we reap. Penguin.

7.Conclusions

- Achieving a 42% reduction in emissions in Scotland by 2020 is certainly still within reach. There are challenges and there will be a need for every sector of Scottish society to play a part in reducing dependence on climate polluting activities.

- There are even choices in how we get to the destination. This study has suggested one pathway which would exceed the target by a small margin, but the limits to action are only sometimes technical, and more often economic or political. In many cases deeper cuts than envisaged here remain feasible.

- Programmes for emissions reduction can deliver substantial wider social benefits, which should be taken into account in establishing a desirable level of effort, alongside the scientific imperatives relating to climate change.

- If we choose to limit our options due to political concerns, for example in transport, then the overall costs and difficulties of reaching the target will rise.

- Focussed effort is needed to improve our understanding of the economic, social and health implications of climate change programmes, so as to ensure we take an optimal pattern of action, with the greatest efforts made where net social benefits are highest.

- Our choices will become much wider if the EU raises its ambition to a 30% reduction by 2020 and sets ETS allocations accordingly.

However, we should also recognise the arguments for choosing to deliver greater reductions than required under the Act's headline provisions.

The analysis of cumulative emissions budgets suggests that even our most optimistic pathways still fall short of a genuinely fair and safe cumulative budget. Any windfall gains, such as from an elevation in the EU's ambition should therefore be translated insofar as possible, into additional reductions over and above 42% by 2020, and in line with earlier delivery of the 2050 target.

We recommend therefore that Scotland should undertake urgent investigation into appropriate cumulative budgets, and models to help meet fair and safe levels, in particular, an examination of the implications of a Greenhouse Development Rights model for Scotland.

Annex 1: Table comparing savings identified in this study with CCC and SG scenarios

	CCC extended	CCC stretch	CCC Stretch 20% ETS	SG RPP (20% world)	SG RPP (30% world)	This study
Baseline						
2008 figures	56671	56671	56671	55325	55325	55325
Projected recession effects in 2009 (non-traded)	695	695	695	0	0	1145
Landuse sink forecasts	-2860	-2860	-2860	-2860	-2860	-2860
Economic forecasts to 2020 [1]	1210	1210	1210	0	0	0
2020 target = 40671						
Savings needed	16955	16955	16955	17514	17514	16369
Savings						
EUETS	10300	10300	7300	7300	10300	7300
EUETS Aviation						
Demand reduction and Energy efficiency						
Renewable - 50% Renewables						
Renewable - Wave and tidal						
CCS						
Traded sector total	10300	10300	7300	7300	10300	7300
Energy - Non Traded						
Sub-total – non-domestic	1570	1570	1570	951	951	951
Energy intensive business policies	na	na	na	162	162	162
Smart metering (non-dom)	na	na	na	74	74	74
Energy Efficiency (non-domestic)	na	na	na	101	101	101
Additional business energy savings	na	na	na	8	8	8
Renewable heat (non-domestic)	800	800	800	561	561	561
Building standards (non-domestic)	na	na	na	45	45	45
Non-domestic: public sector [2]	160	160	160	na	na	0
Non domestic: industry [2]	170	170	170	na	na	0
Non-domestic: commerce [2]	440	440	440	na	na	0
Sub-total – domestic measures	1280	1490	1490	1027	1027	1406
Behaviour change	330	310	310	0	0	330
Renewable heat / heat networks (domestic)	400	400	400	320	320	320
Energy efficiency (domestic funded to 2012) [3]			0	145	145	0
Energy efficiency (domestic post 2013) [3]			0	319	319	0
Domestic energy efficiency total [4]	540	740	740			540
Domestic smart metering			0	27	27	0
New low carbon homes (building standards) [5]	2010 & 2013)10	40	40	216	216	216
Transport total	1430	1870	1870	3190	3190	2840
Vehicle efficiency	1030	1030	1030	746	746	746
Biofuels [6]	400	400	400	640	640	400
Low carbon vehicles (infrastructure and procurement)			0	71	71	71
Bus and Taxi infrastructure and low carbon vehicles			0	217	217	217
Eco driving [7]	110	190	190	87	87	138
Smarter choices' [8]	240	240	240			0
Van efficiency (extra measures)			0	19	19	19
Freight efficiency			0	109	109	109
Freight modal shift			0	102	102	102
Rail efficiencies	30	40	40			
Shipping efficiency [9]	-400	-400	-400	216	216	-184
Travel planning			0	486	486	486
Workplace Parking levy			0	132	132	132
On street parking control			0	87	87	87
Traffic management			0	10	10	10
Cycling and walking infrastructure			0	104	104	104
Car clubs			0	47	47	47
Speed limit enforcement (and 60 limits)	20	40	40	35	35	35
Road pricing [7]	0	330	330	0	0	239
Community hubs & denser development	0	0	0	82	82	82
Farming total	660	1310	1310	875	875	1080
Farming for a better climate [10]	0	0	0	319	319	0
Crops and soils [11]	500	990	990	0	0	500
On farm AD [12]	60	130	130	16	16	130
Cross Compliance [13]	0	0	0	540	540	260
Livestock health	100	190	190	nq	nq	190
Land Use total	380	760	760	454	454	3160
Land and soil management (peat) [14]	0	0	0	nq	nq	2400
Woodland creation	380	760	760	454	454	760
Waste total	94	105	105	605	605	605
Waste measures - diversion				154	154	154
Waste measures - landfill bans				451	451	451
TOTAL incl ETS	15714	17405	14405	14402	17402	17342
Shortfall/surplus	-1241	450	-2550	-3112	-112	973

Notes to annex 1

1. See narrative for discussion of economic projections.

2. The CCC and SG break down non-traded energy measures in commercial, industrial and public sector facilities differently: the CCC by sub-sector, the SG by measure. In this respect we follow the SG.

3. The SG separate already funded domestic energy efficiency measures from future unfunded ones. In this respect we follow the CCC and use an overall total.

4. That total is more ambitious than the SG, but we only use the CCC's lower 'extended' scenario.

5. Using the lower extended scenario also mitigates any risk of double counting in then using the SG's new building standards figure.

6. On biofuels we only apply the lower CCC figure as we have significant concerns over the wider sustainability of biofuels, and their new carbon benefit.

7. These figures are proportionately reduced due to our use of a higher efficiency figure than in the scenario they were originally included in.

8. 'Smarter Choices' is a programme name considered by the CCC, the measures in it are mainly included in travel planning by the SG.

9. Shipping efficiency. We have accepted the CCC forecast of rising shipping activity and emissions between 2010 and 2020, but then offset it partially by the SG's subsequent estimate of improved efficiencies.

10. We have assumed the measures included in this named SG programme are variously covered in other CCC headings, notably crops and soils.

11. We have taken the lower 'extended' scenario, partly to mitigate against any risk of double counting introduced by the inclusion of a separate line for peatland restoration.

12. There is a possibility that some of the potential for on farm anaerobic digestion is included elsewhere in renewable heat. However by taking SG estimates for the other renewable heat headings we have taken a lower figure than the CCC give for renewable heat (even with this higher estimate for on farm AD in the same scenarios).

13. We have arbitrarily halved the estimate for cross compliance to mitigate risks of double counting, and also because full implementation is dependent on EU agreement.

14. We have added in a credible estimate for peatland restoration – acknowledged by others as a significant omission – based on work for the IUCN UK Peatland Programme (referenced in the main text.)

Annex 2: Analysis of cumulative budgets against a central emissions trajectory

Annual emissions based on SG annual targets to 2022, and a steady decline from 2022 to meet the 2050 80% target

	ETS-adjusted emissions (Mt-CO_2(e))	Cumulative emissions (Mt-CO_2(e)
2000	65.46	65.46
2001	64.80	130.26
2002	60.91	191.17
2003	60.51	251.68
2004	58.46	310.14
2005	58.56	368.70
2006	57.77	426.47
2007	57.47	483.94
2008	55.33	539.27
2009	53.90	593.17
2010	53.65	646.82
2011	53.40	700.23
2012	53.23	753.45
2013	47.98	801.43
2014	46.95	848.38
2015	45.93	894.31
2016	44.93	939.24
2017	43.95	983.19
2018	42.97	1026.16
2019	41.98	1068.13
2020	40.72	1108.85
2021	39.30	1148.15
2022	37.93	1186.07
2023	36.60	1222.68
2024	35.33	1258.01
2025	34.10	1292.10
2026	32.91	1325.01
2027	31.76	1356.77
2028	30.65	1387.42
2029	29.58	1417.01
2030	28.55	1445.56
2031	27.56	1473.12
2032	26.60	1499.71
2033	25.67	1525.38
2034	24.77	1550.16
2035	23.91	1574.07
2036	23.08	1597.14
2037	22.27	1619.42
2038	21.50	1640.91
2039	20.75	1661.66
2040	20.02	1681.68
2041	19.32	1701.00
2042	18.65	1719.65
2043	18.00	1737.65
2044	17.37	1755.03
2045	16.77	1771.79
2046	16.18	1787.98
2047	15.62	1803.59
2048	15.07	1818.67
2049	14.55	1833.22
2050	14.04	1847.26

Analysis of alternative 'fair and safe' cumulative budgets according to outcome concentrations

Outcome CO_2	in ppm CO_2(e)	Budget (Mt)	Year exhausted
350	400	1150	2022
400	450	1300	2026
450	500	1500	2033
500	550	1750	2044
550	600	2000	N/a

Note: The budgets assessed above are crudely extrapolated from those derived from the Tyndall centre and cited in the main text. Further detailed analysis is highly recommended.

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