

# Projections of emissions and removals from the UK LULUCF sector to 2050

Contract Report prepared for the Department of Energy and Climate Change (DECC) as part of the contract, *Inventory and Projections of UK Emissions by Sources and Removals by Sinks due to Land Use, Land-Use Change and Forestry (LULUCF)*

DECC Project Code: GA510

CEH Project Code: NEC04637

**Amanda Thomson, Steve Hallsworth & Heath  
Malcolm**

Centre for Ecology and Hydrology, Bush Estate, Penicuik,  
Midlothian, EH26 0QB. [lulucf@ceh.ac.uk](mailto:lulucf@ceh.ac.uk)



**Centre for  
Ecology & Hydrology**

NATURAL ENVIRONMENT RESEARCH COUNCIL

**April 2013**

# Projections of emissions and removals from the UK LULUCF sector to 2050

## 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.
- 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. These projections are calculated at the UK (this report) and Devolved Administration (forthcoming report due to be published in May 2013) levels.
- 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 calculator report (DECC 2010) and take account of land use policies and aspirations.
- The main results are:
  - The UK LULUCF sector is predicted to become a net source of GHG emissions at some point between 2012 and 2050 under all scenarios.
  - All scenarios show an increase from 2012 to a peak in net emissions to the atmosphere around 2035, after which they either stabilize or decline.
  - The LULUCF sector is dominated by CO<sub>2</sub> emissions and removals, although N<sub>2</sub>O emissions also make a significant contribution.
  - The Forest Land, Cropland and Grassland land use categories dominate the trend.
  - The “churn” scenarios increase overall net emissions for all scenarios, as net emissions from Cropland are maintained, rather than declining over time, as in the original scenarios
- Changes in the LULUCF inventory this year include new activities (N<sub>2</sub>O 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 will be given in the 1990-2011 National Inventory Report<sup>1</sup>. The projections follow the same trend as before but the net sink is slightly smaller between 2012 and 2020, and the net source is slightly greater between 2021 and 2050.

---

<sup>1</sup> Available at [http://uk-air.defra.gov.uk/reports/cat07/1304171048\\_ukghgi-90-11\\_main\\_chapters\\_Issue2.pdf](http://uk-air.defra.gov.uk/reports/cat07/1304171048_ukghgi-90-11_main_chapters_Issue2.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.

Projections to 2020 were previously produced under the LULUCF contract. 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<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O)) and removal of CO<sub>2</sub> 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 non-BAU scenarios have also been modified to include continuing cropland-grassland rotations (churn). Projections are reported for the UK: underlying projections have also been developed for each country (England, Scotland, Wales and Northern Ireland) and will be reported after the Devolved Administration inventory report is published in April 2013<sup>2</sup>. The assumptions underlying the projections were developed by a group of representatives from DECC, Defra, CEH and the Devolved Administration governments (see Annex 1).

## 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<sub>2</sub> as negative quantities. Emissions of all three greenhouse gases can be combined together into total CO<sub>2</sub> equivalents, using a Global Warming Potential multiplication factor of 1 for CO<sub>2</sub>, 21 for CH<sub>4</sub> and 310 for N<sub>2</sub>O. 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.

---

<sup>2</sup> Available at [http://uk-air.defra.gov.uk/reports/cat07/1304150833\\_DA\\_LULUCF\\_GHG\\_\\_Inventory\\_report\\_2013\\_final\\_version.pdf](http://uk-air.defra.gov.uk/reports/cat07/1304150833_DA_LULUCF_GHG__Inventory_report_2013_final_version.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 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.

<b>Activity</b>	<b>Description</b>	<b>Inventory category</b>
<i>Afforestation</i>	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 <sub>2</sub> O emissions. Nitrogen fertilization of 'poor' forest soils (a subset of total forest planting) produces N <sub>2</sub> O emissions.	5A Forest Land (carbon stock changes, N <sub>2</sub> O emissions) 5G Harvested Wood Products (carbon stock changes)
<i>Wildfires</i>	Biomass burning emissions from wildfires on forest land, cropland and grassland	5A Forest Land (CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O emissions), 5B Cropland (CH <sub>4</sub> and N <sub>2</sub> O emissions), 5C Grassland (CH <sub>4</sub> and N <sub>2</sub> O emissions)
<i>Land Use Change (soils)</i>	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)
<i>Land Use Change (non-forest biomass)</i>	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 <i>Afforestation</i> and <i>Deforestation</i> activities.	5B Cropland (carbon stock changes) 5C Grassland (carbon stock changes) 5E Settlements (carbon stock changes)
<i>N<sub>2</sub>O emissions from LUC to Cropland</i>	N <sub>2</sub> O emissions due to disturbance associated with land use conversion from forest land and grassland to cropland .	5B Cropland (N <sub>2</sub> O emissions)
<i>Deforestation</i>	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 <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O emissions) 5C Grassland (soil carbon stock changes; CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O emissions) 5E Settlements (soil carbon stock changes; CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O emissions) 5G Harvested Wood Products (carbon stock changes)
<i>Liming</i>	Emissions of CO <sub>2</sub> from the application of lime (dolomite and limestone) to agricultural land.	5B Cropland (CO <sub>2</sub> emissions) 5C Grassland (CO <sub>2</sub> emissions)
<i>Lowland drainage</i>	Carbon stock losses from historic drainage of lowland wetlands (in England only)	5B Cropland (soil carbon stock changes)

<i>Yield improvements</i>	Annual increase in cropland biomass due to yield improvements (improved species strains or management).	5B Cropland (biomass carbon stock changes)
<i>Peat extraction</i>	On-site emissions of CO <sub>2</sub> and N <sub>2</sub> O from peat extraction (abandoned, active and newly established) and off-site emissions of CO <sub>2</sub> from the decomposition of horticultural peat.	5D Wetlands (soil carbon stock changes; CO <sub>2</sub> and N <sub>2</sub> O 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<sub>2</sub>O 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 UK

<b>Activity</b>	<b>Business-As-Usual emission scenario</b>	<b>Low emission scenario</b>	<b>Mid emission scenario</b>	<b>High emission scenario</b>	<b>Reasons for assumptions</b>
<i>Afforestation</i>	Afforestation rates remain at same level as in 2010. UK: 5.143 kha p.a.	Increased afforestation rates from 2012 onwards (see Annex 2) UK: increasing from 13.2 to 27.7 kha p.a. by 2030, 26.7 kha p.a. 2031-2040, reducing to 24.7 kha p.a. by 2045	Afforestation rates are assumed to be midway between the Low and the High emission scenarios. UK: increasing from 10.7 kha p.a. to 17.9 kha p.a. 2012-2030, 17.4 kha p.a. 2031-2040, declining to 16.4 kha by 2045	Afforestation rates remain at same level as in 2011 UK: 8.185 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.
<i>Wildfires (forest and non-forest)</i>	Use Mid emission scenario.	5 <sup>th</sup> percentile of 1990-2011 time series for each vegetation type	Average of previous 10 years (2002-2011) for each vegetation type	95 <sup>th</sup> percentile of 1990-2011 time series for each vegetation type	Simplification of previous trend extrapolation with autoregression- gave misleading impression of forecasting precision
<i>Land Use Change (soils)</i>	Use Mid emission scenario	Based on trajectory C (2050 calculator). UK: 2.5 kha p.a. converted to Cropland from Grassland (Wales only), Settlement area increases 17.5 kha p.a., Grassland area decreases 38-47 kha p.a.  Grassland-Cropland "churn" each way UK: 82.7 kha p.a.	Land use change rates mid-way between the Low and High scenario rates. UK: 5.5 kha p.a. converted to cropland from grassland (Wales only), Settlement area increases 17.5 kha p.a., Grassland area decreases 32.9 – 38.3 kha p.a.  Grassland-Cropland "churn" each way UK: 82.7 kha p.a.	Based on trajectory B (2050 calculator). UK: 10.0 kha p.a. converted to cropland from grassland (Wales only), Settlement area increases 17.5 kha p.a., Grassland area decreases 32.7 kha p.a.  Grassland-Cropland "churn" each way UK: 82.7 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.

<i>Land Use Change (non-forest biomass)</i>	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)
<i>N<sub>2</sub>O emissions from LUC to Cropland</i>	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.
<i>Deforestation</i>	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.
<i>Liming</i>		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)
<i>Lowland drainage</i>		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.



<i>Yield improvements</i>		Flux remains at 2011 value	Flux remains at 2011 value	Flux remains at 2011 value	No clear trend in this activity.
<i>Peat extraction</i>		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 2011-2050

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 3-5. 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.

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

Country	Land use category	2011 area, kha	2020 area, kha	2030 area, kha	2040 area, kha	2050 area, kha	% of land area in 2010	% of land area in 2050
UK	Forest land	3,063	3,225	3,487	3,747	3,985	13%	16%
24,415 kha	Cropland	5,672	5,695	5,720	5,745	5,770	23%	24%
	Grassland	13,338	12,996	12,537	12,077	11,639	55%	48%
	Wetland	171	171	171	171	171	1%	1%
	Settlement	1,916	2,074	2,249	2,423	2,598	8%	11%
	Other	255	255	252	252	252	1%	1%

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

Country	Land use category	2011 area, kha	2020 area, kha	2030 area, kha	2040 area, kha	2050 area, kha	% of land area in 2010	% of land area in 2050
<b>UK</b>	Forest land	3,063	3,153	3,301	3,452	3,593	13%	15%
24,415 kha	Cropland	5,672	5,722	5,777	5,832	5,887	23%	24%
	Grassland	13,338	13,041	12,664	12,283	11,912	55%	49%
	Wetland	171	171	171	171	171	1%	1%
	Settlement	1,916	2,074	2,249	2,424	2,599	8%	11%
	Other	255	255	253	253	253	1%	1%

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

Country	Land use category	2011 area, kha	2020 area, kha	2030 area, kha	2040 area, kha	2050 area, kha	% of land area in 2010	% of land area in 2050
<b>UK</b>	Forest land	3,063	3,081	3,117	3,159	3,204	13%	13%
24,415 kha	Cropland	5,672	5,763	5,863	5,963	6,063	23%	25%
	Grassland	13,338	13,045	12,720	12,395	12,068	55%	49%
	Wetland	171	171	171	171	171	1%	1%
	Settlement	1,916	2,074	2,249	2,423	2,598	8%	11%
	Other	255	281	295	303	311	1%	1%

Projected emissions of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O and CO<sub>2</sub> equivalents for the UK LULUCF sector are shown in Tables 6-9. Graphs of greenhouse gas emissions for the whole LULUCF sector and for the individual land use categories are shown in Figures 1-10.

The LULUCF sector, at the UK level, is predicted to become a net source of GHG emissions at some point between 2012 and 2050 under all scenarios (Figure 1). This occurs at different times under different scenarios: as early as 2013 under the High-churn scenario, but not until 2029 under the Low scenario (where the UK LULUCF sector becomes a net sink again by 2037). The Business-As-Usual scenario follows a similar trend to the High scenario (unsurprisingly, as they use similar afforestation assumptions). All scenarios show an increase from 2012 to a peak in net emissions to the atmosphere around 2035, after which they either stabilize (High, High-churn and BAU scenarios) or decline (the Mid and Low scenarios). The LULUCF sector is dominated by CO<sub>2</sub> emissions and removals (Figure 2), although N<sub>2</sub>O 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.

The Forest Land, Cropland and Grassland categories dominate the trend. Forest Land (Figure 5) is a shrinking net sink (due to a combination of forest management and decreasing age distribution – discussed in more detail in the National Inventory report) and is projected to become a net source of GHG emissions in 2029-2035 and 2047 under the BAU and High scenarios. 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) are a small component of the LULUCF sector and no detailed assumptions have been made. 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. The HWP category (Figure 10) 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.

The “churn” scenarios demonstrate the impact that cropland-grassland turnover can have upon overall GHG emissions (through carbon stock changes and N<sub>2</sub>O emissions arising from conversion to Cropland). They increase overall net emissions 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.

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<sub>2</sub>O 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 will be given in the 1990-2011 National Inventory Report, due to be published in April 2013. Figure 11 illustrates the impact that these changes have had upon the Mid scenario projection: the projection follows the same

trend as before but the net sink is slightly smaller between 2012 and 2020, and the net source is slightly greater between 2021 and 2050.

Table 6: LULUCF emissions and removals of CO<sub>2</sub> 1990-2050

Scenario	Country	1990 emissions/removals, Gg CO <sub>2</sub>	2011 emissions/removals, Gg CO <sub>2</sub>	2020 emissions/removals, Gg CO <sub>2</sub>	2030 emissions/removals, Gg CO <sub>2</sub>	2040 emissions/removals, Gg CO <sub>2</sub>	2050 emissions/removals, Gg CO <sub>2</sub>
Low	UK	3168.61	-3835.59	-1837.27	4.40	-1268.01	-3795.33
Mid	UK	3168.61	-3835.59	-965.13	1769.12	1533.77	51.14
High	UK	3168.61	-3835.59	-295.71	3396.32	4205.05	3760.50
Low_churn	UK	3168.61	-3835.59	1273.19	4369.99	3531.82	995.67
Mid_churn	UK	3168.61	-3835.59	2232.69	6255.35	6467.46	4984.12
High_churn	UK	3168.61	-3835.59	3388.66	8321.77	9560.51	9106.33

Table 7: LULUCF emissions and removals of CH<sub>4</sub> 1990-2050

Scenario	Country	1990 emissions/removals, Gg CH <sub>4</sub>	2011 emissions/removals, Gg CH <sub>4</sub>	2020 emissions/removals, Gg CH <sub>4</sub>	2030 emissions/removals, Gg CH <sub>4</sub>	2040 emissions/removals, Gg CH <sub>4</sub>	2050 emissions/removals, Gg CH <sub>4</sub>
Low	UK	1.15	1.36	1.62	1.32	1.08	1.08
Mid	UK	1.15	1.36	2.00	1.57	1.20	1.19
High	UK	1.15	1.36	3.06	2.48	2.01	2.00
Low_churn	UK	1.15	1.36	1.62	1.32	1.08	1.08
Mid_churn	UK	1.15	1.36	2.00	1.57	1.20	1.19
High_churn	UK	1.15	1.36	3.06	2.48	2.01	2.00

Table 8: LULUCF emissions and removals of N<sub>2</sub>O 1990-2050

Scenario	Country	1990 emissions/removals, Gg N <sub>2</sub> O	2011 emissions/removals, Gg N <sub>2</sub> O	2020 emissions/removals, Gg N <sub>2</sub> O	2030 emissions/removals, Gg N <sub>2</sub> O	2040 emissions/removals, Gg N <sub>2</sub> O	2050 emissions/removals, Gg N <sub>2</sub> O
Low	UK	2.73	1.91	1.54	1.09	0.83	0.68
Mid	UK	2.73	1.91	1.57	1.12	0.86	0.71
High	UK	2.73	1.91	1.66	1.23	0.97	0.82
Low_churn	UK	2.73	1.91	2.50	2.56	2.61	2.64
Mid_churn	UK	2.73	1.91	2.50	2.54	2.58	2.61
High_churn	UK	2.73	1.91	2.61	2.70	2.75	2.79

Table 9: LULUCF emissions and removals of CO<sub>2</sub> equivalents 1990-2050

Scenario	Country	1990 emissions/removals, Gg CO <sub>2</sub> e	2011 emissions/removals, Gg CO <sub>2</sub> e	2020 emissions/removals, Gg CO <sub>2</sub> e	2030 emissions/removals, Gg CO <sub>2</sub> e	2040 emissions/removals, Gg CO <sub>2</sub> e	2050 emissions/removals, Gg CO <sub>2</sub> e
Low	UK	4038.92	-3215.76	-1325.22	370.70	-988.61	-3562.81
Mid	UK	4038.92	-3215.76	-437.60	2150.20	1825.34	295.04
High	UK	4038.92	-3215.76	283.17	3830.39	4549.19	4057.08
Low_churn	UK	4038.92	-3215.76	2081.18	5191.05	4362.31	1837.70
Mid_churn	UK	4038.92	-3215.76	3048.91	7077.09	7291.85	5816.75
High_churn	UK	4038.92	-3215.76	4263.49	9210.61	10455.75	10012.42

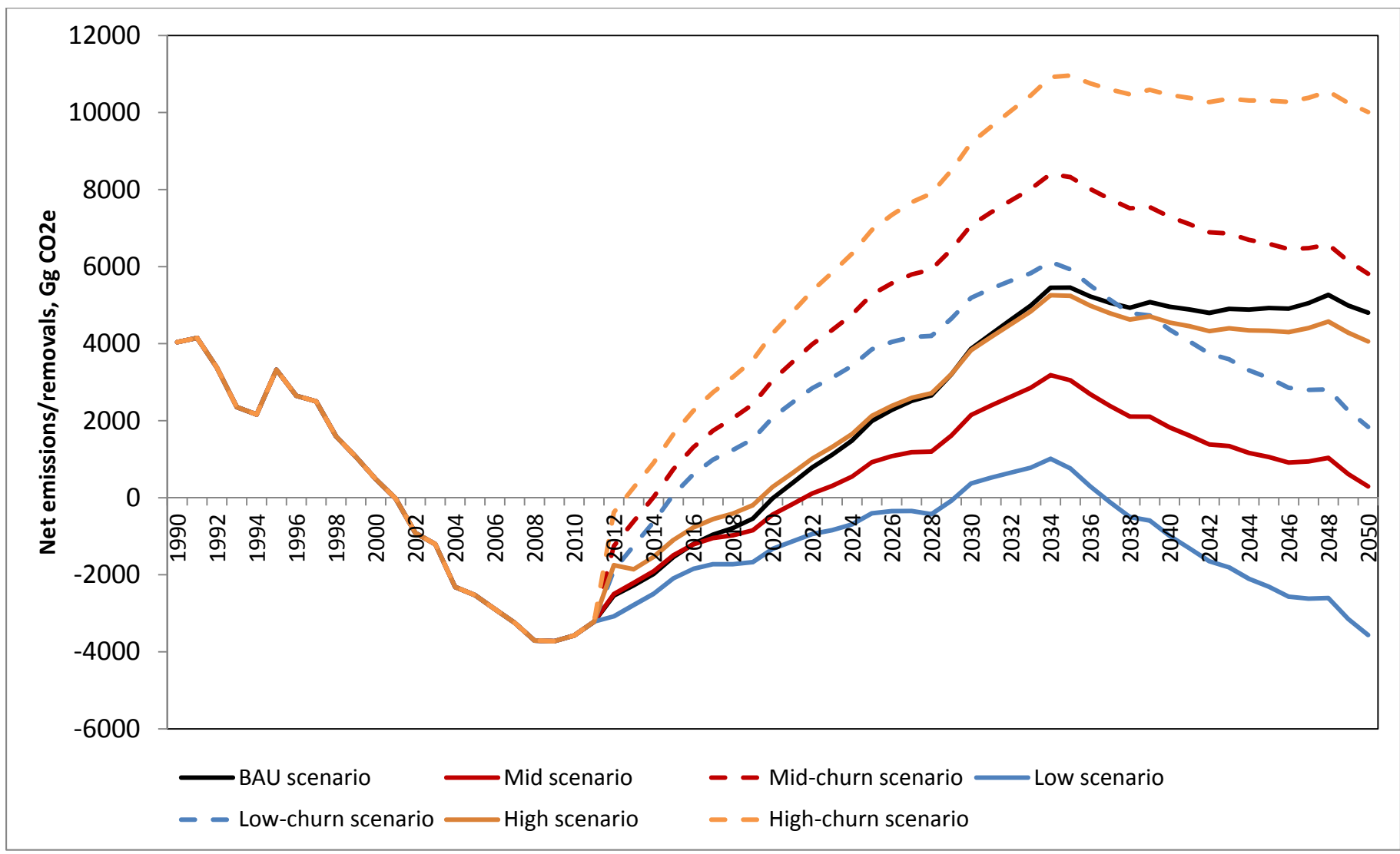


Figure 1: UK LULUCF sector CO<sub>2</sub> equivalents emissions scenarios 1990-2050

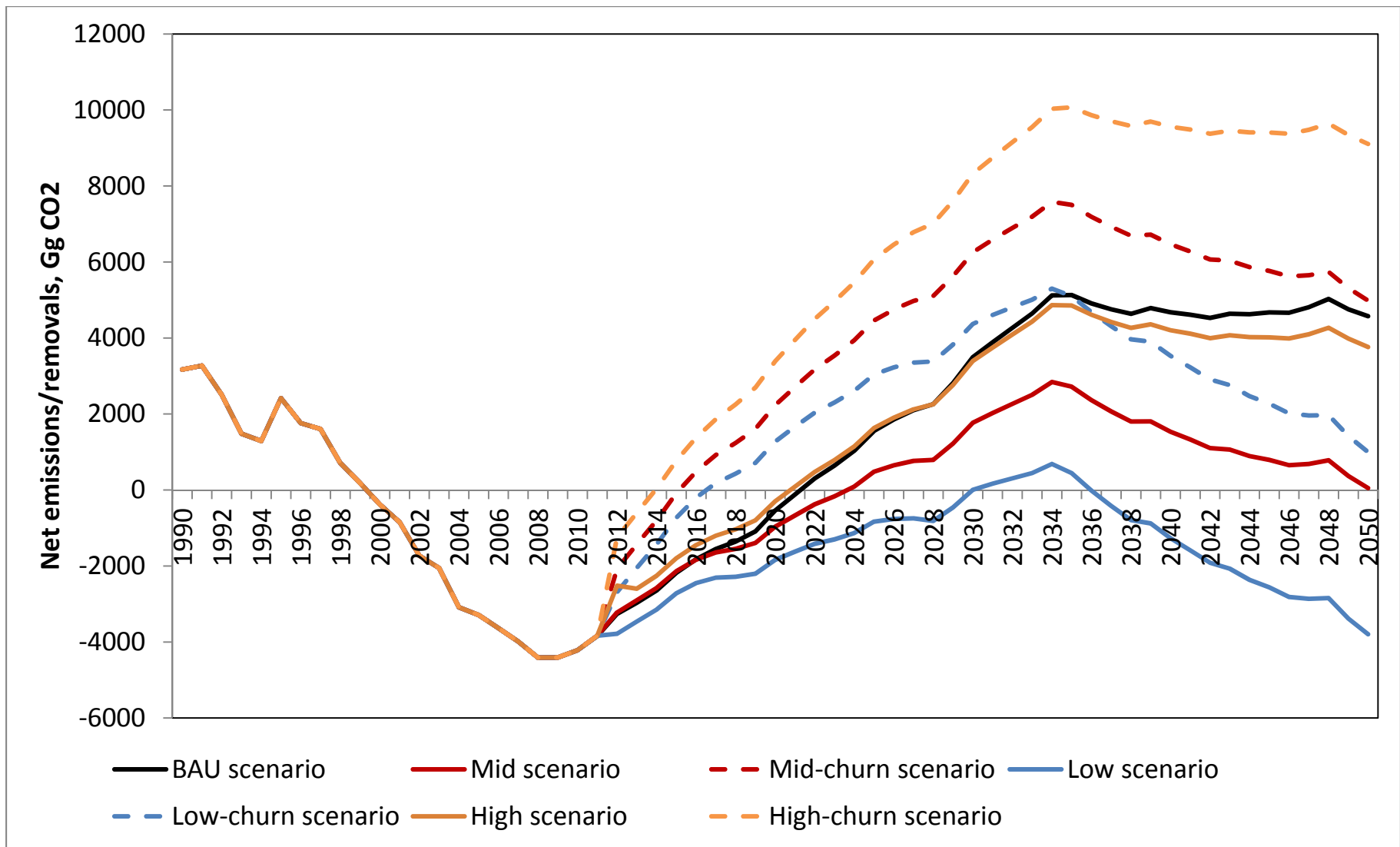


Figure 2: UK LULUCF sector CO<sub>2</sub> emissions scenarios 1990-2050,



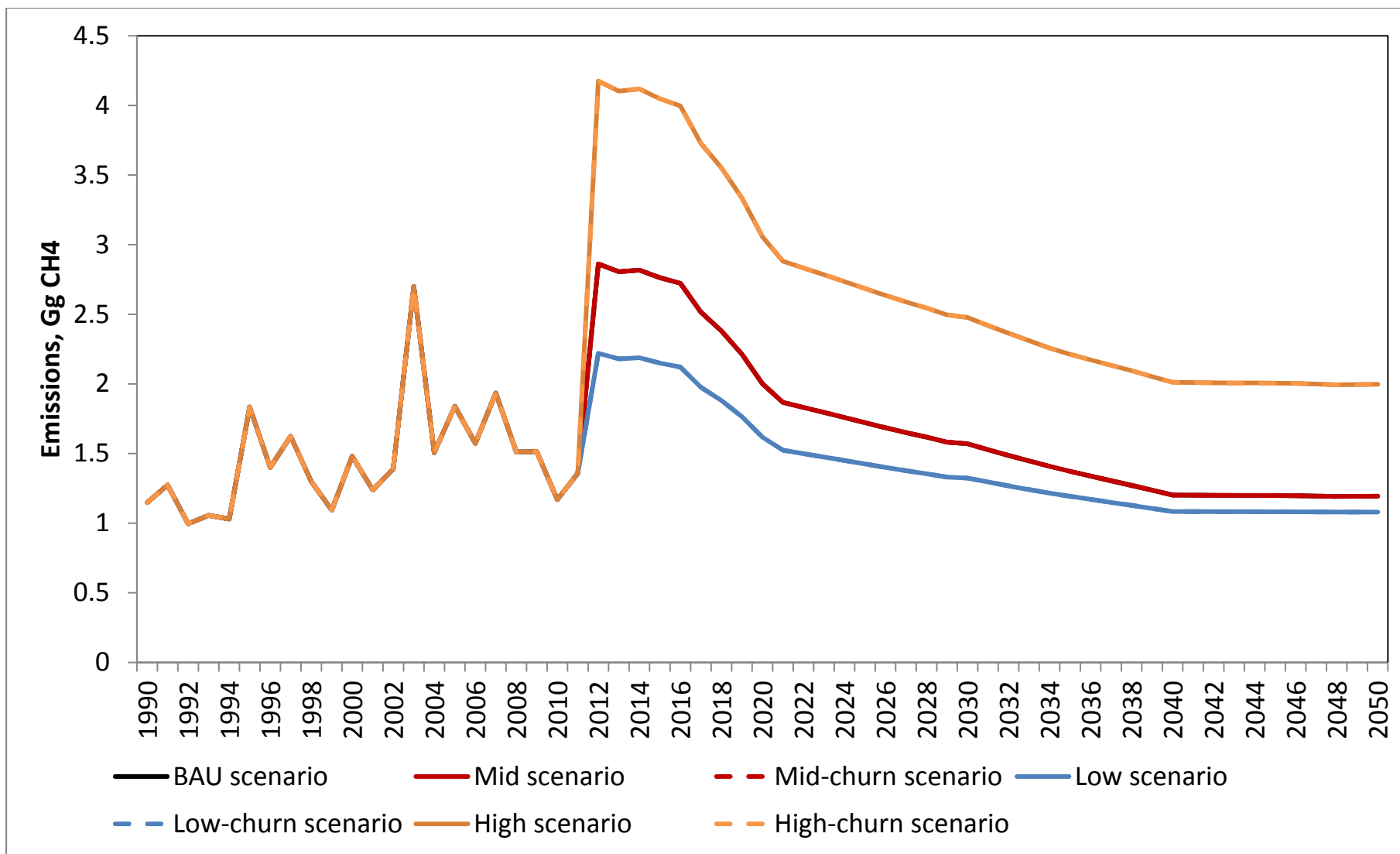


Figure 3: UK LULUCF sector CH<sub>4</sub> emissions scenarios 1990-2050

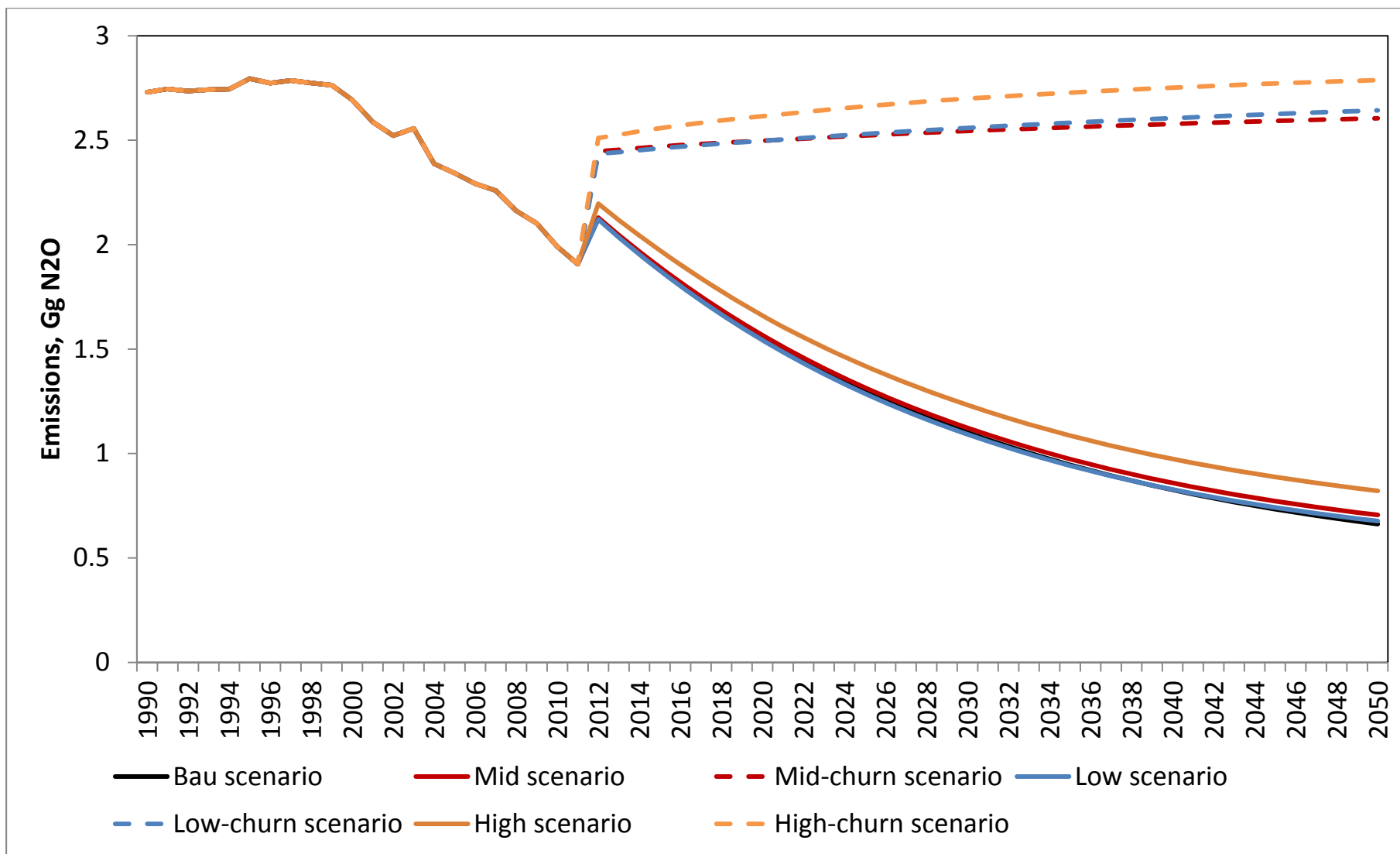


Figure 4: UK LULUCF sector N<sub>2</sub>O emissions scenarios 1990-2050

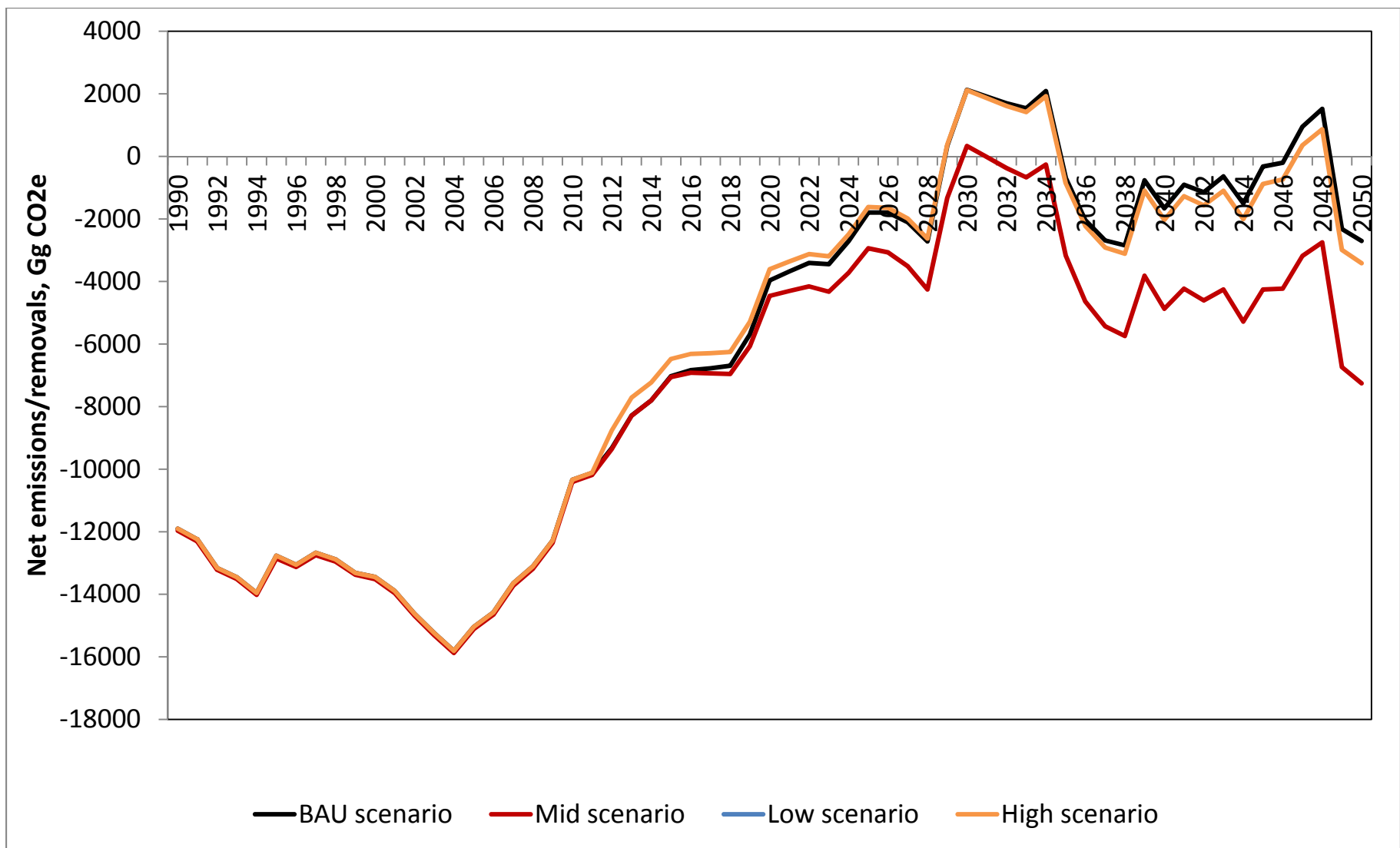


Figure 5: UK Forestland category emissions scenarios 1990-2050

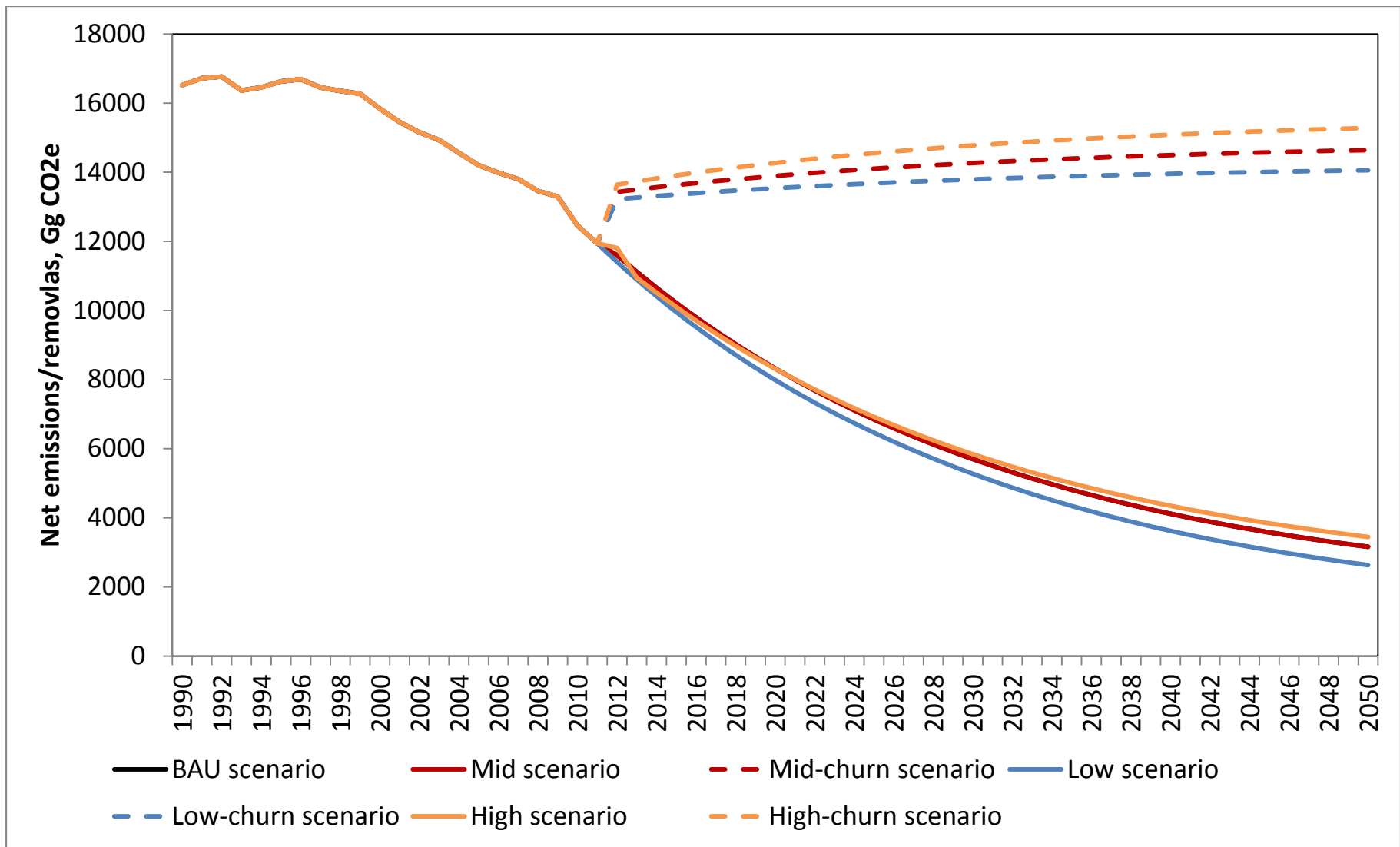


Figure 6: UK Cropland category emissions scenarios 1990-2050

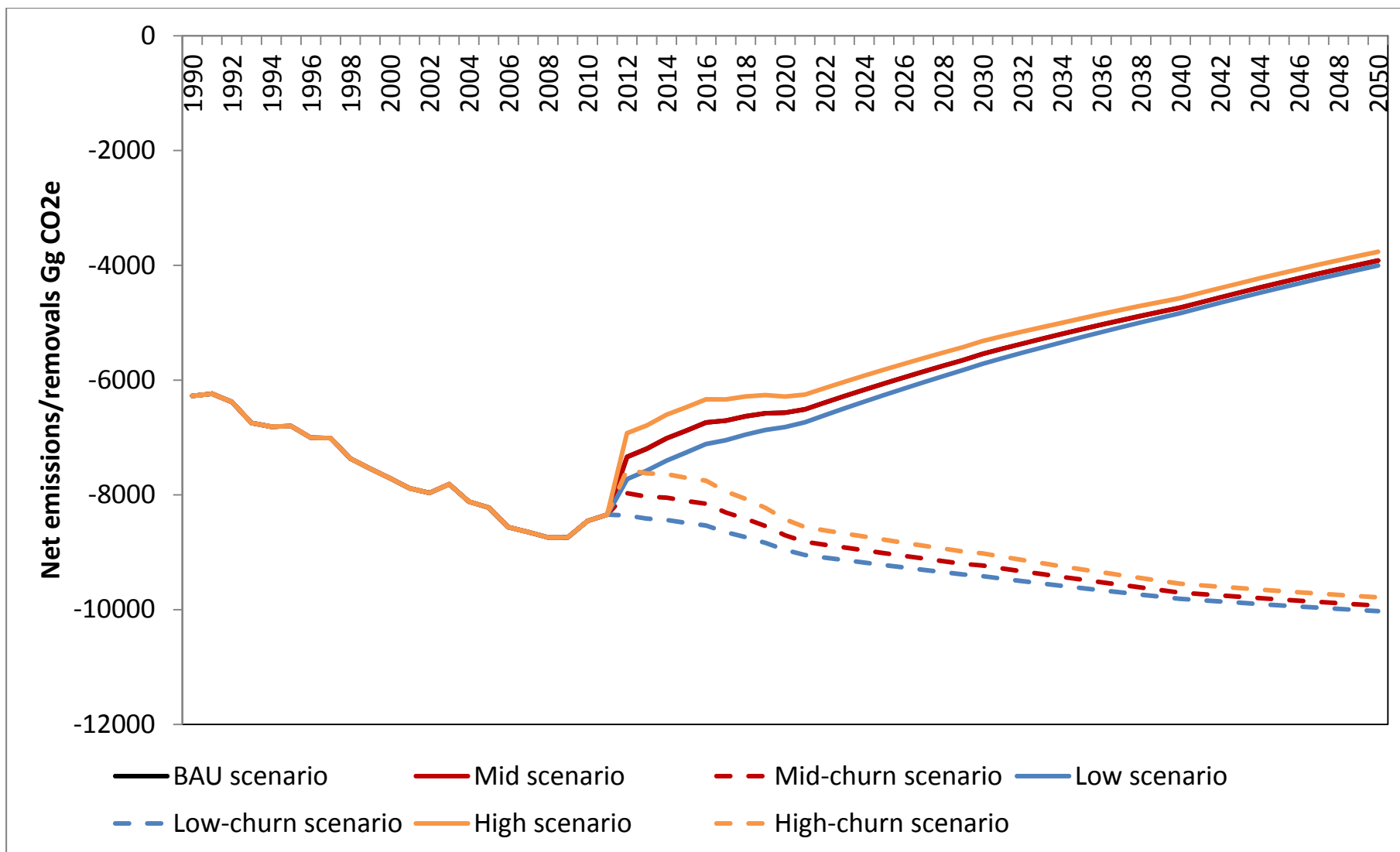


Figure 7: UK Grassland category emissions scenarios 1990-2050

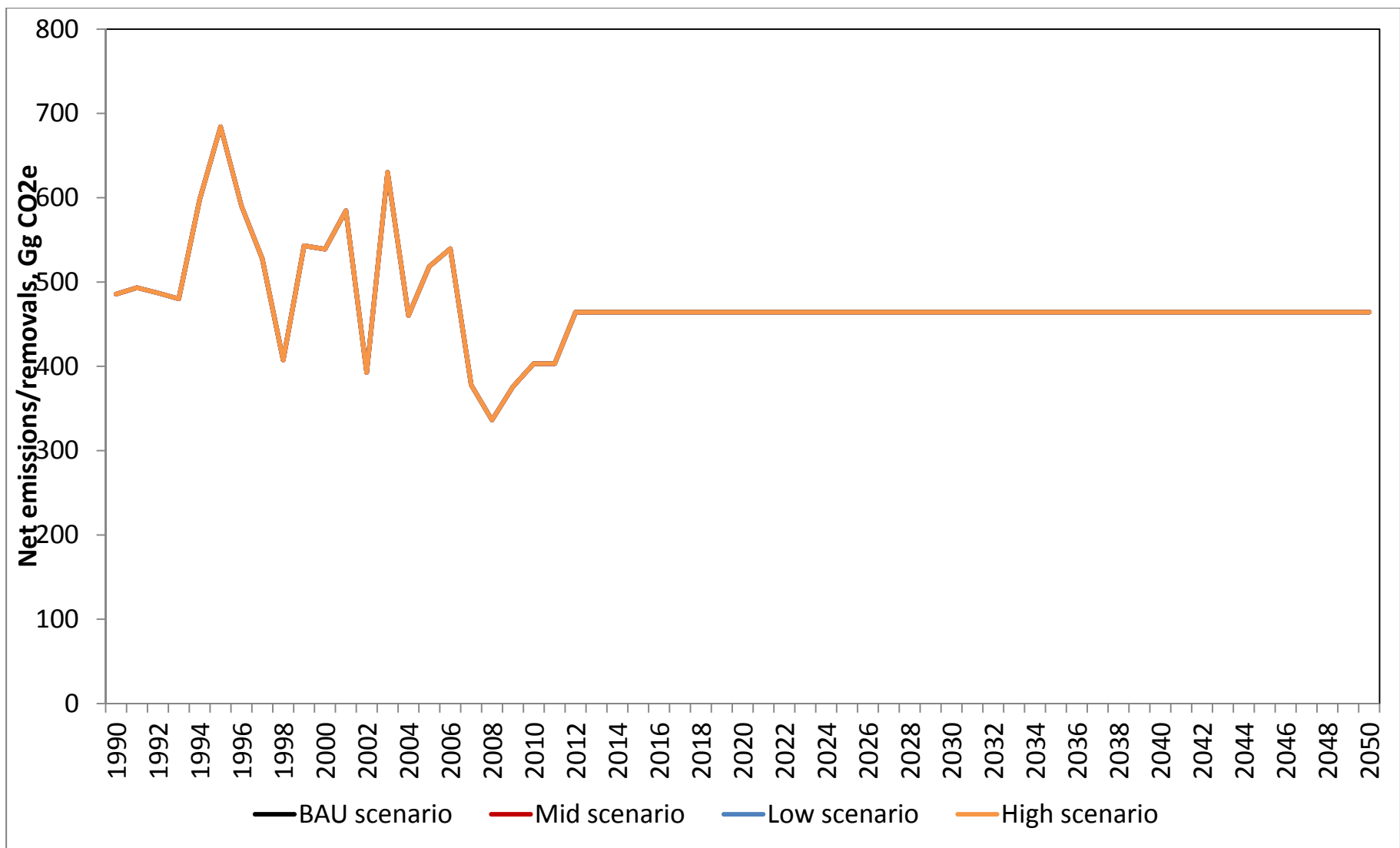


Figure 8: UK Wetlands category emissions scenarios 1990-2050

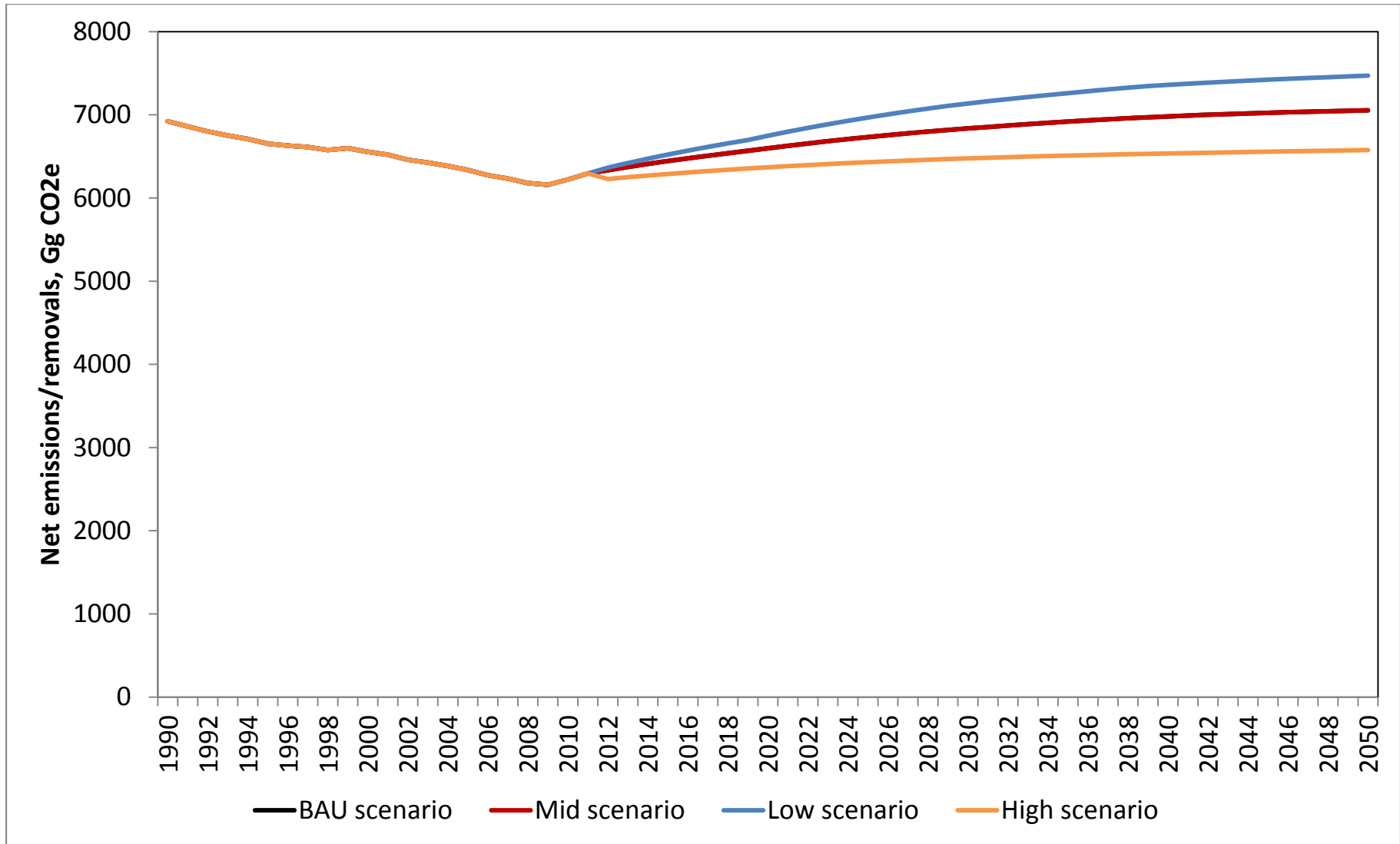


Figure 9: UK Settlements category emissions scenarios 1990-2050

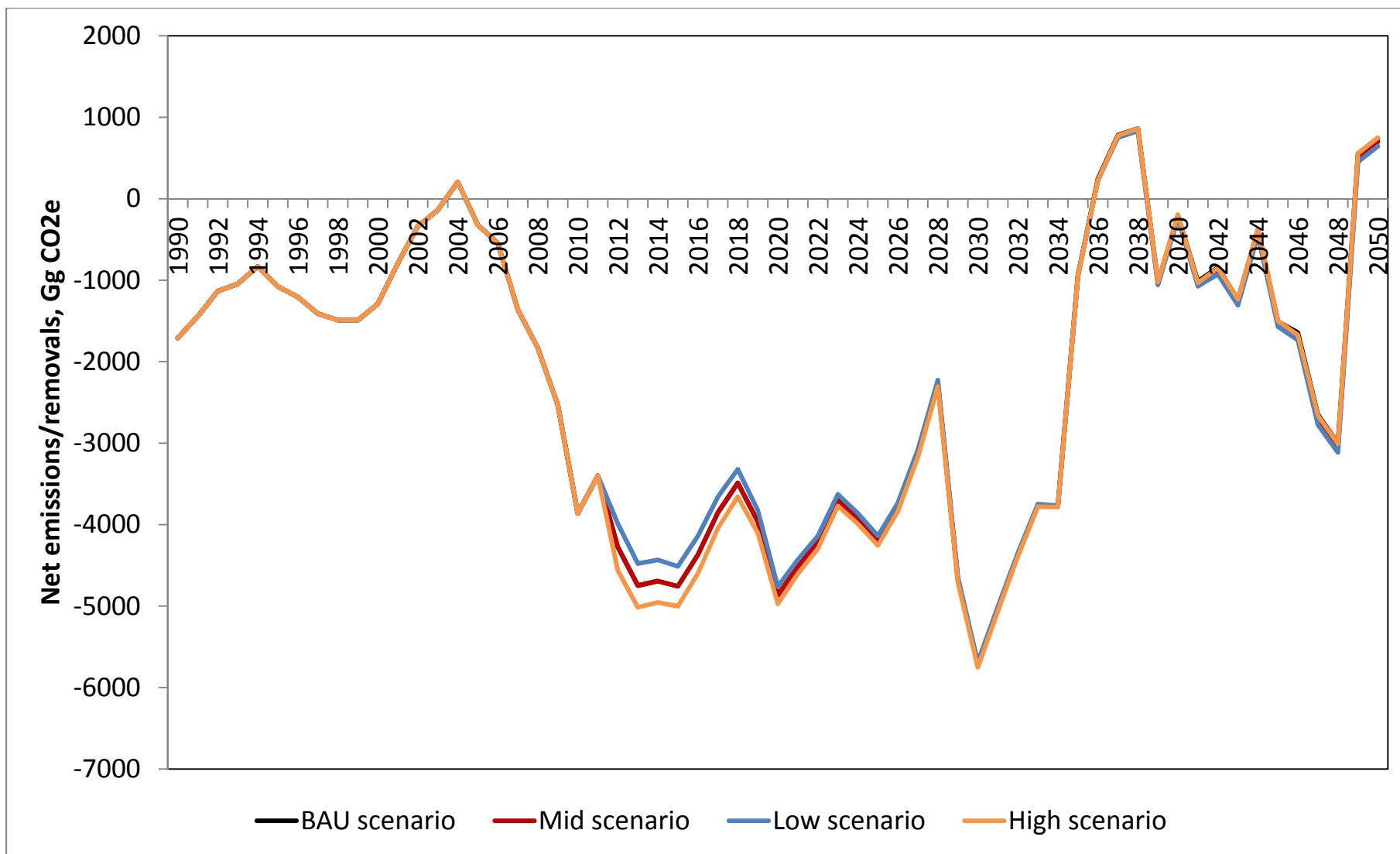


Figure 10: UK Harvested Wood products category emissions scenarios 1990-2050



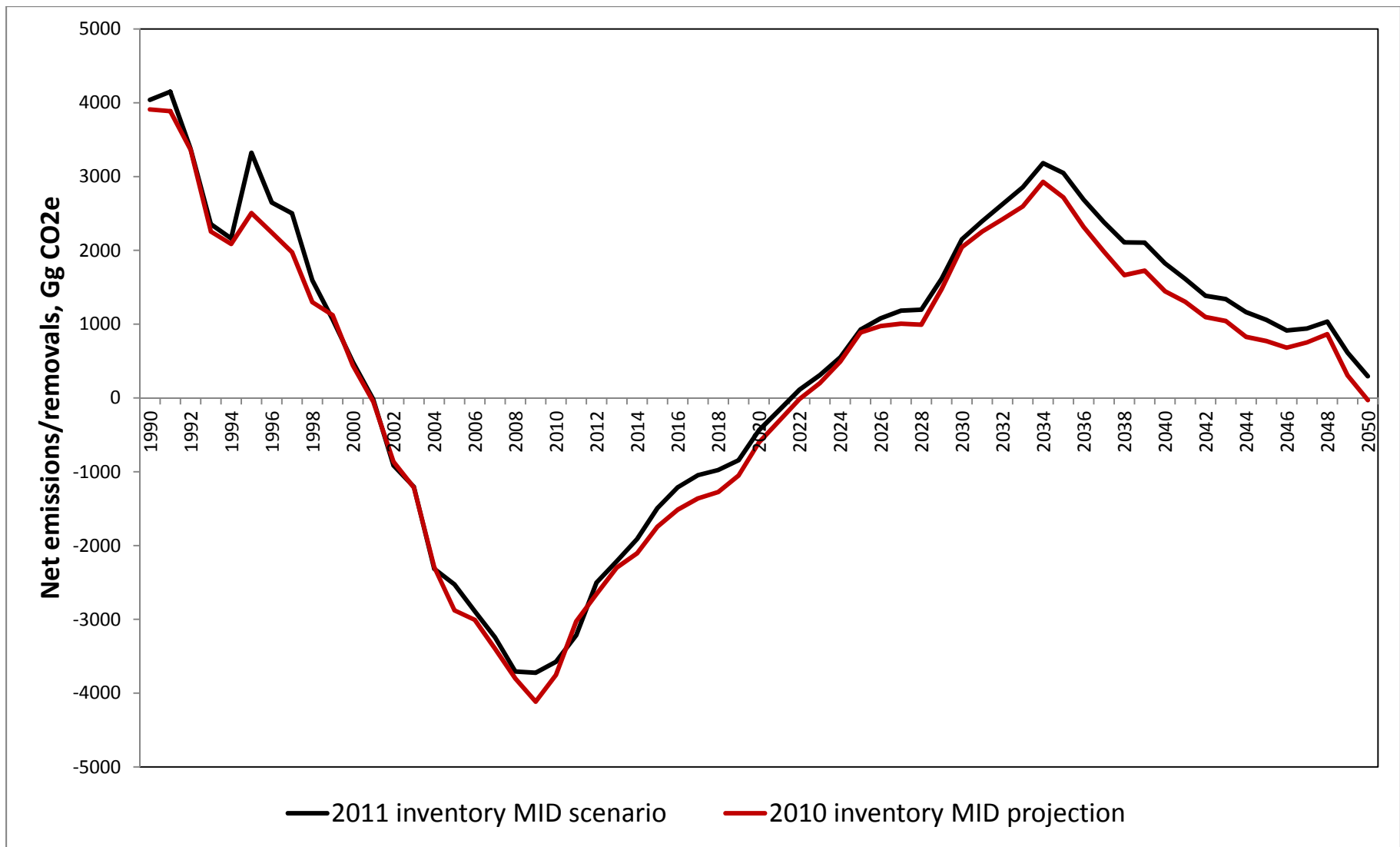


Figure 11: Comparison of the Mid scenarios for the 1990-2010 and 1990-2011 inventory projections to 2050

## 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

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>

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

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

## Annex 1: Members of the projection assumption development group

- Matthew Brown, formerly at Defra
- Judith Stuart, Defra
- Marjorie Roome, DECC
- Philip Earl, Defra
- Bill Parish, Defra
- Marion Rawlins, Defra
- Daniele Viappiani, Defra
- Jim Penman, DECC
- Sekai Ngarize, DECC
- Aimee Griffiths, DECC
- Amanda Thomson, CEH
- Heath Malcolm, CEH
- Mark Broadmeadow, Forestry Commission
- Robert Matthews, Forest Research
- Liam Kelly, Scottish Govt
- Sinclair Mayne, NI Govt
- Peter Scott, NI Govt
- James Skates, Welsh Assembly Govt

## 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