Projections to 2050 of emissions and removals from the LULUCF sector in Scotland, England, Wales and Northern Ireland

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Summary for Policy Makers

- The UK is required to report projections for the Land Use, Land Use Change and Forestry (LULUCF) sector for carbon budgets under the UK Climate Change Act, for the European Union Monitoring Mechanism and the UN Framework Convention on Climate Change. LULUCF activities can result in net emissions or removals of greenhouse gases, and carbon stocks are also calculated. This report provides the UK figures spatially disaggregated to the Devolved Administration level, giving separate projections data for Scotland, England, Wales and Northern Ireland.
- The LULUCF sector (sector 5 in the national greenhouse gas inventory) is divided into six land use types for reporting of emissions/removals: 5A Forest Land, 5B Cropland, 5C Grassland, 5D Wetlands, 5E Settlements, 5F Other Land. (Note that there is a separate inventory sector dedicated to emissions from agricultural activities, although some agricultural activities are reported in the cropland category of LULUCF). Net carbon stock changes from Harvested Wood Products are reported in 5G Other.
- Projections are made for net emissions and removals of greenhouse gases to 2050, arising from LULUCF activities reported in the latest (1990-2011) greenhouse gas inventory, reporting at the Devolved Administration level[1]. These projections are also reported at the UK level in a separate report[2].
- Four initial scenarios (Business-As-Usual (BAU), High emissions, Mid emissions and Low emissions) have been constructed. The non-BAU scenarios have also been modified to include continuing cropland-grassland rotations (churn). The scenarios were developed by a policy maker stakeholder group from trajectories in the 2050 DECC calculator report and take account of land use policies and aspirations.
- The main results are:
    - The LULUCF sector is predicted to be a net source of GHG emissions in England, Wales and Northern Ireland until at least 2040 under all scenarios. Scotland is predicted to be a net sink for the whole period under the Low and Mid scenarios but a net source from between 2025 and 2035 under the remaining scenarios.
    - All scenarios for each DA show an increase from 2012 to a peak in net emissions to the atmosphere between 2025 and 2035, after which they either stabilize or decline.
    - The LULUCF sector in each DA is dominated by CO_2 emissions and removals, although N_2O emissions also make a significant contribution.
    - The Forest Land, Cropland and Grassland land use categories dominate the trend in all DAs.
    - The “churn” scenarios increase overall net emissions for all scenarios for each DA, as net emissions from Cropland are maintained, rather than declining over time, as in the original scenarios

[1] The DA level 1990-2011 Greenhouse Gas Inventory is available at http://naei.defra.gov.uk/reports/reports?report_id=756

[2] Projections to 2050 at the UK level are available at http://naei.defra.gov.uk/reports/reports?report_id=752

- Changes in the LULUCF inventory this year include new activities (N_2O from forest drainage, where emissions can increase due to increased soil mineralisation, and GHG emissions from non-forest wildfires) and the revision of existing activities (forest wildfires, and biomass burning after deforestation). More details are given in the 1990-2011 National Inventory Report[3]. The projections follow the same trend as before but for England, Scotland and Northern Ireland the overall emissions over the full time period are slightly higher. For Wales the overall emissions are higher before and lower after 2011.

[3] Available at http://uk-air.defra.gov.uk/reports/cat07/1305301238_ukghgi-90-11_main_chapters_Issue3.pdf

Introduction

The UK is required to report projections of greenhouse gas emissions and removals from Land Use, Land Use Change and Forestry (LULUCF) activities for carbon budgets under the UK Climate Change Act, for the European Union Monitoring Mechanism and the UN Framework Convention on Climate Change.

Previously, the Centre for Ecology & Hydrology (CEH) projected emissions/removals to 2020 based on the continuation of current trends in forest planting, land use change and other land use activities (the 'Business as Usual' or Mid scenario). Scenarios of high and low emissions above and below the Mid scenario were based on reduced or increased rates of forest planting or the upper or lower limits of the 95% confidence interval of current activity rates.

The UK now requires calculation of projections of emissions/removals up to 2050 (the target date for 80% emissions reductions below the 1990 baseline in the UK Climate Change Act). Such an undertaking is more complex and cannot use the simple trend extrapolation of the 2020 projection methodology. Land use policies and aspirations (e.g. achieving a certain percentage of forest cover by 2050) need to be taken into consideration. Projected land use change also needs to be internally consistent, i.e. the increased area of one land use type will be matched by the reduced area of another.

This report outlines the projections to 2050 which have been made for carbon stock changes (resulting in net carbon dioxide emissions) and emissions of greenhouse gases (carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)) and removal of CO_2 arising from LULUCF activities reported in the latest (1990-2011) greenhouse gas inventory. Four initial policy scenarios (Business-As-Usual (BAU), High emissions, Mid emissions and Low emissions) have been constructed. The assumptions underlying the projections were developed by a group of representatives from DECC, Defra, CEH and the Devolved Administration governments (see Annex 1). The non-BAU scenarios have also been modified to include continuing cropland-grassland rotations (churn). Projections to 2050 have previously been reported for the UK[4]. This report provides the underlying projections which have been developed for each country (England, Scotland, Wales and Northern Ireland) following publication of the Devolved Administration 1990-2011 Greenhouse Gas Inventory report[5].

Basis for projections

The LULUCF sector (sector 5 in the national greenhouse gas inventory) is divided into six land use types for reporting of emissions/removals: 5A Forest Land, 5B Cropland, 5C Grassland, 5D Wetlands, 5E Settlements, 5F Other Land. Net carbon stock changes from Harvested Wood Products are reported in 5G Other, which include carbon stock changes resulting from normal forest management processes (thinning and harvesting) and from conversion of Forest Land to Cropland, Grassland or Settlements (deforestation). Emissions of greenhouse gases to the atmosphere are expressed as positive quantities, and removals of CO_2 as negative quantities. Emissions of all three greenhouse gases can be combined together into total CO_2 equivalents, using a Global Warming Potential multiplication factor of 1 for CO_2, 21 for CH_4 and 310 for N_2O. The net LULUCF emission is the balance of emissions and removals across the seven categories (5A-5G): the net total is smaller than most of the category totals.

[4] Available at http://naei.defra.gov.uk/reports/reports?report_id=752
[5] Available at http://uk-air.defra.gov.uk/reports/cat07/1306070907_DA_GHGI_report_2011_Issue1.pdf

Calculations in the LULUCF inventory are done on the basis of activities, which can fall across several land use types (Table 1). The current inventory methodology was used to make the projections to 2050. There are detailed descriptions of the datasets and methodology in Chapter 7 and Annex 3.7 of the 1990-2011 National Inventory Report (published in April 2013). The *Afforestation* and *Land Use Change (soils)* activities contribute the majority of the emissions/removals in the LULUCF sector. Accordingly, most consideration was given to these activities and to *Deforestation* when developing the assumptions for the different scenarios.

Table 1: Activities producing emissions/removals of greenhouse gases in the LULUCF sector.

Activity	**Description**	**Inventory category**
Afforestation	The CEH carbon flow model, CFlow, models carbon stock changes in forest biomass, litter, soil and timber products, driven by forest planting rates since 1921. Estimates are adjusted to take account of losses due to deforestation. Soil drainage associated with afforestation produces N_2O emissions. Nitrogen fertilization of 'poor' forest soils (a subset of total forest planting) produces N_2O emissions.	5A Forest Land (carbon stock changes, N_2O emissions) 5G Harvested Wood Products (carbon stock changes)
Wildfires	Biomass burning emissions from wildfires on forest land, cropland and grassland	5A Forest Land (CO_2, $CH_4$and N_2O emissions), 5B Cropland ($CH_4$and N_2O emissions), 5C Grassland ($CH_4$and N_2O emissions)
Land Use Change (soils)	Soil carbon stock changes due to land use change (LUC) since 1950 are modelled using a combined land use change matrix/soil carbon model. Continuing changes due to historical LUC (>20 years before) are reported under e.g. Cropland remaining Cropland, and changes due to more recent LUC(<20 years) are reported under e.g. Land converted to Cropland.	5B Cropland (carbon stock changes) 5C Grassland (carbon stock changes) 5E Settlements (carbon stock changes)
Land Use Change (non-forest biomass)	Biomass carbon stock changes are modelled using the same land use change matrix approach as for soils. Biomass carbon stock changes due to changes to and from Forest Land are estimated under the *Afforestation* and *Deforestation* activities.	5B Cropland (carbon stock changes) 5C Grassland (carbon stock changes) 5E Settlements (carbon stock changes)
N_2O emissions from LUC to Cropland	N_2O emissions due to disturbance associated with land use conversion from forest land and grassland to cropland .	5B Cropland (N_2O emissions)
Deforestation	Carbon stock changes in forest biomass and soils due to permanent conversion of forest land. A proportion of the felled trees are burnt, and the remainder are converted to timber products.	5A Forest Land (biomass carbon stock changes) 5B Cropland (soil carbon stock changes; CO_2, $CH_4$and N_2O emissions) 5C Grassland (soil carbon stock changes; CO_2, $CH_4$and N_2O emissions) 5E Settlements (soil carbon stock changes; CO_2, $CH_4$and N_2O emissions) 5G Harvested Wood Products (carbon stock changes)
Liming	Emissions of $CO_2$from the application of lime (dolomite and limestone) to agricultural land.	5B Cropland (CO_2emissions) 5C Grassland (CO_2emissions)
Lowland drainage	Carbon stock losses from historic drainage of lowland wetlands (in England only)	5B Cropland (soil carbon stock changes)

Activity	Description	Inventory category
Yield improvements	Annual increase in cropland biomass due to yield improvements (improved species strains or management).	5B Cropland (biomass carbon stock changes)
Peat extraction	On-site emissions of $CO_2$and N_2O from peat extraction (abandoned, active and newly established) and off-site emissions of CO_2 from the decomposition of horticultural peat.	5D Wetlands (soil carbon stock changes; $CO_2$and N_2O emissions)

Scenarios were developed from trajectories in the 2050 calculator report (Section E: Agriculture and Land Use) (DECC 2010) in discussion with the projections group (Annex 1). The Low emission scenario was based on trajectory C, which emphasizes bio-energy crop production and woodland creation. The High emission scenario was based on trajectory B, where the policy priority is to increase food production, and there is less focus on bio-energy crops and forestry (exploring the highest level of emissions that the sector might produce). The Mid emission scenario used land use change, afforestation and deforestation rates midway between the High and Low scenario rates. The Business-As-Usual (BAU) scenario continued the afforestation rate from 2010 out to 2050: this represents a 'without policy and measures' scenario for Forest Management reference level reporting under the second commitment period of the Kyoto Protocol (DECC 2011). The BAU scenario used the Mid emission scenario assumptions for all other activities.

Assumptions that remained constant across all scenarios:

- Land areas for each country of the UK are assumed to remain constant. They are taken from the Standard Area Measurement (national baseline). (Land loss due to sea level rise is assumed not to have an impact before 2050).
- LULUCF input data for 1990-2011 in the published national inventory have not been changed and will feed through to the projected emissions.
- Afforestation: The split in planting between conifers and broadleaves is assumed to stay the same as in 2011 in each country (conifer: broadleaf ratios are 1:99 (England), 30:70 (Scotland), 3:97 (Wales), 1:99 (Northern Ireland)).
- Afforestation on settlement land (e.g. remediation of mineral workings) continues at same rate as currently. Otherwise, all conversion to forest land was from grassland.
- Land Use Change: the Settlement area increases at 17 kha p.a. across the UK (based on assumption in the 2050 calculator report).
- N_2O emissions resulting from land use conversion to Cropland: emissions are calculated using the same input data as for soil carbon stock changes from land use change.

The assumptions for each activity, by projection scenario, are shown in Table 2.

Table 2: Assumptions for the LULUCF projections for the DAs

Activity	Business-As-Usual emission scenario	Low emission scenario	Mid emission scenario	High emission scenario	Reasons for assumptions
Afforestation	Afforestation rates remain at same level as in 2010. England: 1.994 kha p.a. Scotland: 2.718 kha p.a. Wales: 0.217 kha p.a. N. Ireland: 0.214 kha p.a.	Increased afforestation rates from 2012 onwards (see Annex 2) England: increasing from 3.0 to 9.1 kha p.a. by 2019, 10 kha p.a. 2020-2040, reducing to 6 kha p.a. by 2050 Scotland: increasing from 8 to 10 kha p.a. by 2020, at 10 kha p.a. 2021-2050 Wales: increasing from 2 to 5 kha p.a. by 2015, at 6 kha p.a. 2021-2030, at 5 kha p.a. to 2050 N. Ireland: 0.2 kha p.a. 2011-2014, increasing to 1.7 kha p.a. by 2029, at 1.7 kha p.a. 2030-2050	Afforestation rates are assumed to be midway between the Low and the High emission scenarios. England: increasing from 2.766 kha p.a. to 5.816 kha p.a. in 2019, 6.266 kha p.a. 2020-2040, reducing to 5.266 kha p.a. by 2045 Scotland: increasing from 6.5515 kha p.a. to 7.3015 kha p.a. in 2015, 7.5515 kha p.a. 2016-2050 Wales: increasing from 1.149 kha p.a. to 2.149 kha p.a. in 2014, 2.6490 kha p.a. 2015-2020, 3.149 kha p.a. 2021-2030, 2.6490 kha p.a. 2031-2050 N.Ireland: increasing from 0.226 kha p.a. to 0.926 kha p.a. in 2028, 0.976 kha p.a. 2029-2050.	Afforestation rates remain at same level as in 2011 England: 2.532 kha p.a. Scotland: 5.103 kha p.a. Wales: 0.298 kha p.a. N. Ireland: 0.252 kha p.a.	The BAU scenario is a 'without policies and measures' scenario for baseline comparison to 2050. The Low scenario afforestation rates for individual countries were supplied by the Forestry Commission (based on policy aspirations). The High scenario continues 2011 planting rates (low level compared to historical rates). The Mid scenario assumed afforestation rates midway between those in the Low and High scenarios.
Wildfires (forest and non-forest)	Use Mid emission scenario.	5^{th} percentile of 1990-2011 time series for each vegetation type	Average of previous 10 years (2002-2011) for each vegetation type	95^{th} percentile of 1990-2011 time series for each vegetation type	Simplification of previous trend extrapolation with autoregression- gave misleading impression of forecasting precision

Activity	Business-As-Usual emission scenario	Low emission scenario	Mid emission scenario	High emission scenario	Reasons for assumptions
Land Use Change (soils)	Use Mid emission scenario	Based on trajectory C (2050 calculator). England: Cropland area is stable, Settlement area increases 13.5 kha p.a., Grassland area decreases 18.7-23.2 kha p.a. Scotland: Cropland area is stable, Settlement area increases 1.9 kha p.a., Grassland area decreases 10.7-11.7 kha p.a. Wales: 2.5 kha p.a. converted to cropland from grassland, Settlement area increases 1.4 kha p.a., Grassland area decreases 7.7-9.5 kha p.a. N.Ireland: Cropland area is stable, Settlement area increases 0.7 kha p.a., Grassland area decreases 1.0-2.4 kha p.a. Grassland-Cropland "churn" each way England: 56.60 kha p.a. Scotland: 16.65 kha p.a. Wales: 5.24 kha p.a. N. Ireland: 4.19 kha p.a.	Land use change rates mid-way between the Low and High scenario rates. England: Cropland area is stable, Settlement area increases 13.5 kha p.a., Grassland area decreases 16.1-19.1 kha p.a. Scotland: Cropland area is stable, Settlement area increases 1.9 kha p.a., Grassland area decreases 7.0-8.0 kha p.a. Wales: 5.5 kha p.a. converted to cropland from grassland, Settlement area increases 1.4 kha p.a., Grassland area decreases 8.9-9.6 kha p.a. N.Ireland: Cropland area is stable, Settlement area increases 0.7 kha p.a., Grassland area decreases 0.9-1.6 kha p.a. Grassland-Cropland "churn" each way England: 56.60 kha p.a. Scotland: 16.65 kha p.a. Wales: 5.24 kha p.a. N. Ireland: 4.19 kha p.a.	Based on trajectory B (2050 calculator). England: Cropland area is stable, Settlement area increases 13.5 kha p.a., Grassland area decreases 15.2 kha p.a. Scotland: Cropland area is stable, Settlement area increases 1.9 kha p.a., Grassland area decreases 5.0 kha p.a. Wales: 10.0 kha p.a. converted to cropland from grassland, Settlement area increases 1.4 kha p.a., Grassland area decreases 11.6 kha p.a. N.Ireland: Cropland area is stable, Settlement area increases 0.7 kha p.a., Grassland area decreases 0.9 kha p.a. Grassland-Cropland "churn" each way England: 56.60 kha p.a. Scotland: 16.65 kha p.a. Wales: 5.24 kha p.a. N. Ireland: 4.19 kha p.a.	The High and Low scenarios were based on trajectories from the 2050 calculator report, with the Mid scenario using rates mid-way between these. Separate cropland conversion rates were requested for Wales. Grassland-cropland "churn" rates were based on the average annual conversion of cropland to grassland and vice versa between 1990 and 2010 for each country.
Land Use Change (non-forest biomass)	Use Mid emission scenario	Based on same conversion areas as Land Use Change (soils) above)	Based on same conversion areas as Land Use Change (soils) above)	Based on same conversion areas as Land Use Change (soils) above)	Same assumptions as for Land Use Change (soils)

Activity	Business-As-Usual emission scenario	Low emission scenario	Mid emission scenario	High emission scenario	Reasons for assumptions
N_2O *emissions from LUC to Cropland*	Use Mid emission scenario	Zero post-2011 LUC to cropland for England, Scotland and N. Ireland Wales: 2.5 kha p.a. converted to cropland from grassland Grassland-Cropland "churn" as assumed for Land Use Change (soils)	Zero post-2011 LUC to cropland for England, Scotland and N. Ireland Wales: 5.5 kha p.a. converted to cropland from grassland Grassland-Cropland "churn" as assumed for Land Use Change (soils)	Zero post-2011 LUC to cropland for England, Scotland and N. Ireland Wales: 10.0 kha p.a. converted to cropland from grassland Grassland-Cropland "churn" as assumed for Land Use Change (soils)	Cropland areas assumed stable post-2011 for England, Scotland and N. Ireland. Separate cropland conversion rates were requested for Wales. Grassland-cropland "churn" rates were based on the average annual conversion of grassland to cropland between 1990 and 2010 for each country.
Deforestation	Use Mid emission scenario	Deforestation rate assumed to be 70% of Mid or Business-As-Usual rate	Anticipated rates of deforestation to meet biodiversity/renewable energy/development objectives (see Annex 2).	Deforestation rate assumed to be 130% of Mid or Business-As-Usual rate	Deforestation is considered to be probably under-reported in the current LULUCF inventory, due to a lack of information. The Mid or Business-As-Usual scenario deforestation rates for individual countries were supplied by the Forestry Commission, based on expert knowledge and unpublished data from the latest National Forest Inventory. Current deforestation rates are approximately 70% of the Mid scenario rates (used as the Low scenario), so an equivalent uplift of 30% has been used for the High scenario.
Liming		Amount of lime applied is assumed to be 25% below the average for 2001-2010.	Amount of lime applied is assumed to be the same as the average for 2001-2010.	Amount of lime applied is assumed to be 25% above the average for 2001-2010.	No clear trend in this activity. (No new data for 2011)
Lowland drainage		Flux remains at 2011 value	Flux remains at 2011 value	Flux remains at 2011 value	No clear trend in this activity. Only reported for England.
Yield improvements		Flux remains at 2011 value	Flux remains at 2011 value	Flux remains at 2011 value	No clear trend in this activity.

Activity	Business-As-Usual emission scenario	Low emission scenario	Mid emission scenario	High emission scenario	Reasons for assumptions
Peat extraction		Areas remain at 2011 level and current levels of extraction assumed to remain at same level as mean 2001-2010 level.	Current levels of extraction assumed to remain at same level as mean 2001-2010 level.	Current levels of extraction assumed to remain at same level as mean 2001-2010 level.	No clear trend in this activity. (No new data for 2011)

Projections 2012-2050

A summary of the results is given here. Detailed emission estimates by activity, country and scenario will be made available for download from the NAEI website.

The distribution of land use areas in the UK between 2011 and 2050 is shown in Tables 3 to 5. The modified scenarios with increased cropland-grassland turnover will have the same overall land use areas as cropland-grassland and grassland-cropland conversion are equal. There is greatest land use change in the Low emissions scenario at the UK level (due to increases in forest area), but for Wales the greatest land use change is under the High emission scenario, due to the assumption of grassland-cropland conversion. Grassland is lost at the expense of other land use types under all scenarios.

Projected emissions of CO_2, CH_4, N_2O and CO_2 equivalents for the LULUCF sector for each DA are shown in Tables 6-9. Graphs of greenhouse gas emissions at the DA level for the whole LULUCF sector and for the individual land use categories are shown in Figures 1-10.

At the DA level the LULUCF sector predictions are variable (Figure 1). In England the sector is predicted to be a net source with a peak at around 2030 under all scenarios, with the exception of the Low scenario which predicts a switch to net sink at around 2042. In Scotland the sector is predicted to become a net source under all three churn scenarios and the BAU and High scenarios between 2025 and 2035. The Low and Mid scenarios predict a decrease in the sink up to 2035 followed by a gradual increase again. In Wales all scenarios predict the sector will become an increased source reaching a peak between 2025 and 2030, followed by a gradual decline. Under the Low, Low churn and Mid scenarios the sector becomes a sink later in the period. In Northern Ireland under all scenarios the sector is predicted to become and increased source, reaching a peak around 2030 before beginning to decline. The Low scenario predicts that the sector will become an increasing sink from 2040 onwards. In all DAs the BAU scenario follows a similar trend to the High scenario (unsurprisingly, as they use similar afforestation assumptions).

In each DA the LULUCF sector is dominated by CO_2 emissions and removals (Figure 2), although N_2O emissions (Figure 4) also make a significant contribution when their Global Warming Potential of 310 is taken into account. Methane emissions (Figure 3) arising from biomass burning do not make a significant contribution to the overall totals.

Table 3: Land Use areas 2011-2050 in the Low emission scenario

Country (total area)	Land use category	2011 area, kha	2020 area, kha	2030 area, kha	2040 area, kha	2050 area, kha	% of land area in 2011	% of land area in 2050
England (13044 kha)	Forest land	1,288.0	1,334.4	1,428.3	1,525.5	1,600.6	10%	12%
	Cropland	4,067.0	4,067.2	4,067.4	4,067.4	4,067.4	31%	31%
	Grassland	6,053.0	5,885.1	5,656.1	5,423.9	5,213.8	46%	40%
	Wetland	20.0	20.0	20.0	20.0	20.0	0%	0%
	Settlement	1,489.0	1,610.5	1,745.5	1,880.5	2,015.5	11%	15%
	Other	126.5	126.2	126.2	126.2	126.2	1%	1%
Scotland (7881 kha)	Forest land	1,383	1,461.8	1,557.9	1,655.7	1,753.5	18%	22%
	Cropland	959	959.0	959.0	959.0	959.0	12%	12%
	Grassland	5,161	5,065.1	4,950.0	4,833.2	4,716.4	65%	60%
	Wetland	89	89.0	89.0	89.0	89.0	1%	1%
	Settlement	193	210.1	229.1	248.1	267.1	2%	3%
	Other	96	95.7	95.7	95.7	95.7	1%	1%
Wales (2078 kha)	Forest land	304	338.4	396.8	445.5	494.1	15%	24%
	Cropland	369	391.5	416.5	441.5	466.5	18%	22%
	Grassland	1,232	1,162.5	1,067.7	980.0	892.4	59%	43%
	Wetland	5	5.0	5.0	5.0	5.0	0%	0%
	Settlement	153	165.6	179.6	193.6	207.6	7%	10%
	Other	15	14.8	12.3	12.2	12.2	1%	1%
Northern Ireland (1413 kha)	Forest land	88	90.9	103.5	120.0	136.5	6%	10%
	Cropland	277	277.0	277.0	277.0	277.0	20%	20%
	Grassland	892	882.8	863.2	839.7	816.2	63%	58%
	Wetland	57	57.0	57.0	57.0	57.0	4%	4%
	Settlement	81	87.3	94.3	101.3	108.3	6%	8%
	Other	18	18.0	18.0	18.0	18.0	1%	1%

Table 4: Land Use areas 2011-2050 in the Mid emission scenario

Country (total area)	Land use category	2011 area, kha	2020 area, kha	2030 area, kha	2040 area, kha	2050 area, kha	% of land area in 2011	% of land area in 2050
England (13044 kha)	Forest land	1,288.0	1,311.6	1,364.5	1,420.6	1,466.7	10%	11%
	Cropland	4,067.0	4,067.4	4,067.6	4,067.6	4,067.6	31%	31%
	Grassland	6,053.0	5,907.7	5,719.6	5,528.4	5,347.3	46%	41%
	Wetland	20.0	20.0	20.0	20.0	20.0	0%	0%
	Settlement	1,489.0	1,610.5	1,745.5	1,880.5	2,015.5	11%	15%
	Other	126.5	126.4	126.4	126.4	126.4	1%	1%
Scotland (7881 kha)	Forest land	1,383	1,429.5	1,488.8	1,549.3	1,610.3	18%	20%
	Cropland	959	959.0	959.0	959.0	959.0	12%	12%
	Grassland	5,161	5,097.4	5,019.1	4,939.6	4,859.6	65%	62%
	Wetland	89	89.0	89.0	89.0	89.0	1%	1%
	Settlement	193	210.1	229.1	248.1	267.1	2%	3%
	Other	96	96	96	96	96	1%	1%
Wales (2078 kha)	Forest land	304	321.9	351.5	376.7	401.8	15%	19%
	Cropland	369	418.5	473.4	528.4	583.4	18%	28%
	Grassland	1,232	1,151.6	1,055.4	960.8	866.6	59%	42%
	Wetland	5	5.0	5.0	5.0	5.0	0%	0%
	Settlement	153	165.6	179.6	193.6	207.6	7%	10%
	Other	15	15	13	13	13	1%	1%
Northern Ireland (1413 kha)	Forest land	88	89.8	96.4	105.3	114.4	6%	8%
	Cropland	277	277.0	277.0	277.0	277.0	20%	20%
	Grassland	892	883.9	870.3	854.4	838.3	63%	59%
	Wetland	57	57.0	57.0	57.0	57.0	4%	4%
	Settlement	81	87.3	94.3	101.3	108.3	6%	8%
	Other	18	18	18	18	18	1%	1%

Table 5: Land Use areas 2011-2050 in the High emission scenario

Country (total area)	Land use category	2011 area, kha	2020 area, kha	2030 area, kha	2040 area, kha	2050 area, kha	% of land area in 2011	% of land area in 2050
England (13044 kha)	Forest land	1,288.0	1,292.4	1,303.6	1,318.7	1,335.6	10%	10%
	Cropland	4,067.0	4,067.5	4,067.8	4,067.9	4,067.9	31%	31%
	Grassland	6,053.0	5,918.0	5,768.0	5,617.7	5,465.8	46%	42%
	Wetland	20.0	20.0	20.0	20.0	20.0	0%	0%
	Settlement	1,489.0	1,610.5	1,745.5	1,880.5	2,015.5	11%	15%
	Other	126.5	135.1	138.7	138.7	138.7	1%	1%
Scotland (7881 kha)	Forest land	1,383	1,396.7	1,418.8	1,442.1	1,466.3	18%	19%
	Cropland	959	959.0	959.0	959.0	959.0	12%	12%
	Grassland	5,161	5,116.0	5,066.0	5,016.0	4,966.0	65%	63%
	Wetland	89	89.0	89.0	89.0	89.0	1%	1%
	Settlement	193	210.1	229.1	248.1	267.1	2%	3%
	Other	96	110	119	126	133	1%	2%
Wales (2078 kha)	Forest land	304	303.5	305.3	307.1	308.9	15%	15%
	Cropland	369	459.0	559.0	659.0	759.0	18%	37%
	Grassland	1,232	1,127.6	1,011.6	895.6	779.6	59%	38%
	Wetland	5	5.0	5.0	5.0	5.0	0%	0%
	Settlement	153	165.6	179.6	193.6	207.6	7%	10%
	Other	15	17	17	18	18	1%	1%
Northern Ireland (1413 kha)	Forest land	88	88.6	89.6	91.1	92.7	6%	7%
	Cropland	277	277.0	277.0	277.0	277.0	20%	20%
	Grassland	892	883.9	874.9	865.9	856.9	63%	61%
	Wetland	57	57.0	57.0	57.0	57.0	4%	4%
	Settlement	81	87.3	94.3	101.3	108.3	6%	8%
	Other	18	19	20	21	21	1%	1%

The Forest Land, Cropland and Grassland categories dominate the trend in all DAs. In England under all scenarios Forest Land (Figure 5) is predicted to become a shrinking net sink until 2025, after which the sink increases again until the late 2030s, followed by a period of fluctuation. All scenarios follow a similar pattern with the magnitude of the sink being greatest for the Low and smallest for the High and BAU scenarios. In Scotland under all scenarios the category is predicted to be a decreasing sink, becoming a source in 2030, followed by a period of fluctuation as a net source for the BAU and High scenarios and a net sink for the Mid and Low scenarios. After 2048 net emissions for all scenarios decrease rapidly. In Wales all scenarios predict that Forest Land will change from the current small net sink to a small net source, reaching a maximum around 2020. After that all scenarios show a decrease in net emissions, with the Mid and Low scenario becoming net sinks around 2025 and the High and BAU in 2035. In Northern Ireland the category is predicted to become a small net source between 2017 and 2032 under all scenarios, after which it declines to become a net sink again with the size of the sink dependent on the scenario. In all of the DAs Cropland (Figure 6) is a shrinking net source under the non-churn scenarios (as Cropland conversion is assumed to be minimal after 2011) and Grassland (Figure 7) is a shrinking net sink (under the non-churn scenarios), as its area shrinks through grassland conversion to other land use types.

Greenhouse gas emission from Wetlands, (Figure 8) in all DAs, are a small component of the LULUCF sector and no detailed assumptions have been made. In England and Scotland the Settlement category (Figure 9) is projected to have slowly increasing emissions from 2012 onwards, driven by steady rates of land use conversion to Settlement. In Wales and Northern Ireland emissions from Settlements are predicted to decline steadily under all scenarios due to a predicted lower rate of conversion of land to settlements than has occurred in the last few decades. The HWP category (Figure 10) in each DA shows little difference between the projection scenarios, as the main harvesting of the increased area of afforestation under the Low and Mid scenarios will occur after 2050. In England the category is predicted to have increased net emissions, changing from a sink to a source around 2032 and reaching maximum emissions in 2038 before declining to become a small net sink. In Scotland the category remains a net sink, increasing to a maximum around 2030, until 2048 when it is predicted to become a source of emissions. In Wales the HWP category sink is predicted to decline, becoming a net source in 2035. In Northern Ireland the category is predicted to become an increased sink until 2018 when the sink begins to decrease, reaching a maximum as a source in 2037 and then fluctuating for the remainder of the period.

The “churn” scenarios demonstrate the impact that cropland-grassland turnover can have upon overall GHG emissions (through carbon stock changes and N_2O emissions arising from conversion to Cropland). They increase overall net emissions in all DAs for all scenarios, as net emissions from Cropland are maintained, rather than declining over time, as in the original scenarios (Figure 6). Their impact in the Grassland category is to increase the size of the net sink, which is otherwise projected to shrink under the original scenarios (Figure 7). The assumption about the rate of cropland-grassland turnover remains under consideration, given the significant impact that it has on the net emissions of the LULUCF sector. The issue of cropland-grassland rotation, and its impact on soil carbon stock changes, is currently under investigation in DECC and Defra funded development programmes for the LULUCF inventory. Wales shows a greater range of predictions for the Cropland churn scenarios due to separate crop conversion rates being used for Wales than the other DAs (Table 2).

There have been some modifications to what is included in the LULUCF inventory since the previous published inventory (1990-2010). Emissions from new activities (N_2O from forest drainage and GHG emissions from non-forest wildfires) have been included and existing activity data has been revised (forest wildfires, and biomass burning after deforestation). More details are given in the 1990-2011 National Inventory Report[6]. Figure 11 illustrates the impact that these changes have had upon the Mid scenario projection for each DA. In England, Scotland and Northern Ireland the updates result in a slight increase in net emissions over the majority of the period. In Wales the updates cause an increase in emissions prior to 2011 and a decrease in the emissions for the remainder of the period.

[6] Available at http://uk-air.defra.gov.uk/reports/cat07/1305301238_ukghgi-90-11_main_chapters_Issue3.pdf

Table 6: LULUCF emissions and removals of CO_2 1990-2050

Country	Scenario	1990 emissions/removals, Gg CO_2	2011 emissions/removals, Gg CO_2	2020 emissions/removals, Gg CO_2	2030 emissions/removals, Gg CO_2	2040 emissions/removals, Gg CO_2	2050 emissions/removals, Gg CO_2
England	Low	5674.56	1478.80	2057.10	1758.83	236.18	-626.50
	Mid	5674.56	1478.80	2417.37	2538.22	1436.39	966.38
	High	5674.56	1478.80	2860.65	2860.65	2710.66	2615.56
	Low_churn	5674.56	1478.80	2973.24	2963.45	1440.79	578.12
	Mid_churn	5674.56	1478.80	3343.48	3751.81	2645.81	2172.88
	High_churn	5674.56	1478.80	3797.00	4616.94	3925.91	3824.06
Scotland	Low	-2440.54	-5503.64	-4477.09	-2261.76	-1251.75	-2071.94
	Mid	-2440.54	-5503.64	-4214.82	-1779.57	-484.96	-1019.69
	High	-2440.54	-5503.64	-3863.75	-1212.95	354.93	96.92
	Low_churn	-2440.54	-5503.64	-2641.86	345.74	1355.75	535.57
	Mid_churn	-2440.54	-5503.64	-2354.41	845.63	2130.67	1594.32
	High_churn	-2440.54	-5503.64	-1977.88	1432.05	2979.86	2717.44
Wales	Low	-88.78	74.26	306.56	94.43	-573.52	-1364.09
	Mid	-88.78	74.26	511.46	588.25	206.79	-280.05
	High	-88.78	74.26	736.31	1099.04	998.69	808.86
	Low_churn	-88.78	74.26	449.29	283.55	-384.41	-1174.97
	Mid_churn	-88.78	74.26	888.30	1131.25	746.76	252.72
	High_churn	-88.78	74.26	1347.26	1996.06	1889.59	1685.28
Northern Ireland	Low	23.37	115.00	159.96	222.80	-51.65	-215.51
	Mid	23.37	115.00	198.96	281.56	73.95	-13.43
	High	23.37	115.00	258.22	358.20	224.16	217.85
	Low_churn	23.37	115.00	376.32	506.68	232.24	68.38
	Mid_churn	23.37	115.00	419.41	569.85	360.33	271.19
	High_churn	23.37	115.00	482.83	651.41	513.19	503.13

Table 7: LULUCF emissions and removals of CH_4 1990-2050

Country	Scenario	1990 emissions/removals, Gg CO_2	2011 emissions/removals, Gg CO_2	2020 emissions/removals, Gg CO_2	2030 emissions/removals, Gg CO_2	2040 emissions/removals, Gg CO_2	2050 emissions/removals, Gg CO_2
England	Low	0.57	0.55	0.52	0.33	0.19	0.19
	Mid	0.57	0.55	0.93	0.65	0.45	0.46
	High	0.57	0.55	1.37	1.00	0.75	0.76
	Low_churn	0.57	0.55	0.52	0.33	0.19	0.19
	Mid_churn	0.57	0.55	0.93	0.65	0.45	0.46
	High_churn	0.57	0.55	1.37	1.00	0.75	0.76
Scotland	Low	0.32	0.42	0.30	0.30	0.21	0.20
	Mid	0.32	0.42	0.60	0.60	0.46	0.45
	High	0.32	0.42	0.97	0.96	0.77	0.74
	Low_churn	0.32	0.42	0.30	0.30	0.21	0.20
	Mid_churn	0.32	0.42	0.60	0.60	0.46	0.45
	High_churn	0.32	0.42	0.97	0.96	0.77	0.74
Wales	Low	0.19	0.28	0.18	0.11	0.10	0.10
	Mid	0.19	0.28	0.37	0.25	0.25	0.25
	High	0.19	0.28	0.55	0.40	0.39	0.39
	Low_churn	0.19	0.28	0.18	0.11	0.10	0.10
	Mid_churn	0.19	0.28	0.37	0.25	0.25	0.25
	High_churn	0.19	0.28	0.55	0.40	0.39	0.39
Northern Ireland	Low	0.07	0.11	0.05	0.03	0.02	0.02
	Mid	0.07	0.11	0.10	0.07	0.04	0.04
	High	0.07	0.11	0.17	0.12	0.11	0.11
	Low_churn	0.07	0.11	0.05	0.03	0.02	0.02
	Mid_churn	0.07	0.11	0.10	0.07	0.04	0.04
	High_churn	0.07	0.11	0.17	0.12	0.11	0.11

Table 8: LULUCF emissions and removals of N_2O 1990-2050

Country	Scenario	1990 emissions/removals, Gg CO_2	2011 emissions/removals, Gg CO_2	2020 emissions/removals, Gg CO_2	2030 emissions/removals, Gg CO_2	2040 emissions/removals, Gg CO_2	2050 emissions/removals, Gg CO_2
England	Low	1.05	0.78	0.54	0.36	0.26	0.19
	Mid	1.05	0.78	0.53	0.35	0.25	0.18
	High	1.05	0.78	0.55	0.37	0.25	0.19
	Low_churn	1.05	0.78	0.89	0.92	0.94	0.95
	Mid_churn	1.05	0.78	0.91	0.93	0.95	0.96
	High_churn	1.05	0.78	0.93	0.94	0.96	0.96
Scotland	Low	1.22	0.73	0.69	0.48	0.35	0.28
	Mid	1.22	0.73	0.69	0.47	0.34	0.27
	High	1.22	0.73	0.70	0.49	0.35	0.28
	Low_churn	1.22	0.73	1.12	1.14	1.16	1.17
	Mid_churn	1.22	0.73	1.12	1.14	1.15	1.16
	High_churn	1.22	0.73	1.14	1.15	1.16	1.17
Wales	Low	0.22	0.20	0.17	0.14	0.13	0.12
	Mid	0.22	0.20	0.20	0.19	0.18	0.18
	High	0.22	0.20	0.25	0.27	0.28	0.29
	Low_churn	0.22	0.20	0.22	0.23	0.24	0.24
	Mid_churn	0.22	0.20	0.23	0.23	0.23	0.23
	High_churn	0.22	0.20	0.31	0.36	0.38	0.40
Northern Ireland	Low	0.24	0.20	0.15	0.11	0.09	0.08
	Mid	0.24	0.20	0.15	0.11	0.09	0.08
	High	0.24	0.20	0.15	0.11	0.08	0.07
	Low_churn	0.24	0.20	0.24	0.25	0.26	0.27
	Mid_churn	0.24	0.20	0.24	0.25	0.25	0.26
	High_churn	0.24	0.20	0.24	0.25	0.25	0.25

Table 9: LULUCF emissions and removals of CO2 equivalents 1990-2050

Country	Scenario	1990 emissions/removals, Gg CO_2	2011 emissions/removals, Gg CO_2	2020 emissions/removals, Gg CO_2	2030 emissions/removals, Gg CO_2	2040 emissions/removals, Gg CO_2	2050 emissions/removals, Gg CO_2
England	Low	6011.31	1733.29	2234.73	1877.76	319.60	-562.40
	Mid	6011.31	1733.29	2602.12	2661.34	1521.92	1032.20
	High	6011.31	1733.29	3059.61	3526.81	2805.27	2690.14
	Low_churn	6011.31	1733.29	3261.27	3255.39	1735.21	876.25
	Mid_churn	6011.31	1733.29	3644.91	4054.24	2948.62	2479.02
	High_churn	6011.31	1733.29	4112.65	4930.45	4237.80	4138.95
Scotland	Low	-2054.85	-5269.88	-4256.75	-2107.46	-1138.59	-1981.70
	Mid	-2054.85	-5269.88	-3989.08	-1620.57	-368.92	-927.49
	High	-2054.85	-5269.88	-3625.30	-1042.00	480.87	197.96
	Low_churn	-2054.85	-5269.88	-2287.67	705.73	1718.17	901.48
	Mid_churn	-2054.85	-5269.88	-1994.82	1210.32	2495.96	1962.21
	High_churn	-2054.85	-5269.88	-1605.58	1808.70	3355.05	3094.16
Wales	Low	-15.88	140.58	362.14	141.44	-530.65	-1323.24
	Mid	-15.88	140.58	579.61	651.74	268.93	-218.36
	High	-15.88	140.58	825.82	1190.43	1093.11	905.41
	Low_churn	-15.88	140.58	522.48	357.62	-308.75	-1097.86
	Mid_churn	-15.88	140.58	966.80	1207.68	823.42	329.88
	High_churn	-15.88	140.58	1454.38	2114.50	2016.81	1818.10
Northern Ireland	Low	98.33	180.23	207.51	258.08	-22.52	-189.12
	Mid	98.33	180.23	247.85	317.03	101.81	10.76
	High	98.33	180.23	309.29	394.65	252.30	241.36
	Low_churn	98.33	180.23	451.67	584.68	313.12	152.01
	Mid_churn	98.33	180.23	496.10	648.03	439.94	352.63
	High_churn	98.33	180.23	561.70	730.57	593.10	583.88

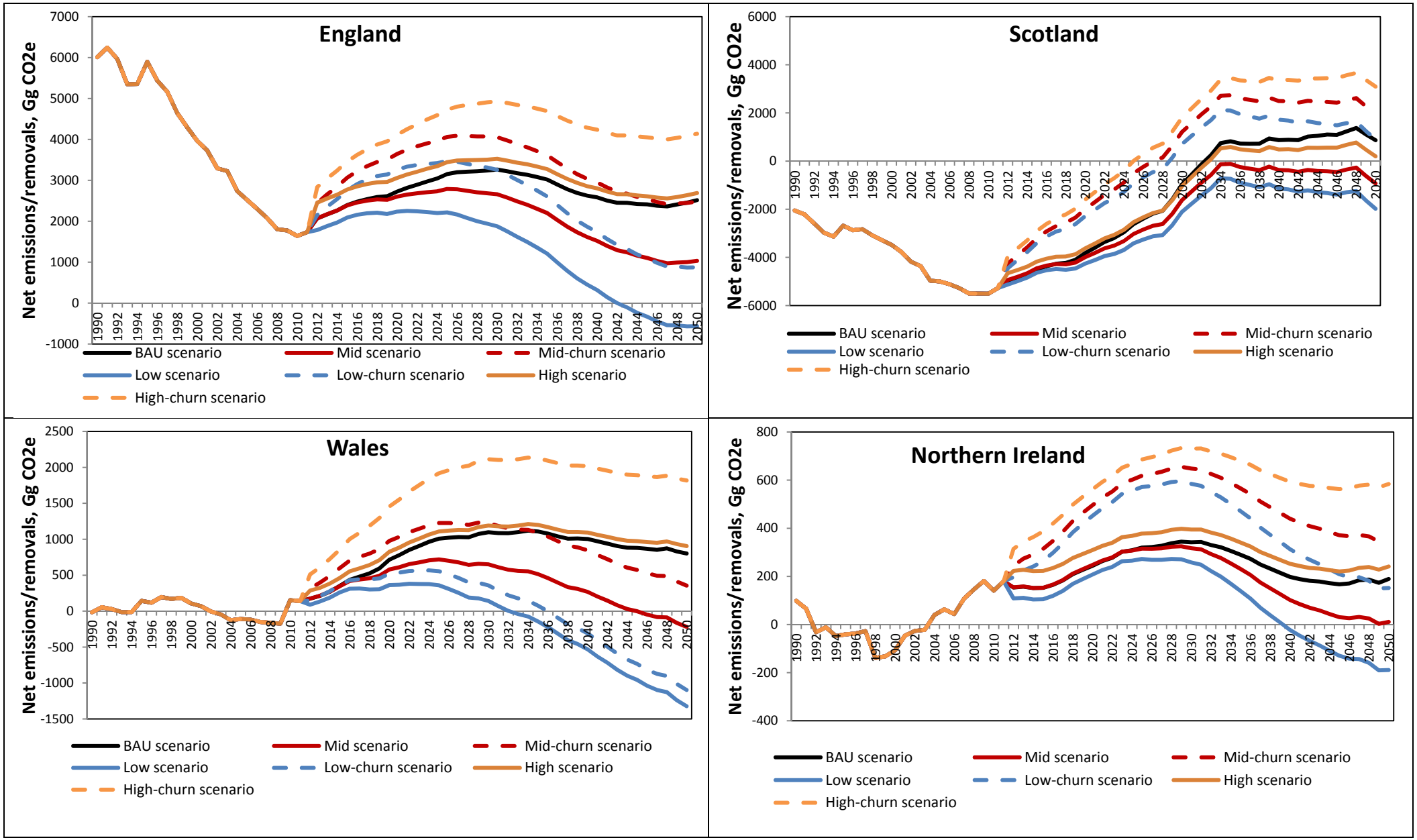

Figure 1: DA LULUCF sector CO_2 equivalents emissions scenarios 1990-2050

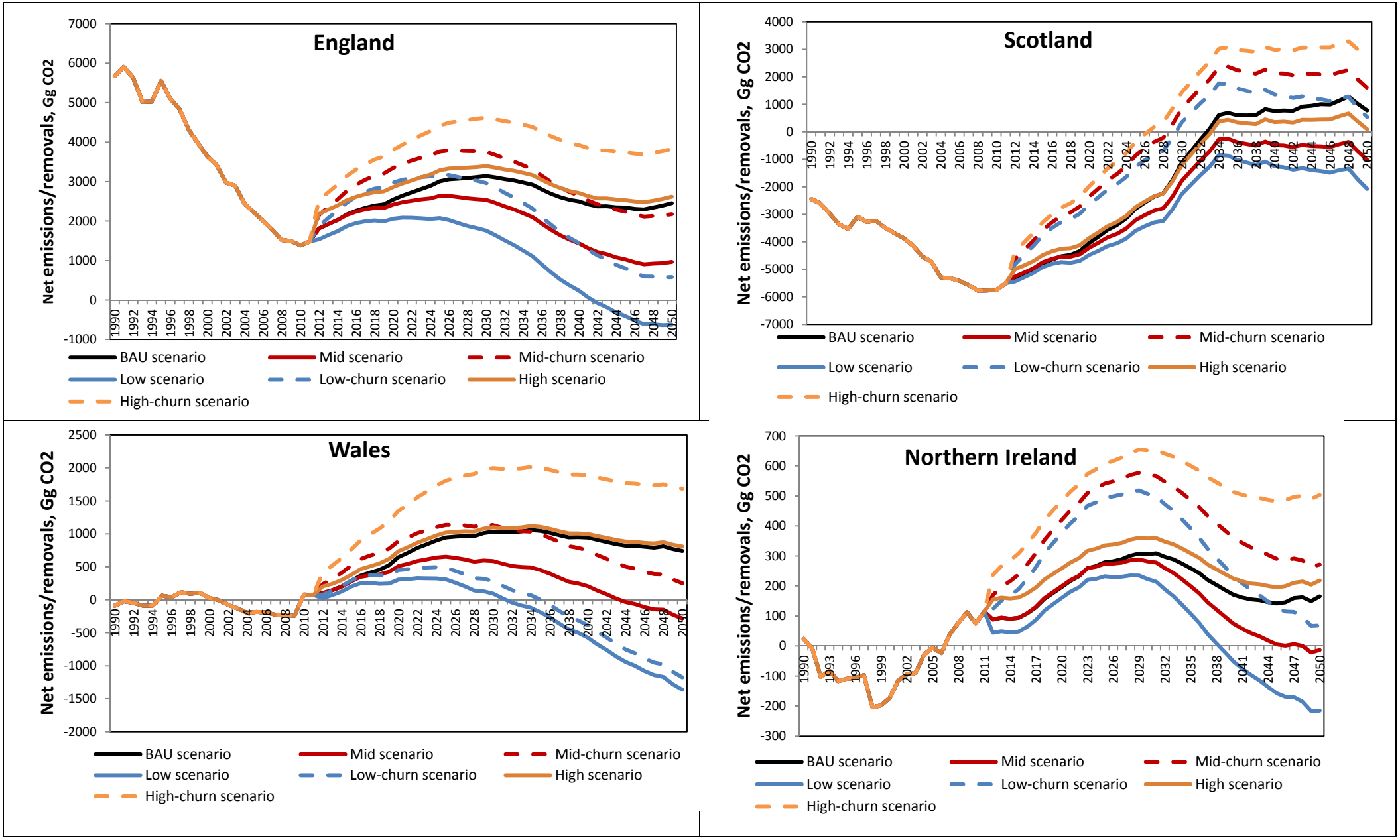

Figure 2: DA LULUCF sector CO_2 emissions scenarios 1990-2050

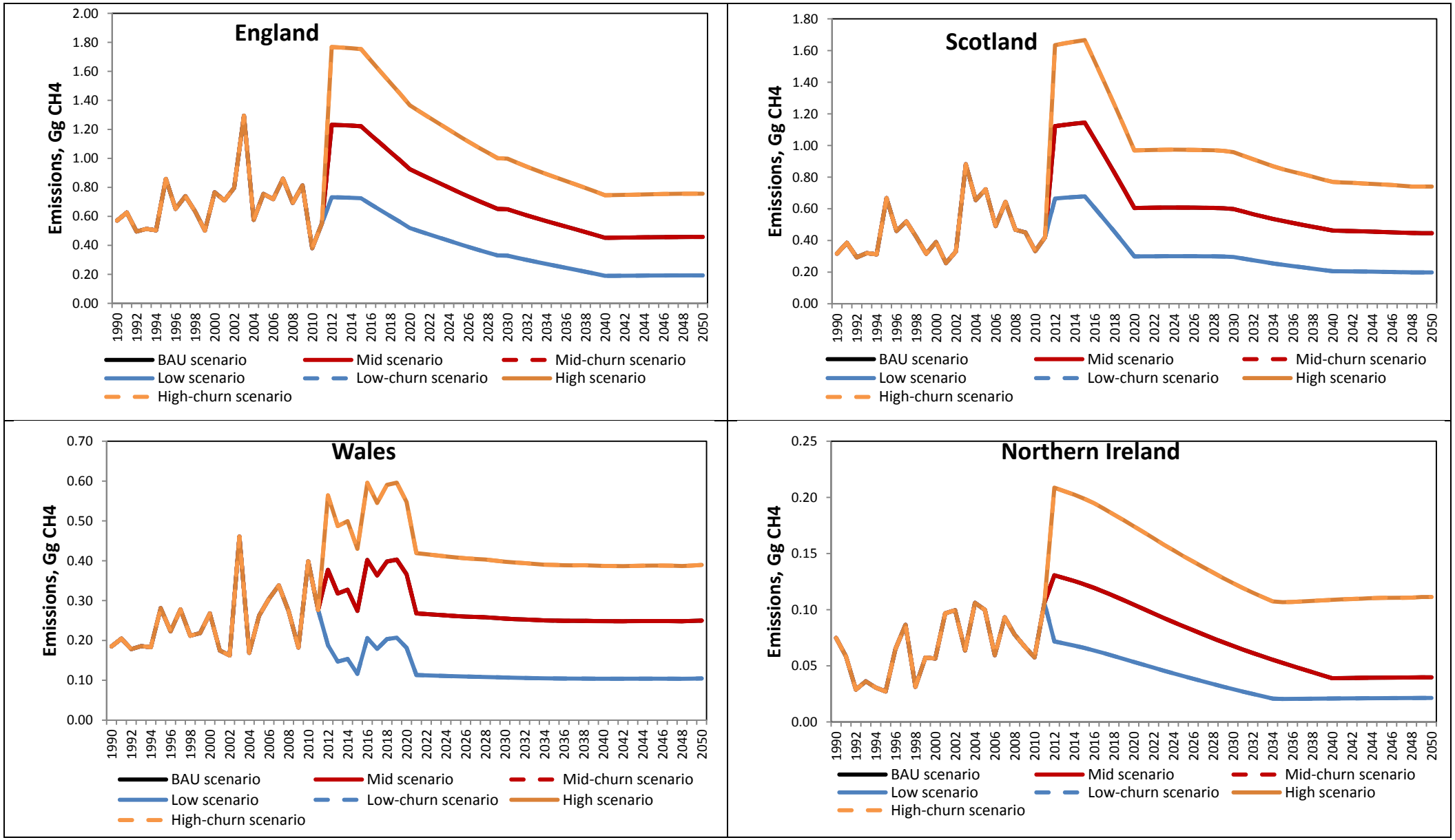

Figure 3: DA LULUCF sector CH_4 emissions scenarios 1990-2050

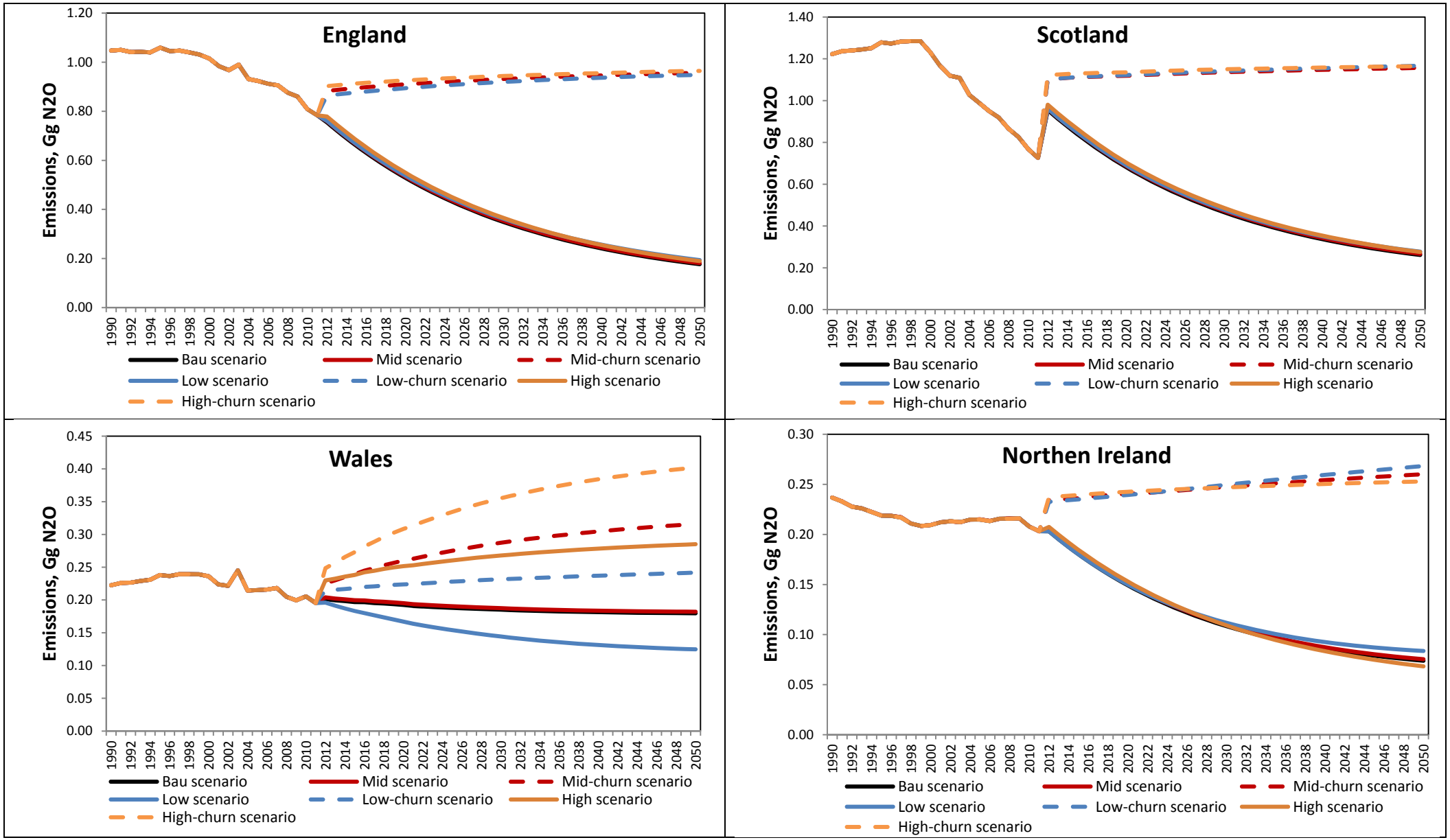

Figure 4: DA LULUCF sector N_2O emissions scenarios 1990-2050

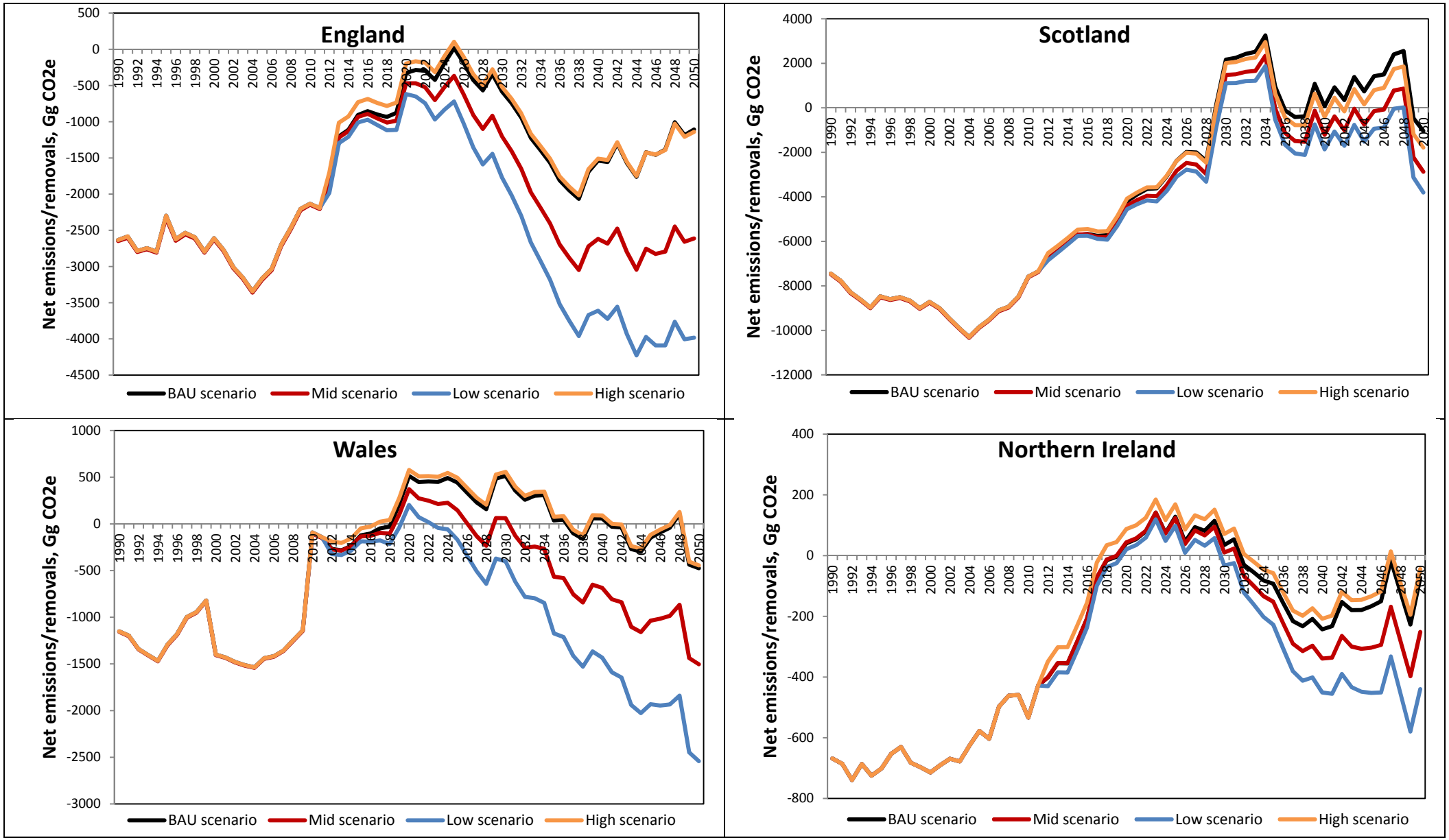

Figure 5: DA Forestland category emissions scenarios 1990-2050

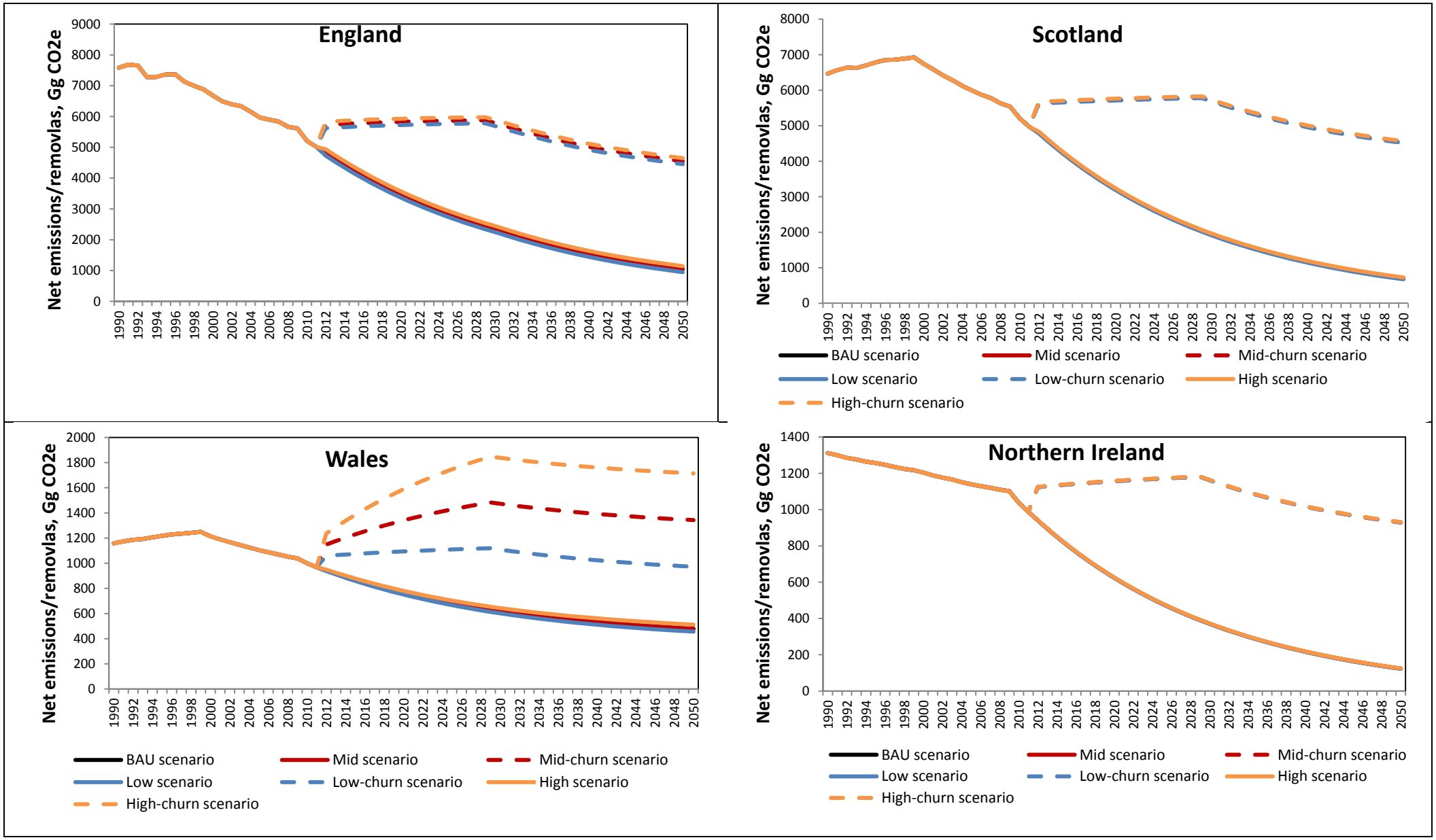

Figure 6: DA Cropland category emissions scenarios 1990-2050

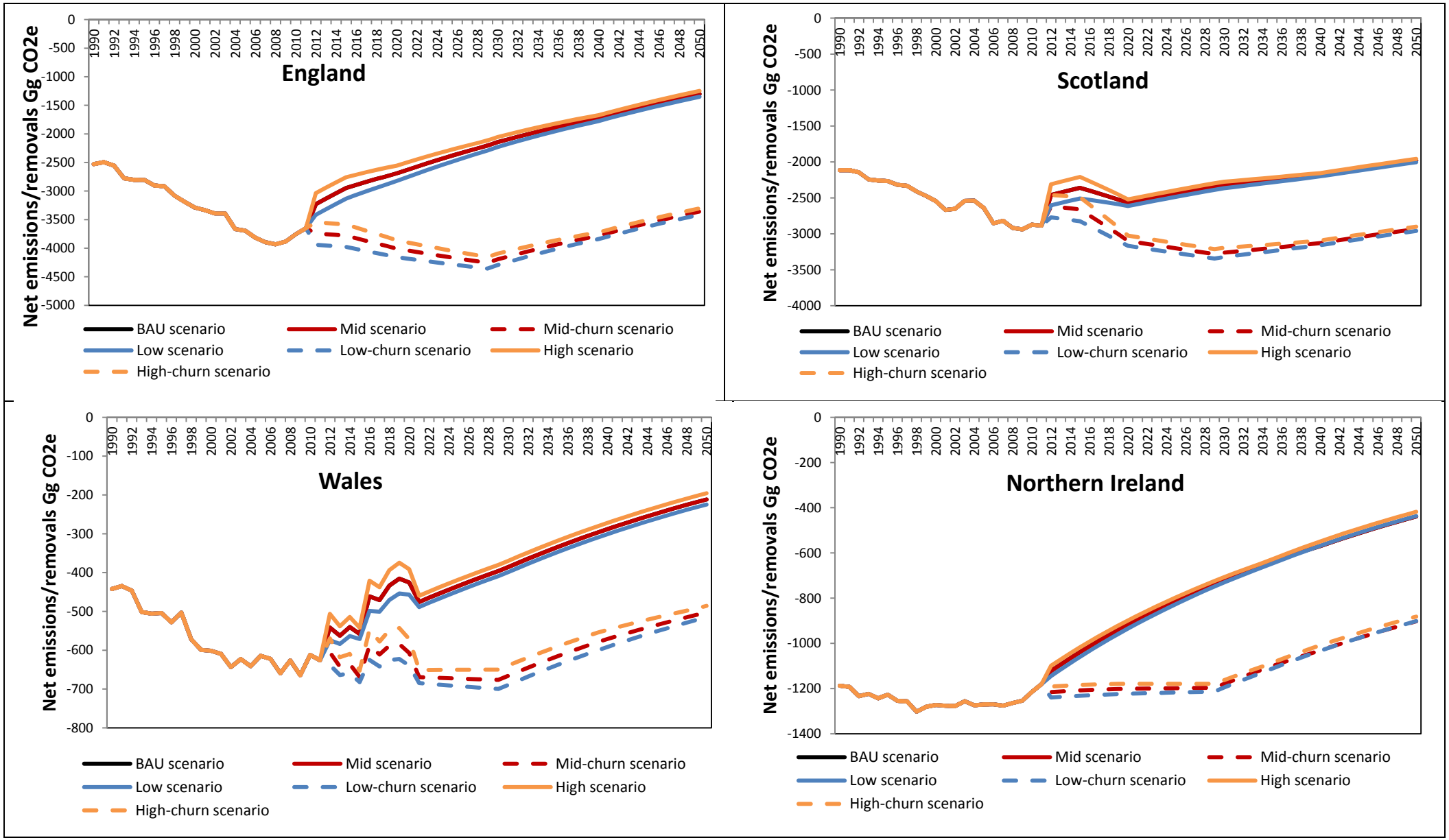

Figure 7: DA Grassland category emissions scenarios 1990-2050

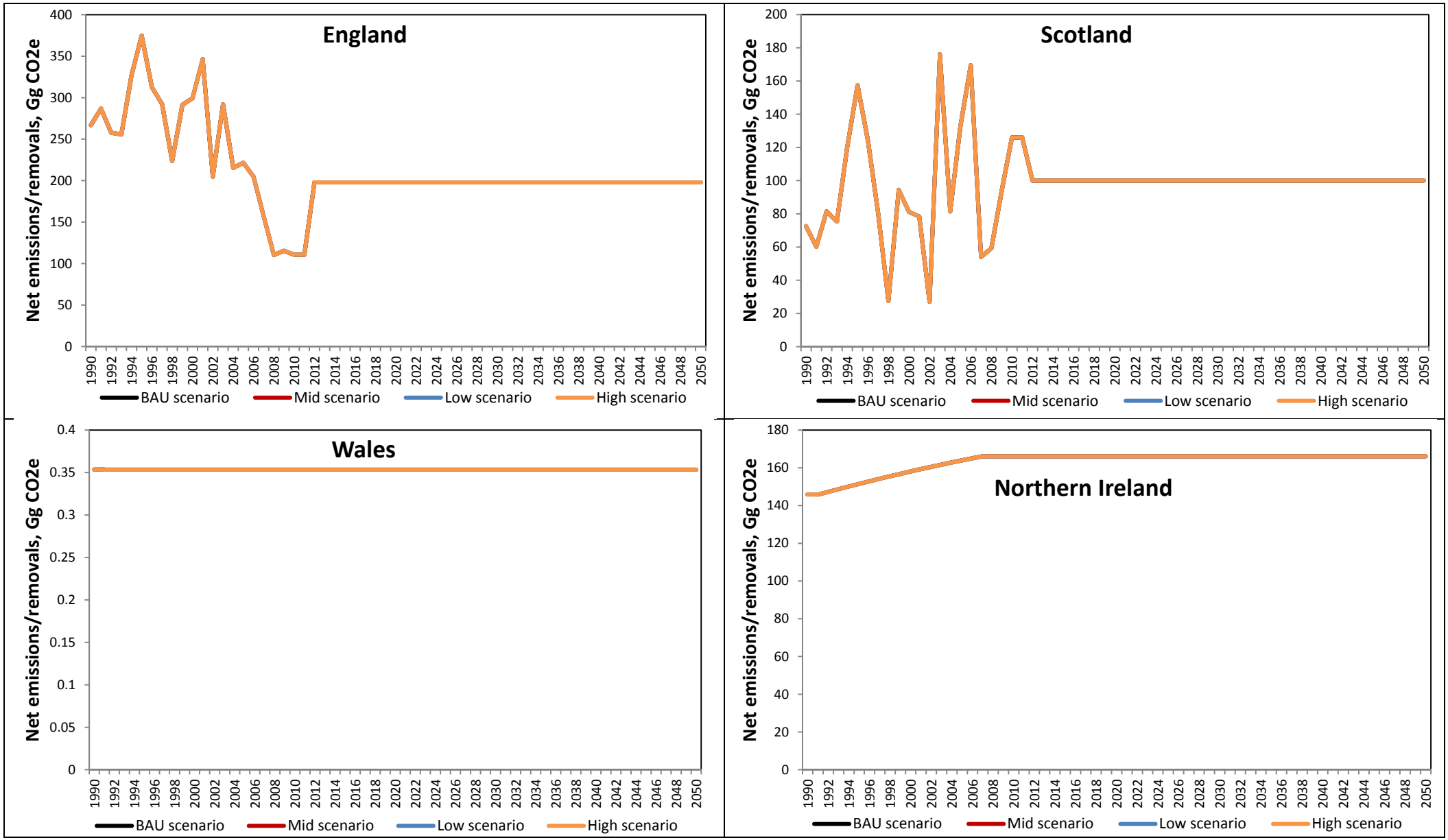

Figure 8: DA Wetlands category emissions scenarios 1990-2050

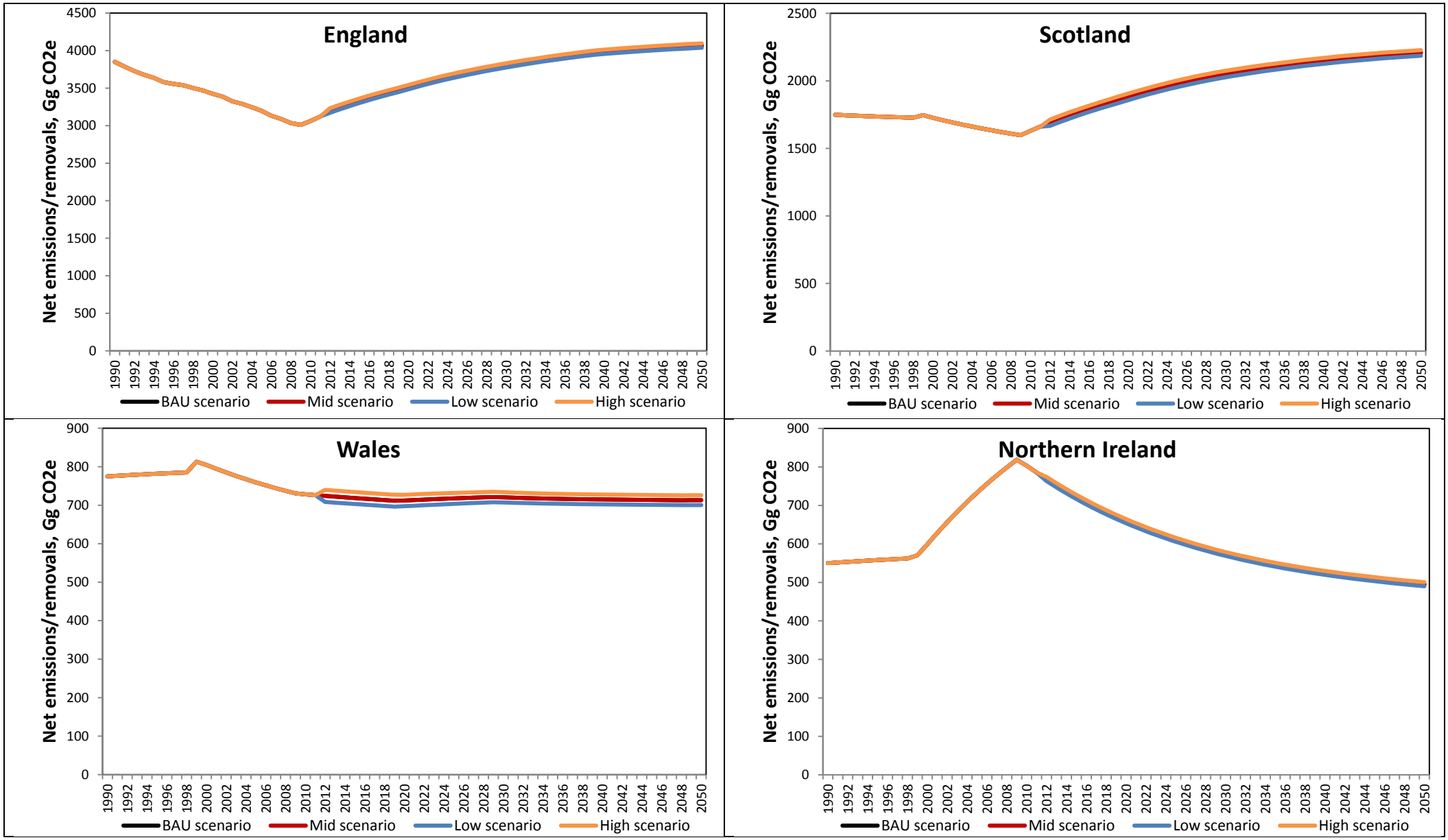

Figure 9: DA Settlements category emissions scenarios 1990-2050

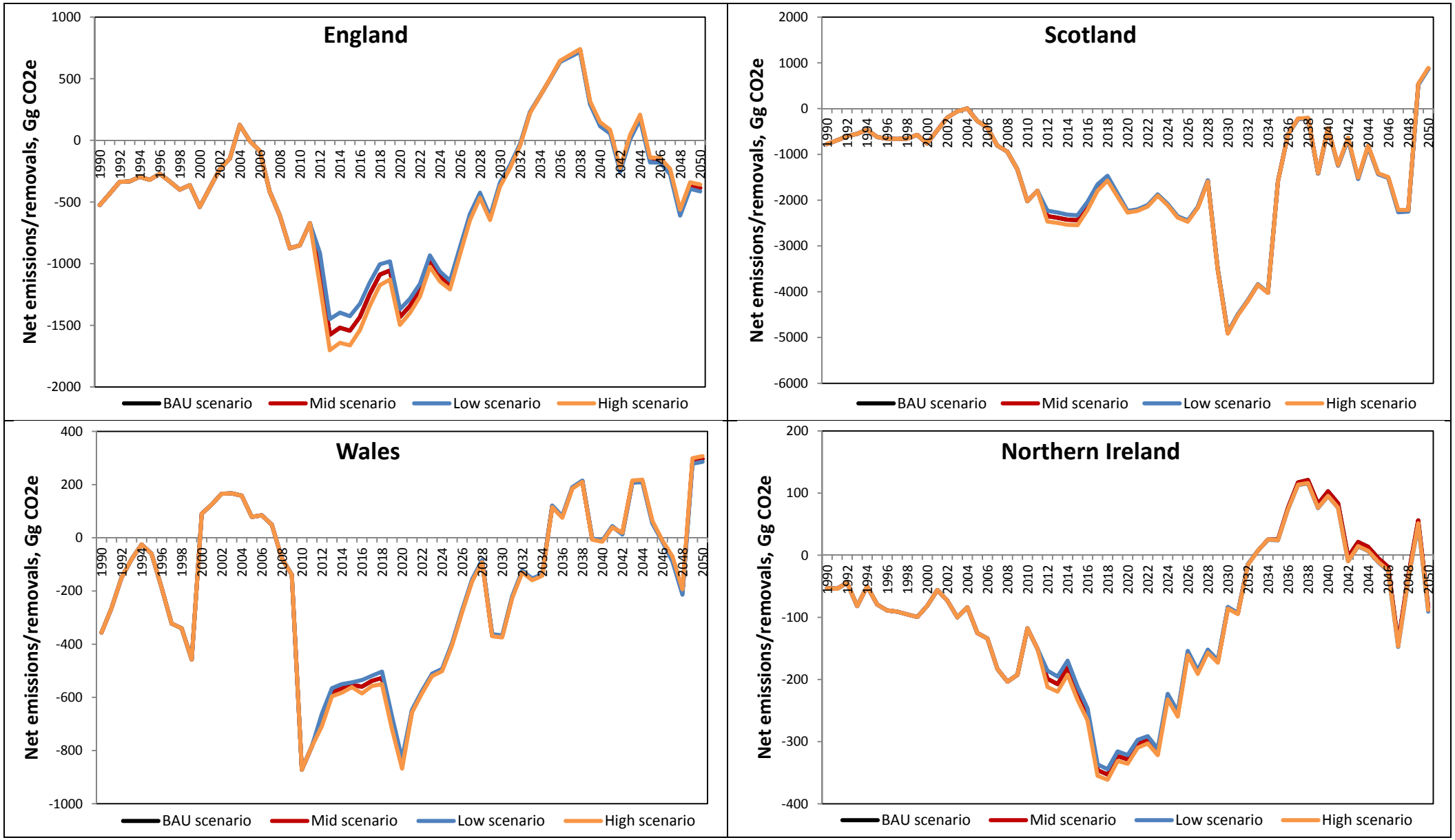

Figure 10: DA Harvested Wood products category emissions scenarios 1990-2050

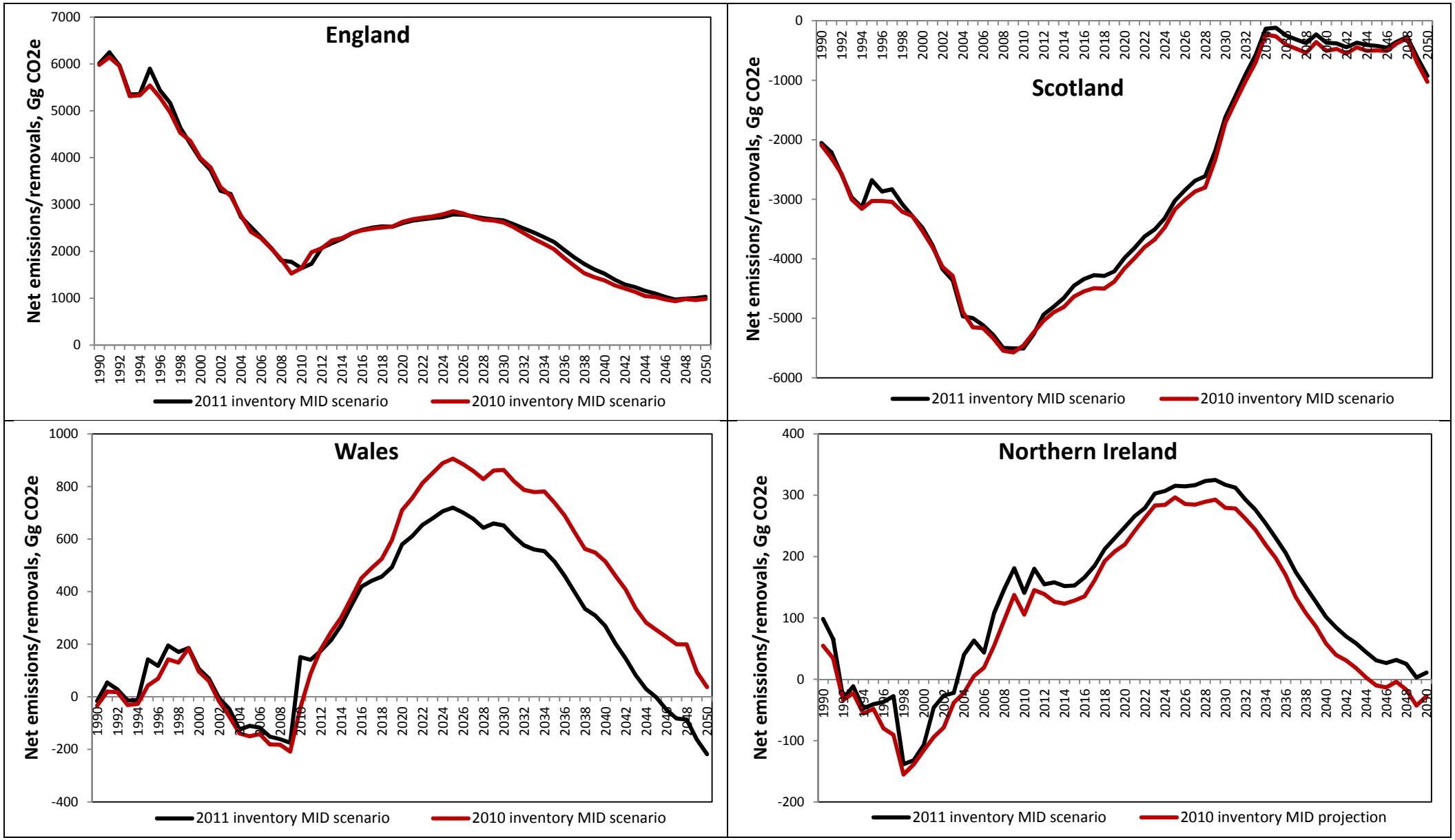

Figure 11: Comparison of the Mid scenarios for the 1990-2010 and 1990-2011 inventory projections to 2050

Further work

The LULUCF projections now have an annual cycle of development and publication, which feed into the Fourth Carbon Budget analysis. The stakeholder group will continue to discuss and modify the assumptions and scenarios as required. Forest Research is undertaking further work looking at the impact of woodland management on net emissions in the Forest Land category. This will be incorporated into the projections once it becomes available. The Defra-funded project SP1113 (reporting in 2014) will look at the impacts of cropland and grassland management on soil carbon, including projections out to 2050, and the results of this project will be incorporated into the LULUCF projections as they become available.

References

Brown, K., Cardenas, L., MacCarthy, J., Murrells, T., Pang, Y., Passant, N., Thistlethwaite, G., Thomson, A., and Webb, N. (2012). UK Greenhouse Gas Inventory, 1990 to 2010: Annual Report for submission under the Framework Convention on Climate Change. AEAT/ENV/R/3264. AEA Technology plc. Didcot, http://naei.defra.gov.uk/reports/reports?report_id=693

DECC (2011) 2050 Pathways Analysis. HM Government. July 2011. http://www.decc.gov.uk/assets/decc/What%20we%20do/A%20low%20carbon%20UK/2050/216-2050-pathways-analysis-report.pdf

DECC (2011). Submission of information on forest management reference levels by United Kingdom of Great Britain and Northern Ireland in accordance with Decision 2/CMP.6

http://unfccc.int/files/meetings/ad_hoc_working_groups/kp/application/pdf/uk_frml.pdf

Annex 1: Members of the projection assumption development group

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- Robert Matthews, Forest Research
- Liam Kelly, Scottish Government
- Sinclair Mayne, NI Government
- Peter Scott, NI Government
- James Skates, Welsh Government

Annex 2: Forestry Commission estimates of afforestation and deforestation

Afforestation rates for the low emission scenario (gross area planted each year, kha)

Year	England	Wales	Scotland	NI
2010	2.3	0.1	2.7	0.2
2011	2.5	1.0	7.5	0.2
2012	3.0	2.0	8.0	0.2
2013	3.7	3.0	8.5	0.2
2014	4.6	4.0	9.0	0.2
2015	5.5	5.0	9.5	0.3
2016	6.4	5.0	10.0	0.4
2017	7.3	5.0	10.0	0.5
2018	8.2	5.0	10.0	0.6
2019	9.1	5.0	10.0	0.7
2020	10.0	5.0	10.0	0.8
2021	10.0	6.0	10.0	0.9
2022	10.0	6.0	10.0	1.0
2023	10.0	6.0	10.0	1.1
2024	10.0	6.0	10.0	1.2
2025	10.0	6.0	10.0	1.3
2026	10.0	6.0	10.0	1.4
2027	10.0	6.0	10.0	1.5
2028	10.0	6.0	10.0	1.6
2029	10.0	6.0	10.0	1.7
2030	10.0	6.0	10.0	1.7
2031	10.0	5.0	10.0	1.7
2032	10.0	5.0	10.0	1.7
2033	10.0	5.0	10.0	1.7
2034	10.0	5.0	10.0	1.7
2035	10.0	5.0	10.0	1.7
2036	10.0	5.0	10.0	1.7
2037	10.0	5.0	10.0	1.7
2038	10.0	5.0	10.0	1.7
2039	10.0	5.0	10.0	1.7
2040	10.0	5.0	10.0	1.7
2041	9.6	5.0	10.0	1.7
2042	9.2	5.0	10.0	1.7
2043	8.8	5.0	10.0	1.7
2044	8.4	5.0	10.0	1.7
2045	8.0	5.0	10.0	1.7
2046	7.6	5.0	10.0	1.7
2047	7.2	5.0	10.0	1.7
2048	6.8	5.0	10.0	1.7
2049	6.4	5.0	10.0	1.7
2050	6.0	5.0	10.0	1.7

Deforestation rates for the Mid emissions scenario (ha per year)

Year	England	Scotland	Wales	N Ireland
2010	1475	1500	318	0
2011	1650	1500	308	170.0
2012	1650	1500	298	164.7
2013	1650	1500	202.7	159.4
2014	1650	1500	218.5	154.2
2015	1650	1500	50	148.9
2016	1550	1300	342.4	143.6
2017	1450	1100	280.6	138.3
2018	1350	900	340	133.0
2019	1250	700	351.3	127.8
2020	1150	500	295.4	122.5
2021	1100	500	36.36	117.2
2022	1050	500	36.4	111.9
2023	1000	500	36.4	106.6
2024	950	500	36.4	101.4
2025	900	500	36.4	96.1
2026	850	500	36.4	90.8
2027	800	500	36.4	85.5
2028	750	500	36.4	80.2
2029	700	500	36.4	75.0
2030	700	500	36.4	69.7
2031	660	480	36.4	64.4
2032	620	460	36.4	59.1
2033	580	440	36.4	53.8
2034	540	420	36.4	48.6
2035	500	400	36.4	43.3
2036	460	380	36.4	38.0
2037	420	360	36.4	32.7
2038	380	340	36.4	27.4
2039	340	320	36.4	22.2
2040	300	300	36.4	17.0
2041	300	300	36.4	17.0
2042	300	300	36.4	17.0
2043	300	300	36.4	17.0
2044	300	300	36.4	17.0
2045	300	300	36.4	17.0
2046	300	300	36.4	17.0
2047	300	300	36.4	17.0
2048	300	300	36.4	17.0
2049	300	300	36.4	17.0
2050	300	300	36.4	17.0