Scottish Energy Study

Volume 5:

Energy and Carbon Dioxide Projections for Scotland

For the Scottish Government

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THE SCOTTISH ENERGY STUDY

Volumes 1, 2 and 3 of the Scottish Energy Study provide extensive and detailed data on the supply and use of energy in Scotland. Volume 4 of the study provides qualitative views on the issues, opportunities and barriers to changing how energy is used in Scotland. In contrast this volume of the study looks at how energy supply and demand in Scotland could change in the future.

The following list summarises the scope of each of the 5 volumes of the Scottish Energy Study:

Volume 1 **Energy in Scotland: Supply & Demand**
Presenting data describing Scottish energy supply and demand, together with associated CO_2 emissions. Information is also given on how the data were derived.

Volume 2 **A Changing Picture**
Addressing how the Scottish energy picture has changed in recent years: the results derived in Volume 1 are compared with the findings of an earlier study based on 1990 data.

Volume 3 **Energy Demand Database**
A brief guide to an energy database: summarising Scottish energy use by sector.

Volume 4 **Issues, Opportunities and Barriers**
Considering the many factors that influence energy use in Scotland today. This volume considers key drivers. Based on this understanding it identifies the opportunities to improve energy use within Scotland and the barriers that must be overcome if this is to be achieved.

Volume 5 **Looking Forward**
Considering how Scotland's energy use could change in the medium term to 2020, using projections of demand and supply informed by different scenarios that will influence energy use in the future.

Contents

Executive Summary

Background

The Scottish Energy Study is the first major study of energy supply and demand to be conducted in Scotland for over a decade. The aim in producing this study is to provide the Scottish Government and other stakeholders with a coherent picture of the energy flows into and out of Scotland, including details of energy supply and consumption across the four main energy demand sectors, namely domestic, transport, industry and services.

Volume 5 of the study examines the prospects for future energy supply and demand in Scotland, and the implications of these trends for energy related CO_2 emissions. Because Scotland's energy economy is strongly linked and influenced by that of the UK overall, these projections[1] for Scotland have been developed from projections for the UK made by the Department for Business Enterprise and Regulatory Reform (BERR)[2].

Projecting future trends in any area of a modern economy is fraught with uncertainty, and energy is no exception due to the many differing factors impacting on the patterns of supply and demand. In particular trends in economic growth, primary energy prices and government policies (e.g. aimed at reducing greenhouse gas emissions or increasing security of supply) can have a major impact on both demand and the mix of energy sources used to meet that demand. The study has addressed these uncertainties in three ways.

Firstly it has examined two scenarios taken from the BERR projections for the UK that consider the impact of different fossil fuel price trajectories, namely:

Central – Central (CC) – in which primary energy prices are assumed to follow a 'central' trajectory and the energy policies set out in the UK Energy White Paper 2007 (EWP) are assumed to have an impact in the centre of their potential range.

High – Central (HC) – in which primary energy prices are assumed to follow a 'high' trajectory and the energy policies set out in the UK EWP are assumed to have an impact in the centre of their potential range.

Secondly the study has adjusted the projections to take account of key factors specific to Scotland, in particular the Scottish Government's targets for economic and population growth, and the expansion of renewable energy production, that are distinct from the overall UK trend used by BERR.

Thirdly the study includes a set of sensitivity analyses, which examine how changes to assumptions impact on Scottish energy demand and supply.

[1] UK updated energy and emissions projections (UEP), The Energy White Paper, BERR Report URN 07/947X (Amended Version), February 2008.
[2] Now the responsibility of the Department for Energy and Climate Change (DECC)

Approach

The starting point for energy projections must be a reference set of data for a recent year. The previously published Scottish Energy Study – Volume 1[3] provides such statistics for Scotland in 2002.

Starting from the reference year, the estimation of future energy demand is a complex issue because consumer demand is not for energy directly but for the services it provides such as warmth, lighting, travel, entertainment, motive power, process heat, etc. Some of the main factors influencing energy demand are:

- Prices of primary energy supply
- Economic growth
- Population growth
- Investment in energy efficiency
- Changes in the mix of fuels used
- Government policies.

BERR's energy and CO_2 projections for the UK give separate projections for each of the main energy consuming sectors, namely domestic, industry, services (including agriculture), and transport. The projections are produced using a mathematical model that uses econometric relationships to project future demands and includes feedback between demand and delivered energy prices. The impact of policy measures that directly affect energy prices (e.g. the EU Emission Trading Scheme) are assessed by the model, while the model can be constrained to include other policy targets (e.g. liquid biofuels). The model delivers solutions that balance energy supply and demand at the UK level.

BERR's projections included the impact of UK level policy measures, including those introduced by the Climate Change Bill, those proposed in the Energy White Paper 2007 and the impact of the EU Emission Trading Scheme (ETS) on the electricity generation sector. However, BERR's projections were produced before the EU 2020 target for renewable energy was agreed, and therefore the measures needed to meet this target across the UK through, for example, accelerated deployment of renewable electricity and heat were not considered. As a consequence these projections for Scotland also do not explicitly incorporate the EU 2020 target, although ambitious targets for renewable electricity and heat are investigated. BERR is currently consulting on the strategy to meet the EU 2020 target, and therefore the policy mechanisms to be used and the division of effort between sectors is currently uncertain[4].

[3] Scottish Energy Study Volume 1 – Energy in Scotland, supply and demand (http://www.scotland.gov.uk/Publications/2006/01/19092748/0)
[4] UK Renewable energy strategy consultation, BERR, July 2008 (http://www.berr.gov.uk/energy/sources/renewables/strategy/page43356.html)

Scottish demand in each sector, and for each fuel type, was escalated from the 2002 reference year by scaling in line with the BERR projections for the UK. While this approach has the advantage of maintaining consistency and comparability with the projections for the UK, it does implicitly assume that Scotland follows the UK average with regard to the key drivers of energy demand (i.e. economic and population growth, impact of UK level policy measures, etc.). Therefore these initial estimates were adjusted to take account of differences between Scotland and the UK average. In particular the projections were adjusted to take account of the Scottish Government's targets for economic or population growth, whichever was considered to be the more influential on the demand sector[5], while sensitivity analyses investigated other variations specific to Scotland.

Baseline scenario energy projections

Final Energy Demand

Table S1 and Figure S1 show projections of overall final energy demand divided by sector. In the CC scenario overall demand falls by about 4% between 2005 and 2020, while in the HC scenario the fall is 7%. These trends compare to falls of 3% and 6% for the UK overall in the CC and HC scenarios respectively. The principal factor driving this reduction in demand, both in Scotland and the UK overall, is the impact of policy measures proposed in the UK Energy White Paper. For example, BERR's central projections estimate that the UK's total final energy demand will be 9% less with the Energy White Paper measures, than it otherwise would have been.

The main drivers that differ between Scotland compared to the UK overall are economic growth (economic growth in Scotland, historically lower that the UK, is assumed to match UK growth by 2011), population growth (lower in Scotland), the different mix of industries in Scottish manufacturing and the different balance between public and commercial activity in the services sector. Overall these factors appear to largely cancel out although there are some significant trends within individual demand sectors.

Figure S2 shows the overall demand projections divided by fuel type. Demand for all energy sources is projected to decline, with the exception of direct use of renewable energy, which increases by over 100%[6], albeit from an initial low base. The main reductions in demand affect natural gas, down by 15% to 19% (UK 14% to 19%) and coal, down by 37% to 38% in the HC and CC scenarios. The reduction in gas demand comes mainly from the domestic sector, while coal consumption falls in the domestic and industry sectors. Oil demand is steady in the HC scenario but increases by 3% in the CC scenario, due to increased demand for transport (UK falls 1% to 3%). Electricity demand decreases slightly (-1%) in the CC scenario and is level in the HC scenario (UK -1% to +1%).

[5] Adjusting for both population and GDP would over compensate because the two are linked.
[6] Note that electricity generation from renewable sources is included in the overall electricity demand.

Table S1 Scottish Final Energy consumption divided by demand sector (TWh)
CC Scenario

	2002	2005	2010	2015	2020	Change 2005 - 2020[7]
Domestic	56.0	54.2	46.6	42.5	37.0	-32%
Services	25.8	26.8	25.3	24.6	24.5	-9%
Industry	36.3	34.5	35.1	36.8	39.6	15%
Transport	47.1	48.6	50.7	55.2	55.9	15%
Total	**165.0**	**164.2**	**157.8**	**159.0**	**156.9**	**-4%**

HC Scenario

	2002	2005	2010	2015	2020	Change 2005 - 2020
Domestic	56.0	54.2	45.6	40.6	35.0	-35%
Services	25.8	26.8	25.3	24.6	24.5	-9%
Industry	36.3	34.5	35.0	36.3	39.3	14%
Transport	47.1	48.6	50.3	53.8	54.0	11%
Total	**165.0**	**164.2**	**156.2**	**155.3**	**152.7**	**-7%**

Note rounding to one decimal place may introduce some small errors in summations.

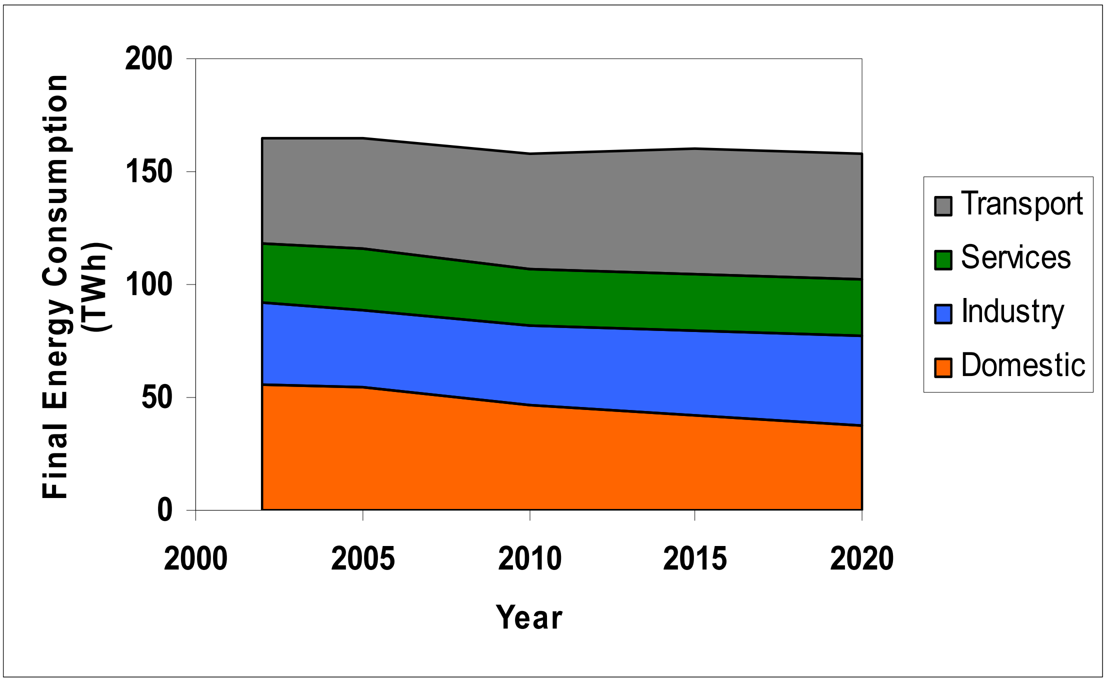

Figure S1 Scottish final energy demand by sector 2002 to 2020 for the CC scenario (TWh)

[7] In some cases the percentage change is obscured by rounding of the energy consumption values to one decimal place.

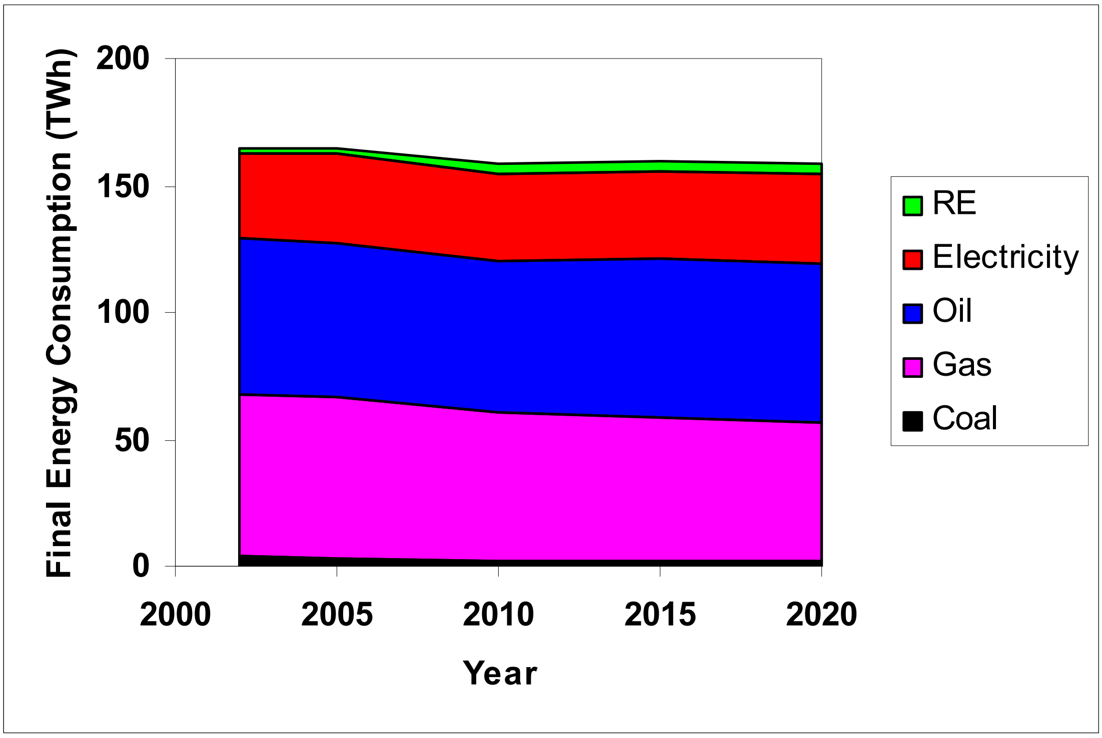

Figure S2 Scottish final energy demand by fuel type in the CC scenario (TWh)

Energy Supply – Electricity Generation

Figures S3 and S4 give estimates for future Scottish electricity generation by fuel type to 2020. Projections for generation from renewable energy sources are based on the assumption that Scotland achieves its targets to generate 31% of Scottish gross electricity consumption from renewable sources by 2011, rising to 50% by 2020[8].

Coal fired generation is anticipated to continue through the projection period following the decision by Scottish Power to fit flue gas desulphurisation (FGD) equipment to Longannet in order to meet the requirements of the EU's Large Combustion Plant Directive, but nuclear generation is expected to decline with the possible closure of Hunterston after 2016[9]. Natural gas generation continues at Peterhead power station, and some additional capacity is added by 2015. The main difference between the CC and HC scenarios is an increase in coal generation with the higher fuel prices of HC. This is because in BERR's assumptions the relative cost of gas to coal is higher in the HC scenario, while the assumed prices for emission allowances in the ETS are unchanged between the scenarios at €20/tCO_2 from 2010-2015 and €25/tCO_2 from 2015 to 2020.

Scotland remains a net exporter of electricity over the full period to 2020 in both the CC and HC scenarios.

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[8] Gross consumption is defined as the amount of electricity generated minus net exports and including losses.

[9] At present Hunterston power station has permission to operate until 2016, but it could seek an extension to operate to 2021 and beyond. A closure date of 2016 has been assumed for the purpose of these projections.

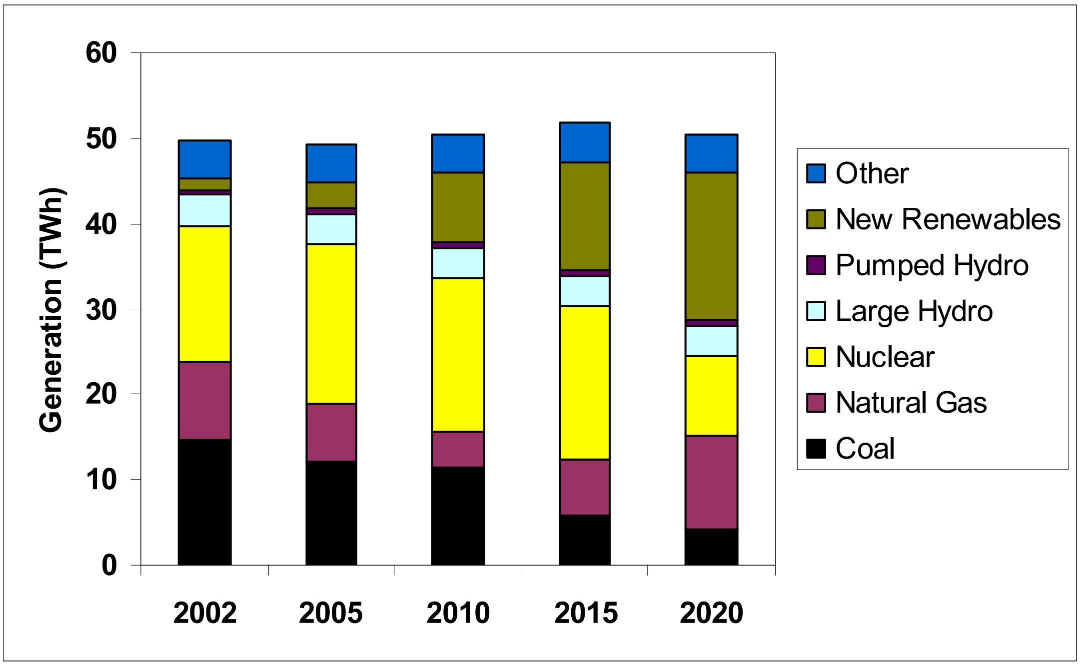


Figure S3 Electricity generation by fuel type in Scotland to 2020 in the CC scenario (GWh)

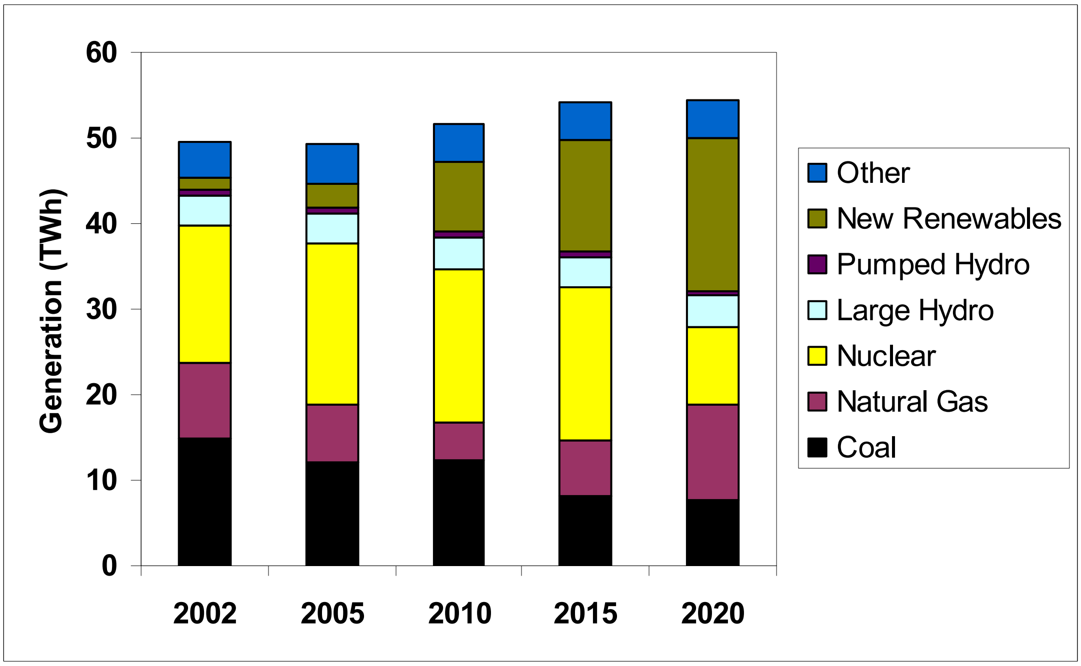


Figure S4 Electricity generation by fuel type in Scotland to 2020 in the HC scenario (GWh)

Energy Supply - Oil Refining

Scotland has one major oil refinery at Grangemouth. The Scottish Energy Study – Volume 1 has estimated that in 2002 this produced 99.6 TWh of saleable products, of which 61% was consumed in Scotland, and emitted 2.8Mt of CO_2. BERR's projections for the UK assume a small increase in refinery activity over the projection period with CO_2 emissions increasing from 5.7 MtC/yr (20.8 $MtCO_2$/yr) in 2002 to 6.1MtC/yr (23.4 $MtCO_2$/yr) by 2020. This trend was the same for the CC and HC scenarios, and it has been assumed here that the same trend will be followed in Scotland.

Primary Energy Demand

Total primary energy consumption[10], shown in Table S2, declines by 10% in the CC scenario and 8% in the HC scenario. This should be compared to falls of 6% and 3% respectively for the UK.

A number of factors lead to the greater fall in Scottish primary energy consumption in the CC scenario compared to the HC scenario. Firstly there is more generation from Scotland's coal fired power plant in the HC scenario because the relative price of gas to coal is greater in the HC scenario. Scotland has less gas fired generation capacity, and consequently the increase in coal generation is not offset by an equivalent reduction in gas, an effect that occurs in the UK projections. Secondly Scottish gross electricity consumption is higher in the HC scenario, and as a consequence Scotland is assumed to increase its power generation from renewable sources to meet its targets. In contrast to this overall trend oil consumption falls in the high oil price scenario, and there is a greater reduction in demand for gas compared to the CC scenario.

Table S2 Total primary energy demand (TWh)

CC Scenario

	2002	**2005**	**2010**	**2015**	**2020**	**Change 2005 - 2020[11]**
Coal	44.1	35.4	33.0	17.8	13.1	-63%
Natural Gas	84.3	78.6	67.3	69.6	74.7	-5%
Oil	72.2	70.9	71.2	74.9	75.1	6%
Nuclear	42.2	49.7	47.7	47.7	24.3	-51%
RE	7.7	9.6	20.6	26.2	32.9	241%
Total	**250.5**	**244.2**	**239.8**	**236.2**	**220.1**	**-10%**

HC Scenario

	2002	**2005**	**2010**	**2015**	**2020**	**Change 2005 - 2020**
Coal	44.1	35.4	35.9	23.7	22.6	-36%
Natural Gas	84.3	78.6	66.2	67.2	72.1	-8%
Oil	72.2	70.9	70.6	73.4	73.1	3%
Nuclear	42.2	49.7	47.7	47.7	24.3	-51%
RE	7.7	9.6	20.7	26.6	33.6	248%
Total	**250.5**	**244.2**	**241.1**	**238.6**	**225.7**	**-8%**

Note rounding to one decimal place may introduce some small errors in summations.

[10] Primary energy has been estimated in line with international convention in which the efficiency of non-fossil thermal sources (i.e. nuclear, biomass) is taken into account in estimating primary supply. The output from non-thermal electricity sources such as hydro and wind are regarded as primary electricity and are not adjusted for generation efficiency.

[11] In some cases the percentage change is obscured by rounding of the energy consumption values to one decimal place.

Sensitivity analysis of final energy demand projections

Uncertainties over key drivers affecting energy demand mean that the baseline scenario projection described above should be regarded as a starting point from which to investigate other potential outcomes. To investigate the potential impact of other possible trends in key factors that influence Scottish energy demand, a sensitivity analysis has been made of how the baseline scenario projections may be altered by:

- Lower growth rate for Scotland's economy (GDP)
- Lower growth rate for population
- Higher growth in car ownership
- Higher and lower growth in air travel

This sensitivity analysis has shown that those factors driving an increase in energy demand (i.e. higher car ownership and air travel) could in total increase overall demand by 3.5% over the CC baseline by 2020. Those factors causing a decrease in energy demand (i.e. lower growth in GDP, population and air travel) could in total reduce demand by about 6% by 2020. The factor having the greatest effect was the lower GDP growth assumption that reduced energy consumption by around 4% compared to the baseline CC scenario projection in 2020. The overall trend in final energy demand for these high and low cases compared to the baseline CC projection is shown in Figure S5.

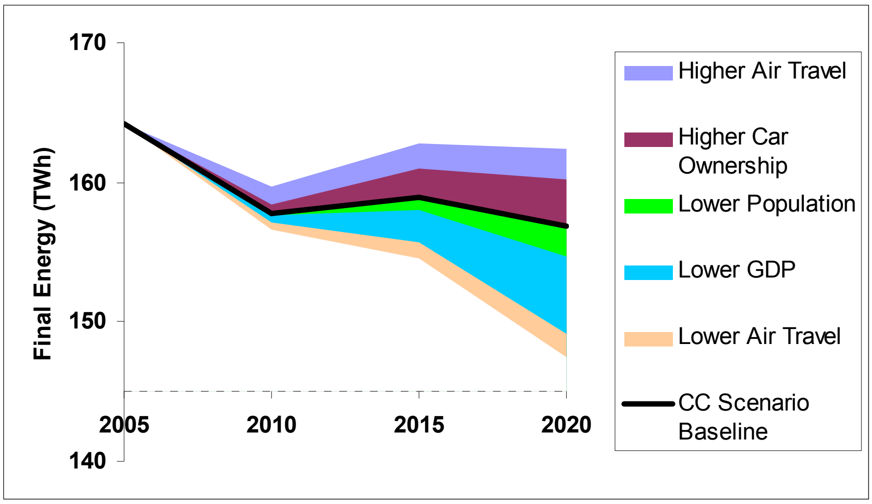


Figure S5 Overall impact of the sensitivity analysis variables on Scottish final energy demand compared to the baseline CC scenario projection.

Baseline scenario projections of energy related CO_2 emissions

Energy related CO_2 emissions actually exceed Scotland's net carbon emissions when sequestration by land use and forestry is taken into account. CO_2 emission projections for Scotland to 2020, classified in line with the national inventory categories are listed in Table S3. Overall Scottish energy related CO_2 emissions are projected to decline, compared to 2005, by between 7% and 9% by 2011 and by between 13% and 18% by 2020 for the HC and CC scenarios respectively.

This is equivalent to a reduction of between 18% and 30% compared with the National Atmospheric Emissions Inventory (NAEI) for 1990[12].

In the CC scenario the reductions occur in the domestic, services and energy industries sectors (except for oil refineries), with the greatest reductions projected to be in electricity generation and the domestic sector. Emissions increase in the industry and transport sectors. Despite the greater reduction in emissions from demand sectors in the HC scenario, it is the CC scenario that attains the greatest overall reduction in emissions. This is because under HC more coal fired generation occurs in Scotland because of the more favourable price differential of coal over gas in this scenario. This highlights the strong influence of power generation on overall Scottish CO_2 emissions.

About 7% of Scottish emissions in 2002 were associated with the export of electricity. By 2020 it is projected that 4%-7% of emissions will continue to be associated with electricity exports, although the absolute quantity is less and the figure is highly sensitive to assumptions regarding power generation in Scotland.

Table S3 Projections of Scottish energy related CO_2 emissions to 2020 disaggregated according to the national inventory classification (Mt CO_2)[13]
<u>CC Scenario</u>

ENERGY	2002	2005	2010	2011	2015	2020	Change 2005-2020[14]
1. Energy Industries	**22.1**	**18.7**	**16.9**	**16.0**	**12.5**	**12.0**	**-36%**
A Electricity	17.2	14.3	12.4	11.5	8.1	7.9	-45%
B Refineries	2.8	2.4	2.8	2.9	2.9	3.0	24%
C Other energy industry	2.1	2.0	1.7	1.6	1.4	1.1	-45%
2. Manufacturing	**5.2**	**4.6**	**4.7**	**4.7**	**4.9**	**5.2**	**14%**
A Iron and Steel	0.0	0.0	0.0	0.0	0.0	0.0	-3%
B Other industries	5.1	4.6	4.6	4.7	4.9	5.2	14%
3. Transport	**11.5**	**11.9**	**12.0**	**12.2**	**13.1**	**13.2**	**12%**
A Road	8.7	8.7	8.8	9.0	9.5	9.3	8%
B Rail	0.1	0.1	0.1	0.1	0.1	0.1	1%
C Marine	0.6	0.7	0.6	0.6	0.7	0.7	2%
D Aviation	2.1	2.5	2.4	2.5	2.8	3.2	28%
4. Other Sectors	**11.5**	**11.1**	**9.4**	**9.2**	**8.5**	**7.5**	**-33%**
A Commercial/Institutional	2.6	2.7	2.5	2.5	2.4	2.3	-15%
B Domestic	8.7	8.1	6.7	6.6	5.9	4.9	-40%
C Agriculture	0.2	0.2	0.2	0.2	0.2	0.2	6%
Total	**50.3**	**46.3**	**43.0**	**42.2**	**38.9**	**38.0**	**-18%**

Note rounding to one decimal place may introduce some small errors in summations.

[12] The present National Atmospheric Emissions Inventory includes emissions from domestic flights that are attributable to Scotland. However, the Scottish Energy Study Volume 1 covered all aviation emissions and these have been included in Table S3 for completeness. Comparisons with NAEI values are made after excluding aviation. The comparison is made with combustion related emissions since the projections do not include fugitive emissions.
[13] The Military aircraft and naval vessels section of the inventory is omitted from these tables. This sector only accounted for 1% of CO_2 emissions in 2005.
[14] In some cases the percentage change is obscured by rounding of the energy consumption values to one decimal place.

Table S3 (continued) Projections of Scottish energy related CO_2 emissions to 2020 disaggregated according to the national inventory classification (Mt CO_2)[15] (continued)
<u>HC Scenario</u>

ENERGY	2002	2005	2010	2011	2015	2020	Change 2005-2020
1. Energy Industries	**22.1**	**18.7**	**17.9**	**17.2**	**14.5**	**15.3**	**-18%**
A Electricity	17.2	14.3	13.4	12.8	10.2	11.2	-22%
B Refineries	2.8	2.4	2.8	2.9	2.9	3.0	24%
C Other energy industry	2.1	2.0	1.7	1.6	1.4	1.1	-45%
2. Manufacturing	**5.2**	**4.6**	**4.6**	**4.6**	**4.8**	**5.1**	**10%**
A Iron and Steel	0.0	0.0	0.0	0.0	0.0	0.0	-3%
B Other industries	5.1	4.6	4.6	4.6	4.7	5.0	10%
3. Transport	**11.5**	**11.9**	**11.9**	**12.0**	**12.7**	**12.8**	**8%**
A Road	8.7	8.7	8.8	8.9	9.3	9.1	5%
B Rail	0.1	0.1	0.1	0.1	0.1	0.1	1%
C Marine	0.6	0.7	0.6	0.6	0.7	0.7	2%
D Aviation	2.1	2.5	2.4	2.4	2.7	2.9	18%
4. Other Sectors	**11.5**	**11.1**	**9.3**	**9.1**	**8.2**	**7.1**	**-36%**
A Services	2.6	2.7	2.5	2.5	2.4	2.4	-14%
B Domestic	8.7	8.1	6.6	6.4	5.6	4.6	-44%
C Agriculture	0.2	0.2	0.2	0.2	0.2	0.2	6%
Total	**50.3**	**46.3**	**43.7**	**43.0**	**40.2**	**40.2**	**-13%**

Note rounding to one decimal place may introduce some small errors in summations.

Sensitivity analysis of baseline CC scenario CO_2 projections

Just as there are uncertainties over the projections of energy demand and supply, so too there are uncertainties over the future levels of energy related CO_2 emissions. The impact of the sensitivity variables affecting energy demand and hence CO_2 emissions is shown in Figure S6. Those factors driving a reduction in energy demand (i.e. lower growth in GDP, population and air travel) result in total in a reduction in CO_2 emissions of about 4% by 2020, and the factors driving an increase (i.e. higher car ownership and air travel) lead in total to CO_2 emissions about 3% above the CC baseline projections.

Figure S7 shows the overall impact of the supply side sensitivity factors on Scottish CO_2 emissions. This illustrates the powerful influence of the electricity generation sector, and in particular decisions on future fossil generation, on Scotland's total CO_2 emissions.

[15] The Military aircraft and naval vessels section of the inventory is omitted from these tables. This sector only accounted for 1% of CO_2 emissions in 2005.

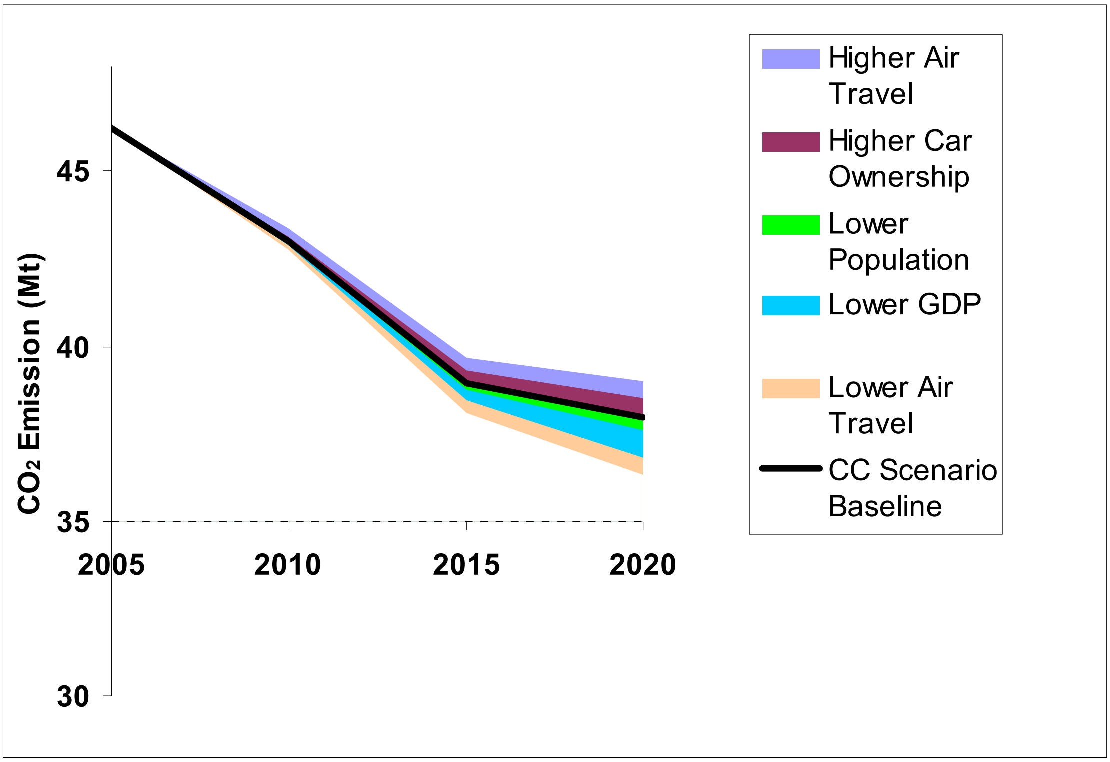


Figure S6 Overall impact of the demand side sensitivity analysis variables on Scottish energy related CO_2 emissions compared to the baseline CC scenario projection

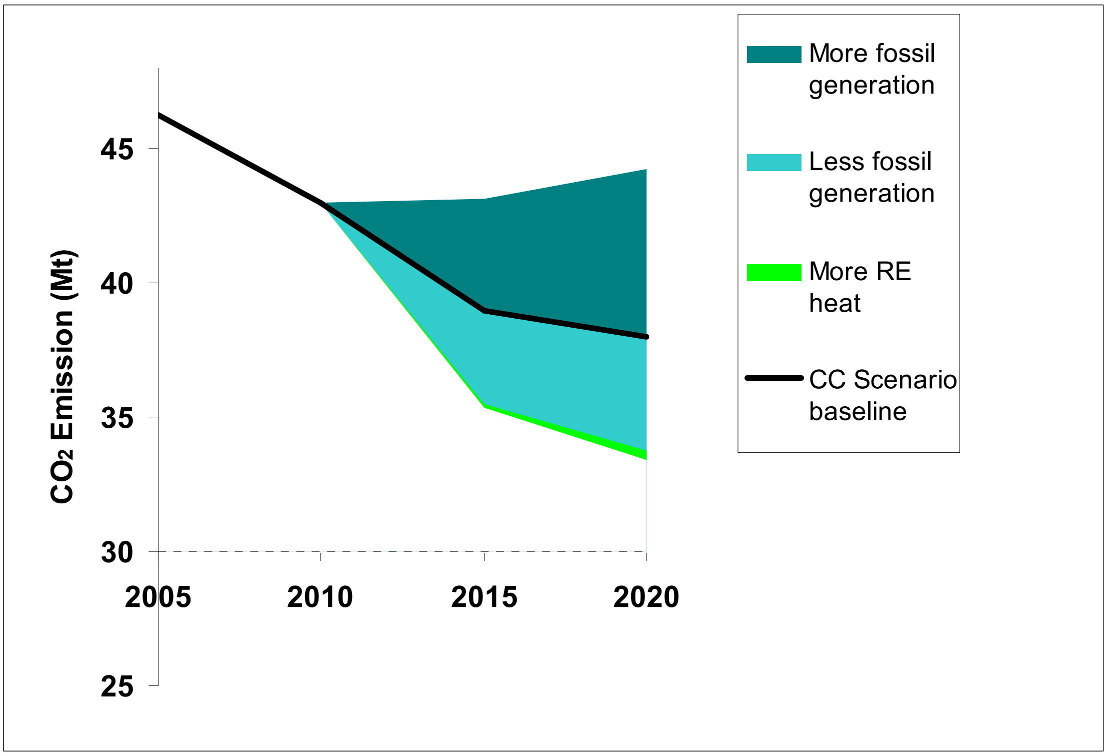


Figure S7 Overall impact of the supply side sensitivity analysis variables on Scottish energy related CO_2 emissions compared to the baseline CC scenario projection

Overall impact of both supply and demand side sensitivity factors

The combined impact of all the sensitivity factors investigated, covering both supply and demand is shown in Figure S8. Together these could cause an increase in CO_2 emissions of about 19% above the central CC scenario projection or a reduction of about 16% both by 2020. These variations are more significant than the change in emissions caused by the difference in price assumptions between the CC and HC scenarios, which was around 6%.

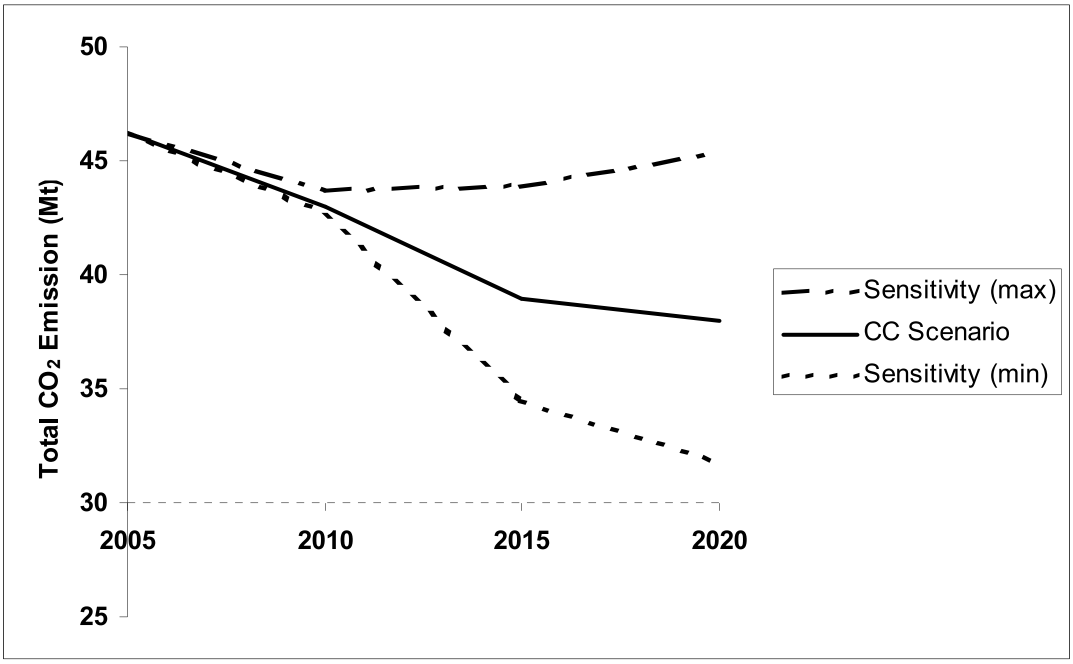


Figure S8 Overall impact of the sensitivity analysis variables on Scottish energy related CO_2 emissions compared to the baseline CC scenario projection.

Key Observations from the projections to 2020

Baseline Scenario Projections (including the Scottish Government's targets for GDP, population and renewable energy)

The following results and trends from the baseline CC and HC scenario projections for energy and CO_2 are particularly noteworthy (see also Table 25):

- Scottish final energy demand falls by 4% and 7% between 2005 and 2020 with the larger fall occurring with the HC scenario.
- The fall in demand occurs in the domestic sector (down 32%-35%) and services sector (down 9%) with demand increasing in the industry and transport sectors.
- Transport overtakes domestic to become the largest demand sector by 2010.
- In the HC scenario, demand for electricity stays fairly level over the period to 2020. With the CC scenario it drops by 1%.
- Scottish primary energy consumption falls by between 8% -10% between 2005 and 2020.

- Nuclear's share of primary energy declines with the possible closure of Hunterston B after 2016. This is replaced mainly by renewable energy which grows substantially (between 241% and 248%), mainly in electricity generation, and by 2020 accounts for about 15% of primary energy supply.
- Oil accounts for 29% of Scottish primary energy in 2002 but increases to 32% - 34% in 2020, driven by growing demand from road and air transport.
- Scottish energy related CO_2 emissions are projected to decline by between 7% and 9% from 2005 to 2011, and by between 13% and 18% between 2005 and 2020. Compared with the National Atmospheric Emissions Inventory (NAEI) inventory for 1990[16] emissions are projected to fall by between 18% and 30% by 2020.
- Electricity is responsible for 34% of Scottish energy related CO_2 in 2002 and is projected to fall to 21%-28% in 2020. Emissions from electricity generation are highly sensitive to decisions on future fossil fuel generation, and in particular coal fired generation capacity.

Sensitivity Analysis

The sensitivity analysis explored the impact on CO_2 emissions of variations and uncertainties specific to Scotland in the baseline projections:

- Scotland's energy related CO_2 emissions are particularly sensitive to the mix of fuels used for power generation. The higher and lower levels of fossil fuel generation investigated in this sensitivity analysis could change Scotland's overall CO_2 emissions by +17% to -11% by 2020. Furthermore, power stations in Scotland operate in the UK market and therefore their operation will be determined at the UK level, i.e. decisions around generation will sometimes need to be taken in the context of that UK market.
- If Scotland's rates of economic growth and population growth follow the lower historic trend, rather than the Scottish Government's targets, CO_2 emissions will be about 2% lower in 2020 compared to the baseline.
- Higher or lower rates of growth in air travel could alter CO_2 emissions by about +/-1% by 2020.
- Increased car ownership to the average for the UK could increase CO_2 emissions by about 1.5% by 2020 compared to the baseline.
- An expansion of renewable heat supply to 10% of demand could reduce CO_2 emissions by about 1.6% by 2020.

[16]The present National Atmospheric Emissions Inventory includes emissions from domestic flights that are attributable to Scotland. However, the Scottish Energy Study Volume 1 did cover all aviation emissions and these have been included in Table 15 for completeness. Comparisons with NAEI values are made after excluding aviation.

Table S4 Summary of key results

	Change in Final Energy Demand 2005-2020 (%)	Change in CO_2 emissions 2005-2020 (%)
CC Scenario	-4%	-18%
HC Scenario	-7%	-13%
CC Scenario Sensitivity – High[17]	-1%	-2%
CC Scenario Sensitivity - Low[18]	-10%	-31%

Energy Prices

Fuel price differences within the range covered by the CC and HC scenarios have a modest impact on total energy demand, but have a more significant influence on the mix of fuels to be used. For example, by 2020 total primary energy demand was 2.5% higher in the HC scenario mainly due to increased electricity generation from coal. This resulted in CO_2 emissions around 6% higher in the higher fuel price scenario.

Projection uncertainty

As indicated previously projections into the future are inherently uncertain. This uncertainty arises from a number of sources including:

- Uncertainty in the baseline (2002) data on which the projections are based (linked to statistical margins and estimating uncertainties).
- Modelling approximations.
- Impact of policy measures (i.e. measures in the UK Climate Change Programme and EWP).
- Variations in future parameters (e.g. GDP, population, etc.)

The uncertainty over future parameters has been covered in this work through the analysis of two scenarios, and a set of sensitivity analyses. The sensitivity analysis has shown that this area of uncertainty can cause variations of about 20% around the central projection of CO_2 emissions by 2020.

The other factors above are analytical uncertainties that are likely to have less impact than the uncertainty over future parameters. For example BERR has estimated the uncertainty around its central projection, in terms of CO_2 emissions, to be about plus or minus 10%.

[17] The "High" sensitivity analysis included higher car ownership and air travel, with higher energy demand and CO_2 emissions, and higher fossil fuel power generation limiting the fall in CO_2 emissions relative to 2005.

[18] The "Low" sensitivity analysis included lower GDP and population growth, with lower energy demand and CO_2 emissions, and lower fossil fuel power generation leading to further decreases in projected CO_2 emissions relative to 2005.

These observations suggest that, for a given scenario (i.e. setting aside the uncertainties in the scenario itself), the uncertainty applying to a particular projection may be of the order of 10-15%. However, since these uncertainties are the same for all projections, they will largely cancel out when considering differences between scenarios. Therefore the relatively small trends between scenarios reported herein are significant, and should not be dismissed as “within the projection error”.

Glossary of acronyms and terms used in this report

BERR[19]	Department for Business Enterprise and Regulatory Reform
CCGT	Combined cycle gas turbine
CCS	Carbon Capture and Storage
CHP	Combined Heat & Power
CO_2	Carbon dioxide
DA	Devolved Administration
DECC	Department of Energy and Climate Change
DEFRA [19]	Department of Environment, Food & Rural Affairs
DTI	Department of Trade and Industry
DUKES	Digest of UK Energy Statistics
EU ETS	European Union Emissions Trading Scheme
EWP	Energy White Paper 2007
GDP	Gross Domestic Product
GVA	Gross Value Added (GDP at basic prices)
GWh	Giga watt hour (1 million kWh)
IPPC	Integrated pollution prevention and control
Kt	Kilo tonne (1,000 tonnes)
MPP	Major power producer
Mt	Mega tonne (1 million tonnes)
MW	Mega Watt
NAEI	National Atmospheric Emissions Inventory
NAP	National Allocation Plan (for EU ETS)
RE	Renewable energy
RO	Renewable Obligation
TWh	Terra watt hour (1,000 million kWh)

[19] 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

The Scottish Energy Study is the first major study of energy supply and demand to be conducted in Scotland for over a decade. The aim in producing this study is to provide the Scottish Government and other stakeholders with a coherent picture of the energy flows into and out of Scotland, including details of energy supply and consumption across the four main energy demand sectors, namely domestic, transport, industry and services.

Volume 5 of the study examines the prospects for future energy supply and demand in Scotland, and the implications of these trends for energy related CO_2 emissions up to 2020. Because Scotland's energy economy is strongly linked to and influenced by that of the UK overall, these projections for Scotland have been developed from projections for the UK made by the Department for Business Enterprise and Regulatory Reform (BERR)[20]. The approach used to do this is described in Section 2.

Projecting future trends in any area of a modern economy is fraught with uncertainty, and energy is no exception due to the many differing factors impacting on the patterns of supply and demand. In particular trends in economic growth, primary energy prices and government policies (e.g. aimed at reducing greenhouse gas emissions or increasing security of supply) can have a major impact on both demand and the mix of energy sources used to meet that demand. The study has addressed these uncertainties in three ways.

Firstly it has examined two scenarios taken from the BERR projections for the UK that consider the impact of different fossil fuel price trajectories, namely:

Central – Central (CC) – in which primary energy prices are assumed to follow a 'central' trajectory and the energy policies set out in the UK Energy White Paper 2007 (EWP) are assumed to have an impact in the centre of their potential range.

High – Central (HC) – in which primary energy prices are assumed to follow a 'high' trajectory and the energy policies set out in the UK EWP are assumed to have an impact in the centre of their potential range.

Secondly the study has adjusted the projections to take account of key factors specific to Scotland, in particular the Scottish Government's targets for economic and population growth, and the expansion of renewable energy production, that diverge from the overall UK trend used by BERR.

Thirdly the study includes a set of sensitivity analyses, which examine how changes to assumptions impact on Scottish energy demand and supply.

[20] Now a responsibility of the Department of Energy and Climate Change (DECC).

Volume 5 is divided into five main sections in addition to this introduction:

Section 2 - Methodology and assumptions
Section 3 - Quantitative projections of energy demand to 2020.
Section 4 - Quantitative projections of energy supply to 2020.
Section 5 – Projections of CO_2 emissions to 2020.
Section 6 – Sensitivity analysis of how the energy and CO_2 projections are affected by variations specific to Scotland.

This work builds upon the quantitative and qualitative information on energy supply and demand, and related CO_2 emissions, provided in Volumes 1 to 4 of the Scottish Energy Study. The following figure illustrates how the projections and scenarios in Volume 5 fit with the other Energy Study Volumes.

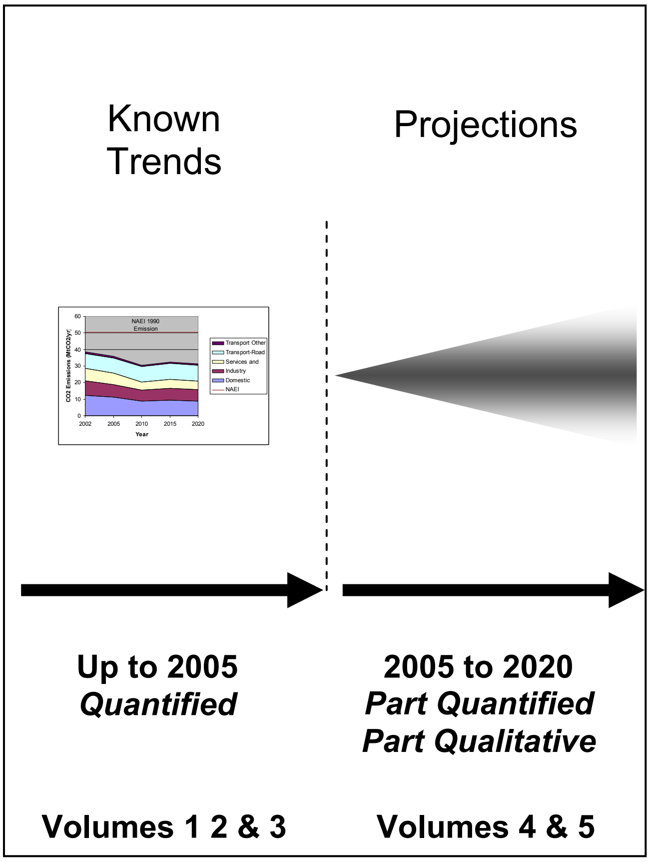


Figure 1 Relationship between Volume 5 and Energy Study Volumes 1-4

2. Methodology and Assumptions

The starting point for energy projections must be a reference set of data for a recent year. The previously published Scottish Energy Study – Volume 1[21] provides such statistics for Scotland in 2002 and these, together with the less detailed regional energy statistics published by BERR[22], have formed the starting point for these projections. The projections give separate consideration to Scottish energy demand and to the activity of the energy supply sector in Scotland.

Starting from the reference year, the estimation of future energy demand is a complex issue because consumer demand is not for energy directly but for the services it provides such as warmth, lighting, travel, entertainment, motive power, process heat, etc. Some of the main factors influencing energy demand are:

- Prices of primary energy supply (i.e. oil, natural gas, coal), which ultimately feed through to the prices paid by final consumers.
- Economic growth (i.e. GDP) that determines the level of business activity and the average wealth of individual consumers, both of which influence the level of demand for energy related services.
- Population, which determines the number of individual consumers as well as affecting the size of the national economy.
- Investment in new more efficient devices and processes that can deliver energy services while using less energy (e.g. better domestic heating boilers, enhanced building standards, more fuel efficient cars).
- Changes in the mix of fuels used, either in response to their relative prices or because one fuel is more convenient to use than another (e.g. use of gas for domestic heating, the growing preference for diesel fueled cars, uptake of biomass etc.).
- Government policies on energy and greenhouse gas emissions.

BERR's energy and CO_2 projections for the UK give separate projections for each of the main energy consuming sectors, namely domestic, industry, services (including agriculture), and transport. These take account of the above factors and include explicit assumptions for future fossil fuel prices, GDP and population growth, and the impact of established and proposed policy measures. The projections are produced using a mathematical model that uses econometric relationships to project future demands and includes feedback between demand and delivered energy prices. The impact of policy measures that directly affect energy prices (e.g. the EU Emission Trading Scheme) are assessed by the model, while the model can be constrained to include other policy targets (e.g. liquid biofuels). The model delivers solutions that balance energy supply and demand at the UK level.

[21] Scottish Energy Study Volume 1 – Energy in Scotland, supply and demand (http://www.scotland.gov.uk/Publications/2006/01/19092748/0)
[22] Regional energy consumption statistics, and regional electricity generation statistics, BERR (http://www.berr.gov.uk/energy/statistics/regional/index.html)

BERR's projections included the impact of UK level policy measures, including those introduced by the Climate Change Bill, those proposed in the Energy White Paper 2007 and the impact of the EU Emission Trading Scheme (ETS) on the electricity generation sector. For the latter the ETS was assumed to trade at €20/tCO_2 from 2010-2015 and €25/tCO_2 from 2015 to 2020 in both the CC and HC scenarios. However, BERR's projections were produced before the EU 2020 target for renewable energy was agreed, and therefore the measures needed to meet this target across the UK through, for example, accelerated deployment of renewable electricity and heat were not considered. As a consequence these projections for Scotland also do not explicitly incorporate the EU 2020 target, although ambitious targets for renewable electricity and heat are investigated in this study.

In July 2008 BERR[23] issued a consultation on the strategy to meet the EU 2020 target, therefore the policy mechanisms to be used and the division of effort between sectors is currently uncertain[24]. In October 2008 the Scottish Government issued a parallel consultation on the Scottish Renewable Action Framework – which sets out proposals for the development of all forms of renewable energy in Scotland.

Scottish demand in each sector, and for each fuel type, was escalated from the 2002 reference year by scaling in line with the BERR projections for the UK according to the general relationship:

$$\text{Scottish Demand in 20XY} = \frac{\text{Scottish Demand in 2002}}{\text{UK Demand in 2002}} \times \text{UK Demand in 20XY}$$

(Where 20XY represents the time-steps 2010, 2015 and 2020.)

While this approach has the advantage of maintaining consistency and comparability with the projections for the UK, it does implicitly assume that Scotland follows the UK average with regard to the key drivers of energy demand (i.e. economic and population growth, impact of UK level policy measures, etc.). Therefore these initial estimates were adjusted to take account of differences between Scotland and the UK average. In particular the projections were adjusted to take account of the Scottish Government's targets for economic or population growth, whichever was considered to be the more influential on the demand sector[25], while sensitivity analyses investigated other variations specific to Scotland. The GDP and population assumptions for Scotland were determined as follows:

- Population – The Scottish Government has set a target for Scotland to match the average European (EU15) population growth between 2007 and 2017. For the purpose of these projections it has been assumed that this will be the same as the historic EU15 population growth[26]. This growth rate was also assumed to continue up to 2020[27].

[23] This consultation is now with the Department for Energy and Climate Change (DECC).
[24] UK Renewable energy strategy consultation, BERR, July 2008 (http://www.berr.gov.uk/energy/sources/renewables/strategy/page43356.html)
[25] Adjusting for both population and GDP would over compensate because the two are linked.
[26] EU15 population growth averaged 0.26% per year between 1995 and 2005, but was 0.5% between 2000 and 2005. An intermediate value of 0.4% per year was used for these projections.
[27] The government economic strategy, November 2007 (http://www.scotland.gov.uk/Resource/Doc/202993/0054092.pdf)

- GDP[28] – The Scottish Government has set a target to raise Scotland's rate of economic growth to match the UK by 2011, and to match the growth rate of the smaller independent EU Member States, defined as Austria, Denmark, Finland, Ireland, Luxembourg, Portugal and Sweden, by 2017. For the purpose of these projections this was achieved by setting Scottish GDP growth to change gradually so that it converged with the growth assumptions for the UK used in BERR's energy projections by 2011. Beyond this time Scottish growth was set to continue to increase gradually to converge with the historic (1975-2005) average growth rate of the smaller EU member states (2.7% per year) by 2017, and to retain this growth rate up to 2020[29]. Historically Scotland's economic growth has lagged behind that of the UK. Therefore the GDP projections for Scotland were started 0.25% below the growth rate assumed in the BERR projections. This differential was gradually reduced to meet the UK growth assumed by BERR in 2011 (2.5%). Beyond 2011 BERR assumed a lower growth rate for the UK of 2.0% per annum, therefore convergence to Scotland's 2017 target was attained by increasing Scottish growth gradually from 2.1% in 2012 to 2.7% in 2017.

The resultant Scottish population and GDP assumptions are presented in Table 1, where they are compared to the assumptions for the UK used by BERR in their energy projections. It is notable that with these assumptions Scottish GDP per capita exceeds the UK average by 2020, but Scotland has a declining share of the UK population.

Table 1 Comparison of UK and Scottish population and GDP assumptions to 2020

	2002	2010	2015	2020	Change 2002-2020
UK					
GDP (£bn at 2003 basic prices)	966.0	1197.9	1329.0	1467.3	+52%
Population (Millions)	59.23	62.33	64.53	66.75	+13%
GDP per capita (£)	16,309	19,219	20,595	21,982	+35%
Scotland					
GDP (£bn at 2003 basic prices)	75.9	93.8	105.3	120.2	+58%
Population (Millions)	5.05	5.19	5.30	5.41	+7%
GDP per capita (£)	15,029	18,073	19,868	22,218	+48%
% of UK GDP	7.9%	7.8%	7.9%	8.2%	-
% of UK population	8.5%	8.3%	8.2%	8.1%	-

[28] Strictly the economic activity for Scotland is measured and reported as Gross Value Added (GVA), which is GDP at basic price (less taxes and subsidies), but for simplicity this is referred to as GDP throughout this report.
[29] These estimates were based on the GDP value for Scotland given in the Office of National Statistics regional accounts.

One exception to the above approach was the year 2005 for which demand was estimated by a combination of extrapolation from the 2002 baseline data and the use of BERR's regional statistics for 2005 when these were available with sufficient disaggregation. Consequently population and GDP assumptions were not needed for 2005.

In order to maintain consistency with the analysis undertaken by BERR and in order to be able to carry out analysis using cash value estimates of GDP for Scotland, the Regional Accounts (produced by ONS) have been used to estimate GDP in Scotland. It is important to note that GDP growth rates for Scotland derived from the Regional Accounts presented in this report will vary considerably from the GDP growth rates produced using the Scottish Government volume (constant prices) index. There are a number of reasons for this. Firstly the ONS current price estimates (from the Regional Accounts) are produced using a different methodology from the Scottish Government volume index, and are based on different data sources. Secondly, in order to create a constant prices series for Scotland using the Regional Accounts a UK level deflator was used to convert Scottish current price estimates into constant prices – as the ONS do not produce constant price estimates for Scotland in the regional accounts. Applying a UK deflator to Scottish figures is not ideal as it obviously does not account for differences in the structure of the Scottish economy relative to the UK – however, despite these limitations, such an approach is required to estimate constant prices for Scotland from this data series. The GDP volume index estimates produced by Scottish Government statisticians applies industry/sector specific deflators at much lower levels to reflect the industry structure of the Scottish economy. The equivalent UK series, produced by the ONS, is the CGCE volume index[30].

With regard to energy supply the key sectors in Scotland are electricity generation and oil refining. BERR's energy model considers existing large fossil fuelled and nuclear power plants on an individual basis, and these results were used directly for the Scottish energy projections. Scottish electricity generation from renewable sources was assumed to meet the targets set by the Scottish Government, which are 31% of Scottish gross consumption in 2011, increasing to 50% in 2020[31]. Energy consumption in oil refining was assumed to vary in line with the UK projections (see Section 4 detailing the analysis of supply side energy sectors). Data for 2005 were taken from BERR statistics for that year.

[30] There has been a long running GDP growth rate differential between Scotland and the UK. For example, the volume (constant prices) GDP indices for Scotland and the UK show that over the last 30 years (1977-2007) average annual growth in Scotland was 1.9% compared to 2.4% in the UK. Over the period 2002-2006 average annual growth was 2.2% in Scotland compared to 2.7% in UK."

[31] Scottish gross consumption is defined as the total amount of electricity generated in Scotland (including autogenerators and companies producing electricity mainly for own use) minus net exports but including losses. (http://www.scotland.gov.uk/Publications/2007/11/30090722/50)

BERR used three scenarios for future variations in primary energy prices to 2020, namely Low, Central and High. These projections for Scotland have used only the Central and High scenarios because the prices considered by the Low scenario appear less realistic given the peak in energy market prices that has occurred since BERR first published its projections. The Central and High fuel price assumptions are listed in Table 2, and it will be noted that these too are low compared to peak market prices seen in early 2008. Until updated projections for the UK are available then it is not possible, with the scaling approach adopted herein, to revise these Scottish projections to take account of higher energy prices without losing consistency and comparability with the UK level results. However, a qualitative discussion is given on the potential implications of higher energy prices for energy demand and CO_2 emissions in Section 6. Because the same ETS allowance prices were assumed by BERR for both the CC and HC scenarios this did not affect the relative price differentials of the fossil fuels between the scenarios.

Table 2 Fossil fuel price assumptions used in BERR's projections for the UK

	Crude Oil ($/bbl)		Natural Gas (p/therm)		Coal (£/tonne)	
	Central	**High**	**Central**	**High**	**Central**	**High**
2010	57	70	42	50	30	38
2015	50	75	38	53	31	41
2020	53	80	40	55	32	45

In addition to the uncertainties associated with projections it should be noted that there are many short term factors that influence the actual energy used in a particular sector in a particular year. The most obvious example is the weather, a mild or cold winter will have a significant affect on the use of heating in the domestic and services sectors, and will have some affect on industrial consumption. These short term factors are included in actual historical data but are not included in longer term projections. Hence trends in historical data will show short term variations whereas long term projections will show more smooth trends.

3. Energy Demand to 2020

The baseline projections for the four demand sectors are presented, starting with the largest demand sector in 2002, the domestic sector.

3.1. Energy Demand in the Domestic Sector

Energy is used in households for space heating in winter and for water heating and cooking throughout the year. Additionally electricity is used throughout the year to run a broad range of appliances and entertainment equipment, to provide lighting and for heating and hot water (particularly where there is limited access to other forms of fuel). Demand for all of these uses is dependent on the total number of households, the level of disposable income and the price of energy supplies. Demand for energy for space heating is also affected by the condition of the housing stock, the efficiency of heating appliances and the level of comfort demanded by residents (i.e. thermostat settings and number of rooms heated).

The Scottish Energy Study – Volume 1 provides estimates of domestic sector energy consumption divided by fuel type in 2002 that take account of the above factors. For example adjustments were made for the energy rating of Scottish homes, the mix of dwellings, Scotland's climate and the availability of gas. In developing projections to 2020 these reference values were firstly escalated in line with the UK projections using the general relationship given in Section 2. This approach captures current differences between Scotland and the UK average, but implicitly assumes that trends in Scotland will parallel the UK. Examples include trends in the number of households, disposable income, energy prices, improvement in the condition of the housing stock, switching between fuels, the level of heating demanded by residents and the effectiveness of UK wide policy measures. In most respects this is a reasonable set of assumptions with the exception that Scotland's population is projected to grow more slowly than for the UK overall (Table 1), which infers that the number of households will also increase more slowly than for the UK. Therefore the projections were adjusted to take account of this lower population trend.

Energy demand projections for the domestic sector are listed in Table 3 for the CC and HC scenarios. Overall Scottish domestic consumption is projected to fall by between 32% -35% between 2005 and 2020. By comparison BERR's projections anticipate UK domestic consumption falling by 29%-33%. This difference is linked to the slower population growth assumed for Scotland, that results in the growth in the number of households being less in Scotland than for the UK overall. The fall in demand occurs for all fuels, including gas and electricity, although the fall in electricity demand is less than for other energy sources (Figure 2). The fall in demand for gas, ranging from 38% to 43% is particularly notable since up to 2005 it was on a rising trend. However, this is in line with the projections for the UK that anticipate gas demand falling by between 35%-40%. As would be expected the fall is greatest in the higher energy price HC scenario.

The projected fall in energy demand is due to the impact of a range of existing measures to improve household energy efficiency, including more efficient boilers and tighter building standards, and new measures proposed in the Energy White Paper (EWP). The latter include (in order of impact) an obligation on energy suppliers to reduce household carbon emissions, improved building standards (including the zero carbon homes initiative), more energy efficient products and improved information to householders on energy use through better billing and real time displays.

Of course there is significant uncertainty over the projected impact of policy measures, which BERR acknowledges by presenting a range of potential impacts for the EWP measures. The projections used herein are based on BERR's central estimate. BERR's lower estimate for the impact has domestic energy demand 5% above the central value while its higher estimate gives an energy demand 5% below the central value.

Table 3 Projected Scottish domestic energy demand to 2020 (TWh)[32]

CC Scenario

	2002	2005	2010	2015	2020	Change 2005-2020
Electricity	12.2	12.4	11.8	11.8	11.3	-9%
Gas	34.4	35.3	29.3	26.2	21.9	-38%
Oil	5.8	4.9	4.2	3.5	2.9	-41%
Coal	3.0	1.1	0.8	0.6	0.4	-63%
Renewable Energy	0.5	0.5	0.5	0.5	0.5	0%
Total	**56.0**	**54.2**	**46.6**	**42.5**	**37.0**	**-32%**

HC Scenario

	2002	2005	2010	2015	2020	Change 2005-2020
Electricity	12.2	12.4	11.7	11.6	11.2	-9%
Gas	34.4	35.3	28.4	24.4	20.0	-43%
Oil	5.8	4.9	4.2	3.5	2.9	-41%
Coal	3.0	1.1	0.8	0.6	0.4	-63%
Renewable Energy	0.5	0.5	0.5	0.5	0.5	0%
Total	**56.0**	**54.2**	**45.6**	**40.6**	**35.0**	**-35%**

Note rounding to one decimal place may introduce some small errors in summations.

[32] 2005 data for Scottish domestic electricity and gas consumption are taken from BERR's regional consumption statistics http://www.berr.gov.uk/files/file43304.pdf, while the values for solid fuel, oil and renewables are extrapolated from 2002.

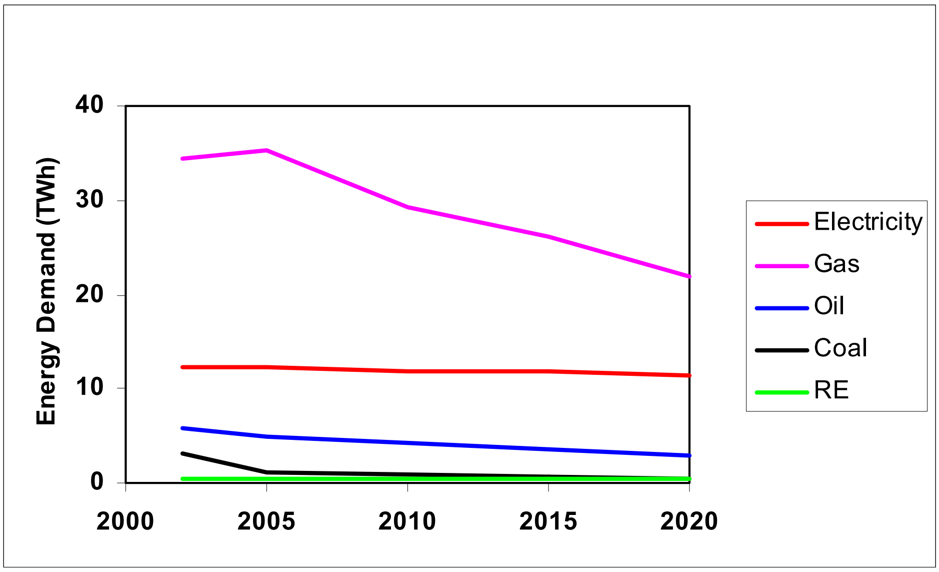


Figure 2 Projected Scottish domestic energy demand to 2020 for the CC scenario (TWh)

Renewable energy use in these projections refers mainly to the use of wood, passive solar, ground source heat, etc. for space and water heating. Electricity generated from renewable energy sources and supplied through the public transmission and distribution system is included in the electricity values, and will be discussed further in Section 4 which covers energy supply. The provision of heat from renewable energy sources stays flat over the period in line with the projections for the UK. However, it should be noted that BERR's projections neglected potential measures that may be introduced to meet possible targets under the EU's proposed directive for the use of energy from renewable sources, that envisages the EU deriving 20% of its energy from RE by 2020[33], with the UK likely to take a 15% target as part of the burden sharing arrangement (NB. the Scottish Government has stated in principle its willingness to make a contribution to the UK target in excess of its population share). The impact of this latter target is examined later in the sensitivity analyses reported in Section 6.

3.2. Energy Demand in Transport

Transport energy use includes fuel for road vehicles, trains, aircraft and shipping. Fuel consumption by road vehicles dominates transport energy use, and can be divided into consumption by private vehicles (mainly cars but also including motor cycles), goods transport and public transport.

[33] Proposal for a directive of the European Parliament and the Council on the use of energy from renewable sources, COM2008/19, January 2008.

Demand for fuel for personal transport is determined by the number of cars in use, their annual mileage and their fuel efficiency. The number of cars in use depends on the population and the level of car ownership (i.e. number of cars per head of population). Car ownership in Scotland in 2005 at about 0.42 cars per capita[34] is only 90% of the UK average[35], although the average annual mileage is estimated to be about 4% higher[35, 36]. The annual mileage of cars is linked to the cost of fuel, household disposable income and the degree of road congestion. Demand for fuel for goods vehicles is linked to the level of economic activity as well as to the cost of fuel.

The Scottish Energy Study – Volume 1 provides estimates for fuel use in road transport in 2002 broken down into petrol cars, motor cycles, diesel cars, light good vehicles, heavy goods vehicles and buses/coaches. BERR's energy projections for the UK provide separate projections for the consumption of diesel and petrol by cars and goods vehicles. Projections of Scottish road fuel use to 2020 were made as follows:

- Petrol consumption and diesel consumption in cars were escalated in line with the UK projections for petrol and diesel consumption in cars, and adjusted for the different rate of population growth assumed for Scotland compared to the UK average.
- Diesel consumption in goods vehicles was escalated in line with the UK projections for diesel consumption in goods and public service vehicles and adjusted for the higher rate of GDP growth assumed for Scotland.
- Diesel consumption by buses and coaches was escalated in line with the UK projections for diesel consumption in goods and public service vehicles and adjusted for the different rate of population growth assumed for Scotland.

By following this approach it was implicitly assumed that Scotland's car ownership and utilisation, and the average fuel efficiency of the car stock would change in line with the UK overall, but that the differences in the absolute levels of car ownership and utilisation would persist. Similarly it was assumed that goods vehicle utilisation and fuel efficiency would parallel the trend projected for the UK. Because car ownership is less than the UK average there is clearly a case for considering a faster growth in transport fuel consumption in Scotland. This has been examined in the sensitivity analysis reported in Section 6. The BERR projections incorporate the Renewable Transport Fuel Obligation and also the potential impact of a successor to the EU voluntary agreement on new car fuel efficiency.

Projections for fuel use in Scottish road transport are listed in Table 4. Total demand increases by 13% and 10% between 2005 and 2020 in the CC and HC scenarios respectively. Within this overall total, demand for petroleum based fuels increases by a lower 6% in the CC scenario and by 4% in the HC scenario, as some of these are replaced by biofuels. The corresponding trends for total road transport fuel demand (including biofuels) across the UK were +6% in CC and +3% in HC.

[34] Scottish Transport Statistics Number 26, 2007
[35] Vehicle Licensing Statistics 2007, Department for Transport (http://www.dft.gov.uk/pgr/statistics/datatablespublications/vehicles/licensing/vehiclelicensingstatistics2007)
[36] National Travel Survey 2007, Department for Transport.

The main reason for the greater increase in demand in Scotland is because of the adjustment for Scotland's increasing share of the UK's GDP affecting the demand for goods transport. With this adjustment, consumption of petroleum fuel by goods vehicles is projected to increase by about 3%-6% between 2005 and 2020, whereas total UK consumption is roughly level in both scenarios.

Figure 3 shows the distribution of demand for petroleum products in road transport for the CC scenario, which also suggests that the demand from car travel may have peaked or at the least have levelled off by 2020. The HC results show a similar trend (Table 4) which suggests that this is not simply a price effect, but also reflects the impact of policy measures to reduce carbon emissions from road transport, the main one being an extension of the EU voluntary agreement on new car fuel efficiency.

Table 4 Projected Scottish energy demands for road transport (TWh)

CC Scenario

	2002	**2005**	**2010**	**2015**	**2020**	**Change 2005-2020[37]**
Private	23.6	22.7	23.9	26.1	24.7	+9%
Goods	10.5	11.0	10.6	10.9	11.6	+6%
Public	1.5	1.6	1.5	1.5	1.5	-4%
Biofuels	0.0	0.0	1.8	1.9	1.9	-
Total	**35.5**	**35.3**	**37.8**	**40.4**	**39.7**	**+13%**
Total Petrol	17.7	15.2	14.2	12.0	11.2	-26%
Total Derv	17.9	20.1	21.8	26.5	26.6	+32%
Total Biofuels	0.0	0.0	1.8	1.9	1.9	-
Total	**35.5**	**35.3**	**37.8**	**40.4**	**39.7**	**+13%**

HC Scenario

	2002	**2005**	**2010**	**2015**	**2020**	**Change 2005-2020**
Private	23.6	22.7	23.7	25.6	24.1	+6%
Goods	10.5	11.0	10.5	10.7	11.3	+3%
Public	1.5	1.6	1.5	1.5	1.5	-5%
Biofuels	0.0	0.0	1.8	1.9	1.8	-
Total	**35.5**	**35.3**	**37.5**	**39.7**	**38.7**	**+10%**
Total Petrol	17.7	15.2	14.1	11.7	10.9	-28%
Total Derv	17.9	20.1	21.6	26.0	26.0	+29%
Total Biofuels	0.0	0.0	1.8	1.9	1.8	-
Total	**35.5**	**35.3**	**37.5**	**39.7**	**38.7**	**+10%**

Note rounding to one decimal place may introduce some small errors in summations.

[37] In some cases the percentage change is obscured by rounding of the energy consumption values to one decimal place.

BERR's projections assumed that the UK would meet its target to derive 5% of road transport fuels from biomass resources by 2010, and this is reflected in the projections for Scotland, where biomass based fuel accounts for ~5% of total petrol and diesel consumption from 2010 to 2020.

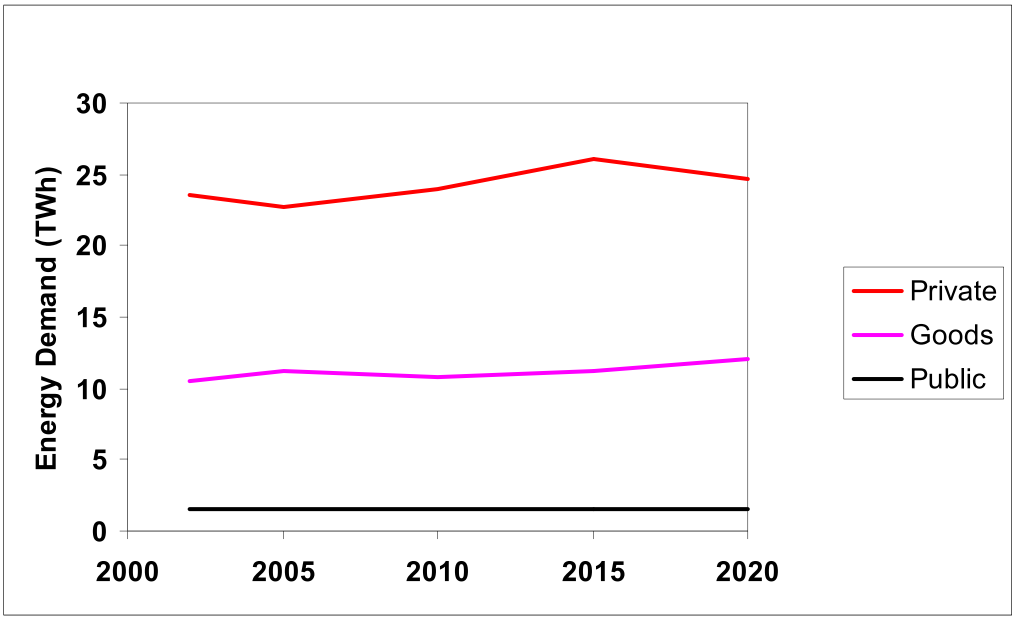


Figure 3 Projected Scottish energy demands for petroleum products in road transport – CC scenario (TWh)

In addition to road transport, energy is used to power rail, air and marine transport. The Scottish Energy Study – Volume 1 gave estimates for the use of diesel and electricity for rail transport, kerosene for aviation and fuel oil for marine transport in 2002. These values were escalated to 2020 in line with the corresponding projections for the UK. No additional adjustments were made to take account of Scottish GDP or population variations since, to some extent, these areas are more influenced by the overall UK economy. Aviation dominates these energy uses (Figure 4) and, in line with the UK, shows substantial growth to 2020. However, Scottish aviation only accounts for a little over 6% of total UK aviation energy consumption.

Overall Scottish energy consumption for transport increases by 11% and 15% for the HC and CC scenarios compared to 7% and 11% for the UK. The higher growth in overall transport energy demand compared to road transport is due to a strong increase in demand for air travel.

Table 5 Projected total Scottish energy demands for all transport applications (TWh)

CC scenario

	2002	2005	2010	2015	2020	Change[38] 2005-2020
Motor Spirit	35.5	35.3	36.0	38.5	37.8	+7%
Aviation	8.5	10.1	9.9	11.5	12.9	+28%
Marine	2.4	2.6	2.4	2.6	2.6	+2%
Rail	0.3	0.3	0.3	0.3	0.3	-
Electricity	0.3	0.3	0.3	0.3	0.3	-
Biofuels	0.0	0.0	1.8	1.9	1.9	-
Total	**47.1**	**48.6**	**50.7**	**55.2**	**55.9**	**+15%**

HC scenario

Transport	2002	2005	2010	2015	2020	Change 2005-2020
Motor Spirit	35.5	35.3	35.7	37.8	36.9	+5%
Aviation	8.5	10.1	9.7	10.9	11.9	+18%
Marine	2.4	2.6	2.4	2.6	2.6	+2%
Rail	0.3	0.3	0.3	0.3	0.3	-
Electricity	0.3	0.3	0.3	0.3	0.3	-
Biofuels	0.0	0.0	1.8	1.9	1.8	-
Total	**47.1**	**48.6**	**50.3**	**53.8**	**54.0**	**+11%**

Note rounding to one decimal place may introduce some small errors in summations.

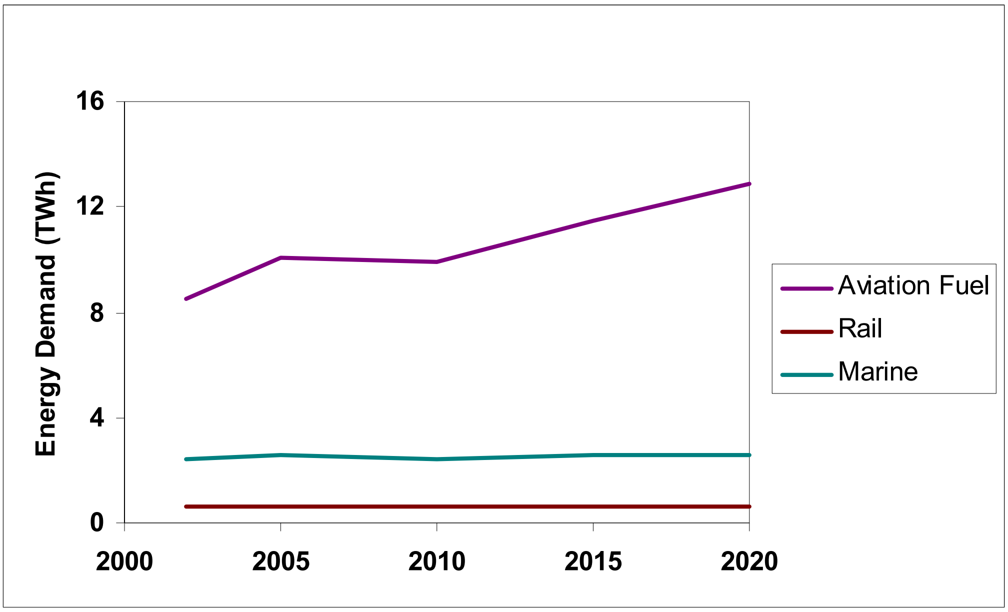


Figure 4 Projected Scottish energy demands for non-road transport – CC scenario (TWh)

[38] In some cases the percentage change is obscured by rounding of the energy consumption values to one decimal place.

3.3. *Energy Demand in Industry*

The industry sector consists of a broad range of processes and activities that differ considerably in the mix of energy sources used and their prospects for future growth. Moreover Scotland's mix of industries differs significantly compared to the UK average. For example the Food & Drink, Paper and Engineering sectors have a significant share of Scotland's industrial economy, whereas iron & steel has a minor share. To accommodate these considerations the projections for industrial energy consumption have been developed at a sub-sector level.

BERR considers industrial energy consumption disaggregated into 9 sub-sectors broadly based on the Standard Industrial Classification (SIC) two digit code as listed in Table 6. Scottish projections for industrial energy consumption were made by grouping the reference data given for 2002 in the Scottish Energy Study – Volume 1 into the same sub-sectors, and then escalating these values in line with the UK projections. These initial values were then adjusted to take account of the higher GDP growth assumed for Scotland.

By following this methodology it has been implicitly assumed that each sector in Scotland will follow the UK trend for fuel switching and that energy efficiency improvements will be in line with the UK average. This recognises that many of the main drivers (e.g. energy prices, energy regulation, market conditions, etc) are the same across the UK.

Table 6 Summary of industrial sub-sectors used for the projections

Industrial Subsector	SIC (03) Classification includes	Includes
Food, Drink and Tobacco	15, 16	Food, Beverages, Tobacco Products
Textiles, Leather and Clothing	17-19	Textiles, Clothing, Footwear products, Leather goods
Paper, Printing and Publishing	21, 22	Pulp, Paper and paperboard products, Printing and publishing
Chemicals	24	Industrial Gases and chemicals, Pharmaceuticals, Agrichemicals, paints and Varnishes, Toiletries
Non-Ferrous Metals	27.4, 27.53, 27.54	Non-ferrous metal production, Castings
Engineering and Vehicles	30-35	Metal products, Electrical and optical equipment, Transport equipment, Other Machinery and Equipment
Mineral Products	14, 26	Mining and quarrying of non-energy producing materials, Glass products, Ceramic goods, Other non-metal products
Iron and Steel	27, excluding 27.4, 27.53, 27.54	Iron and Steel Production, Casting, Blast Furnaces
Construction and Other Industries	13, 20, 25, 36, 37, 41, 45	Construction, Wood and wood products, Rubber and Plastic Products, Water supply, Sports goods and toys, Jewellery

Between 2005 and 2020 overall Scottish industrial energy consumption is projected to increase by about 14% -15% (Table 7) while UK industrial consumption[39] is projected to increase by between 11% and 13%. This difference partly reflects the higher GDP growth assumed for Scotland compared to the UK over this period. This results in Scotland's share of UK GDP increasing from 7.9% in 2005 to 8.2% in 2020 (Table 1). This increase in industrial energy consumption would have been greater, but is partly off-set because, across the UK, some industry sectors are expected to grow more slowly (or even decline) compared to others, and Scotland's industrial energy consumption is greatest in some of these lower growth sectors (see Table 8). Additionally BERR's projections anticipate significant improvements in energy efficiency, driven by a range of measures including the Climate Change Levy and voluntary agreements plus the impact of the EU ETS on energy intensive manufacturing, and this is carried through into the projections for Scotland.

The higher fuel prices of the HC scenario have relatively little impact on overall industrial demand but do cause some fuel switching. Demand for oil falls and the growth in demand for gas is lower in the HC scenario compared to the CC scenario but this is partly balanced by an increase in demand for electricity.

Table 7 Projected Scottish energy demands from industry (TWh)[40]

CC Scenario

	2002	2005	2010	2015	2020	Change 2005-2020[41]
Electricity	10.5	11.3	11.4	11.4	12.6	+12%
Gas	17.9	16.6	17.4	19.2	21.0	+26%
Oil	5.6	3.9	3.7	3.7	3.7	-5%
Coal	1.1	1.5	1.5	1.3	1.2	-25%
Renewable Energy	1.2	1.2	1.2	1.2	1.2	0%
Total	**36.3**	**34.5**	**35.1**	**36.8**	**39.6**	**+15%**

HC Scenario

	2002	2005	2010	2015	2020	Change 2005-2020
Electricity	10.5	11.3	11.7	11.8	13.2	+17%
Gas	17.9	16.6	17.1	18.5	20.2	+22%
Oil	5.6	3.9	3.6	3.5	3.6	-10%
Coal	1.1	1.5	1.4	1.3	1.2	-24%
Renewable Energy	1.2	1.2	1.2	1.2	1.2	0%
Total	**36.3**	**34.5**	**35.0**	**36.3**	**39.3**	**+14%**

Note rounding to one decimal place may introduce some small errors in summations.

[39] Excluding primary iron and steel a sector not present in Scotland.
[40] The values in Table 7 include energy consumption by the Construction Sector that was not covered by the estimates given in the Scottish Energy Study Volume 1. This increases the 2002 energy demand values by 0.2TWh for electricity, 0.3TWh for gas and 0.5TWh for oil products compared to Volume 1.
[41] In some cases the percentage change is obscured by rounding of the energy consumption values to one decimal place.

Table 8 Comparison of Scotland's share of UK industrial sector energy consumption and projected sectoral economic growth to 2020

	Scotland's share of UK energy consumption in 2002 (%)[42]	UK sector GDP growth between 2005-2020 assumed in BERR's projections (%)
Food, Drink and Tobacco	15.8	9.6
Textiles, leather and clothing	12.3	-31.0
Paper, Printing and Publishing	18.5	11.8
Chemicals	6.9	57.5
Non-ferrous metals	9.9	44.1
Engineering	13.5	30.2
Mineral products	6.5	20.4
Construction and other industries	3.6	24.8

Table 7 also shows some general changes to the mix of energy sources used by industry in the CC and HC scenarios. Both scenarios show increases in consumption of gas, and to a lesser extent electricity, while oil and coal continues to decline. The values for electricity do not include autogeneration, but following the convention established in the Scottish Energy Study Volume 1, do include the primary fuels used in autogeneration (i.e. for CHP and self generation). Some sales of power are expected from the industry sector and these are examined in Section 4.

The Scottish Energy Study – Volume 1 provided an estimate for the use of renewable energy (other than electricity) within Scottish industry. BERR's projection has the industrial use of renewable sources staying flat over the projection period, and to be consistent with the UK projection the estimate for Scotland has also been held constant to 2020. However, as noted previously, BERR projections did not include potential measures that may be introduced to meet possible targets under the EU's proposed directive for the use of energy from renewable sources. This is considered further in the sensitivity analyses reported in Section 6.

[42] These percentages were calculated by dividing the estimates of sectoral energy consumption given in the Scottish Energy Study Volume 1 by the corresponding values for the UK taken from the Digest of UK Energy Statistics (DUKES). This involved combining some of the sectors considered in the Scottish Energy Study to match DUKES.

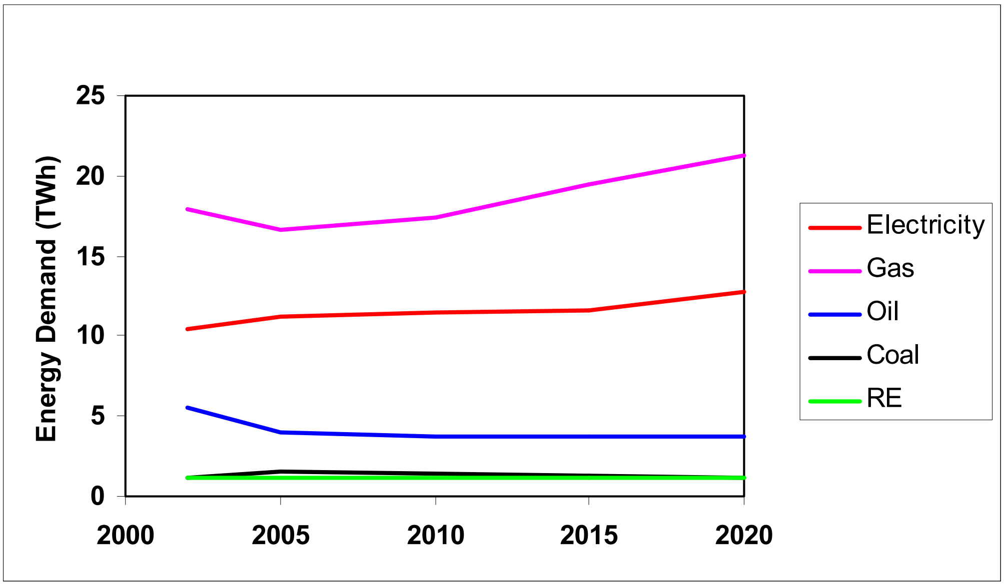


Figure 5 Projected Scottish energy demand from the industry sectors in the CC scenario (TWh)

3.4. Energy Demand in Services and Agriculture

Energy demand in the services sector is principally for space and water heating, cooking, air conditioning, lighting and the operation of a broad range of appliances, including information technology. Demand is driven by the level of economic activity in the sector, which determines the number and size of buildings being used and the number of employees. Agriculture includes farming, fisheries and forestry and involves the use of petroleum products to power machinery as well as energy use in buildings.

The services sector is made up of commercial services and public services and there is a significant difference in the energy mix used by these sub-sectors. For example about 60% of the energy used in commercial services is electricity, but electricity is only about 25% of energy used in the public services. Moreover, the balance of services is different in Scotland compared to the UK overall. Thus in GDP terms in 2005 Scotland had about 9.8% of UK public services but only 6.9% of UK commercial services. It is important to take account of these differences when making projections for this sector.

BERR produced separate projections for the UK public services, commercial services and agriculture, and these results were used to make separate sub-sector projections for Scotland. This involved the following steps:

- The Scottish Energy Study – Volume 1 data for service sector energy consumption in 2002 was divided into commercial and public services in line with the UK split, and then adjusted to take account of the larger proportion of public services in Scotland.
- Scottish commercial and public services energy use was escalated in line with the UK projections.

- The Scottish projections were adjusted to take account of the increasing rate of total GDP growth assumed for Scotland to 2020 (Table 1).
- Scottish agriculture energy use was escalated in line with the UK projections.

By following this approach it was implicitly assumed that Scottish energy intensity would improve in line with the UK average, and that UK policy measures would be equally effective in Scotland. Also the approach assumes that the current balance of commercial to public services will be maintained to 2020.

Table 9 Projected Scottish services sector energy demand divided by sub-sector for the CC scenario (TWh)

	2002	2005	2010	2015	2020
Public Services					
Electricity	3.1	3.3	2.8	2.7	2.6
Gas	5.2	6.1	5.8	5.6	5.6
Oil	1.6	1.1	0.9	0.8	0.7
Coal	0.0	0.0	0.0	0.0	0.0
Renewable Energy	0.2	0.2	0.2	0.3	0.3
Total	**10.2**	**10.7**	**9.7**	**9.3**	**9.2**
Commercial Services					
Electricity	7.2	7.4	7.3	7.3	7.3
Gas	5.3	5.2	5.4	5.1	5.1
Oil	0.9	1.5	0.8	0.8	0.7
Coal	0.0	0.0	0.0	0.0	0.0
Renewable Energy	0.0	0.0	0.0	0.0	0.0
Total	**13.4**	**14.1**	**13.6**	**13.2**	**13.2**
Agriculture					
Electricity	0.9	0.9	1.0	1.0	1.0
Gas	0.9	0.8	0.6	0.7	0.7
Oil	0.3	0.2	0.3	0.3	0.3
Coal	0.0	0.0	0.1	0.1	0.1
Renewable Energy	0.1	0.1	0.1	0.1	0.1
Total	**2.2**	**2.0**	**2.0**	**2.0**	**2.1**

Note rounding to one decimal place may introduce some small errors in summations.

Projections for each of the sub-sectors are set out in Table 9 and the aggregate result is given in Table 10 and Figure 6. Scottish energy demand in this group of sectors is projected to decline by 9% between 2005 and 2020 compared to a fall of 11% for the UK overall. The slower decline in energy consumption in Scotland is due to the assumption presented in Table 1 that Scotland will achieve higher economic growth than the UK average up to 2020.

The overall pattern of falling energy demand, both in Scotland and the UK, despite projected substantial growth in the commercial sector, is linked to the expectation that the historic trend for improvements to the energy intensity in these sectors is continued into the future. In fact this trend is expected to be accelerated by measures introduced by the UK Climate Change Programme 2002 (i.e. building regulations, climate change agreements) and new measures proposed in the Energy White Paper 2007 (i.e. smart metering, energy performance of buildings, carbon reduction commitment).

The modest growth in renewable energy reflects the overall trend expected for the UK, but alternative assumptions specific to Scotland for biomass heat are examined in Section 6.

The fuel price differences between the CC and HC scenarios had no affect on the overall level of energy demand or the balance between the mix of fuels used. This is consistent with BERR's projections for the UK under these scenarios.

Table 10 Projected Scottish energy demands from the services and agriculture sectors (TWh)[43] (CC & HC Scenario yielded the same results)

	2002	2005	2010	2015	2020	Change 2005-2020[44]
Electricity	11.3	11.6	11.1	10.9	10.9	-6%
Gas	11.4	12.2	11.8	11.4	11.4	-6%
Oil	2.8	2.8	2.0	1.8	1.7	-39%
Coal	0.0	0.0	0.1	0.1	0.1	+350%
RE	0.3	0.3	0.3	0.4	0.4	+42%
Total	**25.8**	**26.8**	**25.3**	**24.6**	**24.5**	**-9%**

Note rounding to one decimal place may introduce some small errors in summations.

[43] The Scottish Energy Study Volume 1 includes 1.06TWh of "heat sold". This has not been included in the projections, because the energy used to produce this heat is included in the energy projections for the industry, refineries and power supply sectors.

[44] In some cases the percentage change is obscured by rounding of the energy consumption values to one decimal place.

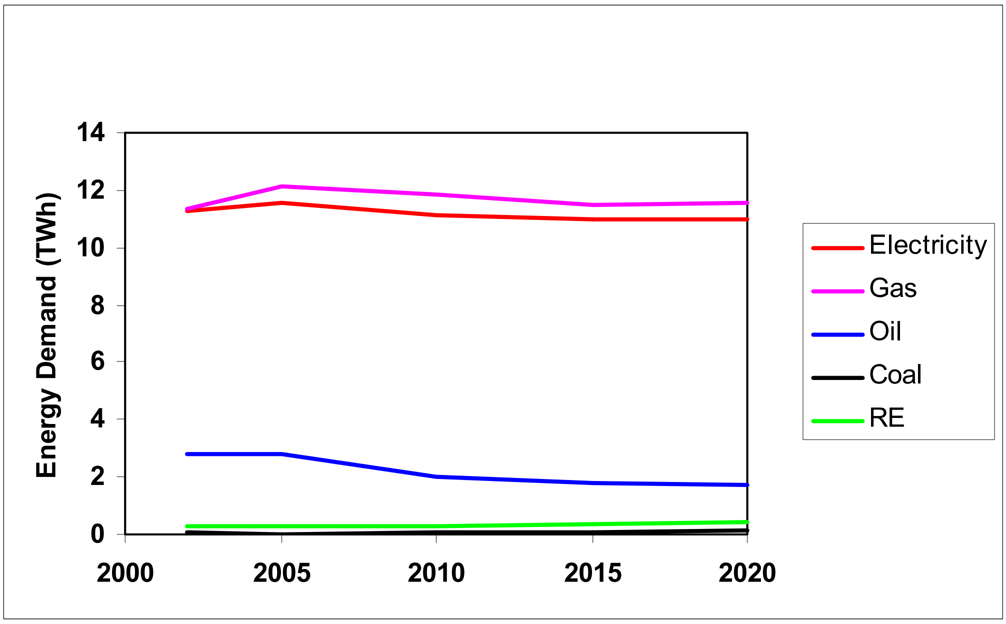


Figure 6 Projected Scottish energy demands from the services and agriculture sectors in the CC scenario (TWh)

3.5. Summary of Scottish Final Energy Demand

Table 11 and Figure 7 show projections of overall final energy demand divided by sector. In the CC scenario overall demand falls by 4% between 2005 and 2020, while in the HC scenario the fall is 7%. These trends compare to falls of 3% and 6% for the UK overall in the CC and HC scenarios respectively. The principal factor driving this reduction in demand both in Scotland and the UK overall is the impact of policy measures proposed in the UK EWP. For example BERR's central projections estimate that the UK's total final energy demand will be 9% less with the EWP measures than it otherwise would have been.

The main drivers that differ between Scotland compared to the UK overall are economic growth (assumed to be higher than long-term trend in Scotland), population growth (lower in Scotland), the different mix of industries in Scottish manufacturing and the different balance between public and commercial activity in the services sector. Overall these factors appear to largely cancel out although there are some significant trends within individual sectors:

- Energy demand in the domestic sector is projected to fall by 32%-35% by 2020 (UK 28% -32%). This is driven by a range of existing measures to improve household energy efficiency, including more efficient boilers and tighter building standards, and new measures proposed in the EWP. The latter include in order of estimated impact an obligation on energy suppliers to reduce household carbon emissions, improved building standards (including the zero carbon homes initiative), more energy efficient products and improved information to householders on energy use through better billing and real time displays.

- Energy demand in services is projected to fall by 9% (UK 10%). The difference in fuel prices between the CC and HC scenarios had no effect on demand in these comparatively low energy intensity sectors. The fall in demand is mainly driven by measures to increase energy efficiency introduced by the UK Climate Change Programme 2002 (i.e. building regulations, climate change agreements) and new measures proposed in the Energy White Paper 2007 (i.e. carbon reduction commitment, smart metering, energy performance of buildings). This fall may seem modest but it represents a substantial improvement in energy intensity since Scotland's GDP is assumed to increase by 58% between 2005 and 2020, and a substantial part of this growth will be in services.
- These falls are partially offset by a 14%-15% increase in consumption by industry (UK +13%). As for services this represents a significant increase in energy intensity given the significant economic expansion assumed between 2005 and 2020.
- Energy demand for transport is also projected to increase by 11% in the HC scenario and 15% in the CC scenario (UK +7 % to +11%). The higher growth in Scotland is driven mainly by faster economic growth that results in higher fuel consumption for goods transportation, with car fuel consumption levelling off and aviation expansion matching the UK average.

Table 11 Scottish Final Energy consumption divided by demand sector (TWh)

CC Scenario

	2002	2005	2010	2015	2020	Change 2005 - 2020[45]
Domestic	56.0	54.2	46.6	42.5	37.0	-32%
Services	25.8	26.8	25.3	24.6	24.5	-9%
Industry	36.3	34.5	35.1	36.8	39.6	+15%
Transport	47.1	48.6	50.7	55.2	55.9	+15%
Total	**165.0**	**164.2**	**157.8**	**159.0**	**156.9**	**-4%**

HC Scenario

	2002	2005	2010	2015	2020	Change 2005 - 2020
Domestic	56.0	54.2	45.6	40.6	35.0	-35%
Services	25.8	26.8	25.3	24.6	24.5	-9%
Industry	36.3	34.5	35.0	36.3	39.3	+14%
Transport	47.1	48.6	50.3	53.8	54.0	+11%
Total	**165.0**	**164.2**	**156.2**	**155.3**	**152.7**	**-7%**

Note rounding to one decimal place may introduce some small errors in summations.

[45] In some cases the percentage change is obscured by rounding of the energy consumption values to one decimal place.

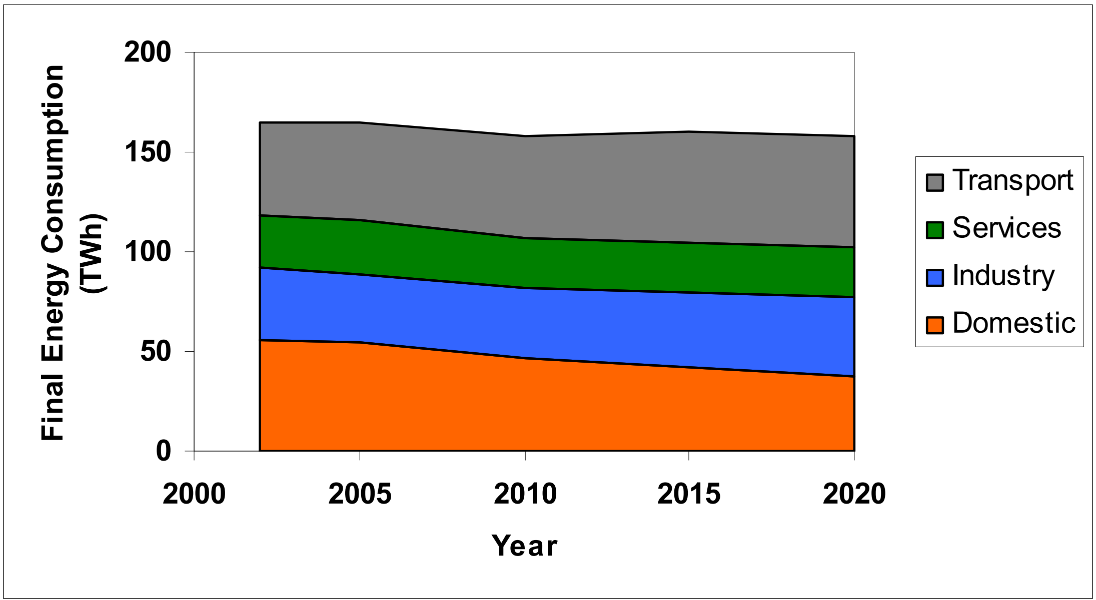


Figure 7 Scottish final energy demand by sector 2002 to 2020 for the CC scenario (TWh)

Table 12 and Figure 8 show the overall demand projections divided by fuel type. Demand for all energy sources is projected to decline with the exception of direct use of renewable energy which increases by over 100%[46] albeit from an initial low base. The main reductions in demand affect natural gas, down by 15% to 19% (UK 14% to 19%) and coal down by 37% to 38%. Oil demand is steady in the HC scenario but increases by 3% in the CC scenario due to increased demand for transport (UK -1% to -3%). Electricity demand decreases slightly (-1%) in the CC scenario but is level in the HC scenario (UK -1% to +1%).

[46] Note that electricity generation from renewable sources is included in the overall electricity demand.

Table 12 Scottish Final Energy consumption divided by energy source (TWh)

CC Scenario

	2002	2005	2010	2015	2020	Change 2005 - 2020[47]
Electricity	34.3	35.5	34.6	34.4	35.1	-1%
Gas	63.7	64.1	58.5	56.8	54.3	-15%
Oil	61.0	59.9	58.6	61.9	62.0	+3%
Coal	4.2	2.7	2.4	1.9	1.7	-38%
RE	1.9	1.9	3.7	3.9	3.9	+103%
Total	**165.0**	**164.2**	**157.8**	**159.0**	**156.9**	**-4%**

HC Scenario

	2002	2005	2010	2015	2020	Change 2005 - 2020
Electricity	34.3	35.5	34.8	34.7	35.6	0%
Gas	63.7	64.1	57.4	54.4	51.6	-19%
Oil	61.0	59.9	58.0	60.5	59.9	0%
Coal	4.2	2.7	2.3	1.9	1.7	-37%
RE	1.9	1.9	3.7	3.9	3.9	+101%
Total	**165.0**	**164.2**	**156.2**	**155.3**	**152.7**	**-7%**

Note rounding to one decimal place may introduce some small errors in summations.

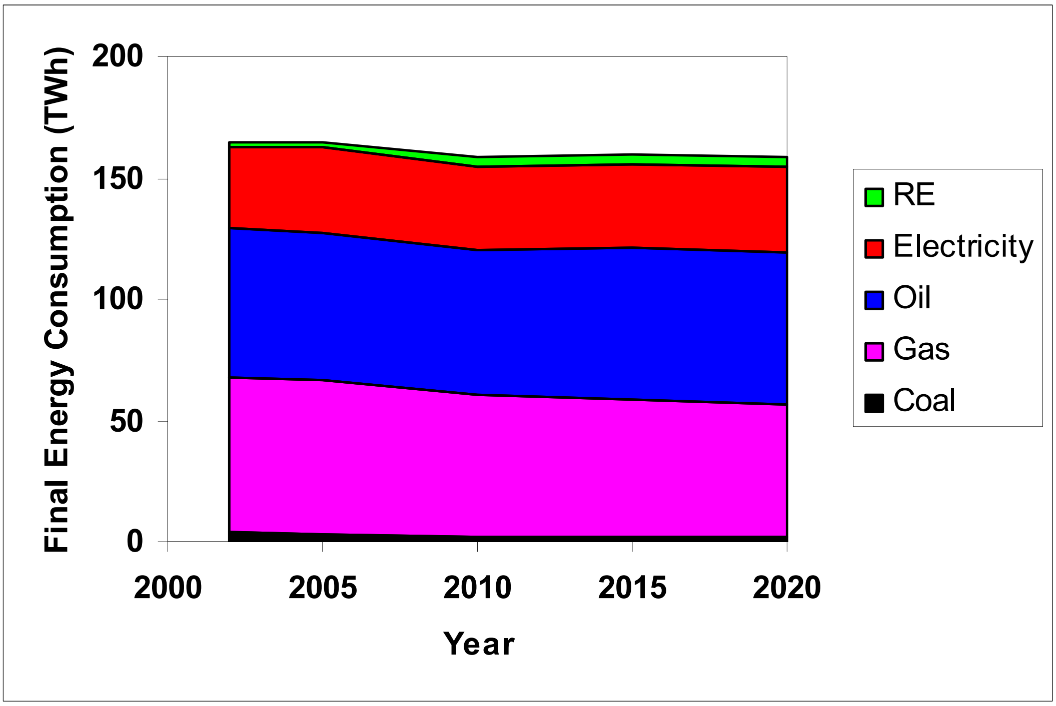


Figure 8 Scottish final energy demand by fuel type in the CC scenario (TWh)

[47] In some cases the percentage change is obscured by rounding of the energy consumption values to one decimal place.

4. Energy Supply

The main energy supply activities in Scotland are electricity generation and oil refining. These activities are considered separately with an additional section to cover all primary energy consumption.

4.1. Electricity Generation

Scotland has power stations that are fuelled with coal (Longannet and Cockenzie), oil and/or gas (Peterhead), nuclear energy (Hunterston and Torness), hydro-electricity and other renewable energy resources including wind, biomass and smaller hydro. Additionally autogenerators (mainly CHP) use a mix of fossil fuels to produce electricity some of which is sold to the public electricity suppliers.

Baseline data for power generation and supply from both the major generators and autogenerators have been gathered in the Scottish Energy Study – Volume 1 and the values are reproduced in Table 13. This gives the total amount of electricity supplied through the public transmission and distribution system, after deduction of own use by generators and transmission/distribution system losses, as 43.3 TWh in 2002. This exceeds total Scottish demand, and the surplus is exported to Northern Ireland and England.

The Scottish Energy Study – Volume 1 estimated total electricity exports in 2002 to be about 8 TWh. When this is added to the Scottish Energy Study's "bottom up" estimate of Scottish electricity demand the total is 42.2 TWh, less than the estimated total supply by about 1 TWh. The reasons for this difference between the "bottom up" estimate of demand and the "top down" estimate of supply have been discussed in detail in Chapter 1 of the Energy Study, and reported as a statistical difference. For the purposes of these projections this statistical difference was removed by adjusting the level of electricity exports to balance Scottish demand (including losses) with Scottish supply. This has no effect on the projections of primary energy and CO_2 emissions, but ensures that energy supply and demand are balanced numerically to 2020.

Table 13 also gives estimates for future generation by fuel type to 2020. The values for generation by large fossil fuel, hydro and nuclear plant in 2005 are taken from statistics published by BERR[48], while for later years they come from BERR's projections for the UK[49]. Projections for generation from renewable energy sources are based on the assumption that Scotland achieves its targets to generate 31% of Scottish gross consumption from renewable sources by 2011, rising to 50% by 2020[50].

[48] Energy Trends, BERR, December 2007 (http://www.scotland.gov.uk/Topics/Statistics/Browse/Environment/TrendElectricity/LinkBERREnergyTrends)
[49] BERR projections are disaggregated to give separate estimates for coal, gas and nuclear generation in England, Scotland and Wales. These projections have been adjusted to take account of life extension of the Hunterston nuclear power station to 2016, which was not anticipated in BERR's projections.
[50] Gross consumption is defined as the amount of electricity generated minus net exports and including losses.

The values for centralised generation from fossil and nuclear plant are reported by the generators and in BERR's projections on a "sent out" basis (i.e. after deduction of own use). For consistency with other parts of the Scottish Energy Study these values were adjusted to estimate gross generation in Table 13 assuming losses and "own use" remains as a fixed percentage of gross generation.

Table 13 Electricity generation and demand in Scotland to 2020 (GWh)

CC Scenario

	2002	**2005**	**2010**	**2015**	**2020**
Coal	14,776	12,092	11,354	5,874	4,217
Oil	186	556	556	556	556
Natural Gas	8,847	6,250	3,777	5,931	10,509
Nuclear	15,863	18,681	17,919	17,919	9,128
Large Hydro	3,693	3,626	3,626	3,626	3,626
Pumped Hydro	622	643	643	643	643
Renewables	1,405	2,881	8,114	12,614	17,115
Other generators	4,227	4,518	4,518	4,518	4,518
Total Generation	**49,619**	**49,247**	**50,506**	**51,681**	**50,312**
Losses and own use	6,340	6,179	6,514	6,484	6,377
Total Supply	**43,279**	**43,068**	**43,992**	**45,197**	**43,935**
Demand	34,262	35,533	34,618	34,443	35,099
Exports	9,017	7,535	9,374	10,753	8,836
Total Demand	**43,279**	**43,068**	**43,992**	**45,197**	**43,935**
Gross consumption	40,602	41,712	41,219	40,928	41,476
RE % of Scottish gross consumption	13%	16%	28%	40%	50%

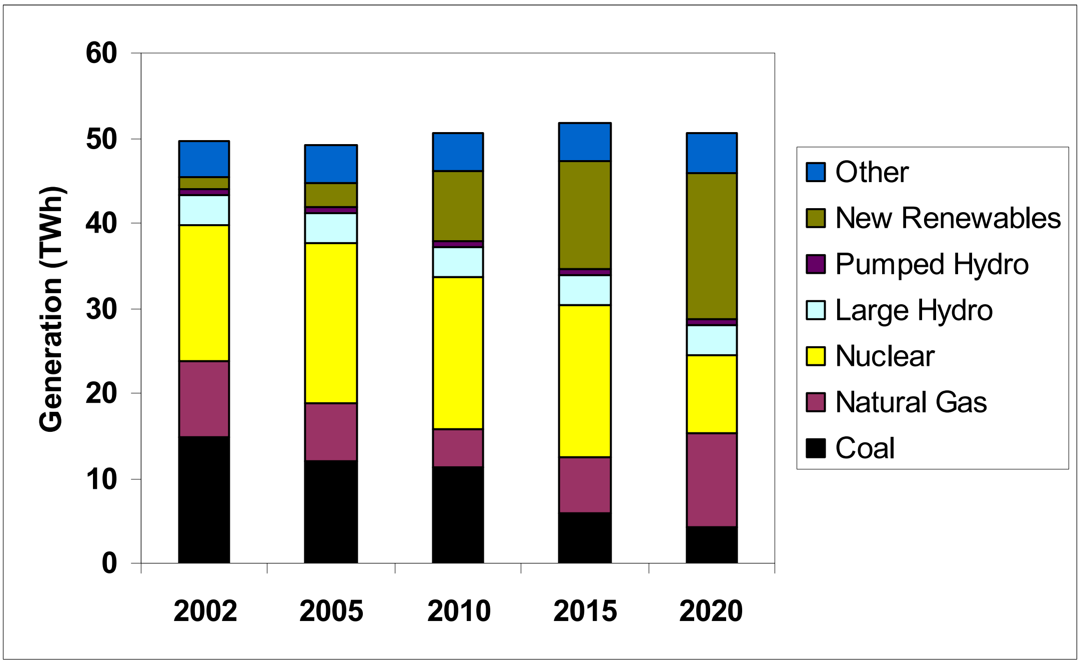
HC Scenario

	2002	**2005**	**2010**	**2015**	**2020**
Coal	14,776	12,092	12,439	8,067	7,734
Oil	186	556	556	556	556
Natural Gas	8,847	6,251	3,777	5,931	10,509
Nuclear	15,863	18,681	17,919	17,919	9,128
Large Hydro	3,693	3,626	3,626	3,626	3,626
Pumped Hydro	622	643	643	643	643
Renewables	1,405	2,881	8,189	12,909	17,630
Other generators	4,227	4,518	4,518	4,518	4,518
Total Generation	**49,619**	**49,248**	**51,666**	**54,169**	**54,343**
Losses and own use	6,340	6,179	6,656	6,796	6,888
Total Supply	**43,279**	**43,069**	**45,010**	**47,373**	**47,455**
Demand	34,262	35,533	34,760	34,699	35,615
Exports	9,017	7,536	10,251	12,673	11,840
Total Demand	**43,279**	**43,069**	**45,010**	**47,373**	**47,455**
Gross consumption	40,602	41,712	41,416	41,496	42,503
RE % of Scottish gross consumption	13%	16%	29%	40%	50%

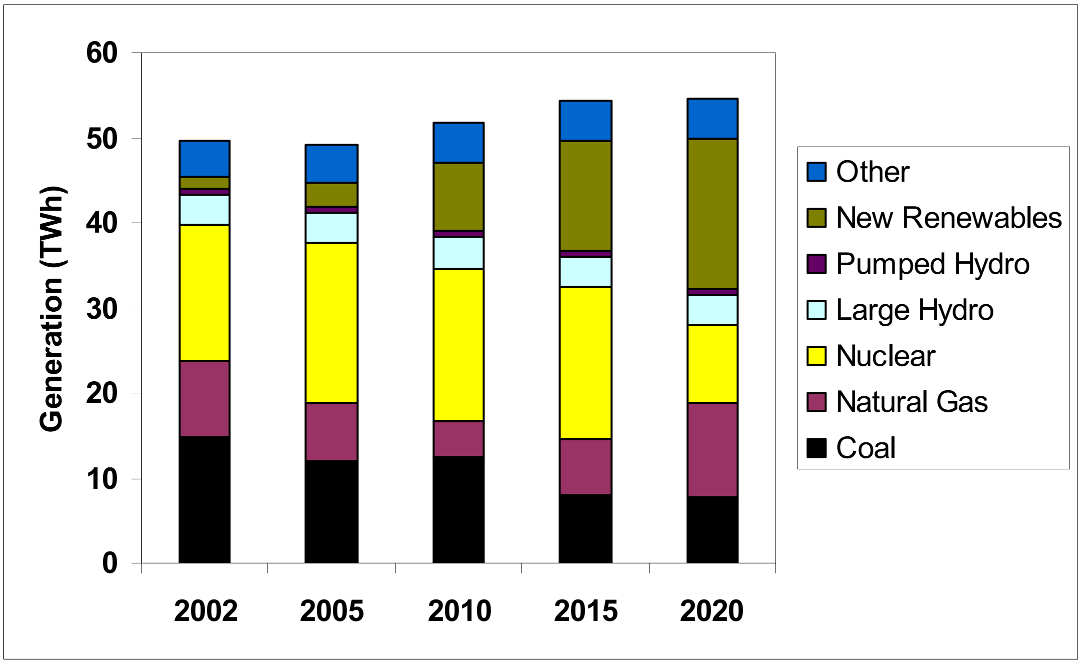
Note rounding to one decimal place may introduce some small errors in summations.

Figure 9 Electricity generation by fuel type in Scotland to 2020 (GWh)[51]

CC Scenario



HC Scenario



[51] For completeness the small amount of oil fired generation given in Table 13 is included in the values for natural gas.

Overall electricity generation increases by 2% and 10% between 2005 and 2020 for the CC and HC scenarios. This matches the overall trend for the UK in which total electricity supply was 7% higher in the HC scenario compared to the CC scenario in 2020. In Scotland electricity demand is roughly level in both the CC and HC scenarios, which might be taken to imply that the difference in generation should also be less between the scenarios. However, this need not be the case because power plant in Scotland are operating within the UK electricity market.

Coal fired generation is anticipated to continue through the projection period following the decision by Scottish Power to fit flue gas desulphurisation (FGD) equipment to Longannet in order to meet the requirements of the EU's Large Combustion Plant Directive, but nuclear generation is expected to decline with the possible closure of Hunterston after 2016 (Figure 9)[52]. Natural gas generation continues at Peterhead power station, and some additional capacity is added by 2015. This addition of new gas generation may seem at odds with Scotland's surplus in electricity supply, but is not unreasonable for the following reasons:

- New gas generation in Scotland is a small fraction of the total for the UK (~6%-8%).
- Scotland is likely to need some additional fossil fuel capacity to back up the considerable expansion of intermittent renewable generation sources.
- Scotland's two major generation companies should be expected to maintain some fossil power capacity in Scotland.

The main difference between the CC and HC scenarios is an increase in coal generation with the higher fuel prices in the HC scenario. This is because in BERR's assumptions the relative cost of gas to coal is higher in the HC scenario, while the assumed prices for emission allowances in the ETS are the same in both scenarios at €20/tCO_2 from 2010-2015 and €25/tCO_2 from 2015 to 2020. Gas generation might have been expected to decline in the HC scenario to counter the increased coal generation. This does not occur in Scotland because the BERR model considers electricity generation for the UK overall. The increased coal fired generation is balanced by reduced gas fired generation in England and Wales rather than Scotland.

Projections of the future mix of fuels used for power generation are particularly sensitive to assumptions on the relative prices of coal, natural gas and oil, the price of ETS allowances and to assumptions on future investment. For example the Peterhead power station may use either gas or oil depending on their relative prices. Similarly Scottish Power is considering options for replacement thermal generation at Longannet and Cockenzie[53]. These factors are investigated as part of the sensitivity analysis reported in Section 6.

Scotland remains a net exporter of electricity over the full period to 2020 in both the CC and HC scenarios.

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[52] At present Hunterston power station has permission to operate until 2016, but it could seek an extension to operate to 2021 and beyond. A closure date of 2016 has been assumed for the purpose of these projections.

[53] See: http://www.scottishpower.com/PressReleases_1535.htm
http://www.scottishpower.com/PressReleases_1645.htm

4.2. *Oil Refining*

Scotland has one major oil refinery at Grangemouth. The Scottish Energy Study – Volume 1 has estimated that in 2002 this produced 99.6 TWh of saleable products, of which 61% was consumed in Scotland, and emitted 2.8Mt of CO_2. BERR's projections for the UK assume a small increase in refinery activity over the projection period with CO_2 emissions increasing from 5.7 MtC/yr (20.8 $MtCO_2$/yr) in 2002 to 6.1MtC/yr (23.4 $MtCO_2$/yr) by 2020. This trend was the same for the CC and HC scenarios, and it has been assumed here that the same trend will be followed in Scotland.

4.3. *Primary Energy Consumption*

Table 14 and Figure 9 draw together direct energy use and indirect energy use in conversion processes to give projections of Scotland's total primary energy consumption. Total primary energy consumption declines by 10% in the CC scenario and by 8% in the HC scenario. This should be compared to falls of 6% and 3% respectively for the UK.

The greater fall in Scottish primary energy consumption in the CC scenario compared to the HC scenario is due to a number of factors:

- Firstly there is more electricity generation from Scotland's coal fired power plant in the HC scenario because the relative price of gas to coal is greater in the HC scenario. Compared to the UK as a whole, Scotland has less gas fired generation capacity, and consequently the increase in coal generation is not offset by an equivalent reduction in gas.

- Secondly, Scottish gross electricity consumption is higher in the HC scenario[54], and as a consequence Scotland is assumed to increase its power generation from renewable sources to meet its RE targets, which adds to primary energy. In contrast to this overall trend there is a greater reduction in demand for gas by final users in the HC scenario compared to the CC scenario.

[54] Gross electricity consumption includes own use at power stations, losses in transmission and distribution, as well as demand by final consumers. In the HC scenario lower fuel prices drive up generation from coal and total generation. Hence own use and losses increase, while final demand increases due to fuel switching.

Table 14 Total Primary Energy consumption (TWh)[55]

CC Scenario

	2002	2005	2010	2015	2020	Change 2005 - 2020[56]
Coal	44.1	35.4	33.0	17.8	13.1	-63%
Natural Gas	84.3	78.6	67.3	69.6	74.7	-5%
Oil	72.2	70.9	71.2	74.9	75.1	+6%
Nuclear	42.2	49.7	47.7	47.7	24.3	-51%
RE	7.7	9.6	20.6	26.2	32.9	+241%
Total	**250.5**	**244.2**	**239.8**	**236.2**	**220.1**	**-10%**

HC Scenario

	2002	2005	2010	2015	2020	Change 2005 - 2020
Coal	44.1	35.4	35.9	23.7	22.6	-36%
Natural Gas	84.3	78.6	66.2	67.2	72.1	-8%
Oil	72.2	70.9	70.6	73.4	73.1	+3%
Nuclear	42.2	49.7	47.7	47.7	24.3	-51%
RE	7.7	9.6	20.7	26.6	33.6	+248%
Total	**250.5**	**244.2**	**241.1**	**238.6**	**225.7**	**-8%**

Note rounding to one decimal place may introduce some small errors in summations.

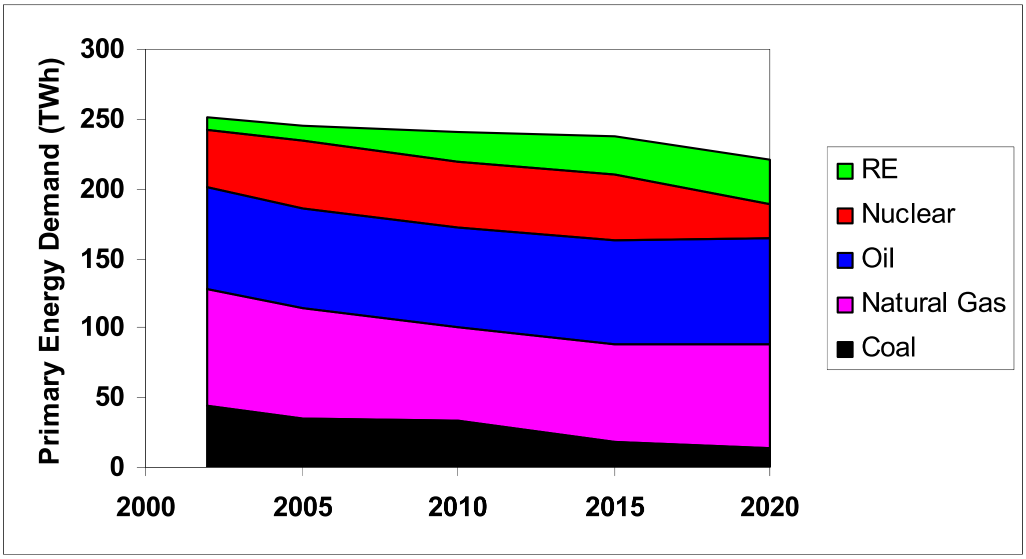

Figure 10 Scottish total Primary Energy consumption for the CC scenario (TWh)

[55] Primary energy has been estimated in line with international convention in which the efficiency of non-fossil thermal sources (i.e. nuclear, biomass) is taken into account in estimating primary supply. The output from non-thermal electricity sources such as hydro and wind are regarded as primary electricity and are not adjusted for generation efficiency.

[56] In some cases the percentage change is obscured by rounding of the energy consumption values to one decimal place.

5. Energy Related Carbon Dioxide Emissions

The energy consumption values given in Sections 3 and 4 have been converted into CO_2 emissions using the emission factors published in the inventory of greenhouse gases for the UK[57]. The resulting emission projections for Scotland to 2020, classified in line with the national inventory categories are listed in Table 15. Overall Scottish energy related CO_2 emissions are projected to decline by 9% and 7% between 2005 and 2011 and by 18% and 13% between 2005 and 2020 for the CC and HC scenarios respectively. The corresponding reductions by 2020 relative to the National Atmospheric Emissions Inventory (NAEI) inventory for 1990 [58] are 30% and 18% for the CC and HC scenarios respectively[59]. Energy related CO_2 emissions actually exceed Scotland's net carbon emissions when sequestration by land use and forestry is taken into account.

In both the CC and HC scenarios reductions in emissions occur in the domestic, services and energy industries sectors (except for oil refineries), with the greatest reductions projected to be in electricity generation and the domestic sector. Emissions increase in the industry and transport sectors. Despite the greater reduction in emissions from demand sectors in the HC scenario, it is the CC scenario that attains the greatest overall reduction in emissions. This is because under HC more coal fired generation occurs in Scotland because of the more favourable price differential of coal over gas in this scenario. This highlights the strong influence of power generation on overall Scottish CO_2 emissions.

An alternative approach for reporting emissions is to attribute those emissions arising in energy conversion and supply to the final energy consuming sectors. The results of this approach to reporting emissions are shown in Table 16.

Table 16 shows that about 7% of Scottish emissions in 2002 were associated with the export of electricity. By 2020 it is projected that 4% -7% of emissions will continue to be associated with electricity exports, although the absolute quantity is less and the figure is highly sensitive to assumptions regarding power generation in Scotland.

[57] Greenhouse gas inventories for England, Scotland, Wales and Northern Ireland:1990 – 2005, a report to DEFRA from AEA Technology, (Ref AEAT/ENV/R/2500, August 2007).

[58]The present National Atmospheric Emissions Inventory includes emissions from domestic flights that are attributable to Scotland. However, the Scottish Energy Study Volume 1 did cover all aviation emissions and these have been included in Table 15 for completeness. Comparisons with NAEI values are made after excluding aviation. The comparison is made with combustion related emissions since the projections do not include fugitive emissions.

[59] The Scottish Energy Study uses data from a wide range of sources, BERR and the NAEI, along with data and analysis specifically collected for the study. One of the main aims of the study was to construct an energy balance, showing energy flowing into Scotland, energy used in Scotland and energy exported by Scotland. To do this some of the reporting conventions used were different from those used in the NAEI. An example is aircraft fuel where there are differences in the reporting methods. For these reasons the Scottish Energy Study and the NAEI datasets cannot always be directly compared - unless adjustments are made to take account of the different reporting methods.

Table 15 Projections of Scottish energy related CO_2 emissions to 2020 disaggregated according to the national inventory classification (Mt CO_2)[60]

CC Scenario

ENERGY	2002	2005	2010	2011	2015	2020	Change 2005-2020[61]
1. Energy Industries	**22.1**	**18.7**	**16.9**	**16.0**	**12.5**	**12.0**	-36%
A Electricity	17.2	14.3	12.4	11.5	8.1	7.9	-45%
B Refineries	2.8	2.4	2.8	2.9	2.9	3.0	+24%
C Other energy industry	2.1	2.0	1.7	1.6	1.4	1.1	-45%
2. Manufacturing	**5.2**	**4.6**	**4.7**	**4.7**	**4.9**	**5.2**	+14%
A Iron and Steel	0.02	0.03	0.03	0.03	0.03	0.03	-3%
B Other industries	5.1	4.6	4.7	4.7	4.9	5.2	+14%
3. Transport	**11.5**	**11.9**	**12.0**	**12.2**	**13.1**	**13.2**	+12%
A Road	8.7	8.7	8.8	9.0	9.5	9.3	+8%
B Rail	0.1	0.1	0.1	0.1	0.1	0.1	+1%
C Marine	0.6	0.7	0.6	0.6	0.7	0.7	+2%
D Aviation	2.1	2.5	2.4	2.5	2.8	3.2	+28%
4. Other Sectors	**11.5**	**11.1**	**9.4**	**9.2**	**8.5**	**7.5**	-33%
A Commercial/Institutional	2.6	2.7	2.5	2.5	2.4	2.3	-15%
B Domestic	8.7	8.1	6.7	6.6	5.9	4.9	-40%
C Agriculture	0.2	0.2	0.2	0.2	0.2	0.2	+6%
Total	**50.3**	**46.3**	**43.0**	**42.2**	**38.9**	**38.0**	**-18%**

HC Scenario

ENERGY	2002	2005	2010	2011	2015	2020	Change 2005-2020
1. Energy Industries	**22.1**	**18.7**	**17.9**	**17.2**	**14.5**	**15.3**	-18%
A Electricity	17.2	14.3	13.4	12.8	10.2	11.2	-22%
B Refineries	2.8	2.4	2.8	2.9	2.9	3.0	+24%
C Other energy industry	2.1	2.0	1.7	1.6	1.4	1.1	-45%
2. Manufacturing	**5.2**	**4.6**	**4.6**	**4.6**	**4.8**	**5.1**	+10%
A Iron and Steel	0.02	0.03	0.03	0.03	0.03	0.03	-3%
B Other industries	5.1	4.6	4.6	4.6	4.7	5.0	+10%
3. Transport	**11.5**	**11.9**	**11.9**	**12.0**	**12.7**	**12.8**	+8%
A Road	8.7	8.7	8.8	8.9	9.3	9.1	+5%
B Rail	0.1	0.1	0.1	0.1	0.1	0.1	+1%
C Marine	0.6	0.7	0.6	0.6	0.7	0.7	+2%
D Aviation	2.1	2.5	2.4	2.4	2.7	2.9	+18%
4. Other Sectors	**11.5**	**11.1**	**9.3**	**9.1**	**8.2**	**7.1**	-36%
A Commercial/Institutional	2.6	2.7	2.5	2.5	2.4	2.4	-14%
B Domestic	8.7	8.1	6.6	6.4	5.6	4.6	-44%
C Agriculture	0.2	0.2	0.2	0.2	0.2	0.2	+6%
Total	**50.3**	**46.3**	**43.7**	**43.0**	**40.2**	**40.2**	**-13%**

[60] The Military aircraft and naval vessels section of the inventory is omitted from these tables. This sector only accounted for 1% of CO_2 emissions in 2005.
[61] In some cases the percentage change is obscured by rounding of the energy consumption values to one decimal place.

For completeness Table 15 contains estimates for CO_2 emissions from "other energy industries". This sector comprises the manufacture of solid fuels as well as collieries and on-shore oil and gas treatment and transmission facilities. The Scottish Energy Study – Volume 1 does not give a figure for the energy used in these activities, but the NAEI attributes 2.1 $MtCO_2$ of emissions to this sector in 2002. These emissions are attributed to the industry sector in Table 16. Future fuel consumption and emissions from these sectors will be determined largely by the level of production from North Sea oil and gas fields. For the purpose of this assessment it has been assumed that energy consumption, and hence CO_2 emissions, fall with declining North Sea production, which is expected to roughly half by 2020[62].

Table 16 Projections of Scottish energy related CO_2 emissions to 2020 disaggregated by end use sector (Mt CO_2)

CC Scenario

	2002	2005	2010	2011	2015	2020	Change[63] 2005-2020
Domestic	13.7	12.3	10.2	9.8	8.1	7.0	-43%
Industry	11.6	10.4	9.7	9.5	8.5	8.7	-16%
Services and agriculture	7.4	6.9	5.9	5.6	4.6	4.6	-33%
Transport-Road	9.7	9.5	9.9	10.0	10.6	10.5	+10%
Transport Other	3.2	3.6	3.6	3.7	4.0	4.4	+23%
Net Total	**45.6**	**42.8**	**39.2**	**38.5**	**35.9**	**35.2**	-18%
Export							
Electricity	3.6	2.5	2.6	2.5	1.9	1.6	-36%
Refineries	1.1	1.0	1.2	1.2	1.1	1.1	+17%
Gross Total	**50.3**	**46.3**	**43.0**	**42.2**	**38.9**	**38.0**	-18%

HC Scenario

	2002	2005	2010	2011	2015	2020	Change 2005-2020
Domestic	13.7	12.3	10.2	9.8	8.2	7.3	-41%
Industry	11.6	10.4	9.9	9.7	8.8	9.4	-10%
Services and agriculture	7.4	6.9	6.1	5.9	5.0	5.2	-25%
Transport-Road	9.7	9.5	9.8	9.9	10.4	10.2	+7%
Transport Other	3.2	3.6	3.5	3.6	3.9	4.2	+16%
Net Total	**45.6**	**42.8**	**39.4**	**38.8**	**36.3**	**36.2**	-15%
Export							
Electricity	3.6	2.5	3.1	3.0	2.7	2.8	-11%
Refineries	1.1	1.0	1.2	1.2	1.2	1.2	+23%
Gross Total	**50.3**	**46.3**	**43.7**	**43.0**	**40.2**	**40.2**	-13%

Note rounding to one decimal place may introduce some small errors in summations.

[62] UK oil and gas production projections, BERR (http://www.berr.gov.uk/energy/energymarketsoutlook/oil/page41852.html)
[63] In some cases the percentage change is obscured by rounding of the energy consumption values to one decimal place.

6. Sensitivity Analysis

The previous sections have developed two projections for Scotland's energy use and CO_2 emissions to 2020, which were based on the corresponding projections for the UK. These projections were based on the Central Fuel/Central EWP (CC) and High Fuel/Central EWP (HC) scenarios developed by BERR (see Introduction), which were then adjusted to take account of Scotland's current pattern of energy supply and demand, and the Scottish Government's targets for increased economic growth and population growth. Of course scenario projections are only indicative of a broad range of possible future trajectories, and the adoption of the CC and HC scenarios should not be taken to infer that these represent the most likely outcome for Scotland. Uncertainties over key drivers affecting both energy demand and the balance of supply side options mean that these projections should be regarded as a starting point or illustrative baseline from which to investigate other potential outcomes. To further scope the possible trends in Scottish energy and CO_2 pathways to 2020 this section assesses how these projections may be altered by a set of factors specific to Scotland.

6.1. Choice of Sensitivity Parameters

The UK's energy and CO_2 projections use scenarios designed to examine three key drivers affecting the energy sector, namely economic growth, fossil fuel prices and policy measures. Clearly these parameters are also important to Scotland's energy sector, and accordingly this sensitivity analysis focuses on how divergence from the baseline UK scenarios may alter Scotland's energy and CO_2 emission patterns. Particular emphasis has been placed on examining the impact of parameters that are more specific to Scotland.

The parameters affecting energy **demand** that have been examined are:

Gross Domestic Product - The level of economic activity, as measured by the rate of growth in Scotland's GDP, affects demand for energy services in the industry and services sectors, and also in freight transport.

Population - Population affects the demand for energy services in the domestic sector as it leads to an increase/decrease in the number of households. It also affects energy demand for public and private transport through greater demand for mobility and increased car ownership.

Car ownership - Scotland's car ownership is presently only about 90% of the UK average. An increase in ownership will affect the demand for road transport fuels.

Air travel - The more people travel by air the greater consumption of aviation fuel.

Clearly there is some interaction between these factors. For example GDP could be increased through an increase in population, and hence work-force. Similarly a higher population could increase demand for air travel. The aim herein is to assess the direct impact of each of these variables, and to avoid double counting.

Factors affecting energy **supply** and its related emissions of CO_2 that have been considered are:

Fuel mix in electricity generation - The balance of fossil, nuclear and renewable energy sources used to generate electricity can have a considerable impact on fossil energy consumption and CO_2 emissions.

Increased renewable heat utilisation - In addition to power generation renewable energy sources including biomass, solar thermal and ground source heat pumps may be used to supply heat to the domestic, industry and services sectors.

The price of energy clearly will have an impact on demand from both business and the private consumer, and may also impact indirectly through its influence on economic growth. This factor is considered separately.

The remainder of this section examines how variations to these individual parameters may affect Scotland's energy sector and its associated CO_2 emissions.

6.2. Demand Sensitivity Analysis

The sensitivity analysis of the key parameters affecting Scottish energy demand has assessed the variations listed in Table 17. For comparison purposes the table also gives the historic trend and the assumptions used either explicitly or implicitly in the baseline scenario projections.

Table 17 Factors affecting energy demand

Parameter	Historic trend	Central scenario assumption	Sensitivity analysis assumption
GDP	Average annual growth rate (1975 – 2005): 1.8%	Average annual growth rate of 2.5% between 2007-2020	Continuation of historic annual growth rate (1.8% per year)
Population	Average annual change (1995-2005): -0.2%	Population increases between 2007 and 2020 at an average annual rate of 0.4%	Population increases in line with the projections of the General Register Office for Scotland (0.27% per year)[64]
Car ownership	Scotland has 42 cars per 100 people compared to 46 per 100 UK wide.	Scottish car ownership increases at the UK average rate (and therefore remains below UK average in 2020)	Scottish car ownership increases faster than the UK average to match the UK average by 2020
Air Travel	57% increase in passengers between 1995 and 2002 to reach 20 million per annum	40 million passengers per annum by 2020	34 and 46 million passengers per annum by 2020

[64] Projections on the population of Scotland, General Register Office for Scotland, October 2008. (http://www.gro-scotland.gov.uk/statistics/publications-and-data/popproj/projected-population-of-scotland-(2006-based)/index.html)

Lower growth rate for Gross Domestic Product (GDP)

Energy demands in the services and industry sectors, and also in freight transport, generally increase with the level of economic activity. It could be argued that energy demand in the domestic sector would also increase with GDP as increasing wealth drives demand for home comfort. However, the view taken herein is that home heating is an essential requirement, the demand for which has very limited market elasticity, and therefore is insensitive to relatively small variations in GDP. Personal transport may also increase with GDP through greater car ownership. However, this parameter has been assessed separately and is not considered as part of the analysis of GDP.

The sensitivity analysis has investigated the potential impact of Scotland's economy growing at a slower rate than assumed in the initial scenario assumptions, which were based on the Scottish Government's targets for increasing economic development. The alternative lower growth rate investigated was an average of 1.8% per year compared to the growth rate used in the scenario, which averaged 2.5% per year over the period 2007 to 2020 (Table 1). This lower rate broadly corresponds to the long term average rate of growth of Scotland's economy over the period 1975-2005. Adjustments to the baseline energy projections were made by assuming a linear relationship between GDP and energy demand for those sectors affected.

Table 18 lists the impact of the lower GDP assumption on energy demand by sector relative to the CC baseline scenario. As discussed above the greatest impact is on the industry and commercial sectors with reductions of 7.4% and 6.9% respectively by 2020. The impact is less with transport because GDP is assumed to only affect commercial operations. Overall Scottish final energy consumption is 3.6% less by 2020 with this slower GDP growth rate than it would have been with the baseline CC and HC scenario assumption for GDP growth.

Table 18 also shows that a lower GDP growth assumption reduces CO_2 emissions but the impact is less than for energy (2.1%) due to the mix of fuels affected.

Table 18 Impact of the lower GDP growth assumption on Scottish final energy demand (results indexed to CC scenario projections = 100.0)

	2002	**2005**	**2010**	**2015**	**2020**
Domestic	100.0	100.0	100.0	100.0	100.0
Services & Agriculture	100.0	100.0	99.4	97.0	93.1
Industry	100.0	100.0	99.4	96.8	92.6
Transport	100.0	100.0	99.9	99.3	98.3
Total energy	**100.0**	**100.0**	**99.7**	**98.6**	**96.4**
CO_2 emissions	100.0	100.0	99.8	99.2	97.9

Lower population growth rate

Population has a direct effect on domestic energy demand because it determines the number of households in a country. It also has a direct affect on the demand for mobility both through public and private transport. Population also has an indirect affect of industry and services, and commercial transport by affecting the number of economically active people in the economy (i.e. assuming constant GDP per capita).

The sensitivity analysis has investigated the potential impact of Scotland's population growing at a slower rate than assumed in the scenario assumptions, which were based on the Scottish Government's targets for increasing population. The alternative population growth rate investigated was based on the projections of the General Register for Scotland, which gave a smaller average annual increase of 0.27% per annum from 2007 to 2020 (Table 17).

The impact of this lower population assumption on energy demand and CO_2 emissions is shown in Table 19. Note the impact of population on transport energy demand is based on a contraction of the existing demand pattern, it does not include a change in car ownership per capita, which is examined later in a separate sensitivity assessments. For the purpose of this assessment population change is assumed not to have a direct affect on passenger aviation, which is also investigated separately below.

Table 19 shows that the impact of the lower population assumption is less than the GDP assumption examined previously with total final energy demand decreasing by just over 1%. This is mirrored by the trend in CO_2 emissions.

Table 19 Impact of different population trends on Scottish final energy demand (results indexed to CC scenario projections = 100.0)

	2002	**2005**	**2010**	**2015**	**2020**
Domestic	100.0	100.0	99.9	99.2	98.3
Services & Agriculture	100.0	100.0	99.9	99.3	98.6
Industry	100.0	100.0	99.9	99.3	98.5
Transport	100.0	100.0	99.9	99.6	98.8
Total energy	**100.0**	**100.0**	**99.9**	**99.4**	**98.6**
CO_2 emissions	**100.0**	**100.0**	**99.9**	**99.6**	**99.1**

Increased car ownership

The projections presented in Section 2 showed transport to be a fast growing energy consumption sector with demand increasing by 11% to 15% between 2005 and 2020. Road transport and aviation accounted for most of this growth, and therefore it is desirable to investigate the sensitivity of these projections to variations in key factors. In addition to the GDP and population variations examined above, another important factor is the level of car ownership.

In 2005 Scotland's car ownership was lower than the UK average at 42 cars per hundred people compared to 46 per hundred for the UK overall [65,66]. In the baseline projections Scottish car ownership was implicitly assumed to increase at the same rate as the UK overall, which meant that the difference in the absolute level of ownership between Scotland and the UK remained. This sensitivity assessment examines the impact of Scottish car ownership growing to match the UK average by 2020.

Table 20 shows the impact of this higher growth in car ownership. By 2020 this would increase road transport energy demand by over 6%, equivalent to about 4% of total transport energy demand but only 1.5% of total Scottish final energy demand. Total CO_2 emissions are also increased by 1.5% by 2020.

Table 20 Impact of increased car ownership on Scottish final energy demand (results indexed to CC scenario projections = 100.0)

	2002	2005	2010	2015	2020
Transport - Road	100.0	100.0	101.3	104.0	106.2
Transport - Total	100.0	100.0	100.9	102.8	104.2
Total Energy	**100.0**	**100.0**	**100.3**	**101.0**	**101.5**
CO_2 emissions	**100.0**	**100.0**	**100.3**	**101.0**	**101.5**

Higher and lower growth in air travel

The baseline projections presented in Section 3 indicated an 18%-28% increase in aviation fuel consumption between 2005 and 2020. This growth in demand was expected to be driven by continued growth in air passenger travel, which has increased by 57% (measured in terms of passenger movements) between 1995 and 2002[67]. Current estimates expect passenger movements to reach 40 million per year by 2020 from a 2002 level of just under 20 million. This sensitivity assessment examines the impact of higher and lower passenger growth to 46 million and 34 million by 2020.

Results presented in Table 21 show that these passenger trends would increase or decrease the baseline transport energy demand by about 3% by 2020, but the impact on overall Scottish final energy demand is only about +/-1%. Overall CO_2 emissions are also affected by about +/-1%.

65 . Vehicle Licensing Statistics 2007, Department for Transport (http://www.dft.gov.uk/pgr/statistics/datatablespublications/vehicles/licensing/vehiclelicensingstatistics2007)

66 Scottish Transport Statistics Number 26, 2007

67 Scottish Transport Statistics, Number 25, 2006 (www.scotland.gov.uk/Publications/2006/12/15135954/115)

Table 21 Impact of different air passenger trends on Scottish energy demand (results indexed to the CC scenario projections = 100.0)

	2002	2005	2010	2015	2020
High Case – increase to 46 million per year by 2020					
Transport – Air	100.0	106.0	110.0	112.9	115.0
Transport - Total	100.0	100.0	101.9	102.7	103.4
Total energy	**100.0**	**100.0**	**100.6**	**100.9**	**101.2**
CO_2 emissions	**100.0**	**100.0**	**100.6**	**100.9**	**101.2**
Low Case – increased to 34 million per year by 2020					
Transport – Air	100.0	100.0	93.3	87.1	85.0
Transport - Total	100.0	100.0	98.7	97.3	96.6
Total energy	**100.0**	**100.0**	**99.6**	**99.1**	**98.8**
CO_2 emissions	**100.0**	**100.0**	**99.6**	**99.1**	**98.8**

6.3. Overall Impact of Demand Sensitivity Analysis

The above analysis has considered a range of factors that could either increase or decrease Scottish final energy demand relative to the baseline CC and HC projections presented in Section 2. Those factors driving an increase in energy demand (i.e. higher car ownership and air travel) could in total increase overall demand by about 3.5% by 2020. Those factors causing a decrease in energy demand (i.e. lower growth in GDP, population and air travel) could in total reduce demand by about 6% by 2020. The factor having the greatest effect was the lower GDP growth assumption that reduced energy consumption by around 4% compared to the baseline CC scenario projection in 2020. The overall trend in final energy demand for these high and low cases compared to the baseline CC projection is shown in Figure 11.

The impact of these factors on CO_2 emissions parallels their effect on energy demand. The factors driving a reduction in energy demand result in a reduction in CO_2 emissions of about 4% by 2020, and the factors driving an increase lead to CO_2 emissions about 3% above the CC baseline projections. The overall trends in CO_2 emissions compared to the CC baseline projection are shown in Figure 12. [NB The changes in CO_2 emissions are slightly different to the energy demand variations because the variables assessed do not affect emissions from power generation or oil refineries.]

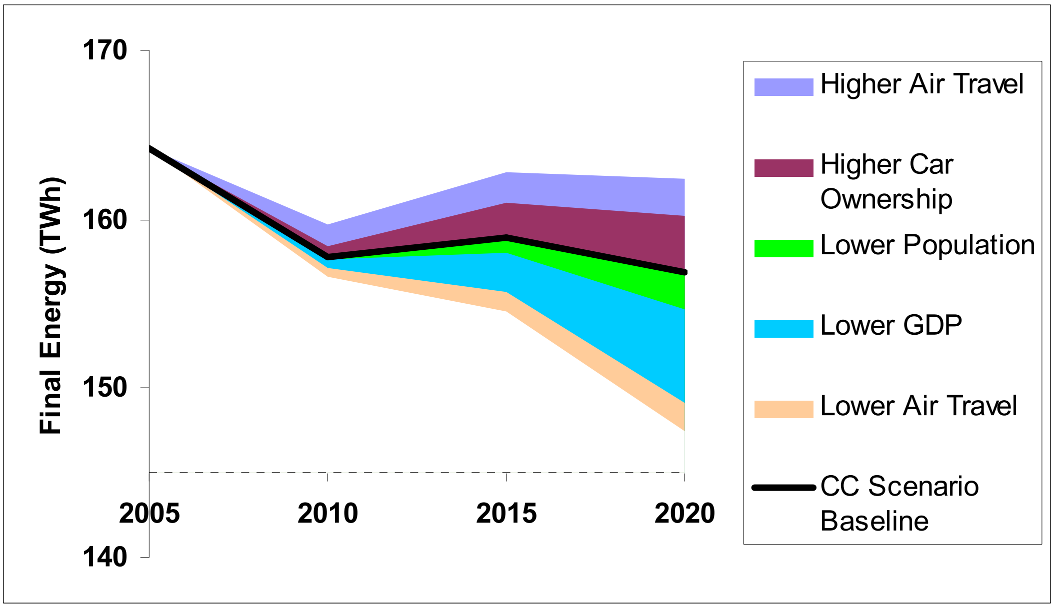

Figure 11 Overall impact of the sensitivity analysis variables on Scottish final energy demand compared to the baseline CC scenario projection.

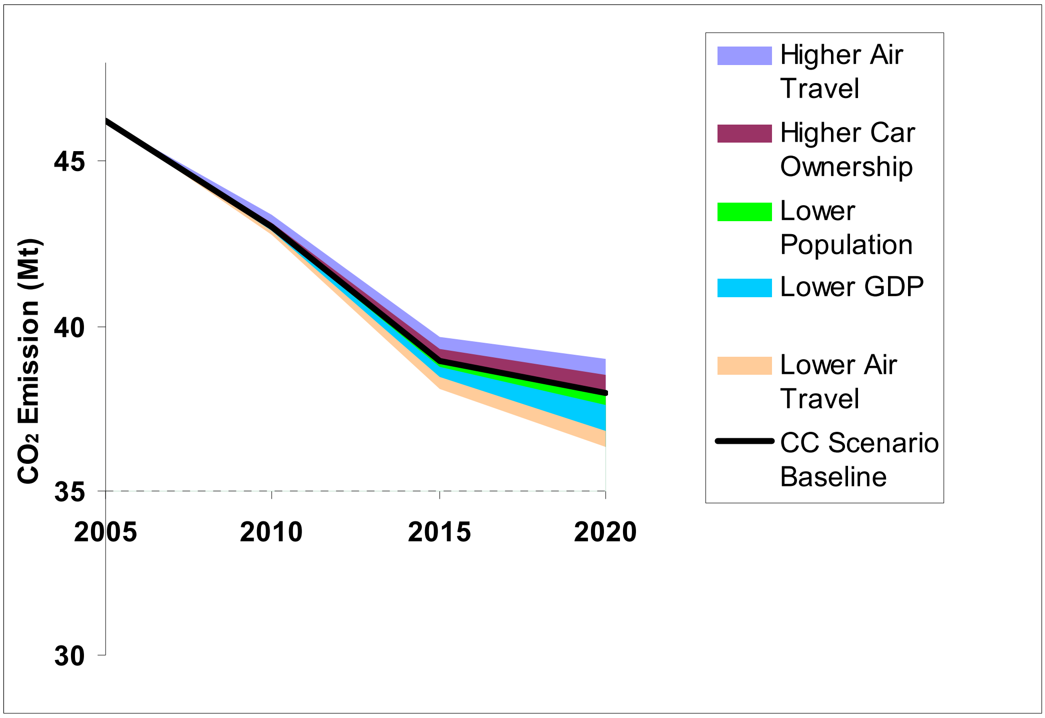

Figure 12 Overall impact of the demand side sensitivity analysis variables on Scottish energy related CO_2 emissions compared to the baseline CC scenario projection

6.4. *Supply Side Sensitivity Analysis*

Supply side variations do not affect Scottish final energy demand, but do affect the mix of primary energy sources used to meet this demand, the level of electricity exports and also the level of CO_2 emissions. This section concentrates on the effect of possible supply side variations on Scottish CO_2 emissions. No analysis has been made of the cost effectiveness, or additional cost of these supply changes, the analysis is concerned only with their impact on CO_2.

Fuel mix in electricity generation

Electricity generation accounts for a significant proportion of Scotland's primary energy consumption and CO_2 emissions, amounting to 34% of CO_2 emissions in 2002, and, in the baseline scenario projections, was still 21% in the CC scenario and 28% in the HC scenario by 2020. There is much uncertainty concerning the mix of power generation capacity in Scotland out to 2020 that will be affected by decisions including:

- Scottish Power is considering replacement options for thermal based generation at both Longannet and Cockenzie.
- There is a possibility that the two nuclear plants in Scotland may get life time extensions that permit their operation up to or beyond 2020.
- The baseline projection indicated some new gas fired generation being built by 2015, but this deployment could be sensitive to the continued operation of nuclear plant, the expansion of renewable energy generation, future plans for coal fired generation and limits on transmission capacity to England and Northern Ireland.
- Scotland has ambitious plans to expand the supply of energy from renewable sources that are likely to present a number of challenges.

To illustrate the impact of these uncertainties, three alternative generation mixes representing possible variations in renewable, coal and gas generation in 2020 are listed in Table 22. It should be stressed that these sensitivity factors were selected purely to investigate the potential variation in CO_2 emissions from power generation. No consideration has been given to their technical viability in terms of load following, transmission constraints and security of supply.

These sensitivity variations considered three situations in which Scotland's electricity supply sector (a) generates more power from fossil fuels (b) generates less power from fossil fuels and (c) falls short of its renewable electricity targets. These variations have been applied to the baseline CC scenario projection for total generation. To illustrate these assumptions:

- (a) Increasing coal fired generation from 9% to 22% in the CC scenario is likely to involve building a new ~1.6GW coal fired power station by about 2015 and operating it at a load factor of around 65% in 2020.
- (b) Generating less from fossil fuels involves building no replacement gas or coal fired power plant in Scotland to 2020 and reducing the load factor of the one remaining coal fired power plant, Longannet, from 20% to 10% by 2020.

- (c) Scotland falls short of its renewable energy target generating only 15TWh from new renewable sources instead of the 17TWh projected using the CC scenario. This gives a total 90% of what is needed to supply 50% of Scotland's gross consumption from all renewable sources (new renewables plus large hydro see Table 13).

Table 22 Factors affecting electricity generation

Factor	Historic position (2002)	CC Scenario assumption (2020)	Sensitivity Analysis (2020)
More Fossil	Share of generation: Coal – 30% Gas – 18% RE – 12%[68]	Share of generation in 2020: Coal - 9% Gas - 18% RE – 43%[69,70]	Additional 9TWh coal generation increasing share to 22% by 2020.
Less Fossil			No new gas generation and coal generation down by 50% reducing share to 4% by 2020
Less Renewables			New renewable sources provide 15TWh of electricity by 2020[71].

The results are presented in Figure 13, which also contains the result from the baseline CC scenario projection to aid comparison. This shows the potential for electricity generation to cause significant variations in Scotland's total CO_2 emissions with at one extreme total CO_2 emissions 17% above the CC scenario baseline and at the other extreme emissions 11% below by 2020.

CO_2 emissions were not sensitive to a reduction in generation from renewable energy sources because small changes in the level of renewable generation are not assumed to affect generation from other sources. This is because Scotland is assumed to generate a surplus of electricity over the full period to 2020. The lower level of renewables generation considered as part of the sensitivity analysis only reduced the level of Scotland's exports to England and Northern Ireland. As the reduction is not assumed to be made up by additional generation from sources using fossil fuels there is no increase in Scottish CO_2 emissions under this sensitivity test.

[68] New renewable sources provide 3% of electricity generation in 2002

[69] New renewable sources provide 17.3 TWh (34.3%) of electricity generation by 2020.

[70] Note the percentages quoted here refer to total generation while Scotland's target for renewable electricity refers to gross consumption. The values given for the CC scenario assumption are consistent with Scotland achieving its target to derive 50% of gross consumption from renewable sources by 2020.

[71] Total generation from renewable sources provide 45% of Scotland's gross consumption, short of the 50% target set by the Scottish government.

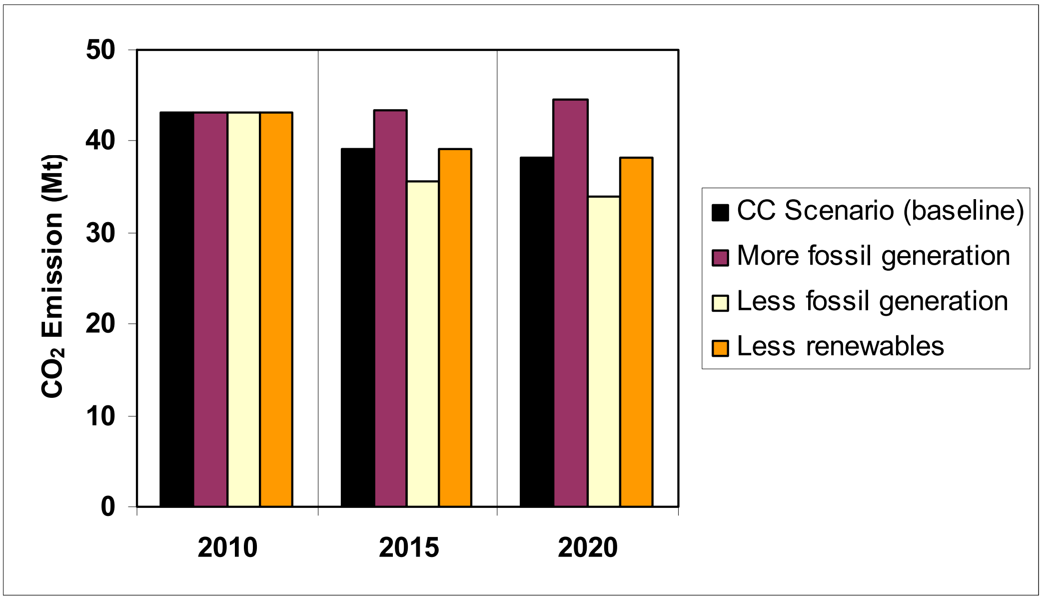

Figure 13 Influence of variations in the fuel mix used for electricity generation on total Scottish CO_2 emissions in the CC scenario

Carbon dioxide capture and storage (CCS) gives the option of continuing to use fossil fuels while reducing the associated CO_2 emissions by up to 85%-90%. Presently the UK government is running a competition to support a full-scale demonstration of this technology, which is scheduled to be operational by 2014-2015. Should this project be located in Scotland, replacing some of the existing coal fired capacity, it would reduce emissions by between 0.9 and 3.7MtCO_2[72] per year, equivalent to a 2-10% reduction in Scotland's overall CO_2 emissions in 2020. One purpose of the CCS demonstration is to facilitate further deployment when the EU ETS allowance price makes this commercially viable. Current estimates of the EU ETS price suggest that commercial deployment of CCS may not occur until after 2020[73].

Renewable heat utilisation

In addition to power generation renewable energy sources including biomass, solar thermal and ground source heat pumps may be used to supply heat to the domestic, industry and services sectors. The Scottish Energy Study Volume 1 indicated that renewable sources only made a modest contribution to heat supply amounting to ~1% of services and 1.3% of domestic demand, and, in line with BERR's projections for the UK, these shares did not change significantly in the baseline projections. This sensitivity assessment has examined the impact of an increased renewable heat contribution on Scottish CO_2 emissions. The assumptions used in the assessment were:

- Renewable energy sources can replace heat demands in domestic, services and industry.
- 72% of fossil energy supplies and 36% of electricity are used for space heating in Scottish domestic dwellings[74].

[72] Energy White Paper, May 2007.
[73] Energy systems analysis of CCS technology, PRIMES model scenarios, Institute of Communication and Computer Systems, NTUA, Athens, October 2007.
[74] Scottish Energy Study Volume 1, 2005

- 75% of fossil energy supplies and 38% of electricity are used for space heating in Scottish commercial buildings[64].
- 44% of fossil energy use in industry is for space heating and low grade process heat[75].
- Industry increases renewable heat utilisation incrementally to 6% in 2010 and 10% in 2020.
- Services increases renewable heat utilisation from 2.5% in 2002, to 5% in 2010 and 10% in 2020.
- Domestic increases renewable heat utilisation from 1.3% in 2002, to 2.5% in 2010 and 10% in 2020.

The impact of these assumptions on sectoral CO_2 emissions is shown in Table 23. Substitution of fossil and electrical heating with 10% renewable sources reduced CO_2 emissions by 5.4%, 4.5% and 1.6% by 2020 for domestic, services and industry respectively. Total Scottish CO_2 emissions were reduced by 1.6%.

Table 23 Reduction in Scottish CO_2 emissions resulting from the deployment of renewable heat reaching 10% in 2020 (indexed to Baseline Project = 100.0)

	2002	2005	2010	2015	2020
Domestic	100.0	100.0	99.1	96.8	94.6
Services & Agriculture	100.0	100.0	97.9	96.7	95.5
Industry	100.0	100.0	99.7	99.2	98.4
Total Emissions	**100.0**	**100.0**	**99.6**	**99.0**	**98.4**

Implications of different assumptions for fossil fuel prices

It was noted in Section 2 that the fossil fuel price assumptions used by BERR in its projections are significantly lower than recent peaks in market prices, particularly for oil and natural gas. Clearly these assumptions carry through to the projections presented here for Scotland.

History shows that in some periods fossil energy prices can be volatile, therefore current prices are not necessarily a sound indication for the future. Nonetheless it is reasonable to consider how these projections may be affected by higher price assumptions. Table 24 compares the price and demand differences for oil, gas, coal and total fossil primary energy between the CC and HC scenarios in 2020. The table shows that the higher prices for oil and gas in the HC scenario results in reductions in final demand for these fuels, but in contrast demand for coal is slightly higher in the HC scenario despite its higher price. Moreover, the total demand for fossil energy in primary consumption is actually 3% higher in the HC scenario (Table 14). This seemingly perverse outcome is due to the absolute price differentials causing significant levels of fuel switching, particularly in power generation, while having a much more limited impact on overall demand for energy services. Therefore the impact of higher price assumptions may be more limited than might otherwise be expected.

[75] Manufacturing industry energy consumption by end use, BERR 2007 (http://stats.berr.gov.uk/energystats/ecuk4_7.xls)

BERR is currently developing a new set of energy and CO_2 projections that will investigate higher fossil fuel prices. The Scottish Government will consider up-dating these projections for Scotland when the new results from BERR are available.

Table 24 Impact of fuel price assumptions on final demand for fossil fuels.

Fuel	Price difference of HC vs. CC scenario (%)	Demand change in HC vs. CC scenario (%)
Oil	51%	-3%
Gas	38%	-5%
Coal	41%	1%

6.5. Overall Impact of Supply Side Sensitivity

Figure 14 shows the overall impact of the supply side sensitivity analyses on Scottish CO_2 emissions. Together these could cause an increase in CO_2 of about 17% above the central CC scenario projection or a reduction of about 13% by 2020. This illustrates the powerful influence of the electricity generation sector, and in particular decisions on future fossil generation, on Scotland's total CO_2 emissions. Heat generation contributes a small proportion of the total Scottish CO_2 emissions projected for 2020, in comparison to the 21% of emissions from electricity generation (see Table 15). The impact on CO_2 emissions from the introduction of 10% of heat supplies from renewable sources is small in comparison to the changes made to fossil electricity generation.

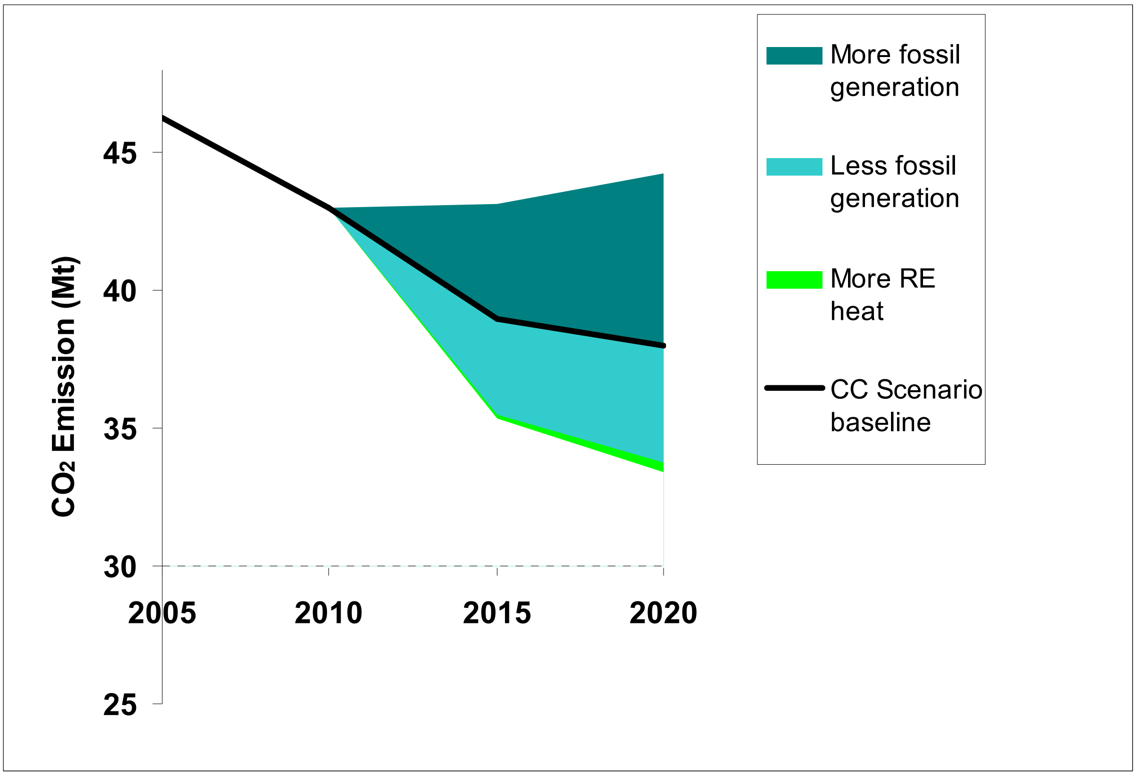

Figure 14 Overall impact of the supply side sensitivity analysis variables on Scottish energy related CO_2 emissions compared to the baseline CC scenario projection

6.6. Overall Impact of both Supply and Demand Side Sensitivity

The combined impact of all the sensitivity factors investigated, covering both supply and demand is shown in Figure 15. Together these could cause an increase in CO_2 emissions of about 19% above the central CC scenario projection or a reduction of about 16% both by 2020. These variations are more significant than the change in emissions cause by the difference in price assumptions between the CC and HC scenarios, which was around 6%. Changes in the supply side have a greater impact upon emissions than changes on the demand side.

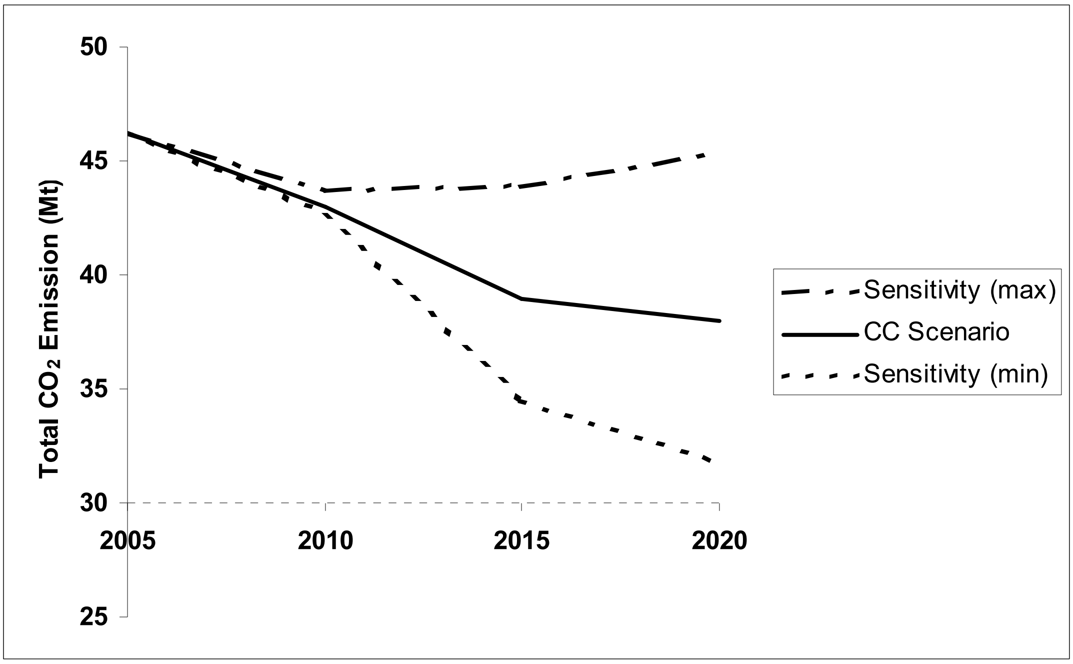

Figure 15 Overall impact of sensitivity analysis variable on energy related CO_2 emissions in the CC scenario

6.7. *Projection Uncertainty*

As indicated previously, projections into the future are inherently uncertain. This uncertainty arises from a number of sources including:

- Uncertainty in the baseline (2002) data on which the projections are based (linked to statistical margins and estimating uncertainties).
- Modelling approximations.
- Impact of policy measures (i.e. measures in the UK Climate Change Programme, and EWP).
- Variations in future parameters (e.g. GDP, population, etc.)

The uncertainty over future parameters has been covered in this work through the analysis of two scenarios, and a set of sensitivity analyses. The sensitivity analysis has shown that this area of uncertainty can cause variations of about 20% around the central projection by 2020.

The other factors above are analytical uncertainties that are likely to have less impact than the uncertainty over future parameters. For example BERR has estimated the uncertainty around its central projection, in terms of CO_2 emissions, to be about plus or minus 10%.

These observations suggest that, for a given scenario (i.e. setting aside the uncertainties in the scenario itself), the uncertainty applying to a particular projection may be of the order of 10-15%. However, since these uncertainties are the same for all projections, they will largely cancel out when considering differences between scenarios. Therefore the relatively small trends between scenarios reported herein are significant, and should not be dismissed as “within the projection error”.

7. Key Observations from the projections to 2020

Baseline Scenario Projections

The following results and trends from the baseline CC and HC scenario projections for energy and energy related CO_2 emissions are particularly noteworthy (see also Table 25):

- Scottish final energy demand falls by 4% and 7% between 2005 and 2020 with the large fall occurring with the HC scenario.
- The fall in demand occurs in the domestic (down 32%-35%) and services (down 9%) with demand increasing in industry and transport.
- Transport overtakes domestic to become the largest demand sector by 2010.
- Demand for electricity stays fairly level over the period to 2020.
- Scottish primary energy consumption falls by between 8% -10% between 2005 and 2020.
- Nuclear's share of primary energy declines with the possible closure of Hunterston B after 2016. This is replaced mainly by renewable energy which grows substantially (~250%), mainly in electricity generation, and by 2020 accounts for about 15% of primary energy supply.
- Oil accounts for 29% of Scottish primary energy in 2002 but increases to 32% -34% in 2020, driven by growing demand from road and air transport.
- Scottish energy related CO_2 emissions are projected to decline by between 7 and 9% from 2005 to 2011, and by between 13% and 18% between 2005 and 2020. Compared with the National Atmospheric Emissions Inventory (NAEI) inventory for 1990[76] emissions are projected to fall by between 18% and 30% by 2020.
- Electricity is responsible for 34% of Scottish energy related CO_2 in 2002 and is projected to fall to 21%-28% in 2020. Emissions from electricity generation are highly sensitive to decisions on future fossil fuel generation, and in particular coal fired generation capacity.

[76]The present National Atmospheric Emissions Inventory includes emissions from domestic flights that are attributable to Scotland. However, the Scottish Energy Study Volume 1 did cover all aviation emissions and these have been included in Table 15 for completeness. Comparisons with NAEI values are made after excluding aviation.

Sensitivity Analysis

The sensitivity analysis explored the impact on energy related CO_2 emissions of variations and uncertainties specific to Scotland in the baseline projections:

- Scotland's CO_2 emissions are particularly sensitive to the mix of fuels used for power generation. The higher and lower levels of fossil fuel generation investigated in this sensitivity analysis could change Scotland's overall CO_2 emissions by +17% to -11% by 2020. Furthermore, power stations in Scotland operate in the UK market and therefore their operation will be determined at the UK level, i.e. decisions around generation will sometimes need to be taken in the context of that UK market
- If Scotland's rates of economic growth and population growth follow the lower historic trend, rather than the Scottish Government's targets, CO_2 emissions will be about 2% lower in 2020 compared to the baseline.
- Higher or lower rates of growth in air travel could alter CO_2 emissions by about +/-1% by 2020.
- Increased car ownership to the average for the UK could increase CO_2 emissions by about 1.5% by 2020 compared to the baseline.
- A realistic expansion of renewable heat supply to 10% of demand could reduce CO_2 emissions by about 1.6% by 2020.

Table 25 Summary of key results

Scenario	Change in Final Energy Demand 2005-2020 (%)	Change in CO_2 emissions 2005-2020 (%)
CC Scenario	-4%	-18%
HC Scenario	-7%	-13%
CC Scenario Sensitivity – High[77]	-1%	-2%
CC Scenario Sensitivity - Low[78]	-10%	-31%

Energy Prices

Fuel price differences within the range covered by the CC and HC scenarios have a modest impact on total energy demand, but have a more significant influence on the mix of fuels to be used. For example, by 2020 total primary energy demand was 2.5% higher in the HC scenario mainly due to increased electricity generation from coal. This resulted in CO_2 emissions being 6% higher in the higher fuel price scenario.

[77] The "High" sensitivity analysis included increased car ownership and air travel, causing an increase in energy demand and CO_2 emissions, and increased fossil fuel power generation causing an increase in CO_2 emissions.

[78] The "Low" sensitivity analysis included lower GDP and population growth, causing a decrease in demand and CO_2 emissions, and decreased fossil fuel power generation causing a decrease in CO_2 emissions.

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