Forest Research

Carbon impacts of biomass consumed in the EU: quantitative assessment

Final report, project: DG ENER/C1/427
Part B: Appendices

December 2015

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Cover photographs

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Part B: Appendices

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Contents

Introduction to Part B

This document is a supplement to the main final report (Part A) for a European Commission project, ENER/C1/427-2012 on 'Carbon impacts of biomass consumed in the EU'. The principal objective of this project is to deliver a qualitative and quantitative assessment of the direct and indirect greenhouse gas (GHG) emissions associated with different types of solid and gaseous biomass used in electricity and heating/cooling in the EU under a number of scenarios focussing on the period to 2030, but also extended to 2050, in order to provide objective information on which to base further development of policy on the role of biomass as a source of energy with low associated GHG emissions.

This supplementary report consists of 12 appendices, which provide information, data, analyses and results supporting the material presented in the main report. Also included are several descriptions of worked examples of the calculations involved in this project in the preparation of datasets and the application of complex models of the agricultural and forestry sectors. These are included as a contribution towards transparency in the methods and calculations employed in the quantitative assessment carried out in this project.

It is important to understand that the material in the appendices in this document needs to be considered in close conjunction with the relevant discussions in the main final report. The table below provides an outline of the appendices and references to the relevant sections in the main final report.

Description of contents of appendices in this report

Appendix number	Description	References to main report
1	A worked example illustrating the application of a decision tree for making qualitative risk assessments of GHG emissions associated with forest bioenergy sources.	Section 2.4
2	A review of previous studies of potentials for biomass supply for energy from within the EU and, in some cases, globally.	Sections 3.1, 3.5 and 3.6
3	A description providing an introduction to, and overview of, a key study of potentials for biomass supply from forest sources (EFSOS II).	
4	A description providing an introduction to, and overview of, a key study of potentials for biomass supply from agricultural sources (Biomass Futures).	
5	A description providing an introduction to, and overview of, the VTT-TIAM model of the energy sector in the EU, which has been applied in the development of the scenarios for this project.	Section 3.4

Description of contents of appendices in this report (continued)

Appendix number	**Description**	**References to main report**
6	A set of the main results of the VTT-TIAM model for each scenario developed in this project, including: • Production and net import of fuels, electricity generation, final consumption and greenhouse gas emissions • Balance table of biomass, bioliquids and biogas • Details of industrial power and heat production from biomass.	Section 3.7
7	Some examples of the calculations of the MITERRA-Europe agricultural sector model.	Sections 4.3, 4.7.1 and 4.9
8	Some examples of the calculations of the CARBINE forest sector carbon accounting model.	Sections 4.4, 4.7.2, 4.8 and 4.10
9	An example of how forest data sources for countries included in this project were assessed and combined, along with certain assumptions, to create input data for the CARBINE model. A set of summary forest area datasets for all relevant countries are also included. These and other tables in the appendix also give details of the key assumptions made in translating data for different countries into a form suitable for input to the CARBINE model.	Sections 4.5.2 and 4.8
10	A summary assessment of the outcomes of a modelling exercise undertaken as part of this project, that involved calibrating the input data to the CARBINE model simulations for each country, particularly in terms of assumptions about forest management, to represent a baseline or business-as-usual scenario.	Sections 4.8.1, especially Figure 4.12
11	A set of key results produced by the CARBINE model, for each of the scenarios developed in this project, shown separately for different regions of the world potentially involved in supplying forest biomass to the EU region for use as energy.	Section 4.10
12	A set of final project results, expressed in terms of total annual GHG emissions over the period 2010 to 2050, for each of the scenarios developed in this project.	Section 6.4

Appendix 1 Example of application of forest bioenergy decision tree

The purpose of this appendix is to illustrate the application of the forest bioenergy decision tree, described in Section 2.4, including Figures 2.1a to 2.1d and Box 2.1.

Suppose a potential consignment of forest biomass for use for energy is to be assessed in terms of the potential risks of causing significant increases in GHG emissions. The forest bioenergy would be produced from a defined catchment of forest areas, and would consist of:

- 20 kodt of biomass derived from harvest residues, that do not include stumps or roots, and that otherwise would have been burned on site. A supplementary assessment has established evidence to support the case that the extraction of the harvest residues (instead of burning them) will not lead to significant depletion of the nutrient status of the soil, or other deleterious effects on the quality of forest sites.
- 10 kodt of biomass derived from harvest residues, that do not include stumps or roots, and that otherwise would have been discarded in the forest. A supplementary assessment has established evidence to support the case that the extraction of the harvest residues will not lead to significant depletion of the nutrient status of the soil, or other deleterious effects on the quality of forest sites.
- 30 kodt of biomass harvested from forest areas that are conventionally managed for wood production. The biomass consists of complete trees (above ground) or complete tree stems. However, the trees are small and are derived from early thinnings in forest stands. If the thinned trees had not been extracted for use as forest bioenergy, they might have been extracted for other purposes (e.g. pulpwood). Alternatively, the thinning might not have been carried out.
- 15 kodt of biomass harvested from forest areas that are conventionally managed for wood production. The biomass consists of small roundwood, co-produced with wood (e.g. sawlogs) supplied for use in material products. If the small roundwood had not been extracted for use as forest bioenergy, it would have been extracted for other purposes (e.g. pulpwood). However, there are no relevant policies in place to ensure the effective recycling and disposal of material wood products (i.e. paper) at end of life.
- 12 kodt of biomass harvested from forest areas that previously were not managed for wood production. Management involving thinning is being introduced in these forest areas in order to achieve wider environmental and/or ecological objectives (e.g. habitat creation or enhancement), and would take place even if the biomass were not used for energy. The biomass consists of complete trees (above ground) or complete tree stems, not all of which can be classified as small.

- 8 kodt of biomass harvested from forest areas that previously were not managed for wood production. Management involving thinning is being introduced in these forest areas only because of the increased demand for forest bioenergy within the catchment area, and would not happen otherwise. The biomass consists of complete trees (above ground) or complete tree stems, not all of which can be classified as small[1].
- 2 kodt of biomass harvested from forest areas that are classified as having very low productive potential.

The total quantity of forest biomass forming the potential consignment for use for energy is 97 kodt.

The quantities of wood described above are entered into the relevant boxes of the decision tree, as shown in Figures A1.1a to A1.1d, with values in all other boxes being set to zero.

Based on the entries in the decision tree, the quantities of forest biomass in the consignment associated with high risk, moderate risk and low risk of increased GHG emissions can be estimated, as shown in Table A1.1 and Figure A1.2.

Based on the assessment in Figure A1.2, it may be possible to assign a grade to the potential consignment of forest biomass for use as energy, for example, based on a system such as:

- 'A+' – 100% low risk
- 'A' – at least 90% low risk, with the remainder moderate risk
- 'B+' – at least 75% low risk, with the remainder moderate risk
- 'B' – at least 75% low risk, with no more than 10% high risk
- 'C' – at least 50% low risk, and no more than 10% high risk
- 'D' – between 10% and 20% high risk
- 'E' – more than 20% high risk.

In the example illustrated, the potential consignment of forest biomass for use as energy might be assigned a grade of 'C'.

It must be strongly emphasised that the grading system suggested here is speculative and for illustrative purposes only.

[1] Note that the possibility that the trees may be of large size but very poor quality has not been considered, which may be regarded as an oversight.

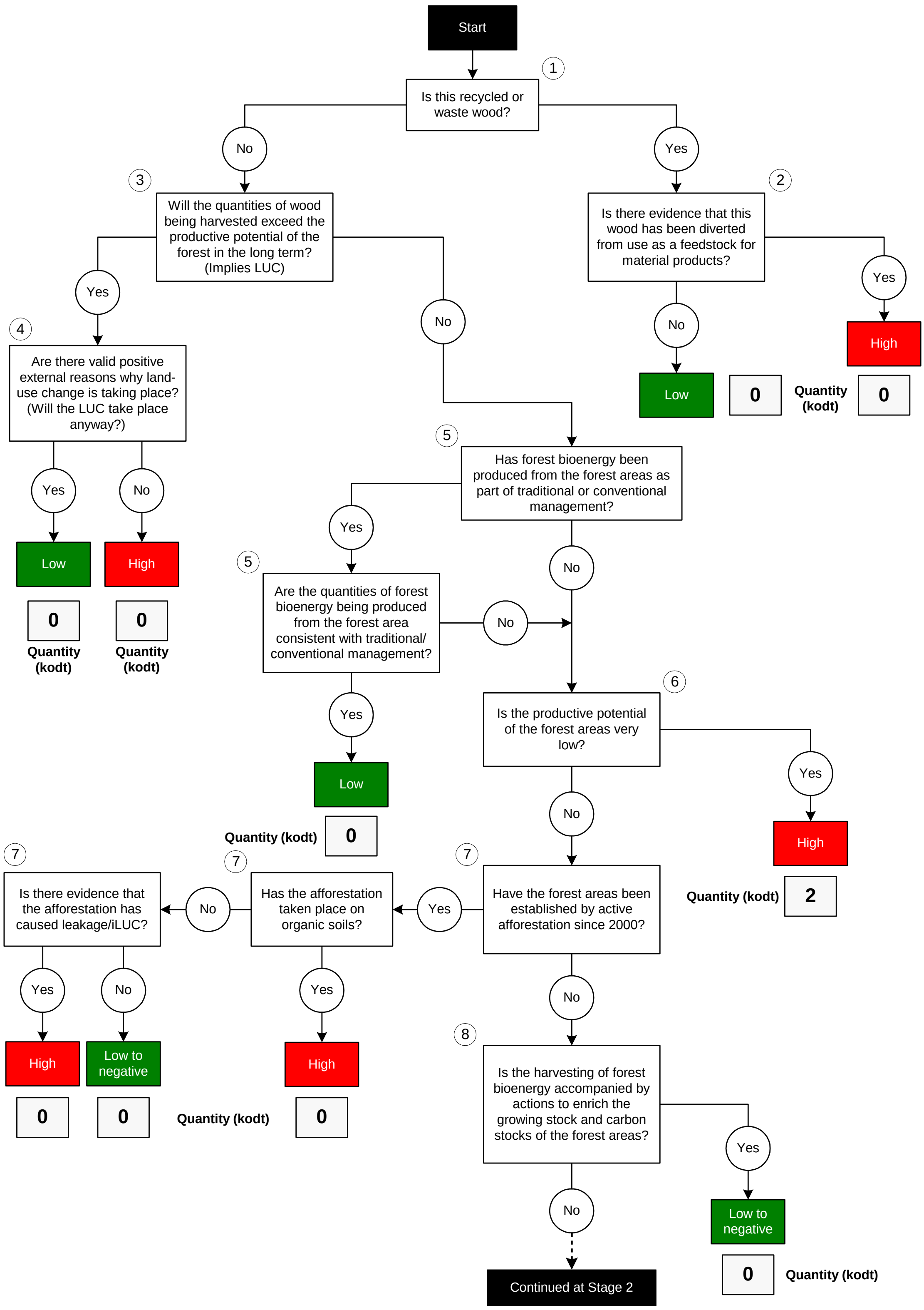


Figure A1.1a. Decision tree showing entries for example biomass consignment.

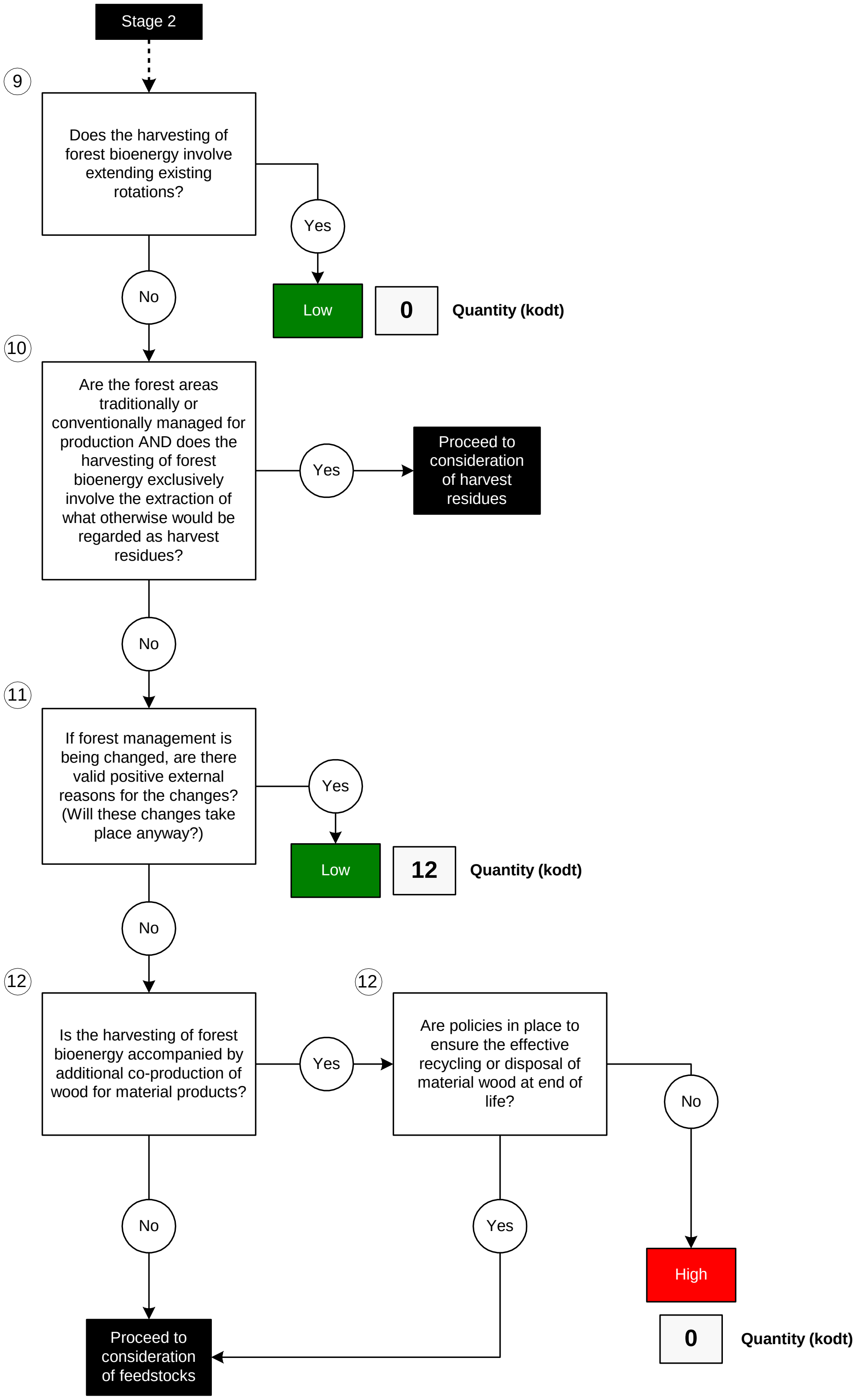


Figure A1.1b. Decision tree showing entries for example biomass consignment.

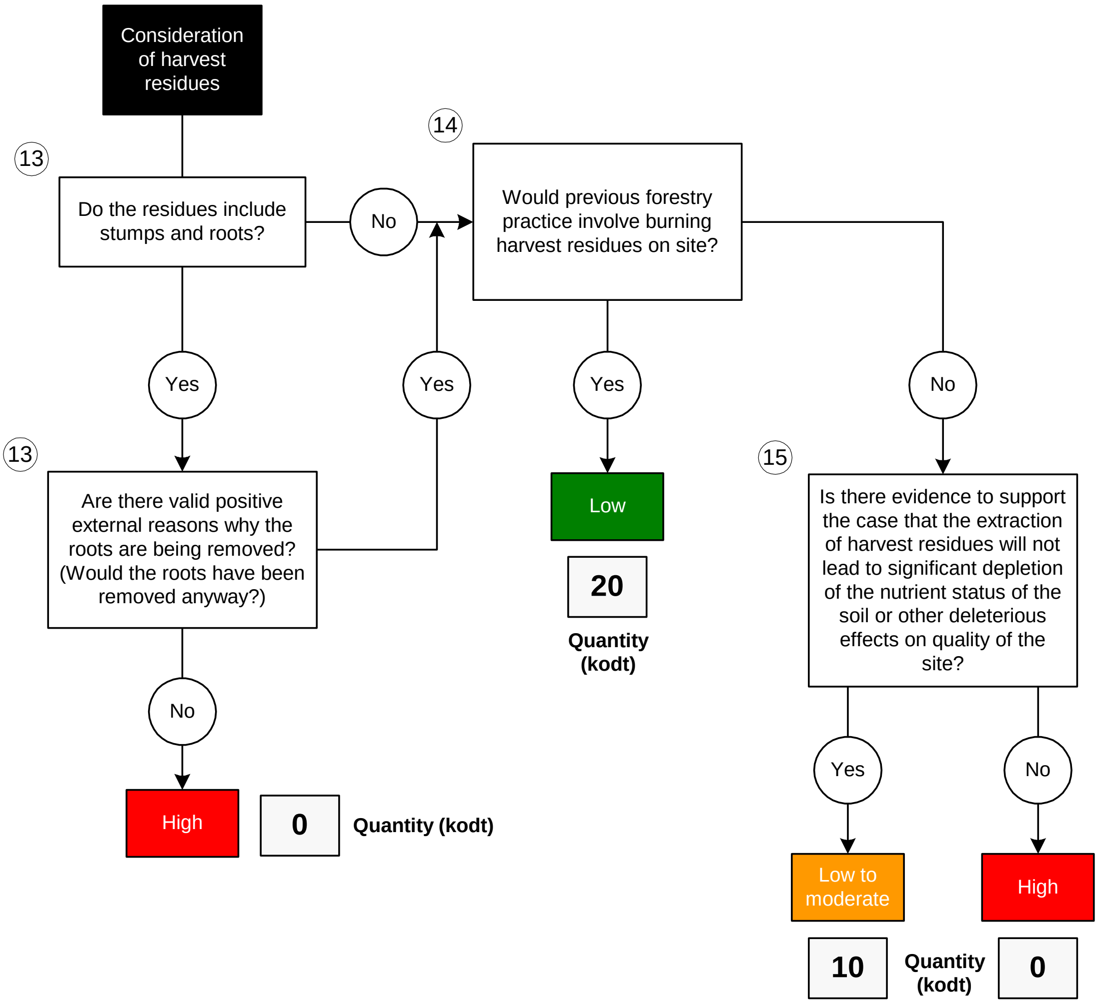


Figure A1.1c. Decision tree showing entries for example biomass consignment.

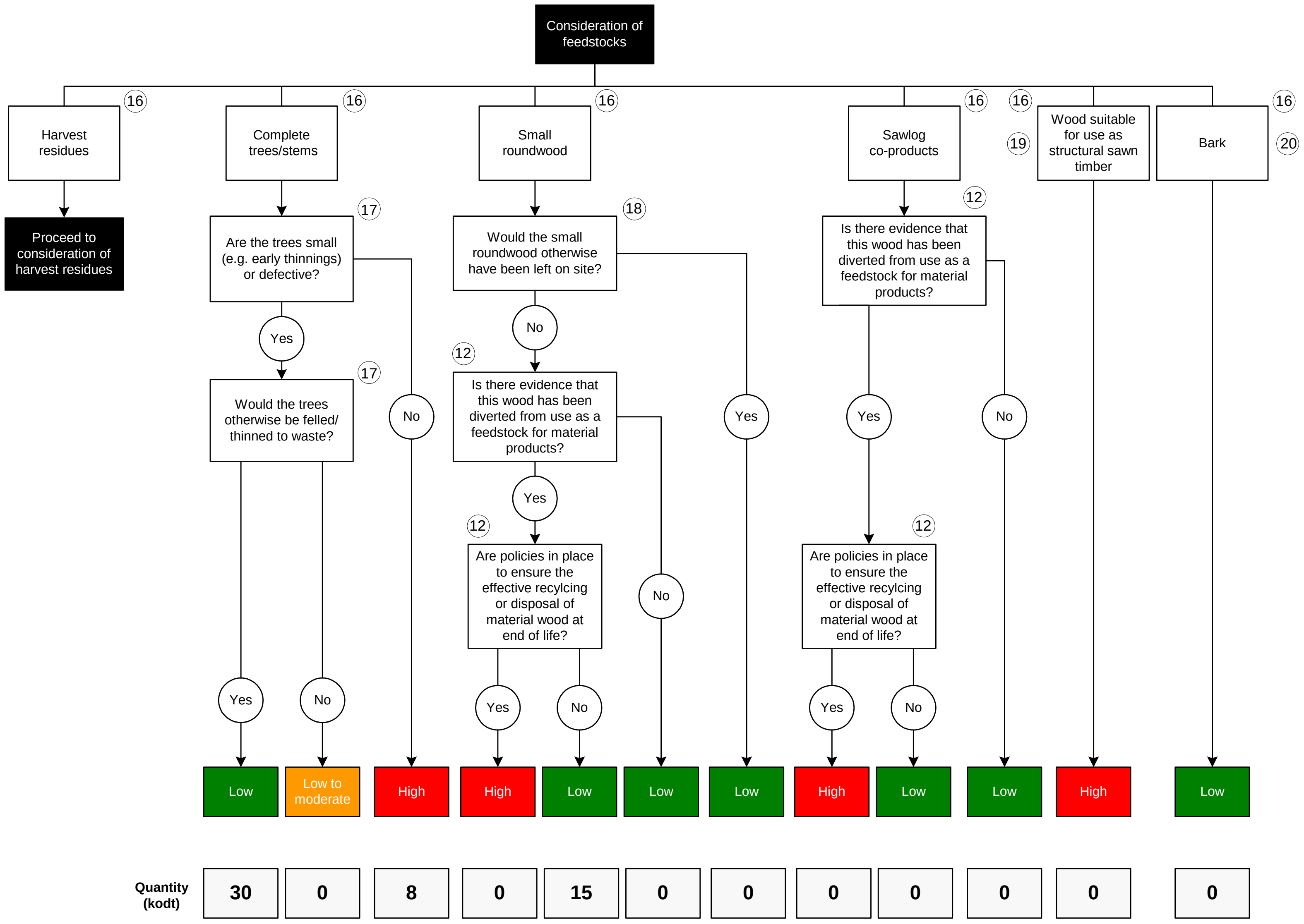


Figure A1.1d. Decision tree showing entries for example biomass consignment.

Table A1.1 Qualitative risk assessment of biomass consignment based on decision tree entries

Risk level	Quantity (kodt)	Percentage in risk category
Low	12 + 20 + 30 + 15 = 77	79.4
Moderate (low to moderate)	10	10.3
High	2 + 8 = 10	10.3

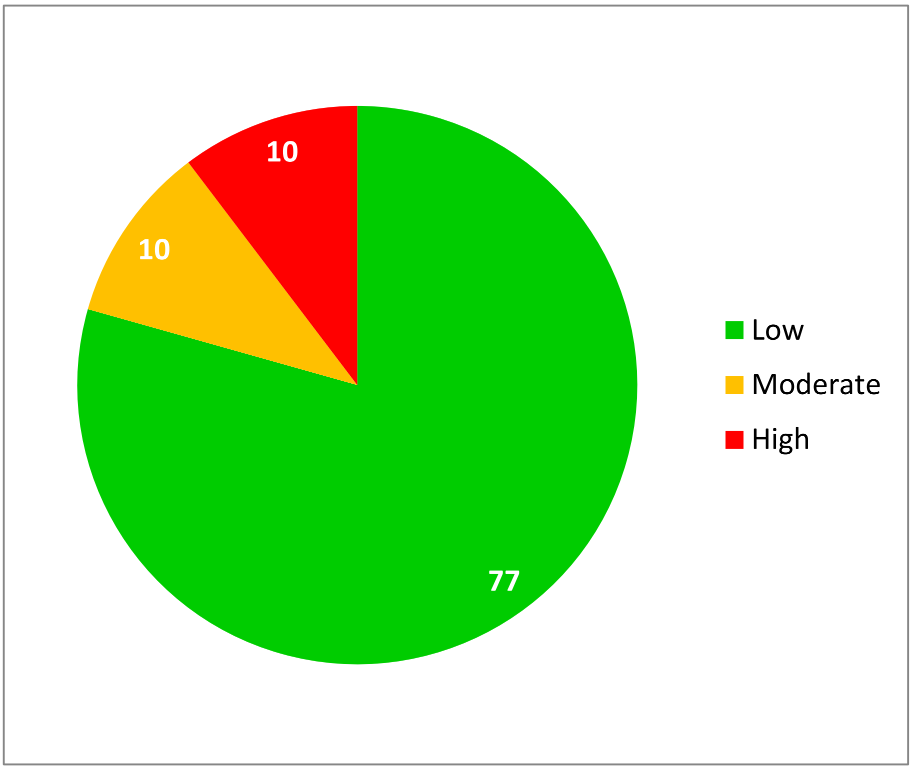


Figure A1.2. Summary assessment of risk associated with biomass consignment.

Appendix 2 Review existing biomass and bioenergy scenario studies

A2.1 Overview

Over the last few years several studies have been completed that have assessed energy and bioenergy demands and biomass potentials. These studies have been collated and reviewed to establish whether they are suitable for the development of the scenarios for this study. Criteria that were included are time horizon, types of biomass distinguished, spatial resolution and whether or not the scenarios come from a peer-reviewed study. This task aims to build on existing studies of biomass potentials and scenarios including:

- Updated PRIMES 2013 scenarios
- Biomass Futures project
- European Forest Sector Outlook Study (EFSOS) II
- Renewable energy projections based on National Renewable Energy Action Plans (NREAPS)
- EC Energy Roadmap 2050
- Global Energy Assessment (GEA, 2012)
- EEA Review on the EU bioenergy potential from a resource efficiency perspective
- IEA Technology roadmap Bioenergy (2012)
- IPCC special report on Renewable Energy Sources and Climate Change Mitigation
- DG Energy study on real potential for changes in growth and use of EU forests (EUwood)
- IMAGE PBL study on future bioenergy potential under various natural constraints.

The demand projections submitted by Member States in NREAPs will also be referred to as a basis for the 2020 reference scenario.

For the review of the different studies we used a template with the following items: Name study, Reference, Website, Short description (main aim and approach), Type of study, Spatial resolution, Spatial extent, Time horizon, Time step, Modelling involved, Types of biomass distinguished, biomass cost information, Biomass conversion technologies distinguished, Competition to non-energy sectors considered, Land use change impacts assessed, Peer reviewed, Scenarios (how many scenarios and short description), Main scenario parameters, Baseline scenario, Related to Energy Roadmap 2050 scenarios, Relevant data, Other remarks. The reviews of the selected studies are presented in Section A2.6 at the conclusions of this appendix. As an exception, the updated PRIMES 2013 scenarios are not included as part of the review in Section A2.6, but are discussed in Section A2.2. The most relevant studies, referred to extensively in scenario development in this project, are also discussed further in Sections A2.3 (NREAPs), A2.4 (Biomass Futures) and A2.5 (EFSOS II).

A2.2 Updated PRIMES 2013 scenarios

The new energy and GHG emission scenario modelling was jointly supervised by DGs ENER, CLIMA and MOVE based on EU energy system and CO_2 emission modelling with PRIMES, transport activity modelling as well as specific modelling related to non-CO_2 GHG with GAINS and CAPRI. The purpose of the new EU Reference scenario is to evaluate for EU policy making the consequences of implementing policies adopted by late spring 2012 including the Energy Efficiency Directive and the achievement of the legally binding targets for GHG and RES. It serves as a reference development for evaluating the energy, transport and climate consequences of no further energy, transport or climate decisions at EU level (no action) as well as for specific policy approaches, for which scenarios are being developed.

The study involved world energy modelling for determining international fossil fuel prices as well as macro-economic and sectoral modelling – all through 2050. The energy modelling is done in five year steps starting with 2015 and based on Eurostat statistics through 2010. The 2012 Ageing report provided the population and long term GDP growth projections, while the short and medium term GDP growth projections were taken from DG ECFIN. The EU economy is assumed to continue growing after having overcome the current crisis. Average annual GDP growth between 2010 and 2030 is projected at 1.5% per year, decreasing thereafter to 1.4% per year due to an ageing population.

The Reference scenario has been developed in the framework of limited global climate action, especially regarding non-EU regions. It assumes that third countries live up to their Copenhagen/Cancun pledges, but there is no assumption on any further significant climate action in these countries. In the reference scenario also the EU does not go beyond their 2020 targets, which results in increasing fossil fuel import prices (oil price of 121 $/barrel in 2030 and 143 $ in 2050 expressed in constant 2010 money). The reference scenario assumes that the legally binding RES and GHG targets (Renewable Energy Directive, Effort Sharing Decision and the EU Emission Trading System (ETS) Directive with linear decrease of the cap continuing also post 2020) are achieved. Moreover, other policies agreed by spring 2012 are included (e.g. the CO_2 from cars / vans regulations, implementation measures of the Eco design directive, energy performance of buildings directive) as well as the Energy Efficiency Directive.

The new reference scenario is the starting point for various policy scenarios for the 2030 Framework on energy and climate policies. It informs about the expected outcome from implementing the already agreed policies in the context of the 2020 package and can therefore enlighten the policy debate on the impacts of additional policy action aimed at the energy and climate framework for 2030. Therefore this new reference scenario is also used in this current study on the carbon impact of biomass use, instead of the first planned energy roadmap scenarios.

Besides the reference scenario also several decarbonisation scenarios have been simulated based on updated data and policy assumptions. For this study we used the decarbonisation scenario *EEMRES30*, which assumes by 2030 a 40% reduction in GHG emissions, a 30% RES target and ambitious energy efficiency stimulation. The main enabling setting regarding biomass in the decarbonisation scenario is that actors in fuel blending and fuel retailing anticipate that significant amounts of biofuels will be available in the future under market conditions at qualities which comply with strict sustainability criteria. This will be made possible as a result of accelerated emergence of advanced biomass conversion technologies (e.g. Fischer-Tropsch technology is projected to become fully mature). This process takes place mainly after 2020 and gradually evolves until 2030, but further becomes more mature after 2030. The PRIMES projection under the EEMRES30 scenario assumptions also show that in the period after 2030 imports of biomass feedstock and ready-to-use biofuels will have to increase (more feedstock imports rather than ready-to-use biofuels), where feedstocks are increasingly constituted by ligno-cellulosic material. The accelerated demand under decarbonisation conditions lead to accelerated learning in the advanced conversion technologies allowing the shifts to second generation feedstock, which also allows meeting very strict sustainability criteria. Figure A2.1 shows the projected bioenergy production and consumption in the EU-28, which is the sum of solid biomass, biofuels and biogas, for the reference and the decarbonisation scenario.

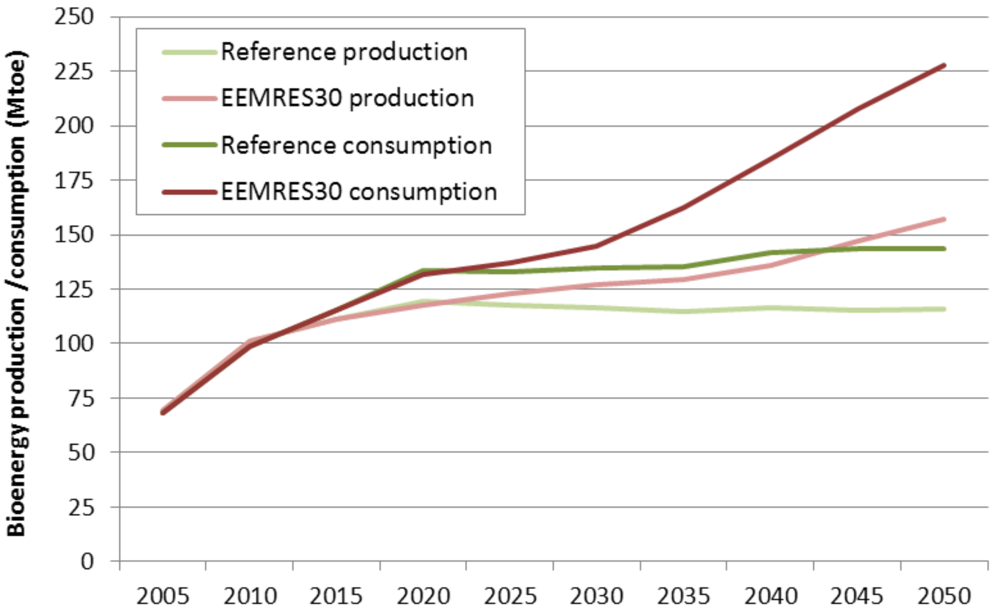


Figure A2.1. Production (incl. recovery of products) and consumption of bioenergy in the EU-28 for the reference and EEMRES30 scenarios

A2.3 National Renewable Energy Action Plans

Article 4 of Directive 2009/28/EC on Renewable Energy required Member States to submit national renewable energy Action Plans (NREAP) in 2010. These plans, to be prepared in accordance with the template published by the European Commission, provide detailed roadmaps of how each Member State expects to reach its legally binding 2020 target for the share of renewable energy in their final energy consumption. Beurskens *et al*. (2011) collected all data from the NREAP documents and made them available in a report and database. The purpose of their study was to allow easy comparison of the National Renewable Energy Action Plan (NREAP) for further analysis. Based on their database we assessed the domestic biomass resource for energy per member state (Figure A2.2) and the primary energy production from biomass (Figure A2.3). These data are used in VTT-TIAM to determine the 2020 bioenergy targets per MS and for verification of the determined biomass potentials for 2020. In addition these data can also be used for downscaling the results from VTT-TIAM to member state level.

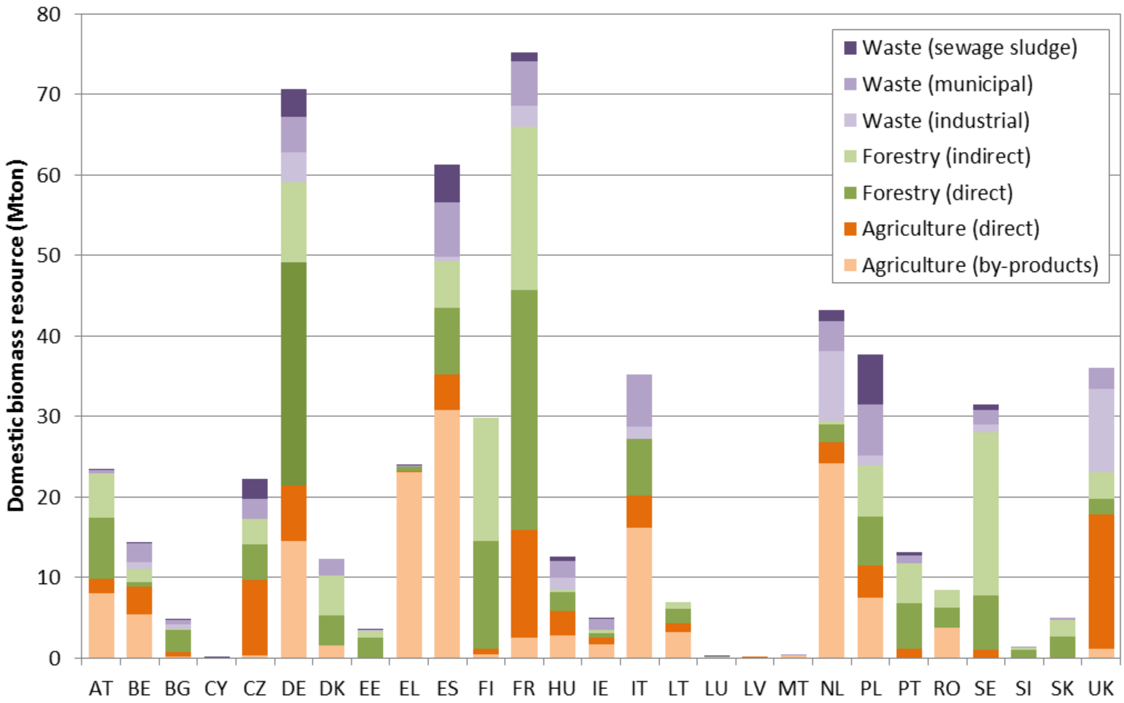


Figure A2.2. Domestic biomass resource in 2020 according to the NREAPs

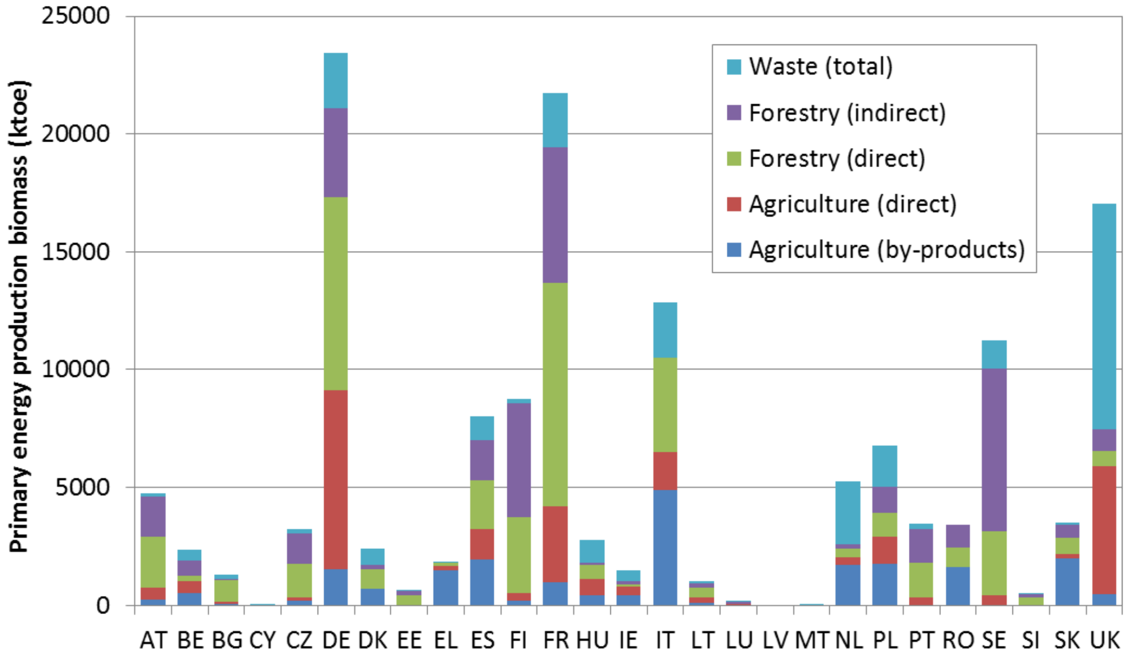


Figure A2.3. Primary energy production from biomass in 2020 according to the NREAPs

A2.4 Biomass Futures

The Biomass Futures Project assessed the role that biomass can play in meeting EU energy policy targets. The project defined the key factors likely to influence biomass supply, demand and uptake over the next twenty years (meeting the RED targets). This study made a comprehensive strategic analysis of biomass supply options and their availability in response to different demands in a timeframe from 2010- 2030. This was done according to the following steps:

1. Identifying different biomass feedstocks and make an inventory of data to quantify and map the technically constrained biomass potentials, including estimates of alternative uses of by- and waste in order to estimate the share that is available for bioenergy purposes and the share that competes with other uses.

2. Map present technically constrained potentials of the different feedstock as spatially explicit at regional level

3. Determine scenario specifications according to which future 2020 and 2030 potentials can be estimated.

4. Quantify actual, 2020 and 2030 potentials according to scenarios.

5. Identifying information on which basis cost levels for the different feedstocks can be established taking into account competing uses and costs for production, yielding and transport. It is aimed at estimating costs for biomass as it is received at the gate of the conversion/pre-treatment plant.

6. Synthesizing the results in terms of economic supply estimates (cost-supply).

The study builds on the state-of-the-art overview of biomass assessment studies provided by BEE and the same biomass classification, definitions and conversions as in BEE are used. The biomass potentials and costs from the Biomass Futures project are currently the most recent and detailed data available for most biomass sources. The biomass potentials are also used by other energy and integrated assessment models, such as PRIMES, RESOLVE and GLOBIOM.

Biomass potentials and costs (technical and sustainable) are presented for EU-27 for biomass types from forest, waste and agricultural sectors. The following biomass types are distinguished: agricultural annual crops (cereals, maize, sugarbeet, sunflower, rapeseed and fodder maize) and perennial crops (woody and grassy perennials), agricultural residues (straw, manure (liquid and solid), prunings, abandoned grassland cuttings), wood, forest residues (primary, secondary and tertiary residues) and waste (MSW (land fill/no-landfill), animal waste, used fats and oils, post-consumer wood).

For all these biomass sources maps with their potential were made for 2008, 2020 and 2030 at regional level (mainly NUTS 2). An example of such a map is shown for straw in Figure A2.4. See Elbersen *et al*. (2012) for further information. The aggregated data at national level have been used to quantify the biomass potentials for the different scenarios. But for Task 3 these data can also be used to downscale the scenario results from VTT-TIAM (which simulates for 5 regions in the EU) to more detailed levels that are needed by the MITERRA model (for agriculture) and CARBINE model (for forest).

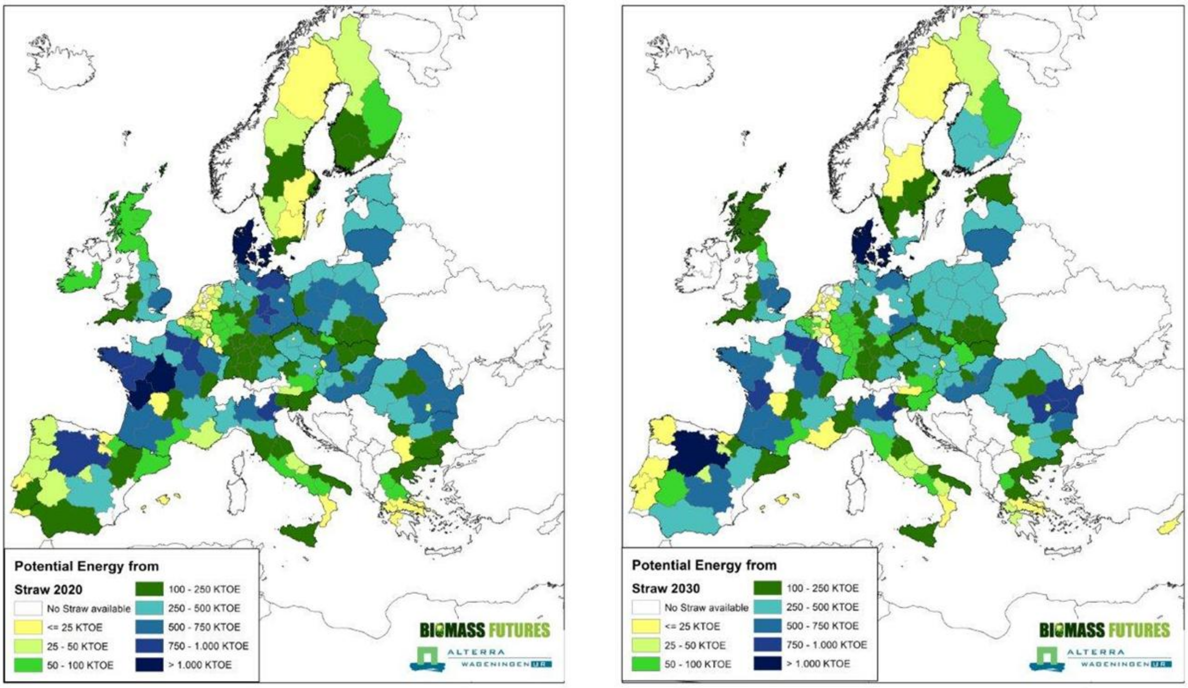


Figure A2.4. Example of biomass potential map for straw for 2020 (left) and 2030 (right)

A2.5 European Forest Sector Outlook Study (EFSOS) II

UNECE/FAO analyses structural developments in the forest sector and periodically produces studies of the long term outlook for supply and demand for wood and the other forest goods and services, to support policy makers and analysts, as well as civil society and private sector decision makers. The European Forest Sector Outlook Study II (EFSOS II) is the latest in a series of studies, to provide a regular outlook report for the European forest sector. All these studies have aimed to map out possible or likely future developments, on the basis of past trends, as a contribution to evidence-based policy formulation and decision making in the forest sector.

EFSOS II is based on scenario analysis. A reference scenario and four policy scenarios have been prepared for the European forest sector between 2010 and 2030, covering the forest resource (area, increment, harvest, silviculture) and forest products (consumption, production, trade). All calculations are at the national level aggregated into five country groups. The starting point of the analysis is a Reference scenario, which provides a picture of a future without major changes from the past: current policies remain unchanged, and current trends continue. For developments outside the forest sector, e.g. GDP growth, the Intergovernmental Panel on Climate Change (IPCC) B2 scenario was used (UNECE and FAO, 2011).

The four policy scenarios help policy makers gain insights into the consequences of certain policy choices. These 'what-if?' scenarios are not meant to give predictions of what will happen in the future, but to give insights into the behaviour of the system and how it could be influenced. The four policy scenarios are Maximising biomass carbon; Promoting wood energy; Priority to biodiversity and Fostering innovation and competitiveness. The Maximising biomass carbon scenario explored how much more carbon could be sequestered by European forests, without reducing the annual harvest of stemwood for products and energy, and without expanding the area of forest. In the Promoting wood energy scenario, absolute priority is given to meeting the official targets for renewable energy. The Priority to biodiversity scenario assumes a significant increase in area of forest protected for biodiversity conservation (6.2 million ha more than in the Reference scenario) and several measures intended to promote biodiversity in forests available for wood supply: no extraction at all of harvest residues or stumps, longer rotations and more mixed stands. Demand for wood (for products and energy) is assumed to remain unchanged from the Reference scenario, as are the non-forest components of wood supply. The Fostering innovation and competitiveness scenario assumes that the forest sector would become considerably more innovative than at present, under the influence of framework conditions transformed by policy measures and the attitudes of actors in the sector. This scenario is only qualitatively described and thus not projected by any of the models (UNECE and FAO, 2011).

The scenarios are based on the results of several different modelling approaches, and in particular of econometric projections of production and consumption of forest products, the Wood Resource Balance, the European Forest Information Scenario model (EFISCEN), the European Forest Institute -

Global Forest Sector Model (EFI-GTM), and competitiveness analysis. The EFSOS II study uses estimates of the theoretical biomass potential from recent, detailed forest inventory data using the EFISCEN model. Constraints reducing the availability of woody biomass were defined and quantified for three mobilisation scenarios (high, medium, low). Finally, the theoretical potentials from EFISCEN were combined with the constraints to assess the realisable potential from EU forests. More details are provided in Annex 3 and in Verkerk *et al*. (2011).

A2.6 Summary reviews of selected studies on biomass potentials

A2.6.1 Biomass futures project

Name study	Biomass Futures: Biomass role in achieving the Climate Change & Renewables EU policy targets. Demand and Supply dynamics under the perspective of stakeholders. In WP 3 of this study a spatially detailed and quantified overview of EU biomass potentials was produced taking into account the main criteria determining biomass availability from different sources.
Reference	Elbersen, B.S. *et al*. (2012). Spatially detailed and quantified overview of EU biomass potential taking into account the main criteria determining biomass availability from different sources. Report for Task 3 in Biomass Futures project. Available at: http://www.biomassfutures.eu/public_docs/final_deliverables/WP3/D3.3%20%20Atlas%20of%20technical%20and%20economic%20biomass%20potential.pdf
Website	http://www.biomassfutures.eu/
Short description (main aim and approach)	In this study a comprehensive strategic analysis of biomass supply options and their availability in response to different demands in a timeframe from 2010- 2030 is made. This is done in different steps: 1) Identifying different biomass feedstocks and make an inventory of data to quantify and map the technically constrained biomass potentials. This also includes estimates of alternative uses of by- and waste in order to estimate the share that is available for bioenergy purposes and the share that competes with other uses. 2) Map present technically constrained potentials of the different feedstock as spatially explicit as possible (regional level) 3) Determine scenario specifications according to which future 2020 and 2030 potentials can be estimated. 4) Quantify actual, 2020 and 2030 potentials according to scenarios. 5) Identifying information on which basis cost levels for the different feedstocks can be established taking into account competing uses and costs for production, yielding and transport. It is aimed at estimating costs for biomass as it is received at the gate of the conversion/pre-treatment plant. 6) Synthesizing the results in terms of economic supply estimates (cost-supply).
Type of study	The results of this assessment served as input for the model chains of PRIMES, RESOLVE and GLOBIOM to assess final bioenergy production and shares and related environmental impacts. The study builds on the state-of-the-art overview of biomass assessment studies provided by BEE and the same biomass classification, definitions and conversions as in BEE are used.

Spatial resolution	National level and for agricultural potentials regional level (NUTS 2/3).
Spatial extent	This is an EU wide study
Time horizon	2010, 2020 & 2030
Time step	10 year steps
Modelling involved? Which model(s)	Yes different model output used and post model assessments done from: CAPRI, MITERRA, GWSI.
Types of biomass distinguished	Biomass potentials and costs (technical and sustainable) are presented for EU-27 for biomass types from forest, waste and agricultural sectors. The following biomass types are distinguished: agricultural annual crops (cereals, maize, sugarbeet, sunflower, rapeseed and fodder maize) and perennial crops (woody and grassy perennials), agricultural residues (straw, manure (liquid and solid), prunings, abandoned grassland cuttings), wood, forest residues (primary, secondary and tertiary residues) and waste (MSW (land fill/no-landfill), animal waste, used fats and oils, post-consumer wood).
Information about costs of biomass available?	Yes, cost estimates were made for all biomass categories assessed. Cost estimates were derived from other studies and own assessments and are specific for countries and sometimes also regions.

Which biomass conversion technologies distinguished?

This study only involved the estimates of the biomass cost supply (before conversion). However for the estimation of the sustainable biomass potential from crops in the sustainability scenario conversion technologies were linked to crops in order to make an assessment of the GHG-LCA and the potential mitigation target. If the mitigation target of 70% GHG savings compared to the fossil alternative could not be reached the biomass category was not regarded sustainable. The conversion technologies involved are the same as those from the EEA/ETC-SIA study and are given in the table below.

Type of biomass	Technology	CO_2eq g/MJ (includes by-product allocation based on energy value)			Energy efficiency (MJ_{bio}/MJ_{out})	Implicit efficiency (%)
		Average	Max	Min	Average	
Electricity						
Straw	Large co-firing ST	8.1	8.1	8.1	2.1	47
Straw	Medium ST	24.4	24.4	24.4	1.9	54
Miscanthus	Large co-firing ST	51.1	193.3	24.5	2.1	47
Miscanthus	Medium ST	62.6	187.1	39.3	1.9	54
RCG	Large co-firing ST	93.7	247.8	46.0	2.1	47
RCG	Medium ST	99.2	234.1	57.4	1.9	54
Switchgrass	Large co-firing ST	54.6	175.0	27.8	2.1	47
Switchgrass	Medium ST	67.5	172.9	44.0	1.9	54
Chips, forest	Large co-firing ST	9.9			2.1	47
Chips, forest	Medium ST	33.4			1.9	53
Chips, SRC	Large co-firing ST	63.2	570.9	25.4	2.1	47
Chips, SRC	Medium ST	80.0	524.4	46.9	1.9	53
Pellets, wood residues	Large co-firing ST	12.2			2.1	47
	Medium ST	34.7			1.9	53
Maize	Biogas ICE	40.1	183.2	18.6	2.7	37
OSR (SVO)	ICE	47.9	204.1	8.8	1.3	76
sunflower (SVO	ICE	45.0	162.5	15.8	1.3	76
Manure, liquid	Biogas ICE (CHP)	5.2			2.7	37
Manure, dry	Biogas ICE (CHP)	5.2				37
Straw co-feed/ manure	Biogas ICE (CHP)	4.7			2.4	41
Heat						
Chips, forest	Boiler district heat	4.9			1.2	86
Chips, SRC	Boiler district heat	33.8	308.6	13.3	1.2	86
Chips, miscanthus	Boiler district heat	30.9	149.2	15.4	1.2	82
Chips, switchgrass	Boiler district heat	32.1	156.1	18.3	1.3	78
Chips RCG	Boiler district heat	52.1	211.1	28.6	1.4	69
Pellets, wood residues	Boiler district heat	6.5			1.2	85
Pellets, wood residues	Stove	5.6			1.1	89
Transport fuels						
Wood chips, residues	BTL	6.0			1.8	56
Wood chips, SRC – willow/poplar	BTL	50.5	474.3	18.9	1.8	56
Chips, miscanthus	BTL	48.7	323.2	31.7	1.9	53
Chips, switchgrass	BTL	50.8	338.4	23.6	2.0	50
Chips, RCG	BTL	72.9	410.0	34.2	2.1	45
Straw	Ligno-EtOH	5.2	5.2	5.2	2.0	50
Wood chips, residues	Ligno-EtOH	6.0			1.8	56
wood chips, SRC – willow/poplar	Ligno-EtOH	50.5	474.3	18.9	1.8	56
Barley	EtOH	42.4	167.7	25.3	1.0	98
Wheat	EtOH	46.8	261.1	26.7	1.0	98
Sugar beet	EtOH	55.4	146.6	41.0	0.8	119
OSR	Biodiesel	38.6	147.6	11.4	0.9	109
Sunflower	Biodiesel	36.6	118.6	16.3	0.9	109

Competition to non-energy sectors considered?

Yes ILUC is extensively addressed. In price estimates for some agro-residues and forest residues competing uses are incorporated (e.g. straw, paper cardboard)

Land use change impacts assessed?

Yes direct and indirect land use change impacts are incorporated in the GHG-LCA calculations. ILUC is taken into account by incorporating ILUC related GHG emission factors in the total GHG-LCA assessments.

<table>
<tr><td>Peer reviewed? (Include references to relevant publications)</td><td>Elbersen, B., Fritsche, U. Petersen, J.-E., Lesschen, J.P., Böttcher, H. and Overmars, K. 2013. Assessing the effect of stricter sustainability criteria on EU biomass potential. Biofuels, Bioproducts & Biorefining (Biofpr), 7(2): 173–192.

Uslu, A.; van Stralen, J.; Elbersen, B.; Panoutsou, C.; Fritsche U. and Böttcher H. (2013). Bioenergy scenarios that contribute to a sustainable energy future in the EU27. Biofuels, Bioproducts & Biorefining (Biofpr) Journal. 7(2): 97–216.</td></tr>
<tr><td>Scenarios? Describe how many scenarios and short definition per scenario</td><td>There are 2 scenarios elaborated:
<table>
<tr><th>Scenario</th><th>GHG mitigation criteria 2020</th><th>GHG mitigation criteria 2030</th><th>Other sustainability constraints 2020 and 2030</th></tr>
<tr><td>Reference</td><td>Only for biofuels and bioliquids consumed in EU a GHG mitigation of 50% as compared to fossil fuel is required. This excludes compensation for iLUC related GHG emissions.</td><td>Only for biofuels and bioliquids consumed in EU a GHG mitigation of 50% as compared to fossil fuel is required. This excludes compensation for iLUC related GHG emissions.</td><td>Only for biofuels and bioliquids consumed in EU limitations on the use of biomass from biodiverse land or land with high carbon stock.</td></tr>
<tr><td>Sustainability</td><td>For all bioenergy consumed in the EU the following mitigation requirements are set:
Biofuel/bioliquids: 70% mitigation as compared to fossil fuel (comparator EU average diesel and petrol emissions 2020).
Bioelectricity and heat: 70% mitigation as compared to fossil energy (comparator country specific depending on 2020 fossil mix) .
This includes compensation for iLUC related GHG emissions.</td><td>For all bioenergy consumed in the EU the following mitigation requirements are set:
Biofuel/bioliquids: 80% mitigation as compared to fossil fuel (comparator EU average diesel and petrol emission 2030)
Bioelectricity and heat: 80% mitigation as compared to fossil energy (comparator country specific depending on 2030 fossil mix)
This includes compensation for iLUC related GHG emissions.</td><td>For all bioenergy consumed in EU limitations on the use of biomass from biodiverse land or land with high carbon stock.</td></tr>
</table></td></tr>
<tr><td>Main scenario parameters</td><td>The sustainability criteria applied in the reference scenario are following the ‘Directive on the promotion of energies from renewable sources’ (Directive 2009/28/EC) (RES Directive) as described above and therefore only apply to biofuels and bioliquids.
In the sustainability scenario stricter sustainability criteria apply and these are also applicable to solid and gaseous biomass sources. In the sustainability scenario these apply to all bioenergy sources both produced inside and outside the EU (either domestically produced or imported). A very important difference with the reference scenario is that this GHG mitigation requirement should also include compensation for emissions from indirect land use changes caused by biomass cropping in the EU.</td></tr>
<tr><td>Baseline scenario</td><td>See above criteria for reference scenario</td></tr>
<tr><td>Related to Energy Roadmap 2050 scenarios?</td><td>No</td></tr>
<tr><td>Relevant data</td><td>All data are available at Alterra for this study</td></tr>
<tr><td>Other remarks</td><td>Many scenario parameters in this study already incorporated in the discussion about the scenario definition for the Carbon Impact study.</td></tr>
</table>

A2.6.2 European Forest Sector Outlook Study (EFSOS) II

Name study	European forest Sector Outlook Studies II (EFSOS II)
Reference	UNECE-FAO, 2011. The European Forest Sector Outlook Study II. 2010-2030. ECE/TIM/SP/28. United Nations, Geneva.
Website	http://www.unece.org/efsos2.html
Short description (main aim and approach)	UNECE/FAO analyses structural developments in the forest sector and periodically produces studies of the long term outlook for supply and demand for wood and the other forest goods and services, to support policy makers and analysts, as well as civil society and private sector decision makers. The European Forest Sector Outlook Study II (EFSOS II) is the latest in a series of studies, which started in 1952, to provide a regular outlook report for the European forest sector. All these studies have aimed to map out possible or likely future developments, on the basis of past trends, as a contribution to evidence-based policy formulation and decision making in the forest sector. EFSOS II is built on the construction and interpretation of scenarios. For the scenario analysis in EFSOS II, a range of models was selected to cover the whole forest sector. Selection criteria used were robustness; transparency; ability to provide analysis at the country level within Europe; being based on validated data sets; and, the ability to address the stated policy challenges.
Type of study	Scenario/outlook study
Spatial resolution	Countries
Spatial extent	Continental Europe, excluding Russian Federation
Time horizon	2030
Time step	Time step of models 1-5 years, output provided 10 years (2010-2020-2030)
Modelling involved? Which model(s)	Mainly EFI-GTM and EFISCEN
Types of biomass distinguished	Stemwood, harvest residues (branches and topwood), stumps, industrial residues, landscape care wood, post-consumer wood.
Information about costs of biomass available?	No
Which biomass conversion technologies distinguished	None
Competition to non-energy sectors considered?	Yes (wood consumption for wood products)
Land use change impacts assessed?	Afforestation/deforestation is included, but only as extrapolation of previous trends (i.e. no dynamic result of competing land uses). Impact on intensity of management is included.
Peer reviewed?	No, but publication in press. Schelhaas, M.J., (in press). European Forest Sector Outlook Studies II: Switzerland in the European context. Schweizerische Zeitschrift für Forstwesen.

Scenarios? Describe how many scenarios and short definition per scenario	One reference scenario and four policy scenarios. The reference scenario is based on GDP development of the IPCC B2 SRES scenario. The four policy scenarios are *Maximising biomass carbon*; *Promoting wood energy*; *Priority to biodiversity* and *Fostering innovation and competitiveness*. The *Maximising biomass carbon scenario* explored how much more carbon could be sequestered by European forests, without reducing the annual harvest of stemwood for products and energy, and without expanding the area of forest. In the *Promoting wood energy scenario*, absolute priority is attached to meeting the official targets for renewable energy. The P*riority to biodiversity scenario* assumes a significant increase in area of forest protected for biodiversity conservation (6.2 million ha more than in the *Reference scenario*) and several measures intended to promote biodiversity in forests available for wood supply: no extraction at all of harvest residues or stumps, longer rotations and more mixed stands. Demand for wood (for products and energy) is assumed to remain unchanged from the *Reference scenario*, as are the non-forest components of wood supply. The *Fostering innovation and competitiveness* scenario assumes that the forest sector would become considerably more innovative than at present, under the influence of framework conditions transformed by policy measures and the attitudes of actors in the sector. This scenario is only qualitatively described and thus not projected by any of the models.
Main scenario parameters	Maximising biomass carbon: changes in rotation length and thinning intensity. Result: forest carbon stock +3.5% in 2030. Biomass sink +53.7% and soil carbon sink +23.7% in 2030. Promoting wood energy scenario: increase in woody biomass used for energy generation. In order to reach the targets for renewable energy by 2020, with a continuation of the trend to 2030, about 860 million m^3 of wood, of all types, should be used for energy in 2030, nearly double the figure of 435 million m^3 for 2010. Priority to biodiversity scenario: set aside of an additional 5% of the forest area currently available for wood supply for biodiversity purposes, increase in rotation length by 10-20 years in the area available for wood supply, and harvest residue extraction is abandoned. Result: stemwood removals are 19% lower in 2010 and 12% lower in 2030 as compared to the reference scenario. Residue extraction and stump extraction is completely abandoned in the Priority to biodiversity scenario. In contrast, 41.1 Tg dry matter residues and 5.5 Tg stumps are extracted in the Reference scenario by 2030.
Baseline scenario	The reference scenario assumes continuation of current trends: development of forest area available for wood supply, increase in demand for wood-based energy, same forest management, and medium mobilisation level of harvest residues. GDP projections are derived from the IPCC B2 SRES scenario, but at short term (5 years) by forecasts from IMF. The reference scenario does not include the energy targets for 2020, but they are part of the promoting wood energy scenario.
Related to Energy Roadmap 2050 scenarios?	No
Relevant data	Simulation outcomes of the different models by country can be downloaded from the website.
Other remarks	

A2.6.3 Renewable energy projections based on National Renewable Energy Action Plans (NREAPS)

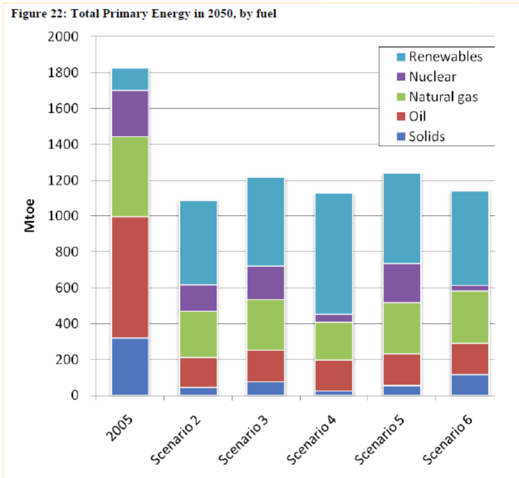
Name study	Renewable Energy Projections based on NREAPs
Reference	Beurskens, L.W.M., Hekkenberg, M., Vethman, P. 2011. Renewable energy projections as published in the National Renewable Energy Action Plans of the European member states. ECN-E-10-069. ECN, The Netherlands.
Website	http://www.ecn.nl/units/ps/themes/renewable-energy/projects/nreap/
Short description (main aim and approach?	The purpose of the study was to allow easy comparison of the National Renewable Energy Action Plan (NREAP) for further analysis. Each Member State is requested to complete a set of tables in this template on how it expects to meet its 2020 target, including the technology mix and the trajectory to reach it. All data have been collected from the NREAP documents and made available in a report and database.
Type of study	Review / analysis of the National Renewable Energy Action Plans
Spatial resolution	National
Spatial extent	All EU-27 member states
Time horizon	Till 2020
Time step	Annual for some parameters, for biomass amount for 2006, 2015 and 2020
Modelling involved? Which model(s)	No, based on national reports, although some of the underlying data might be derived by modelling.
Types of biomass distinguished	Biomass from forest (direct and indirect), biomass from agriculture and fisheries (direct and by-products) and biomass from waste (municipal, industrial and sewage sludge), see Table 7 in database. Furthermore a distinction is made between domestic resource, imported from EU, imported from non-EU, exported, although these last categories are only available for 2006
Information about costs of biomass available?	No, although in the individual NREAP reports information might be found, but this was not within the scope of the ECN study.
Which biomass conversion technologies distinguished	Conversion technologies are not really indicated, energy is specified to energy type (Heating and cooling, Electricity, Transport, see Table 3 of the NREAPs) and type of RE (Solid biomass, Biogas, Bioliquids and other non-biomass RE types, see Table 10 of the NREAPs).
Competition to non-energy sectors considered?	No, although this might be included in underlying analyses by the MS
Land use change impacts assessed?	No
Peer reviewed? (Include references to relevant publications)	Not from a scientific point of view, however, MS have seen the first version(s) and have in several cases corrected their data from the NREAPs. However, in case MS did not correct their data, the reported values are used which in few cases are clearly not realistic (e.g. for Greece)

Scenarios? Describe how many scenarios and short definition per scenario	Most NREAPs distinguish two scenarios, the reference scenario and an 'additional energy efficiency scenario'. The additional energy efficiency scenario includes new energy efficiency measures implemented as from 2010 to allow a reduction in primary energy demand. These scenarios are MS specific and there no general description can be provided. In the reference scenario the primary energy demand in the EU-27 is 1317 Mtoe in 2020 (RE share of 18.6%), while 1189 Mtoe in the additional energy efficiency scenario (RE share of 20.6%).
Main scenario parameters	Not applicable
Baseline scenario	Not applicable
Related to Energy Roadmap 2050 scenarios?	Not directly, although it might be that the Energy roadmap scenarios make use of the NREAP data for 2020, although this is not directly clear from the documents
Relevant data	Data can be downloaded in cvs format from the website: http://www.ecn.nl/units/ps/themes/renewable-energy/projects/nreap/data/
Other remarks	In a related study by JRC the NREAP reports were also assessed, see http://ec.europa.eu/dgs/jrc/downloads/jrc_reference_report_2011_reap.pdf Also the RES4LESS project (http://www.res4less.eu) is largely based on the NREAP data, in this project further analysis of the pathway to 2020 are analyses and the policy options for after 2020 are explored.

A2.6.4 EC Energy Roadmap 2050

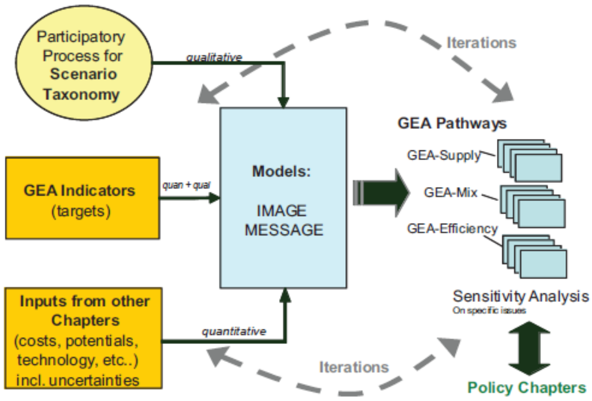
Name study	Energy Roadmap 2050
Reference	European Commission. 2011. Energy Roadmap 2050. Impact assessment and scenario analysis. SEC(2011) 1565 final. Brussels.
Website	http://ec.europa.eu/energy/energy2020/roadmap/index_en.htm
Short description (main aim and approach?	The Energy Roadmap 2050 explores the challenges posed by delivering the EU's decarbonisation objective while at the same time ensuring security of energy supply and competitiveness. The study analysed a reference and current policy initiative scenario and five decarbonisation scenarios (high energy efficiency, diversified supply technologies, high renewable energy sources, delayed CCS and low nuclear). The PRIMES model was used for the simulations.
Type of study	Scenario study for future energy use and pathways towards decarbonisation
Spatial resolution	Modelling is done at country level, but results from the study are only presented at EU-27 level.
Spatial extent	EU-27 and the Western Balkans countries, the EFTA countries and Turkey.
Time horizon	Till 2050
Time step	5 year time steps, but main results are presented for 2020, 2030 and 2050 (in Attachment 1 the results are available for all 5 year timesteps)
Modelling involved? Which model(s)	Yes, PRIMES model is used
Types of biomass distinguished	5 types of biomass and waste are distinguished. Detailed representation of resources (crops, forestry, aquatic biomass and wastes) is available. Energy crops are further distinguished into starch, sugar, oil and wood crops. Regarding wood crops there is a distinction between pure lignocellulosic crops, such as poplar, willow etc., and short rotation herbaceous lignocellulosic crops like miscanthus, switch grass, reed etc. Forestry is split into wood platform, i.e. organised and controlled cutting of whole trees for energy use, and wood residues, i.e. the collecting of forestry residues only. Agricultural residues are included under the waste category. Apart from agriculture residues, several types of wastes have also been identified as potential sources of energy supply. This include industrial solid waste, industrial liquid waste, pulp waste, used vegetable oils, municipal solid waste, sewage sludge, landfill gas, organic manure and animal wastes. This classification was based both on further processing differentiation as well as on data availability. Although all this information is included in PRIMES it is not available from the reports on the Energy Roadmap.
Information about costs of biomass available?	Non-linear cost supply curves are available for biogas produced, biomass solid, and bio-liquid produced or waste.

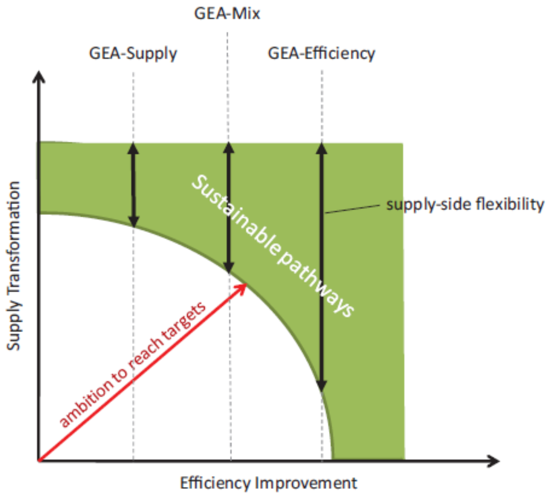
Which biomass conversion technologies distinguished	**Secondary Transformation** *Pelletising* *Wood preparation* *Sugar pre-treatment* *Plant Oil pre-treatment* *Solid waste pre-treatment* *Liquid waste pre-treatment* *Gas waste conditioning* **Final Transformation** **Solid Biomass** *Charcoal* **Biochemical** *Fermentation* *Acid/Enzymatic hydrolysis* *Anaerobic digestion* *Transesterification* **Thermo-chemical** *Pyrolysis* *Hydrothermal* **Gasification** *Partial oxidation* *Fluidized bed* *Steam flow*
Competition to non-energy sectors considered?	Indirectly in the cost-supply curves, but from description it is not clear how this competition is exactly included.
Land use change impacts assessed?	No
Peer reviewed?	Yes, see references below and probably extensive review within the commission: Capros, P., Tasios, N., De Vita, A., Mantzos, L. and Paroussos, L. 2012. Model-based analysis of decarbonising the EU economy in the time horizon to 2050. Energy Strategy Reviews, 1: 76-84. Tasios,N., Apostolaki, E., Capros, P., and De Vita, A. 2013. Analysing the bio-energy supply system in the context of the 20-20-20 targets and the 2050 decarbonisation targets in the EU", Biofuels, Bioproducts & Biorefining, 7(2): 126–146.
Scenarios? Describe how many scenarios and short definition per scenario	Five decarbonisation scenarios were assessed, of which the "High Renewable energy sources (RES)" is the most relevant one for this study. In this scenario strong support measures for RES lead to a very high share of RES in gross final energy consumption (75% in 2050) and a share of RES in electricity consumption reaching 97%.
Main scenario parameters	See part B of the impact assessment. The decarbonisation scenarios are based on the same demographic and macroeconomic assumptions as the Reference scenario and Current Policy Initiatives scenario. GHG emission reduction of 80% by 2050 is taken as constraint in the different scenarios. Fossil fuel prices (oil, coal and gas) are same for all decarbonisation scenarios, but lower compared to the reference scenario (due to lower demand), see Figure 18 for trend in prices up to 2050. In the decarbonisation scenarios a higher RES value was assumed, i.e. 35 €/MWh in Reference and 71 €/MWh in all decarbonisation scenarios, except for the high RES scenario, in which RES support is much more pronounced (382 €/MWh). This RES-value is a modelling tool used to reflect the marginal value of not explicitly modelled facilitation RES policies.

Baseline scenario	Two baseline scenarios were used. The Reference scenario includes current trends and long-term projections on economic development (gross domestic product (GDP) growth 1.7% pa).The scenario includes policies adopted by March 2010, including the 2020 targets for RES share and GHG reductions as well as the Emissions Trading Scheme (ETS) Directive. The Current Policy Initiatives (CPI) updates the reference scenario with measures adopted, e.g. after the Fukushima events following the natural disasters in Japan, and being proposed as in the Energy 2020 strategy; the scenario also includes proposed actions concerning the "Energy Efficiency Plan" and the new "Energy Taxation Directive". Assumptions for baseline are provided in Table 2 of the Impact Assessment part 1 (page 14)
Related to Energy Roadmap 2050 scenarios?	Yes
Relevant data	• Page 4-5 of impact assessment part 2 explains policy assumptions for high RES scenario, however, these are not related to biomass • 80% GHG reduction by 2050 is basis for all decarbonisation scenarios, which means that GHG emission from energy should reduce by 85% compared to 2005  • Page 15 (IA, part 2): • Page 15 (IA, part 2): Table with power generation and feedstock shares, for scenario 4 biomass and waste have a share of 9.6% (represents 493 TWh) • Page 38-39 (IA, part 2): RES targets and biomass and Table mentions amounts of biomass (for High RES scenario total domestic biomass by 2030: 188675 ktoe of which biofuels 26296, by 2050: 301805 of which biofuels 72453) • Attachment 1 (IA, part 2) provides the numerical results for the different year, it also includes the amount of RE imported (which should be mainly biomass) • Part 1 of the impact assessment describes all assumptions for the Reference scenario, incl. all current policies included
Other remarks	Via de Commission we will probably get access to the model data that was used for the Energy Roadmap. However, this will probably only be available at EU27 level and not at MS level.

A2.6.5 Global Energy Assessment (GEA, 2012)

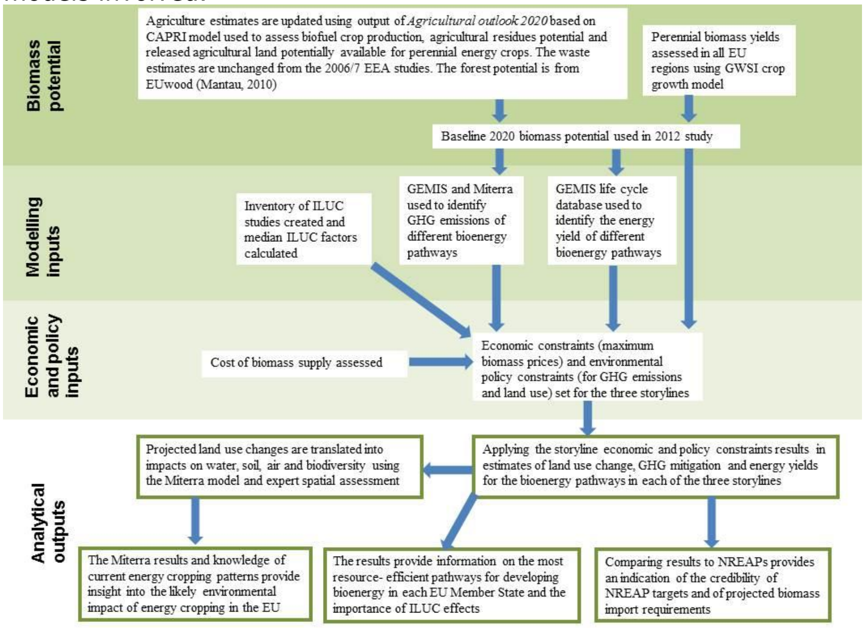
Name study	Global Energy Assessment
Reference	GEA, 2012. Global Energy Assessment - Toward a Sustainable Future, Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria.
Website	http://www.iiasa.ac.at/web/home/research/Flagship-Projects/Global-Energy-Assessment/Home-GEA.en.html
Short description (main aim and approach	The GEA assesses the major global challenges for sustainable development and their linkages to energy; the technologies and resources available for providing energy services; future energy systems that address the major challenges; and the policies and other measures that are needed to realize transformational change toward sustainable energy futures. The GEA provides policy-relevant analysis and guidance to governments and intergovernmental organizations, decision-support material to the commercial sector, and analysis relevant to academic institutions. It provides technical guidance for implementing measures aimed at mitigating climate change and sustainable consumption of resources. In the study three so-called transformation pathways for energy are developed. The study also comprises a database, which contains all data resulting from the scenario analysis as described in Chapter 17.
Type of study	Very broad global study on the assessment of energy development. The study also includes a scenario part with energy pathways for sustainable development (see Chapter 17).
Spatial resolution	Regions (11 regions, for Europe 2 regions are distinguished (Central and Eastern Europe and Western Europe). Few parameters are also available at country level (population and some economic indicators).
Spatial extent	This is a global study, most analyses were done at regional level (11 regions are distinguished
Time horizon	Up to 2100
Time step	10 year time steps

Modelling involved? Which model(s)	Yes the MESSAGE and IMAGE models are used. MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impact) is a systems engineering optimization model used for medium- to long-term energy system planning, energy policy analysis, and scenario development (Messner and Strubegger, 1995 ; Riahi *et al.*, 2007).IMAGE is an integrated assessment modelling framework consisting of a set of linked and integrated models (Bouwman *et al.*, 2006). Together the framework describes important elements in the long-term dynamics of global environmental change, such as air pollution, climate change, and land use change. 
Types of biomass distinguished	In the scenario study all biomass types are aggregated into one biomass class, only a distinction is made between with and with carbon capture and storage (CCS). In Chapter 7.7 biomass potentials (both theoretical and technical) are presented for 18 world regions and different biomass types (Energy crops, forest residues, crop residues, municipal solid wastes, and animal manures), see Table 7.32, 7.33 and 7.35, see also Table 11.7.
Information about costs of biomass available?	Yes, see Table 7.35, which contains four cost categories for energy crops for 18 world regions. For forestry products no detailed information is available and some rough cost estimates from literature are provided.
Which biomass conversion technologies distinguished	A range of conversion techniques are discussed in Chapter 11.2, see e.g. Figure 11.14. Learning rates and investment costs are also discussed and references to other studies are provided. However, from the scenario study it is not clear which technology mix is finally used.
Competition to non-energy sectors considered?	Yes, through the IMAGE model, e.g. feed and food production is taken into account.
Land use change impacts assessed? Please specify how.	Land use change is included through the IMAGE model, and results are (indirectly) taken into account (see also Figure 17.22 and 17.24), but no detailed results are presented.
Peer reviewed?	Yes, the entire assessment has been peer-reviewed anonymously by an additional 200 international experts.

Scenarios? Describe how many scenarios and short definition per scenario	All scenarios all aim at the four main energy challenges: improve energy access, reduce air pollution to improve human health, avoid dangerous climate change and improve energy security (see Table 17.2). From a large ensemble of possible transformations, three distinct groups of pathways have been identified and analysed. GEA-Efficiency Pathway emphasizing demand-side and efficiency improvements, GEA-Supply Pathway emphasizing the supply-side transformation at relatively high energy demand and GEA-Mix Pathway emphasizing regional diversity at an intermediate level of demand between GEA-Efficiency and GEA-Supply.  Besides these three main illustrative pathways also restricted supply pathways were simulated, e.g. limited bioenergy use or no nuclear, which can be considered as sensitivity analysis.
Main scenario parameters	See Chapter 17.3. In Table 17.3 the main external and endogenous parameters are listed.
Baseline scenario.	The hypothetical no-policy baseline (counterfactual) of the GEA describes the evolution of the energy system in absence of any transformational policies to meet the GEA objectives. In the GEA counterfactual fossil fuels more than double their contribution by 2050 (reaching about 900 EJ). The baseline assumes no climate change mitigation, pollution control, or energy security policies other than what is already planned over the next few years.
Related to Energy Roadmap 2050 scenarios?	No
Relevant data	See database: http://www.iiasa.ac.at/web-apps/ene/geadb
Other remarks	Results are presented for both the IMAGE and the MESSAGE model, and these can be quite different in some cases, which expresses high uncertainty.

A2.6.6 EEA Review on the EU bioenergy potential from a resource efficiency perspective

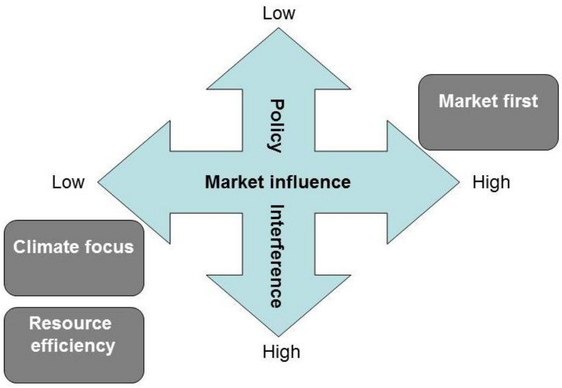
Name study	Review on the EU bioenergy potential from a resource efficiency perspective
Reference	EEA (2013). EU bioenergy potential from a resource efficiency perspective. EEA report No 6/2013. ISSN 1725-9177. Elbersen, B.S.; Fritsche, U.; Petersen, J.E.; Eerens, H.; Overmars, K.; Lesschen, J.P.; Staritsky, I.; Zulka, K.P.; Brodski, L.; Hennenberg; Barbu, A.D. & Clubb, D. (2013). Review of the EU bioenergy potential from a resource efficiency perspective. Background report to EEA study. ETC-SIA & ETC-CC.
Website	http://www.eea.europa.eu/publications/eu-bioenergy-potential http://sia.eionet.europa.eu/activities/announcements/ann1372453123
Short description (main aim and approach)	EU's *Resource Efficiency Roadmap* (EC, 2011) establishes resource efficiency as the guiding principle for EU policies on energy, transport, climate change, industry, and other sectors and regional development. At the same time the Renewable Energy Directive (EU, 2009) still sets a general binding target for the European Union to consume 20 % of its final energy from renewable sources by 2020. From the NREAPs it is apparent that bioenergy will make up more than 50% of all renewable energy in 2020 - implying that it will account for about 10 % of the EU's total gross final energy consumption. In this study the most resource efficient ways for reaching the 2020 bioenergy targets were analysed. Three storylines are used to model the environmental and land use implications, the total bioenergy potential and GHG emissions and mitigation in 2020 from the agricultural, forest, and waste sectors and imports.
Type of study	The study focusses on reaching the EU 2020 bioenergy targets using domestic and imported biomass resources. The focus is on assessing the impacts of EU targets on global GHG emissions and mitigation and on direct land use impacts on EU water, soil and biodiversity resources. The study is organised around 3 storylines/scenarios. Impacts on direct GHG emissions and nitrates in water are assessed with the MITERRA model.
Spatial resolution	Capri regional level (NUTS 2/3). All environmental assessments are done at EU regional level. Biomass potentials from outside the EU were taken from the PBL study (van Vuuren *et al*., 2009).
Spatial extent	This is an EU wide study, most analyses (on biomass potentials and environmental impact assessments) were done at regional level (NUTS 2/3). The focus was on reaching NREAP targets and effects on global GHG emissions (mitigation) and on EU wide regional specific effects on water quality, quantity, soil erosion and biodiversity. Biomass imports from outside EU needed to reach NREAP targets were part of the assessment.
Time horizon	Till 2020
Time step	Comparison of environmental impacts is done by comparing relative changes between 2004 and 2020.

Modelling involved? Which model(s)	Yes different models involved: CAPRI, MITERRA, GWSI, IMAGE (for import mix available globally). See underneath schematic approach of methodology applied and models involved. 
Types of biomass distinguished	Biomass potentials and costs (technical and sustainable) are presented for different biomass types (for agricultural crops (rotational and perennial) and agricultural residues (straw, manure, prunnings, abandoned grassland cuttings), forest residues (primary, secondary and tertiary residues) and waste (MSW (land fill/no-landfill), animal waste, used fats and oils, post-consumer wood)
Information about costs of biomass available?	Yes, using the cost estimates of the Biomass Futures project (Elbersen *et al*., 2012). Types of biomass sources used in reaching NREAP targets is made dependent on whether cost of supply are below max cost threshold (e.g. 3 €/GJ and 6 €/GJ for biomass to heat and power pathways depending on scenario situation).
Which biomass conversion technologies distinguished?	Very wide, but only energy technologies. See Table from Biomass Futures review.
Competition to non-energy sectors considered?	Yes ILUC is extensively addressed. In price estimates for some agro-residues and forest residues competing uses are incorporated (e.g. straw, paper cardboard)
Land use change impacts assessed?	Yes direct and indirect land use change impacts are incorporated in the GHG-LCA calculations. The direct land use change impacts are also used to assess the effects on water quality and quantity, erosion and biodiversity. ILUC is taken into account by incorporating ILUC related GHG emission factors in the total GHG-LCA assessments.
Peer reviewed?	Elbersen, B., Fritsche, U. Petersen, J.-E., Lesschen, J.P., Böttcher, H. and Overmars, K. 2013. Assessing the effect of stricter sustainability criteria on EU biomass potential. Biofuels, Bioproducts & Biorefining (Biofpr), 7(2): 173–192.

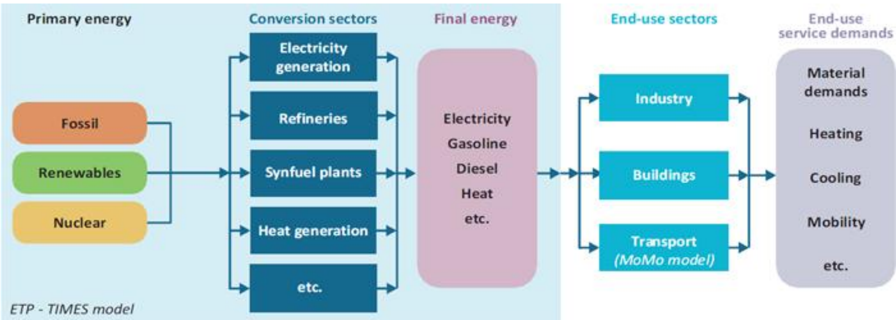
Scenarios? Describe how many scenarios and short definition per scenario.	There are 3 scenarios elaborated:

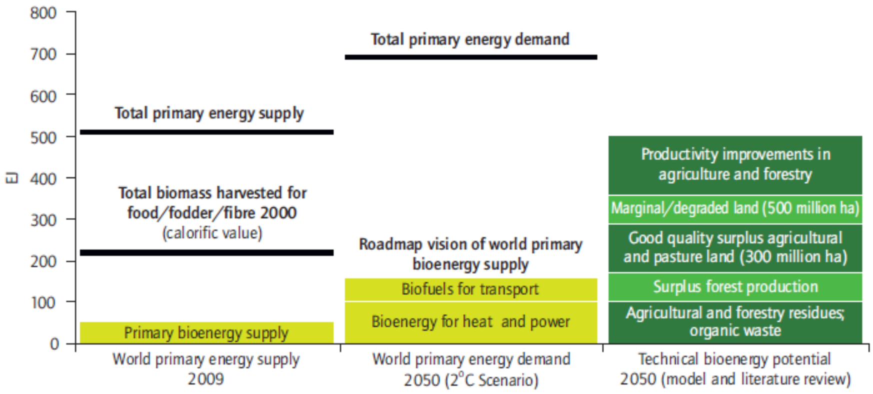
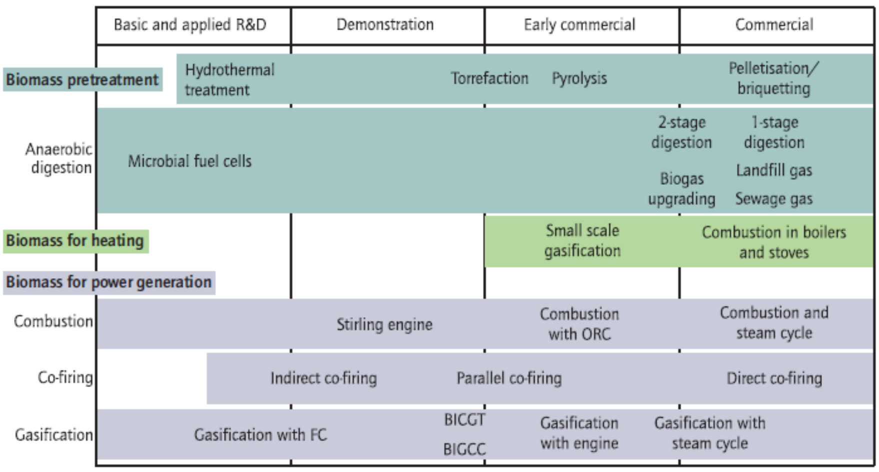
Storyline	Minimum GHG efficiency target	Consideration of iLUC effects	Technology and feedstock assumptions	Environmental constraints
Market first	None	None	Larger centralised installations Feedstock price up to EUR 3/ton	No special constraints No 'no-go' areas
Climate focus	50 % for biofuels only	Yes, for biofuels only	Smaller de-centralised installations; more technol. innovation; feedstock price up to EUR 6/ton	No use of HNV farmland, peat land, permanent grassland or Natura 2000 areas; except use of cuttings
Resource efficiency	50 % for all bioenergy uses	Yes, for all bioenergy uses	Smaller de-centralised installations; more technol. innovation; feedstock price up to EUR 6/ton	No use of HNV farmland, peat land, permanent grassland or Natura 2000 areas; except use of cuttings; keep minimum 10% of fallow land; no irrigation of bioenergy crops

Note: Price for feedstock at gate price for heat and electricity pathways. Form biofuels the feedstock prices are higher and determined by agricultural and oil prices assessed with the CAPRI model.

Main scenario parameters	See above and underneath: 
Baseline scenario	There is no baseline scenario in this study. The assessment on environmental impacts is compared against the situation in 2004. The reason is that there was no scenario assessment available in which there are no targets set for bioenergy.
Related to Energy Roadmap 2050 scenarios?	No
Relevant data	All data available at Alterra for this study
Other remarks	Many scenario parameters in this study already incorporated in the discussion about the scenario definition for the Carbon Impact study.

A2.6.7 IEA Technology roadmap Bioenergy (2012)

Name study	IEA - Technology Roadmap - Bioenergy for Heat and Power
Reference	IEA. 2012. Technology Roadmap - Bioenergy for Heat and Power. IEA, Paris.
Website	http://www.iea.org/publications/freepublications/publication/name,27281,en.html, see also: http://www.iea.org/etp/etp2012/
Short description (main aim and approach)	This roadmap further develops for bioenergy past IEA analysis in line with the Energy Technology Perspectives 2012. The ETP 2012 2°C Scenario sets out cost effective strategies for reducing greenhouse gas emissions in the energy sector by 50% in 2050 compared to 2005 levels. The analysis this scenario and roadmap shows that bioenergy could make an important contribution to reducing emissions and enhancing energy access. It would involve increasing bioenergy from around 10% of world primary energy supply today to 24% by 2050. The roadmap will enable governments, industry and financial partners, in conjunction with civil society, to identify steps needed and implement measures to accelerate the required technology development and uptake and public acceptance.
Type of study	Single scenario study based on previous analyses by IEA and literature reviews
Spatial resolution	Most data at global level, some are available for 8 global regions (Other developing Asia, China, Central and South America, Africa and Middle East, Eastern Europe and FSU, OECD Europe, OECD Asia Oceania and OECD Americas)
Spatial extent	Global
Time horizon	2050
Time step	Some of the results are presented at 5 year time steps
Modelling involved? Which model(s)	Not directly in this study, but the analysis is also based on the ETP 2012 study by IEA for which the ETP model was used, which is based on the TIMES framework. For more details see http://www.iea.org/etp/etpmodel/ 

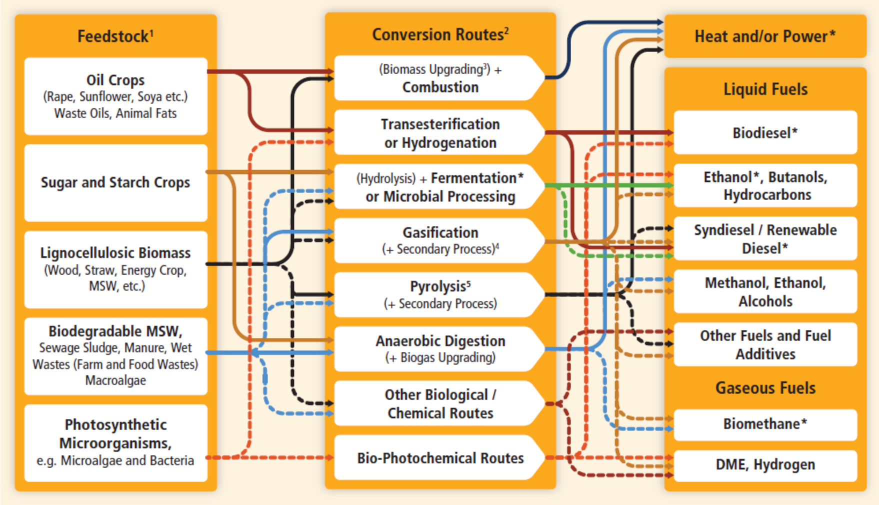
<table>
<tr><td>Types of biomass distinguished</td><td>Not very detailed: see figure below

</td></tr>
<tr><td>Information about costs of biomass available?</td><td>Some very general information is available, see e.g. Figure 4 (page 12).</td></tr>
<tr><td>Which biomass conversion technologies distinguished</td><td>All relevant technologies are discussed, see e.g. Figure 6


Note: ORC = Organic Rankine Cycle; FC = fuel cell; BICGT = biomass internal combustion gas turbine; BIGCC = biomass internal gasification combined cycle
Source: Modified from Bauen *et al.*, 2009</td></tr>
<tr><td>Competition to non-energy sectors considered?</td><td>Yes, but not very clear to what extent</td></tr>
<tr><td>Land use change impacts assessed?</td><td>No</td></tr>
<tr><td>Peer reviewed?</td><td>Yes, large group of external reviewers and participants that contributed at a workshop</td></tr>
</table>

Scenarios? Describe how many scenarios and short definition per scenario	In this study only one scenario is used, the 2 degrees warming scenario from the Energy Transition Perspective 2012 study. In that study also two other scenarios (4 and 6 degrees warming are available, in which the 6 degrees scenario represents continuation of the current trends).
Main scenario parameters	Main assumptions are a 50% reduction in GHG emissions from the energy sector by 2050 and an increase in the use of bioenergy (from 51 EJ in 2009 to 165 EJ in 2050 (incl. transport fuels))
Baseline scenario. Describe	The scenario is based on the Energy Technology Perspectives 2012 study, which includes three scenarios with different degrees of global warming. The 2°C Scenario (2DS) is the focus of ETP 2012, and describes an energy system consistent with an emissions trajectory that recent climate science research indicates would give an 80% chance of limiting average global temperature increase to 2°C. It sets the target of cutting energy-related CO_2 emissions by more than half in 2050 (compared with 2009) and ensuring that they continue to fall thereafter.
Related to Energy Roadmap 2050 scenarios?	Not directly, although it is stated that the roadmap is built on previous roadmaps and studies including the Energy Roadmap 2050.
Relevant data	No further detailed data available.
Other remarks	No.

A2.6.8 IPCC special report on Renewable Energy Sources and Climate Change Mitigation

Name study	Renewable Energy Sources and Climate Change Mitigation - Special Report of the Intergovernmental Panel on Climate Change
Reference	IPCC. 2011. IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change (O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (Eds)). Cambridge University Press, Cambridge, United Kingdom and New York, USA.
Website	http://srren.ipcc-wg3.de/
Short description (main aim and approach)	The report provides an assessment and thorough analysis of renewable energy technologies and their current and potential role in the mitigation of greenhouse gas emissions. The results are based on an extensive assessment of scientific literature, but also an aggregate across studies analysed for broader conclusions. The report combines information on technology specific studies with results of large-scale integrated models, and provides policy-relevant information to decision makers on the characteristics and technical potentials of different resources; the historical development of the technologies; the challenges of their integration and social and environmental impacts of their use; as well as a comparison in levelised cost of energy for commercially available renewable technologies with recent non-renewable energy costs.
Type of study	Review study
Spatial resolution	Most of the data are presented at global level, few data are at regional level, but no fixed classification is used
Spatial extent	Global
Time horizon	Not defined, but for some results up to 2050
Time step	Not defined, some results are presented for 2020 or 2030, others for 2050.
Modelling involved? Which model(s)	No, report is a literature overview, but in underlying studies modelling is used
Types of biomass distinguished	A range of biomass types is discussed in this study, but no consistent classification is used.
Information about costs of biomass available?	Yes, quite some information is available, however all indicated by wide regions, see Annex III, cost estimates are available for different bioenergy technologies and feedstock and also for different biofuel crops. In Table 2.16 and Figure 2.17 simulated costs for energy crops for 17 world regions are provided based on a paper by Hoogwijk *et al*. (2009).

Which biomass conversion technologies distinguished	A range of technologies is described, see also figure below (TS.2.3) 
Competition to non-energy sectors considered?	Yes indirectly, as this is mainly a literature review study it is not clear to what extend competition to non-energy sectors is included in the individual studies.
Land use change impacts assessed?	Only in descriptive terms, based on other studies.
Peer reviewed?	Yes, large group of reviewers, according to review procedures by IPCC
Scenarios?	No.
Main scenario parameters	N.A.
Baseline scenario	N.A.
Related to Energy Roadmap 2050 scenarios?	No
Relevant data	See Table 2.3 for technical potential of rain-fed lignocellulosic plants on unprotected grassland and woodland for seven continental regions. Some cost curves for energy crops in Europe are shown in Figure 2.5 Table 2.4 shows energy yields and costs for different biomass feedstocks Table 2.14 shows potential yield increases (by 2030) for energy crops and residues
Other remarks	The report is very extensive, 1088 pages in total, and for the bioenergy chapter 124 pages. The report provides a good overview of the relevant literature till 2011. Many of these data also form the basis for the work in the Bioenergy technology roadmap of IEA. The report provides a good glossary

A2.6.9 DG Energy study on real potential for changes in growth and use of EU forests (EUwood)

Name study	Real potential for changes in growth and use of EU forests (EUwood)
Reference	Mantau, U. *et al*. 2010. EUwood - Real potential for changes in growth and use of EU forests. Final report. Hamburg/Germany, June 2010. 160 p.
Website	http://ec.europa.eu/energy/renewables/studies/doc/bioenergy/euwood_final_report.pdf
Short description (main aim and approach)	EUwood is based on the Wood Resource Balance, which brings together in structured format all parts of supply and demand of wood. EUwood has made historical balances for 2005 and 2007, and projected balances for 2010, 2020 and 2030. The forecasts compare, on the supply side, the potential wood supply scenarios, from the forest and outside the forest, and on the demand side, future demand for wood raw material from the industry and for energy.
Type of study	Scenario/outlook study, quantification of mismatch between demand and potential supply
Spatial resolution	countries
Spatial extent	EU-27
Time horizon	2030
Time step	10 years (2010-2020-2030)
Modelling involved? Which model(s)	EFISCEN for potential supply from forest. Literature estimates for supply outside forest (landscape care wood, post-consumer wood, short rotation coppices). Econometric modelling for demand for wood products.
Types of biomass distinguished	Stemwood, harvest residues (branches and topwood), stumps, industrial residues, landscape care wood, post-consumer wood.
Information about costs of biomass available?	No
Which biomass conversion technologies distinguished	None
Competition to non-energy sectors considered?	No
Land use change impacts assessed?	No
Peer reviewed?	No
Scenarios? Describe how many scenarios and short definition per scenario	Biomass mobilisation: low-medium-high. Energy demand: baseline or EU 2020 targets Wood product demand: derived from A1 or B2 IPCC SRES scenario
Main scenario parameters	

Baseline scenario	No real baseline included. There is the option to compare different combinations of (sub)scenarios on both supply and demand side to see if total demand can be met by potential supply.
Related to Energy Roadmap 2050 scenarios?	No, although 2020 targets are based on the NREAP's, which are also included in the Energy Roadmap
Relevant data	Country level data are published in the report, and can be viewed via an Excel tool (dashboard).
Other remarks	

A2.6.10 IMAGE PBL study on future bioenergy potential under various natural constraints

<table>
<tr><td>Name study</td><td>IMAGE PBL study: Future bio-energy potential under various natural constraints</td></tr>
<tr><td>Reference</td><td>Van Vuuren D.P., Van Vliet J. and Stehfest E. 2009. Future bio-energy potential under different assumptions. Energy Policy, 37: 4220–30.</td></tr>
<tr><td>Website</td><td>http://www.sciencedirect.com/science/article/pii/S0301421509003425#bbib11</td></tr>
<tr><td>Short description (main aim and approach)</td><td>With the integrated assessment model IMAGE 2 and the global energy model TIMER an estimate is made of the technical and economic potential of bio-energy. First step was to assess, which, areas can be used for bio-energy production based on physical-geographical characteristics and other land requirements. The IMAGE model was used to describe land use excluding biomass production, taking into account future driving forces such as food demand, crop yields and climate change. The area available for biomass production is restricted to abandoned agricultural land and natural grassland systems such as savannah, scrubland, tundra and grasslands, thus excluding land for food production, forests, nature reserves and urban areas. In addition, a land-cover specific accessibility factor is introduced to represent other constraints such as biodiversity protection and alternative land use that reduces the area that can be used for biomass production.
In this study own IMAGE estimates of bio-energy potentials were re-evaluated by using a sensitivity analysis to explore how some uncertainties with respect to bio-energy could influence its future use. Account was taken of yield estimates and land-use scenarios, land degradation, water scarcity and biodiversity constraints. Firstly, the focus was on the potential impact of these factors on the biophysical potential. Secondly, the effect of climate policies was explored on future use of bio-energy, taking into account the uncertainty of the biophysical potential.

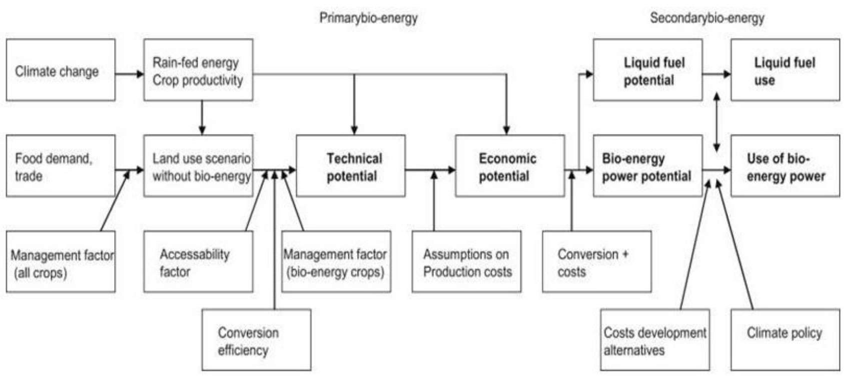


Fig. 1 Methodology of assessing bio-energy potentials.</td></tr>
<tr><td>Type of study</td><td>Assessment of global biomass potential under different natural constraints</td></tr>
<tr><td>Spatial resolution</td><td>IMAGE works at world level at 0.5 ° * 0.5° . The TIMER model works with world regions (26 regions)</td></tr>
<tr><td>Spatial extent</td><td>This is a global study and assessments are done at 0.5 ° * 0.5° .</td></tr>
<tr><td>Time horizon</td><td>Till 2050 at 10 year time steps</td></tr>
<tr><td>Time step</td><td>10 years</td></tr>
</table>

Modelling involved? Which model(s)	IMAGE and TIMER IMAGE is an integrated assessment modelling framework describing global environmental change in terms of cause–response chains (Bouwman *et al*., 2006). The land-cover sub-models in the earth system simulate change in land use and land cover at 0.5°×0.5° (driven by demands for food, timber and bio-energy and changes in climate). A crop module based on the FAO agro-ecological zones approach computes the spatially explicit yields of the different crop groups and the grass, and the areas used for their production, as determined by climate and soil quality. Where expansion of agricultural land is required, a rule-based "suitability map" determines the grid cells selected (on the basis of the grid cell's potential crop yield, its proximity to other agricultural areas and to water bodies). The earth system also includes a natural vegetation model to compute changes in vegetation in response to climate change. IMAGE accounts for feedbacks within the system, such as temperature, precipitation and atmospheric CO_2 feedbacks on the selection of crop types, and the migration of ecosystems. This allows for calculating changes in crop and grass yields and, as a consequence, the location of different types of agriculture, changes in net primary productivity and migration of natural ecosystems. TIMER is an energy-system model that is part of the IMAGE-integrated assessment framework. The model describes the demand and supply of 9 final energy carriers and 10 primary energy carriers for 17/26 world regions (depending on the model version). A full description of the model can be found elsewhere (van Vuuren and de Vries, 2001; Van Vuuren, 2007). The main objective of the TIMER model is to analyse the long-term trends in energy demand and efficiency and the possible transition to renewable sources. The model focuses on several dynamic relationships within the energy system, such as inertia, learning-by-doing, depletion and trade among the different regions. The demand sub-model of TIMER determines demand for fuels and electricity in five sectors (industry, transport, residential, services and other) based on structural change, autonomous and price-induced change in energy intensity ('energy conservation') and price-based fuel substitution. The demand for electricity is fulfilled by fossil fuel or bio-energy-based thermal power, hydropower, nuclear power and solar or wind. All technologies are chosen on the basis of relative costs. The exploration and exploitation of fossil fuels (either for electricity or direct fuel use) is described in terms of depletion and technological development. Bio-energy can be used in place of fossil fuels, and are in their turn also assumed to be subject to technological development and depletion dynamics using the long-term supply cost supply curves described in this paper.
Types of biomass distinguished	The data based on this study include the following biomass categories: Availability agriculture (PJ) Availability residues from forests and SRC wood (PJ) Availability agricultural residues (PJ) Availability waste (PJ)
Information about costs of biomass available?	Yes

Which biomass conversion technologies distinguished?	
Competition to non-energy sectors considered?	Yes ILUC is extensively addressed. In price estimates for some agro-residues and forest residues competing uses are incorporated (e.g. straw, paper cardboard)
Land use change impacts assessed?	Yes, direct and indirect land use change impacts are incorporated in the GHG-LCA calculations. The direct land use change impacts are also used to assess the effects on water quality and quantity, erosion and biodiversity. ILUC is taken into account by incorporating ILUC related GHG emission factors in the total GHG-LCA assessments.
Peer reviewed?	Yes. Van Vuuren D.P., Van Vliet J. and Stehfest E. 2009. Future bio-energy potential under different assumptions. Energy Policy, 37: 4220–30.
Scenarios? Describe how many scenarios and short definition per scenario	
Main scenario parameters	
Baseline scenario	
Related to Energy Roadmap 2050 scenarios?	No
Relevant data	
Other remarks	No

Appendix 3 Forest potentials EFSOS II

A3.1 General approach

Within EFSOS II, the EFISCEN model was first used to assess the realisable harvest potentials for the period 2010-2030 with five-year time-steps, as input to the EFI-GTM model (Moiseyev *et al*., 2011). The potentials were estimated separately for stemwood; branches and harvest losses (further: 'residues'); stumps and coarse roots (further: 'stumps'); and woody biomass from early or energy thinnings in young forests (further: 'other biomass'). The potential supply was estimated based on an approach developed by Verkerk *et al*. (2011) in the EUwood study (Mantau *et al*., 2010). Following this approach, we first estimated the theoretical potential of forest biomass supply in Europe based on detailed forest inventory data. Second, multiple environmental, technical, and social constraints were defined and quantified that reduce the amount of biomass that can be extracted from forests for three mobilisation scenarios for the future. Third, the theoretical potentials from the first step were combined with the constraints from the mobilisation scenarios.

A3.2 Theoretical potential

The theoretical potential was defined by Verkerk *et al*. (2011) as the overall, maximum amount of forest biomass that could be harvested annually within fundamental bio-physical limits (adapted from Vis *et al*., 2010), taking into account increment, the age-structure and stocking level of the forests. The maximum, average harvest level was re-estimated for every five year time-step for the following 50 years to take into account changes in forest structure, growth etc. (i.e. 2010-2060, 2015-2065 etc.). This approach provided direct estimations of the stemwood potentials from thinning and final fellings separately. For countries without detailed inventory data, we assumed the theoretical stemwood harvest potential to be equal to the net annual increment, corrected for harvesting losses.

Upon harvest, stem residues from harvest losses (e.g. stem tops) become potentially available, as well as branches, needles, stumps and coarse roots. The amount of biomass generated during harvest from these tree components were used to assess the theoretical potential of logging residues and stumps/roots from thinning and final fellings separately.

Direct model outputs do not include estimations for the potentials from early thinnings (i.e. thinning in very young stands; also referred to as pre-commercial thinnings) and had to be estimated by post-processing the EFISCEN results. The theoretical potential from early thinnings was estimated by assuming 30% (cf. Kofman, 2006; Tapio, 2007) removal of the stems, branches and needles of 1-10 year old forests. We estimated the potential from early thinning from even-aged forests only; coppice and uneven-aged forests were excluded. The share of even-aged forests in the total FAWS was estimated from Forest Europe *et al*. (2011).

Altogether, the following theoretical forest biomass potentials were estimated for coniferous and broadleaved forests separately: stemwood from thinnings and final fellings, logging residues from thinnings and final fellings, stumps from thinnings and final fellings and stem and crown biomass from early thinnings. Aboveground biomass was based on biomass allocation functions from Teobaldelli *et al*. (2009) and stump biomass was estimated based on data by Asikainen *et al*. (2008).

A3.3 Constraints

The theoretical woody biomass potential is higher than what can be supplied from the forest due to various constraints. Constraints on wood mobilisation were identified from existing biomass harvesting guidelines in the EUwood project (Mantau *et al*., 2010). The selected constraints are listed in Table A3.1. There are many more (especially social and economic) constraints (e.g. Forest Europe *et al*., 2011), but they were excluded from this analysis due to lack of data.

Table A3.1 Constraints used in EUwood

Constraint	Type	Explanation
Soil productivity	Environmental	The nutritional impact of biomass harvesting in forests is influenced by the degree to which foliage and small branches are extracted from a site. If soils are more productive, they can tolerate a higher degree of biomass extraction (Äijälä *et al*., 2010; Forest Research, 2009a).
Soil and water protection	Environmental	Removal of forest biomass inevitably involves vehicle operations and soil disturbances. The extraction of forest residues and stumps increases the risk for erosion, especially on steep slopes (Asikainen *et al*., 2008; Forest Research, 2009b; Vasaitis *et al*., 2008; Fernholz *et al*., 2009). Forests have an important role in the protection of watersheds. Intensive logging and residue extraction may result in the degradation of water quality (Forest Research, 2009b; Fernholz *et al*., 2009). The extraction of forest residues on sites with shallow soils could increase erosion risk (Fernholz *et al*., 2009). Using heavy machinery for extracting biomass can lead to soil compaction, particularly in wet soil (Forest Research, 2009a; Forest Research, 2009b).
Biodiversity protection	Environmental	To prevent loss of biodiversity a significant percentage of the European forest area is protected or managed for conservation purposes with constraints on harvesting activities (Fernholz *et al*., 2009; Fehrenbach *et al*., 2008). An exception could be made in areas with high or very high forest fire risk.

Table A3.1 (continued) Constraints used in EUwood

Constraint	Type	Explanation
Recovery rate	Technical	Part of the woody biomass from forest is lost before reaching the point of utilisation due to, e.g., loss or damage of biomass during harvesting. The technical recovery rate depends on the used harvesting technology (Nurmi, 2007; Peltola *et al*., 2011).
Soil bearing capacity	Technical	On soft soils the bearing capacity of soil can reduce the amount of harvestable biomass, e.g., because logging residues are used to strengthen the bearing capacity of the soil on the forwarding trail (Driessen *et al*., 2001).
Distributed forest ownership	Social/economical	Private owners with small properties may be less motivated to sell wood as harvesting may not be economically significant, transaction costs too high, or due to other management objectives than wood production (Straka *et al*., 1984; Amacher *et al*., 2003).

A3.4 Mobilisation scenarios

Guidelines were not available for all countries and existing guidelines are being updated and may change over time. Hence, we quantified the constraints for all types of biomass and felling activities for two mobilisation scenarios. The scenarios were defined as follows:

The 'high mobilisation scenario' (used as Promoting wood energy scenario in EFSOS II) has a strong focus on the use of wood for producing energy and for other uses. Recommendations on wood mobilisation are successfully translated into measures that lead to an increased mobilisation of wood. This means that new forest owner associations or co-operations are established throughout Europe. Together with existing associations, these new associations lead to improved access of wood to markets. Strong mechanisation is taking place across Europe and existing technologies are effectively shared between countries through improved information exchange. Biomass harvesting guidelines become less restricting, because technologies are developed that are less harmful for the environment. Furthermore, possible negative environmental effects of intensified use of forest resources are considered less important than the negative effects of alternative sources of energy or alternative building materials. Application of fertilizer is permitted to limit detrimental effects of logging residue and stump extraction on the soil.

The 'medium mobilisation scenario' (used as reference scenario in EFSOS II) builds on the idea that recommendations are not all fully implemented or do not have the desired effect. New forest owner associations or co-operations are established throughout Europe, but this does not lead to significant changes in the availability of wood from private forest owners. Biomass harvesting guidelines that have been developed in several countries are considered adequate and similar guidelines are implemented in other countries. Mechanisation of harvesting is taking place, leading to a further shift of motor–

manual harvesting to mechanised harvesting. Application of fertilizer is permitted to limited extent to limit detrimental effects of logging residue and stump extraction on the soil.

In the next step, each of the environmental and technical constraints was quantified separately for the type of biomass (i.e., stemwood, residues, stumps and other biomass) and by type of felling activity (i.e., early thinning, thinnings and final fellings) for the two mobilisation scenarios. For stemwood, the environmental and technical constraints were implicitly quantified by considering only the forest area available for wood supply, i.e., “forests where any legal, economic, or specific environmental restrictions do not have a significant impact on the supply of wood” (Forest Europe *et al*., 2011). The environmental and technical constraints for stemwood were not quantified individually in order to avoid double counting of their effect on potential stemwood supply. Furthermore, it was assumed that the FAWS area remained constant in the high and medium scenario. For the other types of biomass, the potentials were limited as well to the forest area available for wood supply, but additional constraints were applied. Based on the guidelines and recommendations, general assumptions on the extraction rates of biomass from early thinning, and logging residues and stumps from thinnings and final fellings were made. To avoid overlap, a spatially-explicit approach was used to quantify these environmental and technical constraints, with the following spatial datasets:

- Site productivity, soil surface texture, soil depth and soil bearing capacity (EC, 2006).
- Natural soil susceptibility to compaction (Houšková, 2008).
- Slope (USGS, 1996).
- Natura 2000 sites (EC, 2009).
- Fire weather index (average for summer months June–August over the period 1975–2005).

All spatial datasets were combined with the relevant constraint values for the different mobilisation scenarios. A raster layer was created for each constraint with a resolution of 1 km×1 km. Finally, all relevant layers were combined and the lowest, permitted extraction rate according to each mobilisation scenario was defined for each pixel. The resulting raster layers were then combined with the European forest map (Schuck *et al*., 2002, also on a 1 km x 1 km resolution) to calculate the weighted average restriction per EFISCEN region and country. This was done separately for the constraints for logging residues and stumps from thinnings and final fellings and other biomass. Table A3.2 provides an example of how the constraints differ among the mobilisation scenarios for extracting logging residues. More details can be found in the supplementary material of the paper by Verkerk *et al*. (2011).

Table A3.2 Maximum extraction rates for extracting logging residues from final fellings due to environmental and technical constraints for three mobilisation scenarios

Type of constraint	Current (2010) and medium mobilisation	High mobilisation	Low mobilisation
Site productivity	Not a constraining factor	Not a constraining factor	35% extraction rate on poor soils (Acrisol, Podzoluvisol, Histosol, Podzol, Arenosol, Planosol, Xerosol); not a constraining factor on other soils
Soil and water protection: Slope	67%on slopes up to 35%; 0% on slopes over 35%, unless cable-crane systems are used	67% factor on slopes up to 35%; 0% on slopes over 35%, unless cable-crane systems are used	67% factor on slopes up to 35%; 0% on slopes over 35%, unless cable-crane systems are used
Soil and water protection: Soil depth	0% on Rendzina, Lithosol and Ranker (very low soil depth)	0% on Rendzina, Lithosol and Ranker (very low soil depth)	0% on Rendzina, Lithosol and Ranker (very low soil depth)
Soil and water protection: Soil surface texture	0% on peatlands (Histosols)	33% on peatlands (Histosols)	0% on peatlands (Histosols)
Soil and water protection: Soil compaction risk	0% on soils with very high compaction risk; 25% on soils with high compaction risk; not a constraining factor on other soils	0% on soils with very high compaction risk; 50% on soils with high compaction risk; not a constraining factor on other soils	0% on soils with high or very high compaction risk; 50% on soils with medium compaction risk; not a constraining factor on other soils
Biodiversity: protected forest areas	0%; not a constraining factor in areas with high or very high fire risk	0%; not a constraining factor in areas with high or very high fire risk	0%; not a constraining factor in areas with high or very high fire risk
Recovery rate	67% on slopes up to 35%; 0% on slopes over 35%, but 67% if cable-crane systems are used	70% on slopes up to 35%; 0% on slopes over 35%, but 67% if cable-crane systems are used	65% on slopes up to 35%; 0% on slopes over 35%, but 67% if cable-crane systems are used
	Cable cranes are applied in Austria, Italy, France, Germany, Czech Republic, Slovakia, Slovenia, Romania	Cable cranes are applied in Austria, Italy, France, Germany, Czech Republic, Slovakia, Slovenia, Romania, Bulgaria	Cable cranes are applied in Austria, Italy, France, Germany, Czech Republic, Slovakia, Slovenia, Romania
Soil bearing capacity	0% on Histosols, Fluvisols, Gleysols and Andosols	0% on Histosols, Fluvisols, Gleysols and Andosols; not a constraining factor in Finland and Sweden	0% on Histosols, Fluvisols, Gleysols and Andosols

Appendix 4 Biomass crop potentials (Biomass Futures)

A4.1 Scenarios

Biomass Futures developed two alternative EU policy scenarios (reference and sustainability scenarios). The difference in biomass potential between the scenarios shows the effect of additional sustainability criteria. These additional criteria are part of the sustainability scenario while the reference scenario only represents the current legal framework of countries included in the NREAP targets and RED sustainability criteria. The sustainability scenario applies more stringent and more comprehensive sustainability criteria and these are not only applicable to biofuels but also to solid and gaseous biomass sources. A very important difference with the reference scenario is that this GHG mitigation requirement should also account for emissions from iLUC caused by biomass cropping in the EU. There are two major differences to the reference scenario: stricter GHG mitigation thresholds as compared to the fossil equivalent (applied to all bioenergy forms not only biofuels) and constraints on the use of land with high biodiversity and carbon content (Table A4.1). The flow diagram in Figure A4.1 provides an overview of the whole analytical chain employed and the input of different models.

Table A4.1 Sustainability criteria applied in the reference and sustainability scenarios

	GHG mitigation	Other constraints
Reference scenario	Mitigation target for biofuels of 50% as compared to fossil alternatives, excluding compensation of iLUC related emissions. No mitigation target set for bioelectricity and heat.	No use of biomass for biofuels cropped on biodiverse land or land with high carbon stock.
Sustainability scenario	Mitigation target for bioenergy (fuels, heat and electricity) of 70% as compared to fossil alternatives, including compensation of iLUC related emissions.	No use of biomass cropped on biodiverse land, land with high carbon stock and fallow land.

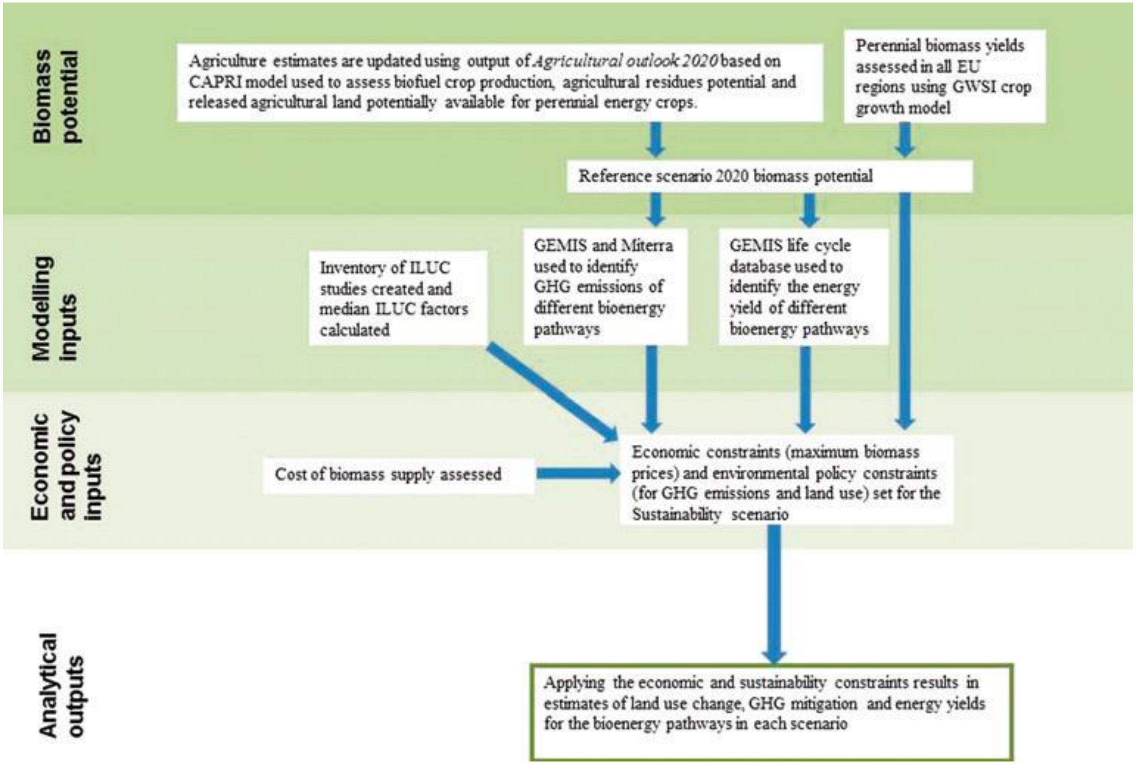


Figure A4.1. Analytical steps and models used to assess bioenergy potential (Elbersen *et al*., 2013)

A4.2 Estimating the land potential for bioenergy cropping

The land estimates in Biomass Futures were built on CAPRI (Common Agricultural Policy Regionalised Impact) model results which predict future land use changes in the EU27 related to agricultural production including those for domestic biofuels. For 2020, the baseline scenario as run with the CAPRI model for the EC report 'Prospects for agricultural markets and income in the EU 2010–2020'22 was used. The use of the CAPRI results is very logical as it is the only available model which predicts the EU markets and production responses at regional level for the whole EU27. It is therefore the only source of information available that gives a plausible overview taking account of the specific diverse regional circumstances in the EU, of what land use changes can be expected by 2020 and the extent to which they can be related to dedicated bioenergy cropping and other renewable energy activities on farms. The emphasis in the CAPRI run is on predicting biofuel cropping response. In addition to this specific information, it also provides detailed information on agricultural land use cropping and livestock patterns. The CAPRI model output serves as an excellent basis for estimating the land use implications and total domestic biofuel feedstock production in the reference scenario situation. It also supports estimates of the unused/released land potential in 2020, compared with 2004 that may be used for dedicated biomass cropping with perennial crops, taking account of the additional sustainability requirements specified in the sustainability scenario developed in this study. The outlook of the CAPRI baseline takes account of the Common Agricultural Policy (CAP) Health Check reform, the 2020 RES

Targets and the most recent OECD-FAO projections on agricultural prices, population and welfare developments.

The CAPRI model endogenously determines the changes in supply and other demand (feed, food, processing) for biofuels feedstocks by purely simulating market response to additional biofuel targets. As the CAPRI market component of the model comprises behavioural functions for oilseed and sugar and starch processing, the demand for biodiesel and bioethanol processing can be covered either by domestic or imported processed vegetable oils, and the domestic processing may be sourced by EU-produced feedstocks or by imported ones. The following technology pathways are covered:

- For total domestic ethanol production both conventional and advanced fuels are included, although the latter take a small share: (i) bioethanol made from starch from cereals sugar from sugar beet; (ii) advanced ethanol based on agricultural residues (e.g. stalks from wheat and corn) and dedicated woody and grassy crops; and (iii) advanced fuels from waste material and wood
- For biodiesel, also both the conventional and advanced fuels are included: (i) conventional fuels based on vegetable oils – differentiated in rape oil, sunflower oil, soya oil, and palm oil; (ii) advanced fuels from agricultural residues; and (iii) advanced fuels from waste and wood (e.g. Fischer-Tropsch diesel and wood diesel).

The CAPRI baseline assessment incorporates domestic use and supply of biofuels in the domestic ethanol and biodiesel production via a profit maximization approach as a function depending on processing margins and no account is taken of the GHG mitigation of the different segments of the biofuel supply. It is simply assumed that the biomass going into the EU biofuel consumed in 2020 also complies with the RED sustainability criteria. The baseline assessment uses a final 2020 mix of renewable biofuels that has been exogenously fed as input into CAPRI. These are based on projections of domestic use and supply of biofuels for the single EU27 MS (PRIMES model) and non-European countries (AgLink model). An important assumption in the CAPRI assessment is that the share of domestic biofuel demand in 2020 results from the implementation of quota obligations as proposed by the EC on a country-by-country basis and as estimated by each MS in its NREAP.

A4.3 Assessing the GHG mitigation potential per scenario for the bioenergy cropping pathways

For the estimation of the bioenergy potential in the sustainability scenario, an estimate of mitigation ability is made in a full life cycle assessment (LCA) analysis for all crops produced in the EU potentially converted into biofuels, including the iLUC effect and taking into account the type of feedstock and related bioenergy delivery pathway. A 20-year payback time for GHG mitigation is assumed. This is implemented by estimating the GHG mitigation efficiency factor which is built from three components: 1) Direct land-use emissions from the cropping process which are strongly linked to input and output levels which differ per EU region. 2) The downstream emissions of the biomass feedstock conversion routes. 3) A possible iLUC GHG emission factor if land use displacement is applicable. This iLUC factor is derived from global modelling studies reviewed as part of this study.

The emissions from the land-based part of the chain are calculated using the MITERRA-Europe model (Velthof *et al*., 2009). This model assesses the impact of measures, policies and LUCs on environmental indicators at the regional (NUTS-2) level in the EU-27. MITERRA-Europe calculates all relevant GHG emissions from agriculture (CH_4 from enteric fermentation and manure management; N_2O from manure management and direct and indirect soil emissions; and CO_2 from changes in soil carbon stocks and cultivation of organic soils), according to the IPCC 2006 guidelines. GHG emissions from fertilizer production and mechanization are also included. The emission and mitigation levels for crops depend very much on the yield at the different locations.

For biofuel crops, the yield potential is taken from the 2020 CAPRI baseline scenario. For perennial crops, the yield potentials for the perennial grasses are derived using the Global Water Satisfaction Index (GWSI) crop growth model and the yield levels for willow and poplar were derived from the Globiom simulations for Europe (see Böttcher *et al*. 2013). The GWSI model takes soil and climate characteristics into account and predicts yield levels for C3 and C4 grasses. The model is calibrated on real observed yield levels in different regions in the EU. The simulation results in a set of regional mean potential and water-limited yields for C3 and C4 perennial grasses. In order to arrive at yield levels per type of cropping system the following post-model processing rules were applied:

- High yield: Modern fully irrigated cropping: all grasses could reach 90% of the potential biomass yield.
- Medium yield: Modern rain-fed cropping (apart from crop establishment irrigation): attainable grass yield equals the lowest value of the following two yield levels: 90% of potential yield and 100% of the water-limited yield.
- Low yield: Extensive cropping: the lowest yield of the following two: 50% of the potential yield and 80% of the water-limited yield.

Since Miscanthus and switchgrass are both C4 crops the simulation results show the same yield levels for both crops. However, a literature review of field trial data showed that yields in different EU environmental zones for both crops show a clear difference. Based on this assessment, final yield correction factor to switchgrass were applied as follows:

- High yield (modern fully irrigated yield): switchgrass reaches 70% of miscanthus yield.
- Medium yield: modern rain-fed: switchgrass reaches 80% of miscanthus yield.
- Low yield: Extensive cropping: switchgrass reaches 90% of miscanthus yield.

The yield levels for the perennial crops were then used as input for the MITERRA-Europe model to calculate the direct emissions at the three management levels per NUTS-2 region in the whole EU27.

The emissions of the downstream part of the bioenergy pathways and of the fossil comparators are based on Global Emissions Model for integrated Systems (GEMIS) developed by Oeko-Institut, which refer to full life-cycle emissions. GEMIS 4.8 is a life-cycle analysis program and database for energy, material, and transport systems. The GEMIS database offers information on: (i) fossil fuels, renewables, nuclear, biomass and hydrogen; (ii) processes for electricity and heat; (iii) materials; and (iv) transport. GEMIS includes all key energy, material, and transport processes for more than 50 countries (including all EU countries) for the years 2000, 2010, 2020, and 2030. The version of GEMIS used for this assessment is updated for the wide range of (renewable) energy and transport processes expected to be technically and economically feasible until 2030.

The iLUC effect is difficult to estimate as it is caused by the introduction of a demand for bioenergy feedstock, but cannot be directly linked to the bioenergy production chain. The effect manifests itself through a change in demand for agricultural commodities at the global market. Modelling studies are therefore needed to estimate how big the effects are and how these translate into additional GHG emissions. Their estimates of iLUC GHG effects differ strongly, however, and illustrate that a unified view on the iLUC GHG emission factor does not exist. The major available studies regarding this issue have therefore been consulted as part of an EEA study (EEA, 2013) and an average iLUC-GHG factor is calculated to estimate the GHG payback and mitigation ability for each bioenergy pathway. In addition the recent IFPRI-Mirage BioF iLUC-GHG factors (Laborde, 2011) are included as well. An overview of the higher and lower iLUC factors per crop-biomass conversion chain used in this study is presented in Table A4.2.

Table A4.2 Difference between median iLUC factors (in g CO_2-eq/MJ biofuel) calculated from the studies considered in EEA (2013) and from the IFPRI-MIRAGE BioF study (Laborde, 2011)

	Median iLUC factor (EEA, 2013)	IFPRI-MIRAGE-Biof iLUC factor
Biodiesel based on rapeseed from Europe	77	55
Ethanol based on wheat from Europe	73	14
Ethanol based on sugar beet from Europe	85	7
Ethanol based on grain maize from Europe	40	10
Biodiesel based on palm oil from South-East Asia	77	54
Biodiesel based on soya from Latin America	140	56
Biodiesel based on soya from the United States	65	56
Ethanol based on sugar cane from Latin America	60	54

Table A4.2 (continued) Difference between median iLUC factors (in g CO_2-eq/MJ biofuel) calculated from the studies considered in EEA (2013) and from the IFPRI-MIRAGE BioF study (Laborde, 2011)

	Median iLUC factor (EEA, 2013)	IFPRI-MIRAGE-Biof iLUC factor
Ligno-cellulosic based land using second-generation ethanol	56	15
Ligno-cellulosic based land using second-generation biodiesel	56	15

To determine the final emission level for each pathway and region, the GHG emission of the whole bioenergy pathway is calculated in the GEMIS model by integrating the dLUC emissions calculated by the MITERRA-Europe model with the downstream emissions in a full GHG LCA analysis. In this way GEMIS covers whole networks of activities, from resource extraction to end-use involving the manufacturing stage for processes involved (cradle-to-grave). The minimum and maximum emissions in the pathways are determined by the extreme values in the up-stream (cropping) emissions in the high-, medium-, and low-input cropping systems.

To come to a final mitigation potential to assess whether the feedstock conversion pathway combination per region fits with the sustainability criteria in every scenario, a comparison is made with the GHG emissions of the fossil-based comparators. For transport fuels the diesel comparator for 2020 is set at 87.5 and for gasoline at 89.4 kg CO_2eq/GJ_{fuel} (assuming 100% efficiency, including upstream effects). The fossil fuel mix for calculating the average emissions of the 2020 fossil comparators for both electricity and heat are based on the PRIMES reference scenario for 2020. These emissions are based on the fossil fuels only (coal, lignite, oil and natural gas), since the assumption is that bioenergy pathways will replace fossil fuels and no other renewable energy sources or nuclear energy.

A4.4 Post-model assessment of released agricultural land to be used for dedicated cropping

Although the actual dedicated cropping area is still very small, the future bioenergy potential from dedicated cropping with these perennials could become more important for several reasons:

- Lignocellulosic material is a good feedstock for heat and power generation in increasingly efficient conversion technologies.
- Other cheaper lignocellulosic waste and by-products from the waste and forest sectors will be used first. However dedicated cropping with lignocellulosic crops could be an attractive option to ensure that there is enough local biomass available year-round, especially when competing uses are diminishing the potential from the other sectors.

- Lignocellulosic material is a feedstock for advanced biofuel production and within the next 10 years it is expected that these advanced pre-commercial types of technologies will become more economic and marketable (e.g. Fischer-Tropsch (F-T) synthesis and Biomass to Liquids (BtL) processes for woody and grassy biomass).
- Lignocellulosic crops generally have a higher GHG efficiency than rotational arable crops since they have lower input requirements and the energy yield per hectare is much higher. At the same time most lignocellulosic crops have lower soil quality requirements then rotational arable crops. If they are grown on lower productive land on which they do not compete with rotational arable crops, acceptable yields can still be reached and displacement eff ects (i.e. iLUC) are limited.
- Because of these reasons, advanced biofuel production is applicable for double counting for the RES-targets which could make lignocellulosic biomass feedstock more attractive. RES-stimulation measures can therefore also be expected to become implemented which make dedicated cropping with lignocellulosic crop on released or recently abandoned land, or even in competition with rotational arable crops a plausible economic option.

In this assessment it is expected that dedicated cropping with perennials for bioenergy production is most likely to take place on land that is neither needed for the production of food and feed nor for biofuel crops. In order to estimate the amount of land that can be included in this potential, a post-model analysis was made of the agricultural production area as modelled in the CAPRI 2020 baseline. By comparing the size of different types of land uses in the future years with the 2004 situation an estimate could be made of the amount of land released, but also of the type of categories of land released. Good quality land is released in the arable cropping category and low quality land in vineyards and olives category and fallow (Figure A4.2). In addition to the land released, there is also a category of land only occurring in the sustainability scenario. It is land that according to the CAPRI 2020 baseline is used for biofuel cropping. In the sustainability scenario 2020 biofuel crops cannot be produced in the EU sustainably as they do not reach the mitigation target of 70% (including the compensation for iLUC). This implies that in the post model assessment these lands in the EU are allocated to dedicated perennial cropping provided these bioenergy chains do comply with the mitigation target of 70% taking account of iLUC.

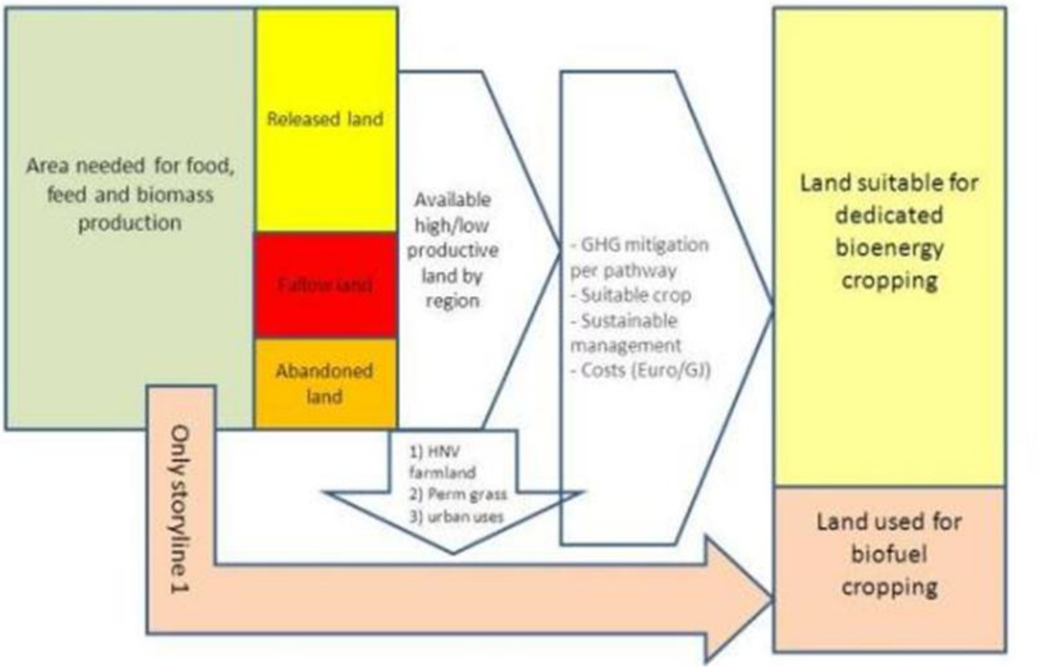


Figure A4.2. Estimation of land availability for bioenergy crop potential

In the reference scenario crops for biofuel cannot be cropped on highly biodiverse areas or areas with a high carbon stocks. In the sustainability scenario this applies to all cropped biomass whether going to biofuels or bioheat or electricity. The EU land availability for bioenergy cropping should therefore be reduced with these types of land use categories. In this study both the NATURA 2000 (farmland) and the HNV farmland areas were regarded as good proxies for highly biodiverse areas and agricultural areas of high carbon stocks, and were therefore taken as no-go areas for biomass cropping. Because of constraints on the use of biodiversity-rich land and land with high carbon stock, less land is available in the sustainability scenario than in the reference scenario. The total utilized agricultural area was 187 million hectares in 2004, which means that 20.6 million hectares (11%) of this area is expected to be released from agriculture (through market forces and policies taken into account in the CAPRI baseline run) until 2020. In the sustainability scenario this amounts to 18.7 million (10%) hectares is potentially available for cropping since the biodiverse and high carbon stock land needs to be subtracted.

Based on the assumptions per scenario and the calculation steps explained in the methodology above the cropped biomass potential for both perennials (woody and grassy crops) and for conventional biofuels were estimated at a regional level. A summary of the results is presented at country level in Table A4.3. It shows that applying the stricter sustainability criteria in the sustainability scenario leads to a crop potential reduction of 32% as compared to the reference scenario in which a total of 75.5 Mtoe is possible. This amounts to only 51.6 Mtoe in the sustainability scenario. The crop mix of which the potential is made up is also very different per scenario. A lower potential occurs because of the reduction in the released land category in the sustainability scenario, which amounts to only 70% of this land resource in the reference scenario. This is the result of the restrictions on the use of biodiversity and/or carbon rich lands.

Table A4.3 Final biomass potentials for bioenergy in 2020 in ktoe (Elbersen *et al.*, 2013)

	Reference			Sustainability	
	Woody	**Grassy**	**Biofuel crops and energy maize**	**Woody**	**Grassy**
Austria	393	362	410	180	285
Bulgaria	1206	184	260	1156	558
Belgium/Luxembourg	160	110	12	160	99
Cyprus	0	0	0	0	0
Czech Rep.	33	481	63	31	506
Germany	3024	2592	2156	3881	2267
Denmark	0	0	977	0	0
Estonia	0	0	0	0	0
Greece	0	2906	0	0	1374
Spain	44	10133	321	14	6064
Finland	0	374	2	0	229
France	5418	5008	5755	8669	4070
Hungary	838	680	1863	599	599
Ireland	0	16	0	0	12
Italy	0	5535	3585	134	4358
Lithuania	272	692	85	382	588
Latvia	0	0	5	0	0
Malta	0	0	0	0	0
Netherlands	25	55	0	24	49
Poland	472	2668	357	392	2653
Portugal	0	489	0	0	252
Romania	5949	3220	649	5418	2660
Sweden	304	323	358	277	274
Slovenia	0	96	0	0	38
Slovakia	63	549	15	42	455
UK	418	3101	462	383	2489
EU-27	18619	39576	17335	21742	29880

The mitigation requirements of 70% while taking account of iLUC make conventional biofuels from crops in the sustainability scenario impossible on lands on which displacement occurs. Instead these lands can be used for perennial cropping, provided these bioenergy chains reach a mitigation of 70% in spite of iLUC effects. In a few regions where yields for these crops are indeed high and where the fossil comparator is also relatively high, because of the large share of lignite-based fossil energy use, it remains possible to grow crops for bioheat and electricity. This is the case in several regions, but certainly not all over the EU. Because of this, the perennial potential is further increased again in the sustainability scenario amounting to 89% of the reference scenario potential for perennial crops. Cropping with energy maize for biogas also remains a competing potential in the reference scenario, but not in the sustainability scenario. This is because energy maize for biogas does not reach the mitigation requirement of 70% in the sustainability scenario. In the reference it is sometimes a cheaper alternative than cropping with perennials for heat and power pathways.

Appendix 5 Overview of VTT-TIAM model

A5.1 Background to VTT-TIAM model

This brief definition of VTT-TIAM energy system model is based on the model description in Koljonen and Lehtilä (2012) and IEA descriptions of the original ETSAP-TIAM and TIMES models.

The VTT-TIAM energy system model is based on the TIMES energy system modelling framework developed under the IEA Energy Technology Systems Analysis Programme (ETSAP) and the global ETSAP-TIAM model[2]. The full model description is published by Loulou *et al*. (2005). TIAM is a dynamic partial equilibrium model with the purpose of analysing the entire energy system in a technology-rich, bottom-up fashion.

As a partial equilibrium model, VTT TIAM maintains equilibrium between the supply and demand of all commodities and determines their prices. The projections for the final demands of commodities are exogenous only in the Baseline scenario, while in policy scenarios the demands are elastic to their own prices, according to price elasticities derived from the literature. In the policy scenarios, the demands of all commodities are thus affected by their prices, and vice versa. The model employs inter-temporal optimisation with the objective of maximising the total discounted cumulative surplus of all consumers and producers (Loulou and Labriet, 2007).

The model includes all greenhouse gas (GHG) emissions and sources controlled by the Kyoto protocol, and includes a simplified climate module that can be used to calculate atmospheric GHG concentrations, radiative forcing and changes in global mean temperature.

A5.2 Basic structure of the model

The IEA-ETSAP TIAM energy system modelling framework is based on the TIMES model generator, which, based on the input information provided by the modeller, generates an instance of a TIAM model. Basically, all TIAM models exploit an identical general mathematical structure (Loulou and Labriet, 2007). However, different model instances may have different actualisations of the general structure according to the user-defined model specification.

The model database can be divided into qualitative and quantitative data. The qualitative data includes, for example, the specification of regions, time-periods and commodities considered in the model, as well as the existing and new technologies that are assumed to be available in each of the model regions. Commodities to be considered in the model may include any energy carriers, material and immaterial commodities, wastes and emissions.

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[2] http://www.iea-etsap.org/web/applicationGlobal.asp

The quantitative data for a TIAM model constitute the largest part of the model database. These data should describe all relevant technological and economic parameter values specific to each region, technology, commodity, and time period.

A5.3 The time horizon

In TIAM models, the time horizon to be considered is divided into a user-chosen number of time-periods, each model period containing an arbitrary, possibly different number of years. Activity-related quantities such as technology operating levels, commodity flows, etc. are assumed to be identical in all years in a given period, with the exception of storage activities, which may increase or decrease within each period. The first model period is usually considered a past period, for which the quantities of interest are calibrated to their historical values, according to the available statistics. The calibration of the initial period is an important task, and involves the primary supply, exports, imports, production and consumption of all commodities and emissions in the model, as well as the capacities and operating levels of all technologies.

In the VTT TIAM model, the base year has been defined to be the year 2005, and a long time horizon extending to 2105 has been chosen to take into account the long-term nature of climate phenomena. Apart from the time-periods, the TIMES models also include user-defined time divisions called time-slices within each year. The use of time-slices is important for commodities that have significant variation in their production and demand at different times of the year, thereby affecting the price of the commodity. The commodities for which time-sliced modelling may be highly important include electricity, heat and other non-storable energy forms. In the global VTT TIAM model, the number of sub-annual time-slices is six for all regions excluding the Nordic countries, for which 10 time-slices have been used.

A5.4 Regional division

The VTT TIAM model is a global model divided into 17 regions. The regions include the four small Nordic countries, Denmark, Finland, Norway and Sweden as separate regions, but the 13 other regions represent larger world regions, and a few of them even represent whole continents. Asia, excluding the Former Soviet Union, is represented by five regions: China, India, Japan and Korea, Other Developing Asia, and the Middle East.

A5.5 Trade between regions

Interactions between model regions can be described in two fundamental ways: by introducing trade links between regions and by introducing arbitrary user-defined constraints involving multiple regions. In the VTT TIAM model, the following energy carriers are endogenously traded between the model regions: crude oil, refined petroleum products (gasoline, light fuel oil, heavy fuel oil, naphtha and natural gas liquids), natural gas, liquefied natural gas, hard coal, nuclear fuel, wood, liquid biofuels, and electricity. In addition, all other petroleum products are considered to be indirectly traded in the model because they are only produced from crude oil in petroleum refineries. The prices of all these energy carriers are thus fully endogenous in the model, and the impacts of energy and environmental policies are reflected in those prices.

In addition to energy commodities, emissions (or emission permits) may also be traded in the model. However, for the purpose of the AME scenario runs, emissions trading was not explicitly included in the model. Instead, global emissions trading was simulated by setting bounds on the global mean radiative forcing, as defined in the common AME scenario assumptions. Moreover, trading in carbon storage services has been explicitly included in the VTT TIAM model, although at the moment only between the European regions. The additional costs of CO_2 transportation between the trading regions was, of course, applied to these trade flows (Teir *et al*., 2010).

A5.6 Demand drivers

TIMES models are driven by demand projections for each of the commodities, representing final useful energy or non-energy demands in the model. The demands are fully exogenous in the Baseline scenario, which produces the base price development for each demand. In any alternate scenarios, for example with stricter climate policies, the demands are usually made elastic to their own prices, according to user-defined price-elasticities. In other words, demands are endogenously adjusted in TIMES through price changes in the alternate scenarios. Hence, the model is said to be driven by *demand curves* (Loulou and Labriet, 2007).

Consequently, in TIMES, the base projections for the final demands have to be constructed from external estimates, either by using other models or by using external data sources. The TIMES user-shell VEDA-FE includes an integrated demand projection facility, which derives the demand trajectories from external driver projections and user-defined driver elasticities. The primary drivers typically consist of GDP, sector outputs, and population in the model regions. By choosing for each demand both its *driver* and the *elasticity of the demand to the driver*, the user can compute the demand trajectories from the driver projections. The driver elasticities reflect the degree of decoupling between the drivers and the demands.

Appendix 6 Scenario results from VTT-TIAM

Scenario A - Production and net import of fuels, electricity generation, final consumption and greenhouse gas emissions

scen A		2010	2020	2030	2040	2050
EU		ktoe	ktoe	ktoe	ktoe	ktoe
Total Primary Energy Supply	Oil products	641016	564368	546178	524309	491513
	Natural Gas	438121	362168	318016	271391	254681
	Coal	272254	243414	201673	177916	167836
	Nuclear	251050	202347	163866	202201	241309
	Biomass, bioliquids, biogas	117886	186929	172642	165223	164223
	Other renewables	57006	104306	163246	186913	213232
	Electricity	-1419	32	2828	1289	-8647
	Total	1775915	1663563	1568449	1529243	1524147
Electricity generation (TWh)	Coal	816	744	548	433	383
	Nuclear	909	740	631	948	1275
	Oil	85	26	21	22	23
	Natural gas	866	754	683	400	313
	Biomass, biogas, biowaste	162	282	341	369	374
	Other renewables	556	1049	1548	1661	1935
	Total	3393	3594	3772	3833	4302
	Electricity from BIO [1]	5%	8%	9%	10%	9%
	Electricity from RES [1]	21%	37%	50%	53%	55%
	Electricity from CCS [1]	0%	0%	0%	2%	6%
Final consumption (excluding feedstock and other non energy use)	Agriculture	31849	34242	36339	39457	39387
	Commercial	146676	141274	139795	137117	144530
	Industry	292390	309509	310877	311847	311200
	Residential	317978	304282	289812	280384	274162
	Transportation	356817	321384	316709	315865	313873
	Oil products	456586	389771	360699	339553	311441
	Natural gas	241531	193393	160830	160823	157994
	Coal	59450	65846	69433	68336	66456
	Biomass, bioliquids, biogas	67571	101189	82677	78930	79383
	Other Renewables	3188	5717	8888	8949	6567
	Electricity	252140	268400	291027	298138	325189
	Heat	65244	86376	103711	108686	114866
	Hydrogen	0	0	16267	21255	21255
	Total	1145711	1110691	1093532	1084670	1083152
	Bioenergy share [2]	8%	13%	12%	12%	13%
	Renewable energy share [2]	12%	21%	25%	26%	28%
GHG emissions	**Total GHG (MtCO2eq)**	4767	4131	3705	3335	2927
	Total CO2 (MtCO2)	3957	3389	3005	2660	2280
	Total nonCO2 (MtCO2eq)	810	743	700	675	647
	Total ETS (MtCO2eq)	2166	1913	1624	1334	1044
	Total nonETS (MtCO2eq)	2600	2218	2081	2002	1883

1) The share of produced electricity includes the net imports of electricity.
2) The share of bioenergy and renewable energy includes the share of power and heat generated with those fuels.

Scenario A - Balance table of biomass, bioliquids and biogas

scen A		2010	2020	2030	2040	2050
EU		ktoe	ktoe	ktoe	ktoe	ktoe
Supply	Agriculture biomass	14513	33663	33856	32310	32790
	Crops, for energy	3	2549	2346	2215	2215
	Crops, for biofuels	10733	16597	6147	6413	6529
	Wood	23967	26591	24881	23581	22892
	Forest residues	8509	16239	14137	14137	14137
	Industry waste wood	9470	9664	10174	11028	11550
	Biowaste	20558	27404	28616	18406	16814
	Black liquor	11769	12558	14223	14994	14866
	Biogas	11695	16496	15041	13949	13910
	Total supply	111217	161761	149422	137032	135705
Trade	Import of solid biomass	4503	15537	18645	21773	24646
	Import of bioliquids	1697	7779	3682	6418	3873
	Export of solid biomass	0	0	0	0	0
	Export of bioliquids	0	0	0	0	0
	Net Imports	6199	23316	22328	28191	28519
Upstream / Transformation of biomass	to power and heat generation	41930	64457	74636	75652	73106
	to bioliquid production	16992	40648	29478	22648	25552
	to other upstream	45	61	46	36	27
	Produced electricity	13896	24262	29343	31727	32137
	Produced bioliquids	9122	21278	15087	12043	13846
	Net Upstream (excl. produced elc)	-49845	-83888	-89073	-86293	-84840
Final consumption of bioproducts	Agriculture	1384	4251	2796	3735	4734
	Commercial	1678	1318	1032	453	366
	Industry	20184	29120	28164	31229	32235
	Residential	33524	37544	32809	26444	26301
	Transportation	10801	28956	17876	17069	15747
	Biomass	55888	69640	63211	60848	61886
	Bioliquids	10819	29031	18400	18074	17487
	Biogas (other than power&heat)	865	2518	1065	9	10
	Total consumption	67571	101189	82677	78930	79383

In VTT-TIAM, the upstream sector includes the transfer of the fuels to other fuels, e.g. blast furnaces, petroleum refining and biorefineries. Upstream is separated as an individual sector to exclude its energy balance from the supply and final energy consumption.

Scenario A – Details of power and heat production from biomass

Final energy consumption of electricity		2010	2020	2030	2040	2050
		ktoe	ktoe	ktoe	ktoe	ktoe
	Agriculture	5567	7885	10970	11970	12620
	Commercial	67012	69416	77238	75941	82002
	Industry	91925	100395	106395	106611	111488
	Residential	81379	83842	83472	85951	90645
	Transport	6257	6862	12951	17664	28434
	Total	252140	268400	291027	298138	325189

Final energy consumption of Heat		2010	2020	2030	2040	2050
		ktoe	ktoe	ktoe	ktoe	ktoe
	Agriculture	984	1277	992	1870	3035
	Commercial	23501	29988	36101	37035	40779
	Industry	10610	13171	15625	18898	20504
	Residential	30149	41940	50994	50883	50548
	Transport	0	0	0	0	0
	Total	65244	86376	103711	108686	114866

Scenario B - Production and net import of fuels, electricity generation, final consumption and greenhouse gas emissions

scen B		2010	2020	2030	2040	2050
EU		ktoe	ktoe	ktoe	ktoe	ktoe
Total Primary Energy Supply	Oil products	641016	559253	510098	405114	244669
	Natural Gas	438121	368774	282993	234564	224264
	Coal	272254	239677	167913	119898	169623
	Nuclear	251050	194683	186979	261440	264027
	Biomass, bioliquids, biogas	117886	187371	233188	272501	341897
	Other renewables	57006	110419	163890	192494	253896
	Electricity	-1419	-530	2771	-2835	8133
	Total	1775915	1659647	1547832	1483175	1506509
Electricity generation (TWh)	Coal	816	722	469	293	778
	Nuclear	909	707	772	1300	1425
	Oil	85	26	22	21	21
	Natural gas	866	759	559	365	801
	Biomass, biogas, biowaste	162	277	437	554	593
	Other renewables	556	1113	1571	1883	2537
	Total	3393	3604	3831	4415	6155
	Electricity from BIO [1]	5%	8%	11%	13%	9%
	Electricity from RES [1]	21%	39%	52%	56%	50%
	Electricity from CCS [1]	0%	0%	1%	12%	25%
Final consumption (excluding feedstock and other non energy use)	Agriculture	31849	35863	34816	32633	33792
	Commercial	146676	141577	133345	133754	139128
	Industry	292390	310248	308568	300253	300211
	Residential	317978	303380	276805	256383	252876
	Transportation	356817	317796	300867	258058	219233
	Oil products	456586	382983	326133	220539	62717
	Natural gas	241531	197871	144780	124024	37398
	Coal	59450	64426	50027	36917	36188
	Biomass, bioliquids, biogas	67571	99924	111903	125639	169894
	Other Renewables	3188	6212	6235	4520	5252
	Electricity	252140	270240	296315	335349	471897
	Heat	65244	87209	104809	116711	126713
	Hydrogen	0	0	14200	17383	35183
	Total	1145711	1108865	1054401	981080	945241
	Bioenergy share [2]	8%	13%	18%	21%	27%
	Renewable energy share [2]	12%	21%	30%	37%	49%
GHG emissions	**Total GHG (MtCO2eq)**	4767	4123	3223	2148	1074
	Total CO2 (MtCO2)	3957	3379	2589	1565	532
	Total nonCO2 (MtCO2eq)	810	745	634	583	542
	Total ETS (MtCO2eq)	2166	1913	1430	805	348
	Total nonETS (MtCO2eq)	2600	2210	1793	1343	726

1) The share of produced electricity includes the net imports of electricity.
2) The share of bioenergy and renewable energy includes the share of power and heat generated with those fuels.

Scenario B - Balance table of biomass, bioliquids and biogas

scen B		2010	2020	2030	2040	2050
EU		ktoe	ktoe	ktoe	ktoe	ktoe
Supply	Agriculture biomass	14513	35405	67160	67160	67745
	Crops, for energy	3	2645	20006	27554	33639
	Crops, for biofuels	10733	16597	6312	6353	6602
	Wood	23967	26501	20765	25674	49857
	Forest residues	8509	17113	15979	20347	25475
	Industry waste wood	9470	9627	10094	10945	20016
	Biowaste	20558	27475	20700	19036	19204
	Black liquor	11769	11951	12837	13500	14866
	Biogas	11695	16496	15249	15245	15238
	Total supply	111217	163812	189101	205815	252644
Trade	Import of solid biomass	4503	15537	31908	48297	64687
	Import of bioliquids	1697	6170	11094	17249	23404
	Export of solid biomass	0	0	0	0	0
	Export of bioliquids	0	0	0	0	0
	Net Imports	6199	21706	43001	65546	88091
Upstream / Transformation of biomass	to power and heat generation	41930	64193	101417	113593	111402
	to bioliquid production	16992	44239	38370	65244	140501
	to other upstream	45	65	58	43	33
	Produced electricity	13896	23792	37596	47658	50963
	Produced bioliquids	9122	22902	19646	33158	81250
	Net Upstream (excl. produced elc)	-49845	-85595	-120200	-145722	-170686
Final consumption of bioproducts	Agriculture	1384	5380	6130	3510	9995
	Commercial	1678	1392	1193	470	29
	Industry	20184	26520	35107	40341	37862
	Residential	33524	37677	40399	32963	25830
	Transportation	10801	28956	29074	48356	96178
	Biomass	55888	68383	80365	74347	64203
	Bioliquids	10819	29031	30266	49981	104502
	Biogas (other than power&heat)	865	2511	1272	1311	1189
	Total consumption	67571	99924	111903	125639	169894

In VTT-TIAM, the upstream sector includes the transfer of the fuels to other fuels, e.g. blast furnaces, petroleum refining and biorefineries. Upstream is separated as an individual sector to exclude its energy balance from the supply and final energy consumption.

Scenario B – Details of power and heat production from biomass

Final energy consumption of electricity		2010	2020	2030	2040	2050
		ktoe	ktoe	ktoe	ktoe	ktoe
	Agriculture	5567	7711	10024	11629	13583
	Commercial	67012	70458	75391	78972	92129
	Industry	91925	101597	108195	109300	164473
	Residential	81379	82236	81816	91218	139931
	Transport	6257	8237	20891	44230	61782
	Total	252140	270240	296315	335349	471897

Final energy consumption of Heat		2010	2020	2030	2040	2050
		ktoe	ktoe	ktoe	ktoe	ktoe
	Agriculture	984	982	983	1855	2218
	Commercial	23501	29769	36122	37148	41954
	Industry	10610	13636	14245	17246	20201
	Residential	30149	42822	53460	60462	62340
	Transport	0	0	0	0	0
	Total	65244	87209	104809	116711	126713

Scenario C1 - Production and net import of fuels, electricity generation, final consumption and greenhouse gas emissions

scen C1		2010	2020	2030	2040	2050
EU		ktoe	ktoe	ktoe	ktoe	ktoe
Total Primary Energy Supply	Oil products	641016	559282	507914	410141	244719
	Natural Gas	438121	375145	293860	239596	247245
	Coal	272254	236950	165317	119024	190449
	Nuclear	251050	194683	192670	261545	264027
	Biomass, bioliquids, biogas	117886	187809	220429	238813	292271
	Other renewables	57006	109459	179171	204986	257936
	Electricity	-1419	-2868	1107	3754	6341
	Total	1775915	1660460	1560467	1477861	1502988
Electricity generation (TWh)	Coal	816	706	453	295	856
	Nuclear	909	707	803	1300	1425
	Oil	85	26	22	21	21
	Natural gas	866	800	609	357	889
	Biomass, biogas, biowaste	162	280	390	497	427
	Other renewables	556	1101	1629	1909	2522
	Total	3393	3620	3906	4379	6141
	Electricity from BIO [1]	5%	8%	10%	11%	7%
	Electricity from RES [1]	21%	38%	51%	54%	47%
	Electricity from CCS [1]	0%	0%	1%	13%	27%
Final consumption (excluding feedstock and other non energy use)	Agriculture	31849	35863	39885	37944	33657
	Commercial	146676	141515	135590	131252	137567
	Industry	292390	310418	308504	303525	302884
	Residential	317978	303371	276824	255851	252729
	Transportation	356817	317812	300826	257214	219327
	Oil products	456586	383037	323341	225408	63209
	Natural gas	241531	198957	145951	126155	40209
	Coal	59450	64577	51044	35757	36559
	Biomass, bioliquids, biogas	67571	100046	110327	116895	160899
	Other Renewables	3188	6212	10866	9153	5253
	Electricity	252140	269101	299790	338366	468611
	Heat	65244	87049	105953	116462	127501
	Hydrogen	0	0	14358	17587	43923
	Total	1145711	1108979	1061630	985785	946164
	Bioenergy share [2]	8%	13%	17%	19%	23%
	Renewable energy share [2]	12%	21%	30%	36%	45%
GHG emissions	**Total GHG (MtCO2eq)**	4767	4125	3223	2148	1074
	Total CO2 (MtCO2)	3957	3381	2602	1579	544
	Total nonCO2 (MtCO2eq)	810	744	620	569	530
	Total ETS (MtCO2eq)	2166	1913	1449	800	358
	Total nonETS (MtCO2eq)	2600	2212	1773	1348	716

1) The share of produced electricity includes the net imports of electricity.
2) The share of bioenergy and renewable energy includes the share of power and heat generated with those fuels.

Scenario C1 - Balance table of biomass, bioliquids and biogas

scen C1		2010	2020	2030	2040	2050
EU		ktoe	ktoe	ktoe	ktoe	ktoe
Supply	Agriculture biomass	14513	35405	50496	50496	50496
	Crops, for energy	3	2645	11690	9056	12520
	Crops, for biofuels	10733	16597	6312	6546	6602
	Wood	23967	27247	26337	26251	41366
	Forest residues	8509	16805	17186	16047	17186
	Industry waste wood	9470	9627	10175	11029	22544
	Biowaste	20558	27475	22411	20419	19484
	Black liquor	11769	11951	14270	15009	15561
	Biogas	11695	16496	17611	17500	17485
	Total supply	111217	164250	176489	172354	203245
Trade	Import of solid biomass	4503	15537	31908	48297	64687
	Import of bioliquids	1697	6170	11094	17249	23404
	Export of solid biomass	0	0	0	0	0
	Export of bioliquids	0	0	0	0	0
	Net Imports	6199	21706	43001	65546	88091
Upstream / Transformation of biomass	to power and heat generation	41930	64560	88026	95304	78049
	to bioliquid production	16992	44190	42826	52530	126864
	to other upstream	45	64	55	43	34
	Produced electricity	13896	24043	33532	42771	36711
	Produced bioliquids	9122	22902	21743	26873	74643
	Net Upstream (excl. produced elc)	-49845	-85911	-109163	-121005	-130304
Final consumption of bioproducts	Agriculture	1384	4732	5929	3409	9757
	Commercial	1678	1372	1148	429	4
	Industry	20184	27310	30603	37392	35740
	Residential	33524	37677	40418	32961	25831
	Transportation	10801	28956	32229	42704	89567
	Biomass	55888	68504	76512	71931	61897
	Bioliquids	10819	29031	32545	43751	97897
	Biogas (other than power&heat)	865	2511	1270	1213	1105
	Total consumption	67571	100046	110327	116895	160899

In VTT-TIAM, the upstream sector includes the transfer of the fuels to other fuels, e.g. blast furnaces, petroleum refining and biorefineries. Upstream is separated as an individual sector to exclude its energy balance from the supply and final energy consumption.

Scenario C1 – Details of power and heat production from biomass

Final energy consumption of electricity		2010	2020	2030	2040	2050
		ktoe	ktoe	ktoe	ktoe	ktoe
	Agriculture	5567	7711	11066	12580	13661
	Commercial	67012	70476	77793	76689	89856
	Industry	91925	100394	108054	112909	166760
	Residential	81379	82281	81966	91954	139514
	Transport	6257	8237	20911	44234	58821
	Total	252140	269101	299790	338366	468611

Final energy consumption of Heat		2010	2020	2030	2040	2050
		ktoe	ktoe	ktoe	ktoe	ktoe
	Agriculture	984	982	376	1589	2159
	Commercial	23501	29708	36026	37022	42690
	Industry	10610	13579	16268	19033	20400
	Residential	30149	42780	53283	58819	62251
	Transport	0	0	0	0	0
	Total	65244	87049	105953	116462	127501

Scenario C2 - Production and net import of fuels, electricity generation, final consumption and greenhouse gas emissions

scen C2		2010	2020	2030	2040	2050
EU		ktoe	ktoe	ktoe	ktoe	ktoe
Total Primary Energy Supply	Oil products	641016	559291	516341	421879	251397
	Natural Gas	438121	369337	284605	236245	256490
	Coal	272254	240032	168264	115386	174132
	Nuclear	251050	194683	177706	261523	264027
	Biomass, bioliquids, biogas	117886	187765	231282	248334	293763
	Other renewables	57006	109504	169805	203947	255808
	Electricity	-1419	-570	2549	-4037	5006
	Total	1775915	1660042	1550552	1483278	1500624
Electricity generation (TWh)	Coal	816	722	482	283	711
	Nuclear	909	707	721	1300	1425
	Oil	85	26	22	21	21
	Natural gas	866	756	574	360	760
	Biomass, biogas, biowaste	162	278	460	569	653
	Other renewables	556	1102	1579	1952	2512
	Total	3393	3592	3838	4484	6083
	Electricity from BIO [1)]	5%	8%	12%	13%	11%
	Electricity from RES [1)]	21%	38%	53%	57%	51%
	Electricity from CCS [1)]	0%	0%	1%	12%	23%
Final consumption (excluding feedstock and other non energy use)	Agriculture	31849	35863	37018	35420	34269
	Commercial	146676	141527	133360	133797	139509
	Industry	292390	310314	310778	305466	311742
	Residential	317978	303380	276873	256511	252624
	Transportation	356817	317812	300847	256820	218392
	Oil products	456586	382949	332435	237324	69932
	Natural gas	241531	199253	145194	125288	40426
	Coal	59450	64339	50779	36664	36663
	Biomass, bioliquids, biogas	67571	99935	105532	107740	138127
	Other Renewables	3188	6212	7404	5688	5252
	Electricity	252140	269082	295538	339065	462776
	Heat	65244	87127	107687	118743	128212
	Hydrogen	0	0	14307	17503	75147
	Total	1145711	1108896	1058876	988014	956536
	Bioenergy share [2)]	8%	13%	17%	20%	24%
	Renewable energy share [2)]	12%	21%	30%	36%	45%
GHG emissions	**Total GHG (MtCO2eq)**	4767	4125	3223	2148	1074
	Total CO2 (MtCO2)	3957	3380	2627	1602	563
	Total nonCO2 (MtCO2eq)	810	745	596	546	512
	Total ETS (MtCO2eq)	2166	1913	1448	792	365
	Total nonETS (MtCO2eq)	2600	2211	1775	1356	710

1) The share of produced electricity includes the net imports of electricity.
2) The share of bioenergy and renewable energy includes the share of power and heat generated with those fuels.

Scenario C2 - Balance table of biomass, bioliquids and biogas

scen C2		2010	2020	2030	2040	2050
EU		ktoe	ktoe	ktoe	ktoe	ktoe
Supply	Agriculture biomass	14513	35405	67329	67329	67329
	Crops, for energy	3	2645	28115	34686	41238
	Crops, for biofuels	10733	16597	6312	6546	6602
	Wood	23967	26895	22222	26294	44957
	Forest residues	8509	17113	15051	17138	17268
	Industry waste wood	9470	9627	10108	10990	25969
	Biowaste	20558	27475	21174	20078	19110
	Black liquor	11769	11951	13088	14312	14866
	Biogas	11695	16496	22496	21857	20965
	Total supply	111217	164206	205897	219230	258305
Trade	Import of solid biomass	4503	15537	18645	21773	24900
	Import of bioliquids	1697	6170	5749	6418	9623
	Export of solid biomass	0	0	0	0	0
	Export of bioliquids	0	0	0	0	0
	Net imports	6199	21706	24395	28191	34523
Upstream / Transformation of biomass	to power and heat generation	41930	64612	107265	116338	118892
	to bioliquid production	16992	44201	35543	48330	95197
	to other upstream	45	64	50	43	33
	Produced electricity	13896	23942	39520	48955	56147
	Produced bioliquids	9122	22899	18098	25030	59553
	Net Upstream (excl. produced elc)	-49845	-85978	-124759	-139681	-154568
Final consumption of bioproducts	Agriculture	1384	5269	7174	4940	10577
	Commercial	1678	1372	1126	404	0
	Industry	20184	26661	34091	39249	41115
	Residential	33524	37677	40377	32940	25684
	Transportation	10801	28956	22764	30207	60751
	Biomass	55888	68377	80748	75414	67882
	Bioliquids	10819	29031	23514	31163	69103
	Biogas (other than power&heat)	865	2526	1270	1163	1142
	Total consumption	67571	99935	105532	107740	138127

In VTT-TIAM, the upstream sector includes the transfer of the fuels to other fuels, e.g. blast furnaces, petroleum refining and biorefineries. Upstream is separated as an individual sector to exclude its energy balance from the supply and final energy consumption.

Scenario C2 – Details of power and heat production from biomass

Final energy consumption of electricity		2010	2020	2030	2040	2050
		ktoe	ktoe	ktoe	ktoe	ktoe
	Agriculture	5567	7711	10011	11460	13486
	Commercial	67012	70468	75279	79071	90890
	Industry	91925	100385	107510	111979	166946
	Residential	81379	82281	81850	92004	139994
	Transport	6257	8237	20888	44551	51461
	Total	252140	269082	295538	339065	462776

Final energy consumption of Heat		2010	2020	2030	2040	2050
		ktoe	ktoe	ktoe	ktoe	ktoe
	Agriculture	984	982	983	1820	2163
	Commercial	23501	29729	36160	37155	43603
	Industry	10610	13627	16269	19203	20286
	Residential	30149	42790	54275	60565	62160
	Transport	0	0	0	0	0
	Total	65244	87127	107687	118743	128212

Scenario C3 - Production and net import of fuels, electricity generation, final consumption and greenhouse gas emissions

scen C3		2010	2020	2030	2040	2050
EU		ktoe	ktoe	ktoe	ktoe	ktoe
Total Primary Energy Supply	Oil products	641016	559229	511405	421396	248227
	Natural Gas	438121	370859	287552	237776	254840
	Coal	272254	239163	169752	115763	201422
	Nuclear	251050	194683	181923	262183	264027
	Biomass, bioliquids, biogas	117886	187429	224115	228328	275442
	Other renewables	57006	109592	178431	207393	257804
	Electricity	-1419	-1258	3625	4950	4587
	Total	1775915	1659699	1556804	1477787	1506350
Electricity generation (TWh)	Coal	816	715	473	287	790
	Nuclear	909	707	744	1304	1425
	Oil	85	26	22	20	21
	Natural gas	866	770	600	347	866
	Biomass, biogas, biowaste	162	279	404	509	489
	Other renewables	556	1103	1624	1940	2520
	Total	3393	3601	3867	4407	6112
	Electricity from BIO [1]	5%	8%	10%	11%	8%
	Electricity from RES [1]	21%	39%	52%	55%	49%
	Electricity from CCS [1]	0%	0%	1%	12%	26%
Final consumption (excluding feedstock and other non energy use)	Agriculture	31849	35863	40024	38084	33670
	Commercial	146676	141568	134459	132590	139529
	Industry	292390	310466	308578	304957	308003
	Residential	317978	303369	277455	255698	252340
	Transportation	356817	317812	300803	255583	218140
	Oil products	456586	383015	326990	236689	66717
	Natural gas	241531	199276	144886	126890	43616
	Coal	59450	64601	51543	35208	36679
	Biomass, bioliquids, biogas	67571	99785	107038	103039	140556
	Other Renewables	3188	6212	10591	8877	5252
	Electricity	252140	269129	298394	341588	463587
	Heat	65244	87061	107471	116970	128726
	Hydrogen	0	0	14406	17649	66548
	Total	1145711	1109078	1061319	986912	951682
	Bioenergy share [2]	8%	13%	17%	18%	22%
	Renewable energy share [2]	12%	21%	30%	35%	44%
GHG emissions	**Total GHG (MtCO2eq)**	4767	4126	3223	2148	1074
	Total CO2 (MtCO2)	3957	3381	2628	1604	562
	Total nonCO2 (MtCO2eq)	810	744	595	545	512
	Total ETS (MtCO2eq)	2166	1913	1465	793	362
	Total nonETS (MtCO2eq)	2600	2212	1758	1355	713

1) The share of produced electricity includes the net imports of electricity.
2) The share of bioenergy and renewable energy includes the share of power and heat generated with those fuels.

Scenario C3 - Balance table of biomass, bioliquids and biogas

scen C3		2010	2020	2030	2040	2050
EU		ktoe	ktoe	ktoe	ktoe	ktoe
Supply	Agriculture biomass	14513	35405	55455	55455	55455
	Crops, for energy	3	2645	13188	15478	18107
	Crops, for biofuels	10733	16597	6312	6562	6602
	Wood	23967	26860	29320	29437	53011
	Forest residues	8509	16812	25475	23866	25475
	Industry waste wood	9470	9627	10174	11028	25909
	Biowaste	20558	27475	22206	20496	19484
	Black liquor	11769	11951	14223	14994	15587
	Biogas	11695	16496	22427	21907	20927
	Total supply	111217	163871	198781	199224	240558
Trade	Import of solid biomass	4503	15537	18645	21773	24900
	Import of bioliquids	1697	6170	5749	6418	9048
	Export of solid biomass	0	0	0	0	0
	Export of bioliquids	0	0	0	0	0
	Net Imports	6199	21706	24395	28191	33948
Upstream / Transformation of biomass	to power and heat generation	41930	64444	93684	101170	91058
	to bioliquid production	16992	44180	45764	47866	111140
	to other upstream	45	65	57	43	36
	Produced electricity	13896	23996	34755	43727	42028
	Produced bioliquids	9122	22896	23367	24703	68416
	Net Upstream (excl. produced elc)	-49845	-85792	-116138	-124376	-133818
Final consumption of bioproducts	Agriculture	1384	4373	6454	4007	9773
	Commercial	1678	1396	1119	402	0
	Industry	20184	27384	30463	37016	35959
	Residential	33524	37677	40540	31908	25823
	Transportation	10801	28956	28462	29706	69002
	Biomass	55888	68227	76994	70992	62130
	Bioliquids	10819	29031	28847	30834	77321
	Biogas (other than power&heat)	865	2526	1197	1213	1105
	Total consumption	67571	99785	107038	103039	140556

In VTT-TIAM, the upstream sector includes the transfer of the fuels to other fuels, e.g. blast furnaces, petroleum refining and biorefineries. Upstream is separated as an individual sector to exclude its energy balance from the supply and final energy consumption.

Scenario C3 – Details of power and heat production from biomass

Final energy consumption of electricity		2010	2020	2030	2040	2050
		ktoe	ktoe	ktoe	ktoe	ktoe
	Agriculture	5567	7711	10882	12395	13653
	Commercial	67012	70462	76454	78007	90669
	Industry	91925	100392	108135	114885	168050
	Residential	81379	82327	82014	92045	137829
	Transport	6257	8237	20908	44257	53386
	Total	252140	269129	298394	341588	463587

Final energy consumption of Heat		2010	2020	2030	2040	2050
		ktoe	ktoe	ktoe	ktoe	ktoe
	Agriculture	984	982	376	1593	2163
	Commercial	23501	29703	36043	37022	43842
	Industry	10610	13615	16268	19028	20455
	Residential	30149	42761	54783	59328	62266
	Transport	0	0	0	0	0
	Total	65244	87061	107471	116970	128726

Scenario D - Production and net import of fuels, electricity generation, final consumption and greenhouse gas emissions

scen D		2010	2020	2030	2040	2050
EU		ktoe	ktoe	ktoe	ktoe	ktoe
Total Primary Energy Supply	Oil products	641016	559316	498133	403842	265929
	Natural Gas	438121	396455	312328	249160	305619
	Coal	272254	225276	151231	116803	156450
	Nuclear	251050	202347	243756	296351	343207
	Biomass, bioliquids, biogas	117886	166998	134610	129240	138832
	Other renewables	57006	122894	246022	260312	292815
	Electricity	-1419	-1849	2982	8227	4186
	Total	1775915	1671437	1589062	1463933	1507038
Electricity generation (TWh)	Coal	816	676	442	359	727
	Nuclear	909	740	1076	1307	1425
	Oil	85	28	22	21	21
	Natural gas	866	954	893	501	1024
	Biomass, biogas, biowaste	162	246	201	234	166
	Other renewables	556	1148	2074	2301	2827
	Total	3393	3793	4707	4724	6191
	Electricity from BIO [1)]	5%	7%	4%	5%	3%
	Electricity from RES [1)]	21%	37%	48%	53%	48%
	Electricity from CCS [1)]	0%	0%	1%	14%	27%
Final consumption (excluding feedstock and other non energy use)	Agriculture	31849	35268	39172	39089	34818
	Commercial	146676	141766	138429	129281	134339
	Industry	292390	310607	308873	310245	324676
	Residential	317978	302793	273348	253034	245317
	Transportation	356817	317653	284479	239114	218146
	Oil products	456586	382548	314077	219953	84892
	Natural gas	241531	201814	132294	125448	39763
	Coal	59450	65000	39534	27952	28142
	Biomass, bioliquids, biogas	67571	87362	81356	76322	90553
	Other Renewables	3188	7758	12956	10912	6441
	Electricity	252140	282716	361264	367116	471404
	Heat	65244	80892	91421	114878	124484
	Hydrogen	0	0	11399	28183	111616
	Total	1145711	1108088	1044301	970763	957296
	Bioenergy share [2)]	8%	11%	11%	11%	12%
	Renewable energy share [2)]	12%	21%	30%	33%	37%
GHG emissions	**Total GHG (MtCO2eq)**	4767	4125	3223	2148	1074
	Total CO2 (MtCO2)	3957	3376	2573	1545	578
	Total nonCO2 (MtCO2eq)	810	749	649	604	496
	Total ETS (MtCO2eq)	2166	1913	1455	800	396
	Total nonETS (MtCO2eq)	2600	2212	1767	1349	678

1) The share of produced electricity includes the net imports of electricity.
2) The share of bioenergy and renewable energy includes the share of power and heat generated with those fuels.

Scenario D - Balance table of biomass, bioliquids and biogas

scen D		2010	2020	2030	2040	2050
EU		ktoe	ktoe	ktoe	ktoe	ktoe
Supply	Agriculture biomass	14513	22425	21791	21791	21791
	Crops, for energy	3	1453	2542	2542	2542
	Crops, for biofuels	10733	16218	0	0	0
	Wood	23967	29135	22911	22911	22911
	Forest residues	8509	9611	9801	9801	9801
	Industry waste wood	9470	9627	10139	10995	20208
	Biowaste	20558	27460	27366	20507	19501
	Black liquor	11769	11951	13614	14329	15657
	Biogas	11695	15780	12501	12503	12476
	Total supply	111217	143661	120666	115378	124887
Trade	Import of solid biomass	4503	15641	10296	10212	10296
	Import of bioliquids	1697	6407	3649	3649	3649
	Export of solid biomass	0	0	0	0	0
	Export of bioliquids	0	0	0	0	0
	Net Imports	6199	22047	13945	13862	13945
Upstream / Transformation of biomass	to power and heat generation	41930	59754	41640	44922	34016
	to bioliquid production	16992	41175	27875	21197	47614
	to other upstream	45	57	57	38	33
	Produced electricity	13896	21176	17287	20164	14261
	Produced bioliquids	9122	22640	16318	13239	33655
	Net Upstream (excl. produced elc)	-49845	-78346	-53254	-52918	-48008
Final consumption of bioproducts	Agriculture	1384	1859	1865	1785	9460
	Commercial	1678	1318	992	290	0
	Industry	20184	17685	24331	28666	26623
	Residential	33524	37544	34234	28851	25472
	Transportation	10801	28956	19934	16729	28998
	Biomass	55888	56545	60213	58122	51973
	Bioliquids	10819	29031	19934	16840	37305
	Biogas (other than power&heat)	865	1786	1209	1359	1276
	Total consumption	67571	87362	81356	76322	90553

In VTT-TIAM, the upstream sector includes the transfer of the fuels to other fuels, e.g. blast furnaces, petroleum refining and biorefineries. Upstream is separated as an individual sector to exclude its energy balance from the supply and final energy consumption.

Scenario D – Details of power and heat production from biomass

Final energy consumption of electricity		2010	2020	2030	2040	2050
		ktoe	ktoe	ktoe	ktoe	ktoe
	Agriculture	5567	8713	12350	13163	14017
	Commercial	67012	70435	82818	76298	87500
	Industry	91925	103138	142558	135291	186216
	Residential	81379	92092	97175	96041	138386
	Transport	6257	8337	26364	46323	45286
	Total	252140	282716	361264	367116	471404

Final energy consumption of Heat		2010	2020	2030	2040	2050
		ktoe	ktoe	ktoe	ktoe	ktoe
	Agriculture	984	703	71	1624	2122
	Commercial	23501	30030	35734	37089	41825
	Industry	10610	14337	12914	18751	18549
	Residential	30149	35822	42702	57413	61989
	Transport	0	0	0	0	0
	Total	65244	80892	91421	114878	124484

Appendix 7 Examples of calculations using MITERRA-Europe

The calculations made by the MITERRA-Europe model can be illustrated by considering simplified examples. Two example calculations are illustrated here, one for CO_2 emissions arising from agricultural land-use change, and one for CO_2 emissions due to increased straw removal for bioenergy. These simplified examples show how the calculation rules are applied in the MITERRA-Europe model, based on hypothetical land areas forming a notional NUTS2 region.

A7.1 Example 1

The first example (Table A7.1) shows how CO_2 emissions due to agricultural land-use change are calculated. This example is based on a notional NUTS2 area consisting of 1000 ha of agricultural land, where land-use change is occurring between 2010 and 2030. In this particular case there is a strong increase in the area of perennial energy crop Miscanthus, displacing fallow land and the use of land to grow wheat. For each crop, a characteristic per-hectare SOC balance is calculated by RothC using crop-specific carbon input data (manure and crop residues) from MITERRA-Europe. In this example, grass and Miscanthus have a positive SOC balance, i.e. these crops sequester carbon in the soil. The total SOC balance for the entire region is slightly negative in 2010 (-9.55 tC per year), indicating net loss of carbon from the soil. The equivalent net CO_2 emissions/removals for the total land area are calculated by changing the sign of this estimate and multiplying by the conversion factor from C to CO_2 of 44/12, which gives a result of net CO_2 emissions for this example of 35 tCO_2 per year in 2010.

If land use does not change between 2010 and 2030, the same result would be obtained for the total SOC balance and CO_2 emissions/removals. However, by 2030, the land area planted with Miscanthus has greatly increased and the area of fallow land and the land area planted with wheat have decreased commensurately. (There is also a very small change in the land area planted with potatoes.) As a consequence, the total SOC balance in 2030 becomes positive (net carbon sequestration of 22.5 tC per year). The total CO_2 emissions/removals for 2030 are calculated as before, giving net CO_2 removals of -83 tCO_2 per year. It follow that the impact of land-use change between 2010 and 2030 on biogenic CO_2 emissions is a change from 35 tCO_2 per year in 2010 to net CO_2 removals of -83 tCO_2 per year in 2030, a net change in CO_2 emissions of -118 tCO_2 per year (i.e. a net reduction in emissions).

Table A7.1 Example calculation of CO_2 emissions related to agricultural land-use change

Variable	Units	Breakdown by land use					Total[6]
		Wheat	Grass	Potato	Miscanthus	Fallow	
Modelled characteristic SOC balance per ha for land use[1]	kgC ha^{-1} yr^{-1}	-50	150	-200	250	-100	-
Situation in 2010							
Land areas[2]	ha	500	300	99	1	100	1000
Total SOC balance[3]	tC yr^{-1}	-25	45	19.8	0.25	-10	-9.55
CO_2 emissions/ removals[4]	tCO_2 yr^{-1}	92	-165	73	-1	37	35
Situation in 2030							
Land area[2]	ha	450	300	100	100	50	1000
Total SOC balance[3]	tC yr^{-1}	-22.5	45	-20	25	-5	22.5
CO_2 emissions/ removals[4]	tCO_2 yr^{-1}	83	-165	73	-92	18	-83
Biogenic CO_2 emissions in 2030 due to land-use change since 2010							
CO_2 emissions/ removals[5]	tCO_2 yr^{-1}	-9	0	0	-91	-19	-118

Notes to Table A7.1:

1 Calculated by the RothC model for the NUTS2 region using crop-specific carbon input data from MITERRA-Europe.
2 Land areas under different crops in 2010 and 2030 have been assumed for the purposes of illustration.
3 Calculated by multiplying the characteristic SOC balance for each land use by the area under the land use in 2010 and dividing by 1000.
4 Calculated by changing the sign of the estimate for total SOC balance and converting from units of tC to tCO_2 by multiplying by 44/12.
5 Calculated as the CO_2 emission/removal in 2030 minus the CO_2 emission/removal in 2010.
6 Calculated as the sum for all land uses.

A7.2 Example 2

The second example of calculations made by the MITERRA-Europe model (Table A7.2) illustrates the estimation of biogenic CO_2 emissions due to increased removal of straw for use as bioenergy. This example is also elaborated to show how biogenic CO_2 emissions can be related to levels of biomass supply, in turn to meet levels of bioenergy consumption such as specified in the scenarios developed in Task 2 of this project. The example is based on a notional NUTS2 region which includes 1000 ha of straw-producing crops (wheat, barley, rye, oats, grain maize, sunflower, rapeseed and other cereals).

Using the RothC model, the mean per-hectare SOC balance for straw crops is first calculated assuming that no straw is removed. In this example, a mean SOC balance of 0.2 tC per hectare per year is obtained (net soil carbon sequestration). The RothC model is then used again to calculate the mean per-hectare SOC balance assuming that 100% of available straw in the NUTS2 region is removed. In this example, a mean SOC balance of -0.2 tC per hectare per year is obtained (net soil carbon lose).

When working out the impacts of a scenario for increased bioenergy consumption on biogenic CO_2 emissions, the next step is to calculate the potential amount of straw available in each NUTS2 region, based on the areas of straw crops and estimated crop yields (these details are not shown in Table A7.2). For the notional NUTS2 region considered in the example, the potential amount of straw available is estimated at 3000 odt per year. Taking a lower heating value of straw of 17.1 GJ per odt, this equates to a potential for energy supply from straw in this region of 51,330 GJ per year, or 1226 toe per year. Such potentials can be worked out for all NUTS2 regions in the EU. In this example, it is supposed that the consumption of straw in a particular year (say 2030) is 1000 toe for the notional NUTS2 region, as derived from the downscaled results for this example bioenergy scenario in Task 2 of this project. For the purposes of this project, the straw supply from different NUTS2 regions to meet the required level of consumption is calculated on a pro-rata basis with respect to the potentials for each NUTS2 region. It follows that the proportion of the total potential straw supply needed to meet this level of consumption is 1000 / 1226 = 0.82.

If no straw is removed, the total SOC balance for land planted with straw crops in the NUTS2 region can be calculated simply as shown in Table A7.2 as 200 tC per year (net soil carbon sequestration). The equivalent net CO_2 emissions/removals are calculated by changing the sign of this estimate and multiplying by the conversion factor from C to CO_2 of 44/12, which gives a result for net CO_2 emissions in the case of no straw removal of -733 tCO_2 per year (net CO_2 removals). Under a scenario in which 82% of straw is removed for bioenergy production, the total SOC balance is estimated as shown in Table 3.2 to be -128 tC per year (net soil carbon loss). The equivalent net CO_2 emissions/removals under this scenario are 469 tCO_2 per year (net CO_2 emissions). If no straw removal took place prior to 2030, the change in CO_2 emissions/removals due to removing straw to meet a specified level of energy supply as considered in this example are calculated as 469 – (-733) = 1 202 tCO_2 per year (i.e. a net increase in CO_2 emissions).

Table A7.2 Example calculation of CO_2 emissions due to straw removal for bioenergy

Variable	Units	Value
Characteristic modelled SOC balance per ha for straw crops with no straw removal[1]	$tC\ ha^{-1}\ yr^{-1}$	0.2
Characteristic modelled SOC balance per ha for straw crops with 100% straw removal[1]	$tC\ ha^{-1}\ yr^{-1}$	-0.2
Area of straw crops in NUTS2 region[2]	ha	1 000
Total SOC balance (no straw removal)[3]	$tC\ yr^{-1}$	200
Total SOC balance (100% straw removal)[3]	$tC\ yr^{-1}$	-200
Mean potential yield of straw crops[4]	$odt\ ha^{-1}\ yr^{-1}$	3
Total potential supply of straw from NUTS2 region[5]	odt	3 000
Lower heating value of straw[6]	$GJ\ odt^{-1}$	17.1
Total potential energy supply from straw in NUTS2 region[7]	GJ	51 330
	toe	1 226
Total energy supply from straw required from NUTS2 region in 2030 as specified by downscaled results from Task 2 scenario[8]	toe	1 000
Proportion of total potential energy supply from straw in the EU required to meet level specified in Task 2 scenario for the year 2030[9]	per cent	82%
Total SOC balance (82% straw removal)[10]	$tC\ yr^{-1}$	-128
Change in total SOC balance in NUTS2 region due to straw supply[11]	$tC\ yr^{-1}$	469
Change in CO_2 emissions/removals in NUTS2 region due to straw supply[12]	$tCO_2\ yr^{-1}$	1 202

Notes to Table A7.2:

1 Calculated by the RothC model for the NUTS2 region using crop-specific carbon input data from MITERRA-Europe, allowing for straw removal as appropriate.

2 Land area under straw crops has been assumed for the purposes of illustration.

3 Calculated by multiplying the characteristic SOC balance (no straw removal or 100% straw removal as appropriate) by the area of straw crops.

4 Mean yield of straw crops in the NUTS2 region has been assumed for the purposes of illustration.

5 Calculated by multiplying the mean yield of straw crops by the area of straw crops in the NUTS2 region.

6 Lower heating value of straw has been assumed for the purposes of illustration.

7 Calculated by multiplying the total potential supply of straw from the NUTS2 region by the lower heating value of straw. Result then converted from units of GJ to toe.

8 Total energy supply from straw from the NUTS2 region specified for the year 2030 in a Task 2 scenario has been assumed for the purposes of illustration.

9 Calculated by dividing the energy supply from straw from the NUTS2 region specified for the year 2030 by the total potential energy supply from straw in the NUTS2 region.

10 Calculated as 18% of the total SOC balance for no straw removal (in the NUTS2 region) plus 82% of the total SOC balance for 100% straw removal (in the NUTS2 region).

11 Calculated as the total SOC balance for 82% straw removal minus the total SOC balance for no straw removal (assuming no straw removal prior to 2030).

12 Calculated by changing the sign of the estimate for the change in total SOC balance and converting from units of tC to tCO_2 by multiplying by 44/12.

Appendix 8 Examples of calculations using CARBINE

The calculations made by the CARBINE model can be illustrated by considering simplified examples. Before describing an example of particular relevance to this project, it should be noted that examples of CARBINE simulations have been presented in several previous reports. It is suggested that reference is made to the examples already reported in Section 3 of Matthews *et al.* (2014a)[3] and Section 3 of the Task 1 report for this project (Matthews *et al.,* 2014b). These examples focus on results of CARBINE for forest carbon stocks and stock changes. The example presented here illustrates results for carbon stocks and also for other outputs of CARBINE of relevance to this project. This example also represents one of the ways in which CARBINE can be applied to assess the impacts of forest management interventions to increase the supply of forest bioenergy.

A8.1 Basic input data for example

Section 4.4.6 of the main final project report describes the input data that needs to be supplied to the CARBINE model. The example CARBINE results presented below are for a notional stand of 1 hectare of Scots pine, with full details of input data given in Table A8.1.

Table A8.1 Input data to CARBINE used in example simulation

Input data	Details
Area	1 ha
Year of planting or regeneration	1900
Soil type	100% mineral soil
Previous land use	Grassland
Species composition	Scots pine
Potential productivity	4 m^3 ha^{-1} yr^{-1}
Management prescription	Up to the year 2015: no thinning or felling (i.e. no management for production) Clearfell in year 2015 After year 2015: regular thinning (every 5 years starting at age 40) and felling on 100 year rotation. Thinning volumes specified to maximise productivity over the rotation.
Natural disturbance	No natural disturbance
Production of raw harvested wood	10% by mass of felled stemwood allocated to harvest residues 90% by mass of stemwood harvested and converted to raw wood products (small roundwood, sawlogs, bark)

[3] Note that examples of results for CARBINE reported in Matthews *et al*. (2014a) have been produced using version 2 of the soil carbon sub-model of CARBINE. Version 3 has been used in this project, which produces quite different results, generally more conservative in terms of potential for soil carbon sequestration.

In the basic example, management for production is introduced in 2015, involving clearfelling. The forest component is then replanted or regenerated and managed for production through regular thinning interventions and clearfelling on a 100 year rotation.

A8.2 Example 1: wood production

Table A8.2 shows the pattern of wood production over time estimated by CARBINE for the example forest component specified in Table A8.1. The initial clearfelling produces a total of 146.6 odt ha^{-1} of harvested wood, with 71.7 odt ha^{-1} of woody biomass left on site in the forest as unextracted harvest residues. Much of the biomass in the harvest residues will consist of branchwood. The trees felled in 2015 are relatively old and of large size, hence a significant proportion of the total biomass production is formed of sawlogs. Following clearfelling, the regrowth of the restocked forest component is quite slow (the potential productivity of 4 m^3 ha^{-1} yr^{-1} is relatively low, although quite commonly observed in forest of boreal or temperate regions, see Section 2.4.2 of the Task 1 report for this project, (Matthews *et al.,* 2014b). Consequently, in this example, the first production from thinning of the restocked forest component does not occur until 2055 (age 40 years).

Table A8.2 Wood production up to 2115 predicted by CARBINE for the forest component described in Table A8.1

Year	Biomass by raw wood product (odt ha^{-1})						
	Left in forest	Total production	Extracted harvest residues	Small round-wood (under bark)	Small round-wood bark	Sawlogs	Sawlog bark
2015	71.7	146.6	0.0	3.7	0.7	120.9	21.3
2055	2.6	5.3	0.0	2.8	2.5	0.0	0.0
2060	2.6	5.3	0.0	2.8	2.5	0.0	0.0
2065	2.6	5.3	0.0	2.9	2.3	0.0	0.0
2070	2.6	5.3	0.0	4.0	1.3	0.0	0.0
2075	2.6	5.3	0.0	4.2	0.9	0.1	0.0
2080	2.6	5.3	0.0	4.0	0.8	0.4	0.1
2085	2.6	5.3	0.0	3.5	0.7	0.9	0.2
2090	2.6	5.3	0.0	2.9	0.6	1.5	0.3
2095	2.6	5.3	0.0	2.4	0.5	2.1	0.4
2100	2.4	5.0	0.0	1.8	0.3	2.4	0.5
2105	2.0	4.1	0.0	1.2	0.2	2.2	0.4
2110	1.5	3.1	0.0	0.8	0.1	1.9	0.4
2115	44.2	90.4	0.0	10.6	1.9	66.2	11.7

The mean size of trees predicted by CARBINE as felled in early thinnings is relatively small, with the result that no sawlogs are produced. The proportion of total biomass production formed by sawlogs becomes progressively bigger in later thinnings, and sawlogs represent the main component of harvested biomass at the end of the rotation in 2115. The pattern of production illustrated in Table A8.2 is typical of what is observed over the 'forest management cycle' of a forest stand managed on a long rotation (see Section 2.3 of the Task 1 report of this project, Matthews *et al.,* 2014b).

A8.3 Example 2: finished wood products

Section A8.2 and Table A8.2 give an illustration of how the CARBINE model simulates wood production, through thinning and felling, within a stand of trees. The estimates in Table A8.2 show simulated production of raw wood products, i.e. extracted harvest residues, small roundwood, sawlogs and bark. As explained in Section 4.4.5 of the main final project report, the CARBINE model can also be applied to estimate quantities of finished wood products derived from the harvesting of these raw wood products. This involves specifying a set of allocation coefficients as inputs to CARBINE, which determine how raw wood products are converted into finished wood products.

Table A8.3 shows two examples of sets of allocation coefficients, applied in conjunction with the input data in Table A8.1, representing two possible scenarios for the utilisation of finished wood products:

1. A 'low bioenrgy' scenario, in which no harvest residues are extracted for use as bioenergy, there is some use of harvested small roundwood, sawlogs and bark for bioenergy, but with co-production of a range of material wood products.
2. An 'enhanced bioenergy' scenario, in which 40% by mass of harvest residues are extracted for bioenergy, and harvested small trees/early thinnings are diverted entirely for use as bioenergy, along with 90% of associated branchwood. The diversion of small trees in this way has the effect of reducing the quantities of harvested biomass utilised for material wood products (with the exception of structural timber).

Table A8.4 shows example results for the projected out-turn of finished wood products, as simulated by the CARBINE model, based on the input data in Table A8.1 and the two scenarios for wood utilisation in Table A8.3. Results are shown for two example harvesting interventions:

1. The clearfelling event taking place in 2015
2. The first thinning event in the regenerating successor stand of trees in 2055.

For the clearfelling event in 2015, the trees involved are relatively large and contain significant sawlog volume. Consequently, there is negligible diversion of harvested wood in the form of small trees for use as bioenergy, and the pattern of utilisation of stemwood, simulated by the CARBINE model, is the same in both the 'low bioenergy' scenario and the 'enhanced bioenergy' scenario. The key difference in the results in Table A8.4 for the two scenarios in 2015 concerns the extraction of a proportion of harvest residues (about 29 odt ha^{-1}) under the 'enhanced bioenergy' scenario, which is left in the forest under the 'low bioenergy' scenario.

Table A8.3 Examples of allocation coefficients for two scenarios for the conversion of raw harvested wood products into finished wood products

Raw wood product	Allocation coefficients (%) by scenario	
	'Low bioenergy'	'Enhanced bioenergy'
Tree stumps and roots	100% left in forest	
Branchwood and other harvest residues, not including stumps and roots	100% left in forest	60% by mass left in forest 40% by mass extracted for use as bioenergy See also entry for small roundwood for treatment of small trees/early thinnings
Bark	30% by mass used for bioenergy 70% by mass used for non-bioenergy applications (horticultural mulch)	
Small roundwood	20% by mass used for bioenergy 10% by mass used for paper 35% by mass used for wood-based panels (20% MDF, 60% particleboard, 20% OSB) 35% by mass used for pallets and fencing products (50% fencing, 50% pallets)	As baseline, except the threshold for small trees/early thinnings set so that trees are harvested completely for bioenergy, along with 90% of associated branchwood, if the harvested trees have mean proportion of sawlogs less than 5%.
Sawlogs	20% by mass used for bioenergy 55% by mass used for sawn timber products (40% structural timber, 30% fencing products, 30% pallets) 25% by mass used for wood-based panels (20% MDF, 60% particleboard, 20% OSB)	As baseline, except see entry for small roundwood for treatment of small trees/early thinnings

For the early thinning event in 2055, the differences in results for the two scenarios are more extensive. Firstly, as with the felling event in 2015, a proportion of harvest residues are extracted under the 'enhanced bioenergy' scenario, whereas these residues are left in the forest under the 'low bioenergy' scenario. Secondly, there is no production under either scenario of structural timber (from sawlogs), or of sawlog co-products for fuel, since the trees are too small to contain significant material with the dimensions of sawlogs. Finally, the effect of diverting small trees for use entirely as bioenergy under the 'enhanced bioenergy' scenario is very apparent in the results in Table A8.4. Specifically, under the 'low bioenergy' scenario, there is significant production of a range of material wood products alongside some bioenergy production. In contrast, under the 'enhanced bioenergy' scenario, all of the harvested stemwood is used for bioenergy and there are no material wood co-products.

It should be stressed that the preceding example illustrates just one possible set of changes that can be made to the wood product allocation coefficients referred to by the CARBINE model. All of the coefficients described in Table A8.3 can be varied dynamically over time, as specified by the model user.

Table A8.4 Two scenarios for the out-turn of finished wood products in 2015 and 2055 predicted by CARBINE for the forest component described in Table A8.1

Finished product	Biomass production for scenario (odt ha^{-1})			
	Low bioenergy		Enhanced bioenergy	
	2015	2055	2015	2055
Extracted harvest residues	0.00	0.00	28.66	1.80
Small roundwood for fuel	0.75	0.56	0.75	2.80
Sawlog co-products for fuel	24.17	0.00	24.17	0.00
Bark for fuel	6.60	0.75	6.60	2.49
Paper	0.37	0.28	0.37	0.00
MDF	6.30	0.20	6.30	0.00
Chipboard	18.91	0.59	18.91	0.00
OSB	6.30	0.20	6.30	0.00
Pallets and packaging	20.60	0.49	20.60	0.00
Fencing and joinery	20.60	0.49	20.60	0.00
Structural timber	26.59	0.00	26.59	0.00
Bark for mulch	15.39	1.74	15.39	0.00
Total	**146.58**	**5.29**	**175.25**	**7.09**

A8.3 Example 3: forest carbon stocks

Figure A8.1 shows the development over time of carbon stocks (in trees, litter and soil), as simulated by the CARBINE model, for the example stand of trees as represented by the input data in Table A8.1. As can be seen in Figure A8.1, prior to the initial clearfelling intervention in 2015, the combined carbon stocks in the trees, litter and soil forming the forest stand are relatively high, at just over 250 tC ha^{-1} in total. The felling event in 2015 causes a significant reduction in tree carbon stocks (essentially, because the trees have been cut down). In contrast, carbon stocks in deadwood and litter rise sharply in 2015. This occurs because a significant proportion of the biomass of the trees (roots, stumps, branchwood, foliage and some stemwood) is not converted into products and is left on site in the forest rather than extracted. Hence, this unutilised biomass forms a large additional contribution to carbon stocks in litter in 2015. Subsequently, the enhanced carbon stocks in deadwood and litter decrease as a result of progressive decay, returning to the levels observed prior to felling over a period of about 20 to 30 years.

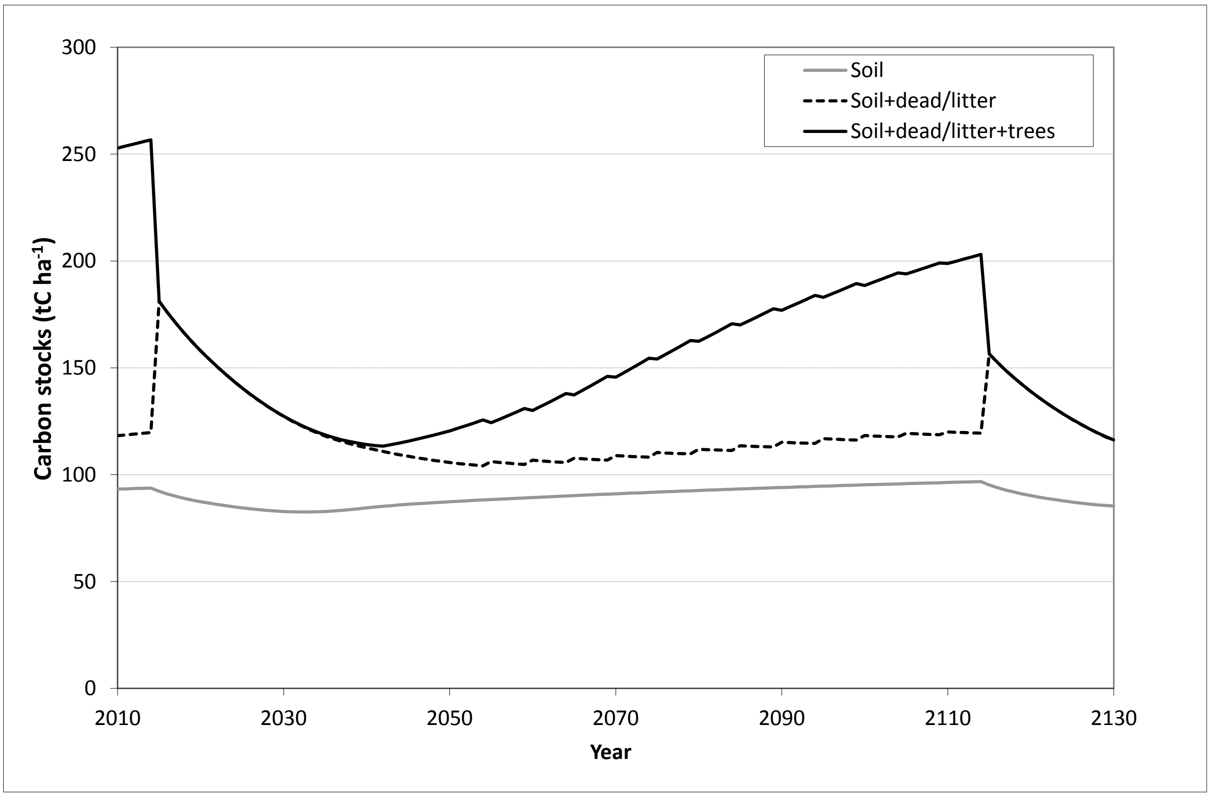


Figure A8.1. Development of carbon stocks over time predicted by CARBINE for the forest component described in Table A8.1.

Following felling, the carbon stocks in trees steadily increase over many decades, as a successor stand regenerates and becomes established. However, the carbon stocks in trees do not return to the same levels as in 2015 prior to felling, because the successor stand is subjected to regular thinning from 2055 onwards and is clearfelled again in 2115.

The results in Figure A8.1 also show changes in soil carbon stocks over time, in response to the felling of the stand of trees in 2015, and the subsequent regeneration of a successor stand. Following the felling of the stand disruption of the soil leads to a progressive loss of carbon stocks over about 20 years. However, soil carbon stocks recover subsequently, as a result of enhanced inputs of carbon to the soil from decaying litter (see earlier), and the reinstatement of carbon inputs to soil from trees, as the successor stand becomes established.

The results in Figure A8.1 illustrate the very long timescales involved in the dynamics of forest carbon stocks in response to stand management.

In Figure A8.2, the simulated total forest carbon stocks for the example stand, as represented by the input data in Table A8.1, are compared with results for an alternative scenario, in which management for production is *not* introduced in 2015 and, instead, the stand continues to grow and accumulate carbon stocks, in the absence of significant natural disturbance.

As can be seen in Figure A8.2, carbon stocks in the stand not managed for production continue to accumulate at a relatively slow rate. However, the cumulative increase in carbon stocks over 100 years is significant, rising from just over 250 tC ha^{-1} in 2015 to about 290 tC ha^{-1} by 2115. The extent of the short-term and long-term reductions in carbon stocks caused by introducing management for production in the example stand, as opposed to not managing for production, are very apparent in Figure A8.2.

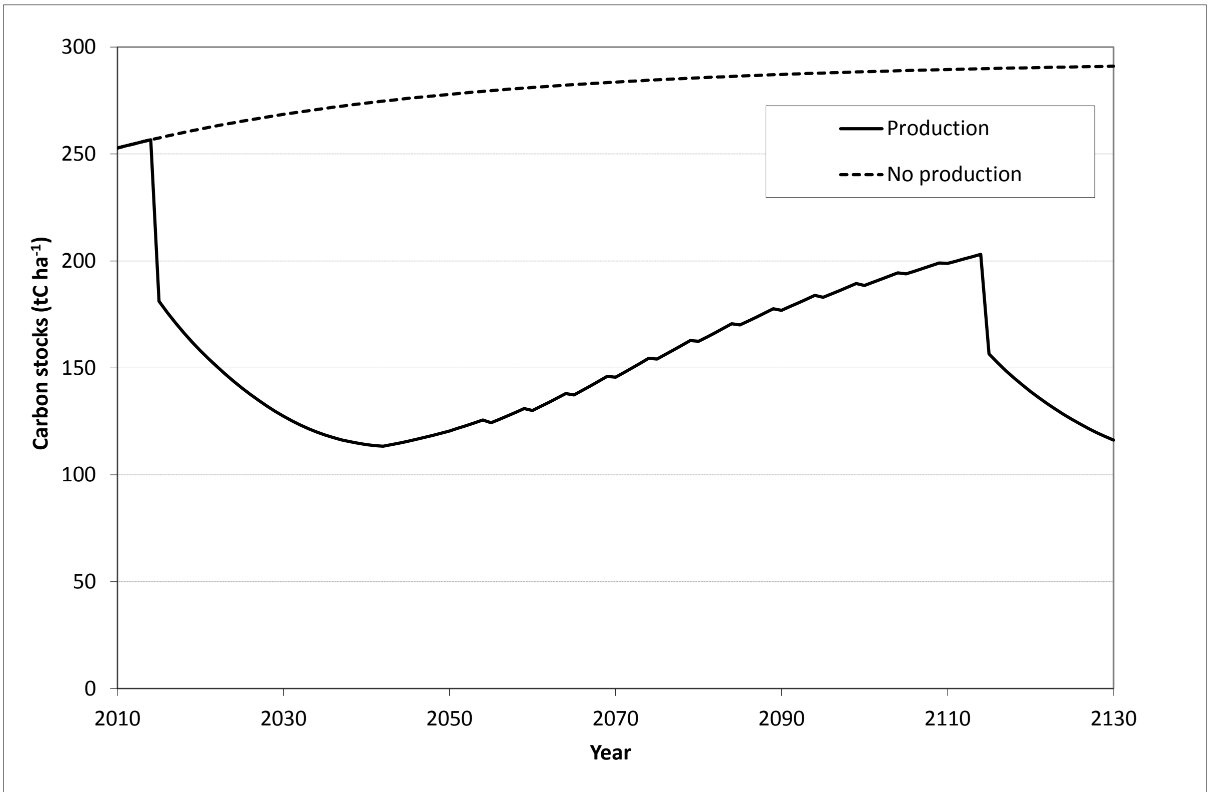


Figure A8.2. Development of carbon stocks over time predicted by CARBINE for the forest component described in Table A8.1, under ‘Production’ and ‘No production’ scenarios.

A8.4 Example for: forest carbon net sink/source

Figure A8.3 shows the development of the net carbon sink or source, as simulated by the CARBINE model for the example stand of trees as represented by the input data in Table A8.1. Results are also shown for the same forest stand under the alternative scenario in which management for production is *not* introduced in 2015. The results in Figure A8.3 are very closely related to the results for carbon stocks in Figure A8.2, and are calculated as simple annual first differences in forest carbon stocks, i.e. results for the net forest carbon sink/source over time are imputed from net annual forest carbon stock changes.

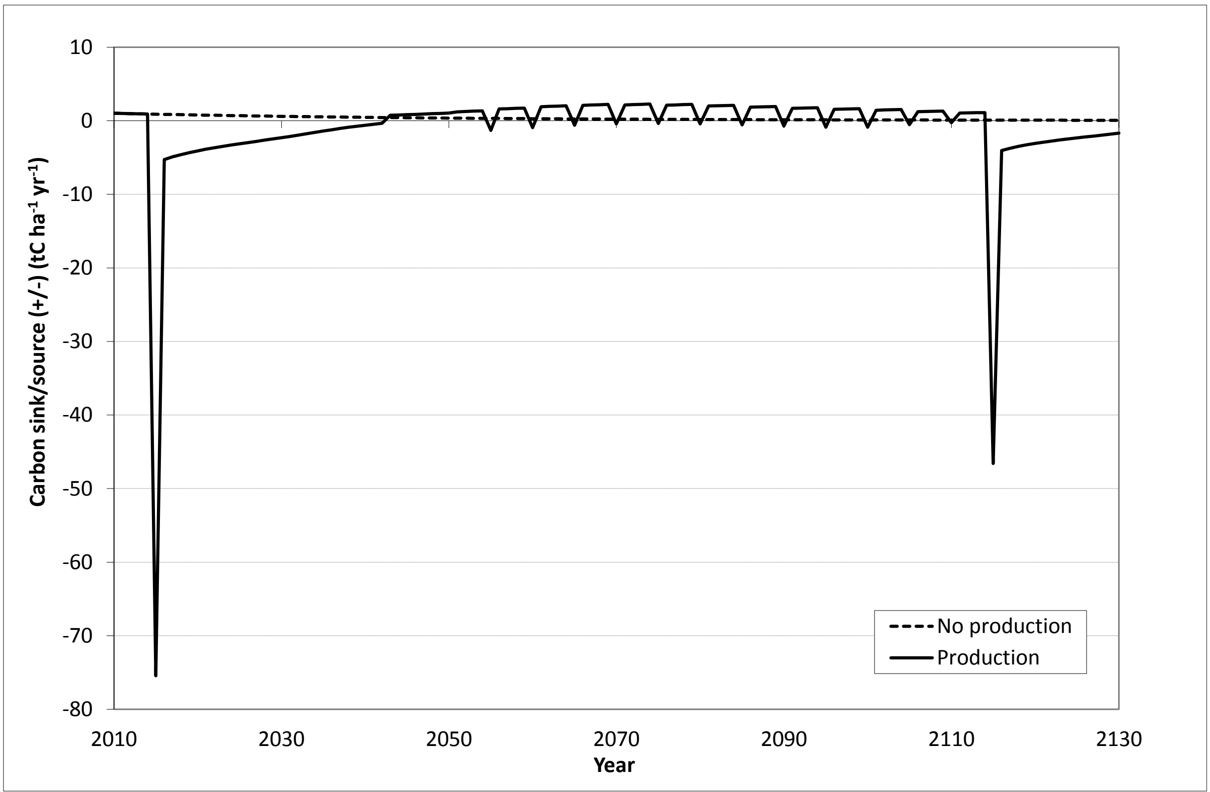


Figure A8.3. Development of the net carbon sink/source over time predicted by CARBINE for the forest component described in Table A8.1, under ‘Production’ and ‘No production’ scenarios.

The results for the ‘production’ and ‘no production’ scenarios are strongly contrasting. For the ‘no production’ scenario, the CARBINE model results suggest a small but noticeable net carbon sink associated with the forest stand. The magnitude of this sink decreases over time, as the stand grows older, and becomes very small, whilst never reaching zero. In contrast, the results for the ‘production’ scenario exhibit a very large carbon source in 2015, due to the felling of the trees and the extraction and removal from the forest of the harvested wood. The carbon dynamics of the forest stand do not recover and return to being a net carbon sink until about 25 years after this harvesting event. Subsequently, for a period of many decades, the net carbon sink in the forest stand under the ‘production’ scenario is actually bigger than would be the case under the ‘no production’ scenario. This reflects the fact that the trees forming the regenerating successor stand are relatively young and faster growing, and sequester carbon at a faster rate than the older trees that would be left to grow on under the ‘no production’ scenario. Periodically, the net carbon sink associated with the successor stand becomes a short-term source, due to periodic thinning interventions. Under the ‘production’ scenario, a further significant carbon source occurs in the year 2115, when the successor stand is itself clearfelled for wood production. The magnitude of this source is not as great as exhibited in 2015, mainly because the carbon stocks in the successor stand at time of felling in 2115 are not as large as prior to felling of the original unmanaged stand in 2015.

Although the net sink in the successor stand is generally enhanced compared with the sink due to the older trees under the ‘no production’ scenario, over a period of many decades, the overall effect on carbon sequestration of the balance of sinks and sources over time in the forest stand is a net source under the ‘production’ scenario, compared with the modest net sink under the ‘no production’ scenario. This remains the case over the 100 year period illustrated in Figure A8.3.

A8.5 Example 5: soil carbon

Figure A8.4 is similar to Figure A8.3, in that it shows the development of the net carbon sink or source, as simulated by the CARBINE model for the example stand of trees as represented by the input data in Table A8.1. However, the results in Figure A8.4 illustrate how the outputs of the CARBINE model are sensitive to assumptions about the characteristics of soils associated with forest areas. Results for two scenarios are shown in Figure A8.4:

1. A scenario based on the unmodified input data in Table A8.1, which includes an assumption that 100% of the forest area is on soils of the ‘mineral’ type (including brown earths, gleys and sandy soils, generally without a high organic component such as a layer of peat).
2. As for the first scenario, but with 20% of the forest area on soils of the ‘organic’ type, i.e. including a significant peaty layer or, essentially, consisting of a peat soil in entirety.

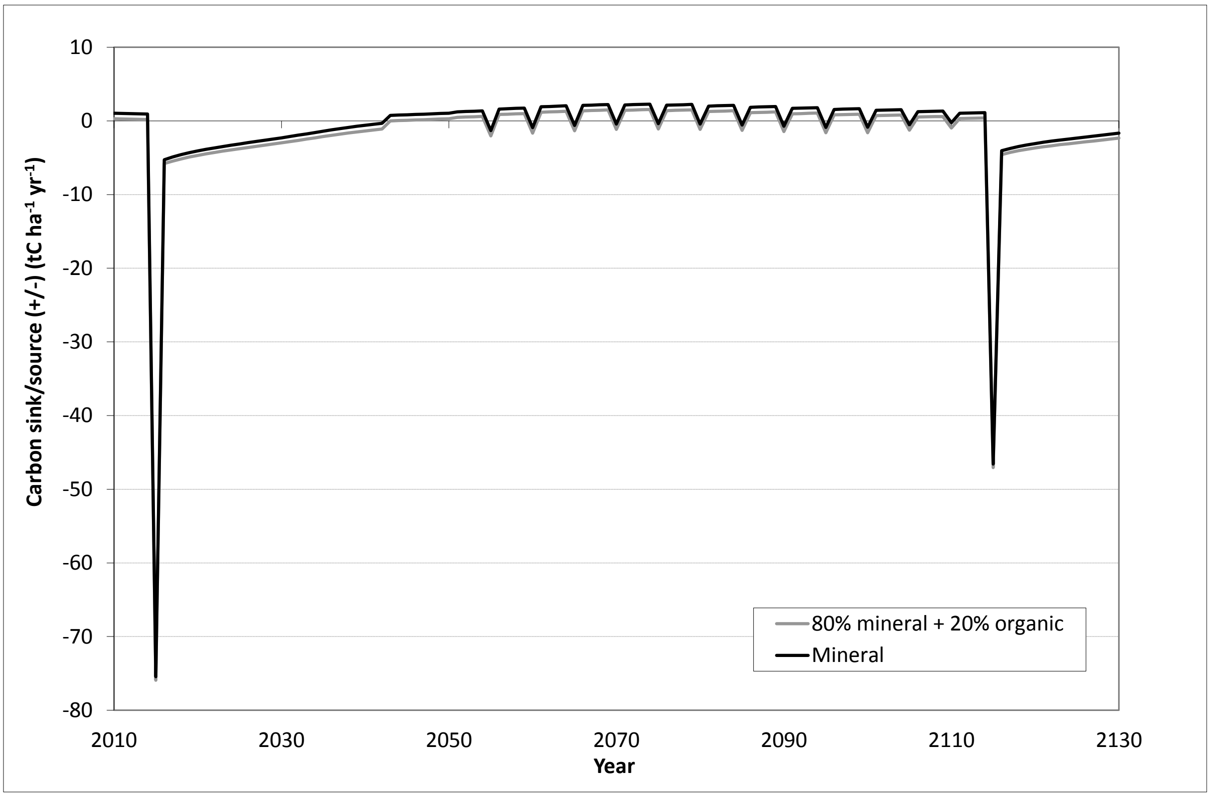


Figure A8.4. Development of the net carbon sink/source over time predicted by CARBINE for the forest component described in Table A8.1, for two examples of associated forest soils.

The projected development of the net carbon sink/source for the forest stands representing these two scenarios look very similar. This is because the biggest impacts on the development of the net forest carbon sink/source are due to management interventions, notably clearfelling events. However, there are notable secondary influences due to the types of soil associated with the forest stands. For example, in the period 2010 up to 2015, the forest stand associated with 100% mineral soil(s) exhibits a small but noticeable net carbon sink, whereas the forest stand associated with 80% mineral soil(s) and 20% organic soil(s) exhibits a negligible carbon sink over this period.

In general, it is important to represent variations in forest carbon dynamics due to the types of soils associated with forest stands, but the effects tend to be secondary, compared with the impacts of forest management for production (particularly when considered relative to the case of not producing wood from forest areas).

A8.6 Example 6: net biogenic carbon emissions in forest

Table A8.5 shows an example of how biogenic carbon emissions associated with wood production (for bioenergy and/or material wood products) may be calculated based on the outputs of the CARBINE model. It is very important to understand the conventions adopted in the calculation of such results, and how such results should be interpreted.

The calculations in Table A8.5 are based on the results already presented in Table A8.4 and Figure A8.3. Firstly, a result is derived for the net carbon stock change that occurs in the forest in 2015 as a result of the introduction of management for production (compared with the alternative of not introducing management for production). As shown in Table A8.5, this result is a net reduction in carbon stocks (i.e. an implied net carbon source) of -76.35 tC ha^{-1} yr^{-1}. However, it is important to appreciate that the atmosphere does not "see" a net carbon source from the forest of 76.35 tC ha^{-1} yr^{-1}. This is because some of the carbon stocks in the felled trees are harvested and retained in wood products. In the case of bioenergy products, the biogenic carbon in the biomass is released relatively quickly (assuming the bioenergy is burned in the same year it is produced). If the contribution to the GHG emissions of the bioenergy due to biogenic carbon is allowed for at the time the bioenergy is burned, then the emissions would be double-counted (i.e. firstly as part of the carbon stock changes in the forest, then secondly when the harvested bioenergy is burned). In the case of material wood products, such double-counting of biogenic carbon emissions would also occur if these were counted as part of carbon stock changes in the forest and then again, when the wood products are disposed of at end of life. This situation may also be complicated by other greenhouse gases being involved in emissions occurring at the time of disposal of material wood products.

To prevent the possibility of double-counting as identified in the preceding discussion, a contribution to forest carbon stocks removed from the forest but retained in harvested wood (used for bioenergy or material wood products) is included in the calculations of biogenic carbon emissions occurring in the forest, as shown in Table A8.5. (GHG emissions associated with the biogenic carbon in the harvested wood are registered in a later stage of LCA calculations for wood production and consumption systems, i.e. at time of burning in the case of bioenergy products or at time of disposal at end of life in the case of material wood products.)

Table A8.5 Example calculation (for the year 2015) of net biogenic carbon emissions associated with forest carbon stocks for the forest component described in Table A8.1

Contribution	Calculation/result (tC ha^{-1} yr^{-1} unless indicated otherwise)
Net carbon sink/source under 'No production' scenario[1]	0.90
Net carbon sink/source under 'Production' scenario[2]	-75.45
Change in net carbon/sink source due to introducing production in 2015	-75.45 – 0.90 = -76.35
Carbon removed from forest but retained in harvested wood used for bioenergy (prior to burning)[3]	15.76

Table A8.5 (continued) Example calculation (for the year 2015) of net biogenic carbon emissions associated with forest carbon stocks for the forest component described in Table A8.1

Carbon removed from forest but retained in harvested wood used for material wood products (prior to disposal at end of life)[3]	57.53
Total carbon removed from forest but retained in harvested wood (prior to burning or disposal at end of life)[4]	15.76 + 57.53 = 73.29
Net change in biogenic carbon associated with forest and harvest wood (prior to burning or disposal at end of life)	-76.35 + 73.29 = -3.06
Net biogenic carbon emission associated with forest due to wood harvesting (tCO_2 ha^{-1} yr^{-1})[5]	-(-3.06) × 44 / 12 = 11.22 tCO_2 ha^{-1} yr^{-1})

Notes to Table A8.5:

1 Result obtained from Figure A8.3 for the 'no production' scenario in 2015

2 Result obtained from Figure A8.3 for the 'production' scenario in 2015

3 Calculated as the sum of the out-turn of biomasses of relevant finished wood products in 2015, as shown in Table A8.4, multiplied by a value for the carbon content of wood of 0.5 (Matthews, 1993)

4 Note that the result of 73.29 tC ha^{-1} yr^{-1} is exactly one half of the equivalent result in Table A8.4 (146.6 tC ha^{-1} yr^{-1}), due to conversion from units of biomass to units of carbon (see note 3)

5 By convention carbon stock changes expressed in units of carbon are shown as negative numbers when carbon stocks are reduced (net source) and as positive numbers when carbon stocks are increased (net sink). In contrast, results expressed in units of carbon dioxide are expressed as positive numbers in the case net emissions and as negative numbers in the case of net removals.

As shown in Table A8.5, the net change in biogenic carbon associated with the forest carbon stocks and harvested wood in 2015 is -3.06 tC ha^{-1} yr^{-1} (i.e. a net reduction in carbon stocks, implying a carbon source in 2015). This can be expressed as an equivalent emission of carbon dioxide from the forest in 2015 due to biogenic carbon, by changing the sign of the previous result and multiplying it by the standard conversion factor of 44/12, giving a final result for the year 2015 of 11.22 tCO_2 ha^{-1} yr^{-1} (the positive sign indicating net emissions).

In Table A8.6, example calculations and results are shown that are similar to those in Table A8.5, but for the year 2016, i.e. one year after the initial clearfelling event and harvesting of wood. These results are quite different to those for the year 2015, because no wood is harvested in 2016, but the full impacts of the harvesting event in 2015 on the dynamics of forest carbon stocks and associated sinks or sources are still apparent. As a result, the estimated biogenic carbon emissions associated with the forest in 2016 are very much bigger than estimated for the year 2015 (22.52 tCO_2 ha^{-1} yr-1 as opposed to 11.22 tCO_2 ha^{-1} yr^{-1}).

Table A8.6 Example calculation (for the year 2016) of net biogenic carbon emissions associated with forest carbon stocks for the forest component described in Table A8.1

Contribution	Calculation/result (tC ha^{-1} yr^{-1}, unless indicated otherwise)
Net carbon sink/source under 'No production' scenario[1]	0.87
Net carbon sink/source under 'Production' scenario[2]	-5.26
Change in net carbon/sink source due to introducing production in 2015	-5.26 – 0.87 = -6.14
Carbon removed from forest but retained in harvested wood used for bioenergy (prior to burning)[3]	0.00
Carbon removed from forest but retained in harvested wood used for material wood products (prior to disposal at end of life)[3]	0.00
Total carbon removed from forest but retained in harvested wood (prior to burning or disposal at end of life)[3]	0.00 + 0.00 = 0.00
Net change in biogenic carbon associated with forest and harvest wood (prior to burning or disposal at end of life)	-6.14 + 0.00 = -6.14
Net biogenic carbon emission associated with forest due to wood harvesting (tCO_2 ha^{-1} yr^{-1})[4]	-(-6.14) × 44 / 12 = 22.52 tCO_2 ha^{-1} yr^{-1}

Notes to Table A8.6:

1 Result obtained from Figure A8.3 for the 'no production' scenario in 2016
2 Result obtained from Figure A8.3 for the 'production' scenario in 2016
3 There is no production of harvested wood in 2016
4 By convention carbon stock changes expressed in units of carbon are shown as negative numbers when carbon stocks are reduced (net source) and as positive numbers when carbon stocks are increased (net sink). In contrast, results expressed in units of carbon dioxide are expressed as positive numbers in the case net emissions and as negative numbers in the case of net removals.

Figure A8.5 shows the development of biogenic carbon emissions associated with the example forest area (expressed in units of tCO_2 ha^{-1} yr^{-1}), over the period 2010 to 2130, as estimated using the approach described in Tables A8.5 and A8.6. As can be seen in the figure, the introduction of management for wood production in the example forest stand in 2015 leads to net biogenic carbon emissions from the forest for a period of about 30 years. This is followed by a period of net carbon sequestration, which is sustained over a number of decades, until the successor stand is itself clearfelled in 2115. Prior to the impacts of clearfelling in 2115, the cumulative balance between biogenic carbon emissions and sequestration associated with the example forest area over a 100 year period from 2015 to 2115 is negative (i.e. net sequestration overall).

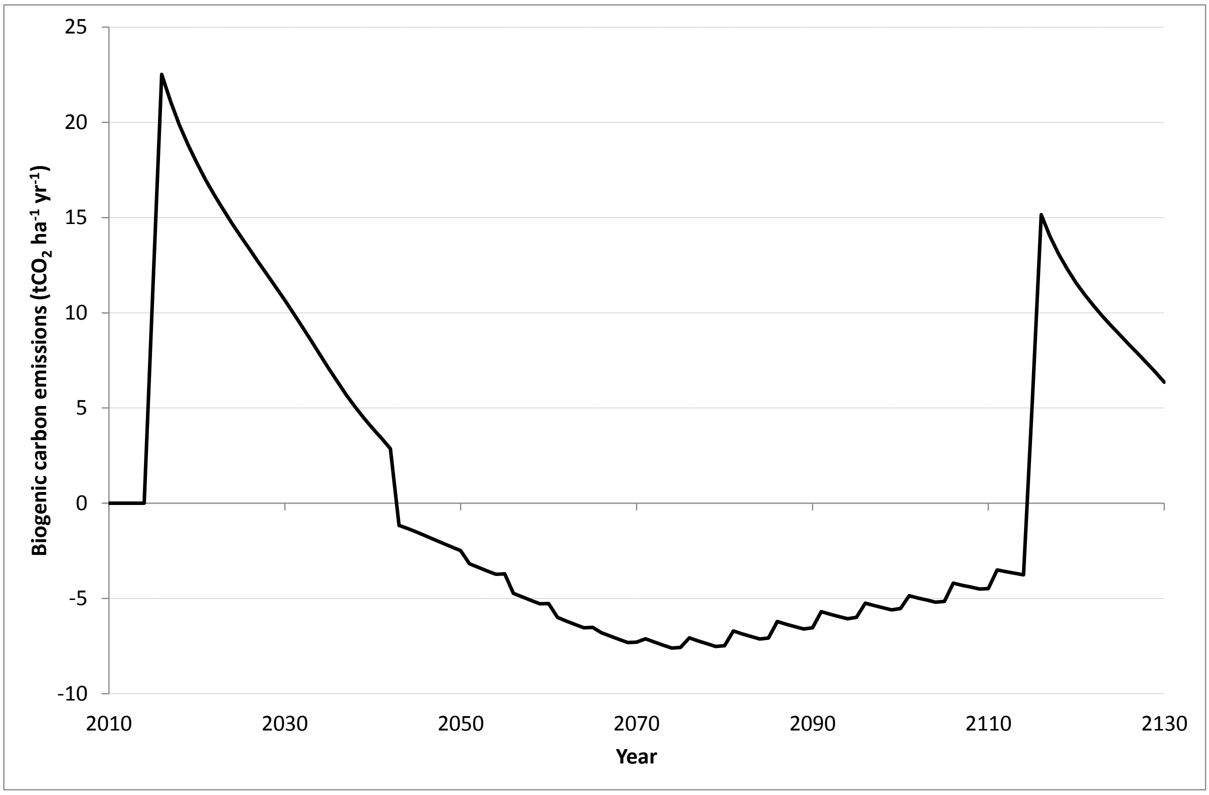


Figure A8.5. Development of net biogenic carbon emissions (or sequestration) associated with an example forest area predicted by CARBINE for the forest component described in Table A8.1, as a result of introducing management for wood production in 2015.

A8.7 Example 7: indirect GHG emissions from forest operations

Figure A8.6 shows an example of results for GHG emissions due to forest operations, as simulated by the CARBINE model for the example stand of trees as represented by the input data in Table A8.1. Types of forest operations represented include:

Routine forest maintenance (e.g. repairs to roads and fences)

Tree establishment (e.g. ground preparation, growing of young plants in nurseries, weed and pest control, fertilisation where appropriate/relevant)

Thinning and felling of trees for wood production

Extraction of felled wood (including harvest residues, as appropriate) for utilisation as bioenergy or for material wood products

The CARBINE model calculates results for emissions of notable greenhouse gases, i.e. CO_2, CH_4 and N_2O, which can be expressed in units of $kgCO_2\ ha^{-1}\ yr^{-1}$, and added together to estimate total GHG emissions associated with forest operations, as shown in Figure A8.6. Some contributions to indirect GHG emissions from forest operations cannot be disaggregated into the individual greenhouse gases, due to the non-availability of disaggregated emissions factors for use in calculations. These aggregated GHG emissions are shown in Figure A8.6 using CO_2-equivalent units. The calculations in the CARBINE model to produce these results are too numerous and complex to describe in detail in this appendix. However, it may be noted that the magnitudes of GHG emissions due to forest operations are small, compared with the GHG emissions/sequestration due to forest carbon dynamics (i.e. biogenic carbon). Further details of the approaches to calculating GHG emissions of forest operations are given in Morison *et al.* (2012). However, it should be noted that these calculations have been elaborated for the purposes of this project to apply relevant GHG emissions factors, as described in Section 5 of the main final report for this project. It should also be noted that other indirect GHG impacts, for example, due to wood processing, energy conversion, and also due to possible counterfactuals to wood products have been calculated in subsequent stages of this project, as described in Section 5 and Section 6.4 of the main final project report.

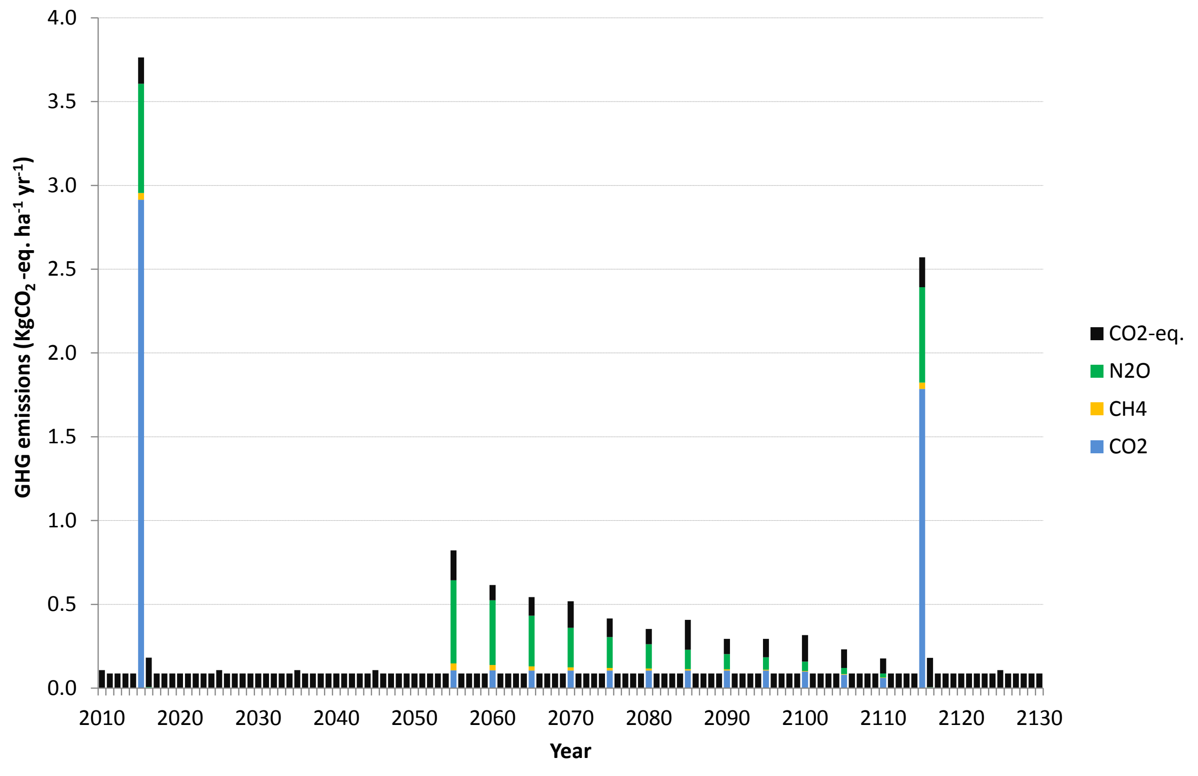


Figure A8.6. GHG emissions due to forest operations in an example forest area predicted by the CARBINE model for the forest component described in Table A8.1, associated with management for wood production.

As already observed, the results in Figure A8.6 indicate that GHG emissions associated with forest operations involved in wood production are small in magnitude, particularly when compared with contributions due to biogenic carbon emissions (see for example the equivalent results for biogenic carbon emissions in Figure A8.5). However, peaks in GHG emissions are apparent in Figure A8.6, generally associated with wood harvesting and extraction operations at times of felling and thinning. These occur against a low level background of annual GHG emissions associated with forest operations involved in general maintenance of forest stands.

Appendix 9 Processing of forest data

A9.1 Introduction

The purpose of this appendix is to illustrate the approach taken to fusing data sources for forests in EU27 Member States, countries in the CIS region and Canada. The processing of data was simpler in the case of the USA, because national forest inventory data was more complete. The approach to representing relevant forest areas in Latin America (essentially Brazil) has been described in Box 4.1 of Section 4.8.3 of the main project report.

The appendix also includes summary tables showing estimates of forest areas, by species, age class and growth class, for all countries modelled as part of this project.

A9.2 Key forest area data sources

The key data sources on forest areas referred to in this project have been described in Section 4.5.2 of the main project report:

- For the EU27 region and for countries representing CIS, several available data sources were referred to notably an on-line database maintained by UN-ECE (http://w3.unece.org/pxweb/), and the EFISCEN on-line database (http://www.efi.int/portal/virtual_library/databases/efiscen/inventory_database/).
- EU27 data was supplemented by a number of supporting sources of information, notably a published review of European forests and forestry (Arkuszewska *et al.*, 2006).
- For Canada and the USA, National Forest Inventories are reported on-line (https://nfi.nfis.org/reporting.php?lang=en and http://apps.fs.fed.us/Evalidator/evalidator.jsp respectively).
- For Latin America, the most relevant forest types were considered to be high-productivity tree plantations established on degraded former agricultural land (see ABRAF, 2011, www.youblisher.com/p/200491-ABRAF-Statistical-yearbook-2011; Couto *et al.*, 2011, http://ieabioenergytask43.org/wp-content/uploads/2013/09/IEA_Bioenergy_Task43_PR2011-02.pdf).

A9.3 Example of forest area data processing

The approach taken to fusing forest area datasets is illustrated for the example EU27 Member State of Estonia.

The two main datasets on forest areas available for Estonia consisted of the UN-ECE report and records from the EFISCEN database. The forest area data reported by UN-ECE are shown in Table A9.1. Areas are reported for age classes ranging from 0-10 years up to greater than 140 years, and for inventory base years of 2000, 2005 and 2010.

Table A9.1 UN-ECE data on forest areas by age class in Estonia for the base years of 2000, 2005 and 2010

Age class (years)	Forest area by age class for base year (kha)					
	Total			Available for wood supply		
	2000	2005	2010	2000	2005	2010
0-10	207.0	234.0	258.2	201.1	231.6	256.2
11-20	123.1	125.8	119.3	120.0	120.9	115.0
21-40	425.5	378.0	327.8	411.8	361.8	311.7
41-60	531.9	525.9	508.1	507.8	487.7	465.6
61-80	310.6	322.9	325.9	281.2	288.7	291.3
81-100	109.6	120.5	123.8	96.7	101.2	100.4
101-120	29.8	32.1	34.3	23.1	25.0	26.1
121-140	5.7	9.8	13.1	3.4	6.0	8.5
>140	4.6	6.0	6.2	2.1	2.2	2.3
Total	**1747.6**	**1755.0**	**1716.8**	**1647.3**	**1625.0**	**1577.3**

Information on forest areas in Estonia, as reported by the EFISCEN database is shown in Table A9.2. This dataset has a stated base year of 2000.

Table A9.2 EFISCEN data on forest areas by tree species and age class in Estonia for a base year of 2000

Age class (years)	Forest area by tree species and age class (kha)					
	Scots pine	Norway spruce	Grey alder	Black alder	Aspen	Birch
1-15	45.0	52.2	29.9	4.0	19.5	85.2
16-25	24.6	24.8	24.2	3.4	3.9	47.1
26-35	34.9	38.8	45.5	4.2	5.7	51.8
36-45	53.9	42.2	56.3	11.0	11.4	112.8
46-55	79.4	36.3	26.3	15.3	26.7	134.1
56-65	83.6	48.3	4.3	14.0	25.6	119.2
66-75	82.8	54.9	0.0	5.5	11.3	65.4
76-85	76.3	44.9	0.0	2.9	7.4	28.3
86-95	58.7	27.2	0.0	2.3	2.8	10.4
96-105	42.4	15.4	0.0	0.8	0.8	3.1
106-115	16.1	7.3	0.0	0.0	0.0	0.4
116-125	16.3	6.2	0.0	0.0	0.0	0.0
126-135	3.8	0.0	0.0	0.0	0.0	0.0
136-145	3.0	0.0	0.0	0.0	0.0	0.0
146-155	2.8	0.0	0.0	0.0	0.0	0.0
156-165	3.4	0.0	0.0	0.0	0.0	0.0
Total	**626.8**	**398.6**	**186.3**	**63.3**	**115.0**	**657.8**

It is difficult to compare the UN-ECE and EFISCEN datasets directly due to the use of different age classes. There is reasonable consistency in terms of the distribution of area within age classes, but there is notably more area overall reported in the EFISCEN data. As a convention in this project, in such cases of discrepancies between datasets, an assumption was made that UN-ECE data should be regarded as the most authoritative source. However, the EFISCEN data add value in providing information about the species composition of forest areas. Consequently, the UN-ECE data were accepted as the primary source, but the EFISCEN dataset was used to allocate the UN-ECE forest areas, as reported for each age class, to tree species, on a pro-rata basis. This required first processing the EFISCEN data to refer to the same age classes as used by UN-ECE. The UN-ECE data for a base year of 2000 were also referred to, as the nearest equivalent to the EFISCEN dataset base year. The forest areas reported by UN-ECE as "available for wood supply" were referred to, thereby excluding some forest areas as available for wood production (including forest bioenergy production) as part of the subsequent modelling undertaken in this project.

A further data processing step involved allocating growth rates and notional rotations to forest areas for each tree species. The data sources referred to and assumptions made for this exercise have been described in Sections 4.5.2 and 4.8.1 of the main project report. A table was constructed, assigning a notional rotation to each tree species and defining the percentages of forest area for each tree species associated with specified growth rates, expressed in classes of 2 $m^3 ha^{-1} yr^{-1}$. The relevant table for forest areas as derived for Estonia is shown in Table A9.3. The table also shows how, for some tree species, a 'mapped' or equivalent tree species has been referred to for the purposes of modelling forest carbon dynamics using the CARBINE model.

Table A9.3 Allocation of area by tree species to growth rates, rotations and mapped tree species represented in the CARBINE model

Growth rate ($m^3 ha^{-1} yr^{-1}$)	Proportion of area allocated by tree species (%)					
	Scots pine	Norway spruce	Grey alder	Black alder	Aspen	Birch
2	10	0	40	40	40	40
4	75	30	50	50	50	50
6	10	40	10	10	10	10
8	5	20	0	0	0	0
10	0	10	0	0	0	0
Rotation (years)	100	80	50	80	70	70
Mapped species	Scots pine	Norway spruce	Sycamore	Sycamore	Poplar	Birch

A final, fused dataset was produced, based on the combination of UN-ECE data (Table A9.1) and EFISCEN data (Table A9.2), as described earlier, followed by allocating growth rates on a pro-rata basis to the area for each (mapped) tree species, and assigning the characteristic rotations shown in Table A9.3. This final dataset is shown in a table in Section A9.4, along with similar tables describing datasets for other countries modelled as part of this project.

These tables refer to a "model species", consisting of a two-letter code. This specifies the model for stand growth and development referred to in the CARBINE model simulations, defined in terms of a 'mapped', equivalent or nearest species. A list of codes for model species is given in Table A9.4.

Table A9.4 CARBINE model species codes and their meanings

Model species code	Tree species represented by model
NS	Norway spruce
SS	Sitka spruce
CP	Corsican pine
LP	Lodgepole pine
SP	Scots pine
DF	Douglas fir
GF	Grand fir
NF	Noble fir
EL	European larch
JL	Japanese larch
RC	Western red cedar
WH	Western hemlock
AH	Ash
BE	Beech
BI	Birch
OK	Oak
PO	Poplar
SY	Sycamore

The mapping of tree species, and the assignment of rotations to forest areas, were relatively complex in the case of Canada and the USA, particularly in the case of the USA. Further information on the interpretation and mapping and assignment of characteristic rotations to Canadian National Forest Inventory (NFI) species groups is given in Table A9.5. Information on the interpretation and mapping and assignment of characteristic rotations to USA Forest Inventory Assessment (FIA) species groups is given in Table A9.6.

The details of the data fusion exercise undertaken to represent forest areas for different countries depended on the availability and the assessment of the quality of the data sources. Further information about this process is given in Table A9.7.

It is important to note that the datasets described in this appendix required further processing before they could be applied as inputs to the CARBINE model. In particular, a set of detailed assumptions about forest management needed to be developed for each country, to represent 'baseline' or 'business-as-usual' management and wood production, and then to represent changes in management associated with the additional supply of forest biomass to the EU for use as energy. The methods and associated assumptions involved in this exercise have been described in Section 4.8 of the main final project report.

An important intermediate step involved converting the various datasets on forest areas described in the tables in Section A9.4, from the form shown of discrete distributions for a set of arbitrary and variable tree/stand age classes, into equivalent smooth frequent polygons of forest area distributed according to annual age classes.

Table A9.5 Detailed assumptions about mapping of tree species groups and characteristic rotations for forest areas in Canada

Canada NFI tree species grouping	CARBINE model code	Characteristic rotation (years)
Birch	BI	100
Cedar and other conifers	RC	100
Douglas-fir	DF	100
Fir	NF	100
Hemlock	WH	100
Larch	EL	100
Maple	SY	100
Other hardwoods	SY	100
Pine	SP	100
Poplar	PO	80
Spruce	NS	100
Unclassified	NS	100
Unspecified conifers	NS	100
Unspecified hardwoods	SY	100

Table A9.6 Detailed assumptions about mapping of tree species groups and characteristic rotations for forest areas in USA

USA FIA tree species grouping	CARBINE model code	Characteristic rotation (years)
Alder/maple group	SY	100
Aspen/birch group	BI	100
California mixed conifer group	SP	80
Douglas-fir group	DF	100
Elm/ash/cottonwood group	AH	100
Exotic hardwoods group	SY	40
Exotic softwoods group	SP	50
Fir/spruce/mountain hemlock group	NS	100
Hemlock/Sitka spruce group	SS	100
Loblolly/shortleaf pine group	CP	60
Lodgepole pine group	LP	100
Longleaf/slash pine group	CP	60
Maple/beech/birch group	SY	100
Oak/gum/cypress group	OK	120
Oak/hickory group	OK	120
Oak/pine group	SP	120
Other eastern softwoods group	CP	80
Other hardwoods group	OK	100
Other softwoods group	SP	80
Other western softwoods group	CP	80
Pinyon/juniper group	SP	100
Ponderosa pine group	CP	80
Redwood group	GF	100
retired (Other western hardwoods group)	SY	120
Spruce/fir group	SS	80
Tanoak/laurel group	OK	100
Tropical hardwoods group	OK	100
Tropical softwoods group	GF	60
Western larch group	JL	100
Western oak group	OK	120
Western white pine group	SP	80
White/red/jack pine group	SP	80
Woodland hardwoods group	BI	100

Table A9.7 Assessment of available data sources on forest areas

Country	Availability of data				Assessment
	UN-ECE (previous 2005 report, withdrawn)	UN-ECE (2010, forest area available for wood supply)	UN-ECE (2010, total forest area)	EFISCEN database (and base year)	
Austria	No	No	Yes	1994	EFISCEN data appears to represent even-aged and uneven-aged stands available for wood supply, whilst UN-ECE data appears to be just for even-aged stands. Discrepancies between previously reported and more recent UN-ECE data seem to be related to the base year and 125 kha of forest area now recorded as "unspecified". Use UN-ECE data but allocate separate information (EU forestry review). Refer to previous UN-ECE data to inform representation of uneven-aged stands available for wood supply.
Belarus	Yes	Yes	Yes	2001	All datasets are in reasonable agreement if forests unavailable for wood supply are excluded. Some disagreements amongst age classes. Have to assume the UN-ECE is the most authoritative source. Use UN-ECE data but allocate species based on EFISCEN data.
Belgium	Yes	Yes	Yes	1998	EFISCEN total forest area agrees reasonably well with total UN-ECE area less the area denoted as unspecified from UN-ECE for 2005. The unspecified area probably equates to a separately reported area in the 2005 UN-ECE data. Age distribution of EFISCEN data is notably different from UN-ECE data, particularly up to age 40. Have to assume the UN-ECE is the most authoritative source. Use UN-ECE data but allocate species based on EFISCEN data and to inform older age classes.

Table A9.7 (continued) Assessment of available data sources on forest areas

Country	Availability of data				Assessment
	UN-ECE (previous 2005 report, withdrawn)	UN-ECE (2010, forest area available for wood supply)	UN-ECE (2010, total forest area)	EFISCEN database (and base year)	
Bulgaria	Yes	No	Yes	2000	Total areas for high forest are in good agreement for all datasets. It is possible that the large differences between EFISCEN data (2000) and 2005 UN-ECE data for particular age classes could be due to changing definitions of high forest and coppice. Comparison of EFISCEN data with UN-ECE data (all even-aged forests) suggests that EFISCEN data is in reasonable agreement, but with age 0-10 represented and areas unavailable for wood supply discounted. Attempt to fuse UN-ECE data with EFISCEN data. The principal relevance of EFISCEN data is to inform the allocation of species and representation of coppice.
Czech	Yes	2005, 2010	Yes	2000	Good consistency amongst datasets, allowing for differences in base years/missing data. Use EFISCEN dataset.
Denmark	Yes	2005, 2010	2005, 2010	1990	All datasets are reasonably consistent but notable discrepancies for individual age classes. Have to assume the UN-ECE data is the most authoritative source. Use UN-ECE data but allocate species based on EFISCEN data.
Estonia	Yes	Yes	Yes	2000	Difficult to compare datasets directly due to use of different age classes. There is reasonable consistency, but quite a bit more area in EFISCEN data. Have to assume the UN-ECE data is the most authoritative source. Use UN-ECE data but allocate species based on EFISCEN data.
Finland	Yes	Yes	Yes	1990	Reasonable consistency between datasets, but UN-ECE data has rather more total area than EFISCEN. Some quite big differences between UN-ECE and EFISCEN data in terms of age classes. EFISCEN data is quite old. Use UN-ECE data but allocate species based on EFISCEN data. Also use to inform older age classes.

Table A9.7 (continued) Assessment of available data sources on forest areas

Country	Availability of data				Assessment
	UN-ECE (previous 2005 report, withdrawn)	UN-ECE (2010, forest area available for wood supply)	UN-ECE (2010, total forest area)	EFISCEN database (and base year)	
France	Yes	Yes	Yes	1988	Datasets display considerable inconsistencies. Have to assume latest UN-ECE is most authoritative. Use UN-ECE data and inform species allocation using EFISCEN data.
Germany	Yes	Yes	Yes	1990	There could have been an issue in downloading the EFISCEN data. Datasets are not in perfect agreement but are reasonably consistent. Have to assume latest UN-ECE data is most authoritative. Use UN-ECE data but use EFISCEN data to inform species allocation and older age classes.
Greece	No	No	No	No	Very limited data available. Base total forest area and species composition on country report and assume age distribution close to rectangular but skewed based on forest fire data.
Hungary	Yes	Yes	Yes	2000	Datasets are not in perfect agreement but are reasonably consistent. Have to assume latest UN-ECE data is most authoritative. Use UN-ECE data but use EFISCEN data to inform species allocation and older age classes.
Iceland	No	Yes	Yes	No	Not relevant to project.
Ireland	Yes	No	Yes	1992 (conifers)	No data from EFISCEN for broadleaves. Have to assume the UN-ECE is the most authoritative source. Use UN-ECE data in conjunction with underlying data from EFISCEN to inform allocation of conifer species and yield classes, and assume reasonably high afforestation for conifers.
Italy	Yes	Yes	Yes	1984	There seemed to be an issue when downloading the EFISCEN data. Use the UN-ECE data but allocate species by referring to the EFISCEN data.
Latvia	Yes	2005, 2010	Yes	2000	EFISCEN data is in extremely good agreement with UN-ECE data (all forests, including areas not available for wood supply). Use the EFISCEN data but use UN-ECE data to inform down-marking to represent area available for wood supply.

Table A9.7 (continued) Assessment of available data sources on forest areas

Country	Availability of data				Assessment
	UN-ECE (previous 2005 report, withdrawn)	UN-ECE (2010, forest area available for wood supply)	UN-ECE (2010, total forest area)	EFISCEN database (and base year)	
Lithuania	Yes	Yes	Yes	2000	Have to assume the UN-ECE is the most authoritative source. Use the UN-ECE but allocate species etc. by referring to EFISCEN data. Need to look carefully at how to represent area available for wood supply, noting that EFISCEN data is classified according to broad management objectives. Site classes are difficult to interpret and it may be necessary to amalgamate data for all site classes and allocate a productivity distribution.
Luxembourg	Yes	No	2000, 2005	1989	Total area suggested by EFISCEN data is much higher than for 2010 UN-ECE data and areas for age classes do not agree terribly well. Comparison with 2005 UN-ECE data strongly indicates that this is due to the omission of data for uneven aged stands from 2010 UN-ECE data. Attempt to fuse EFISCEN and UN-ECE data to allocate species and represent uneven aged areas.
Netherlands	Yes	2000	2000	1997	Have to assume the UN-ECE is the most authoritative source. Total area suggested by EFISCEN data is higher than suggested by UN-ECE data. The discrepancy seems to be related to the representation of forest areas available for wood supply as opposed to total forest area. Use UN-ECE data but allocate species based on EFISCEN data.
Poland	Yes	No	Yes	1993	Have to assume the UN-ECE is the most authoritative source. Total area in reasonable agreement but areas for age classes do not agree terribly well. Use UN-ECE data but allocate species based on EFISCEN data.
Portugal	No	No	2005	1998	Very limited/abbreviated data available from UN-ECE. Use EFISCEN data.

Table A9.7 (continued) Assessment of available data sources on forest areas

Country	Availability of data				Assessment
	UN-ECE (previous 2005 report, withdrawn)	UN-ECE (2010, forest area available for wood supply)	UN-ECE (2010, total forest area)	EFISCEN database (and base year)	
Romania	Yes	No	No	1982	No data available as part of 2010 UN-ECE report. UN-ECE data reported in 2005 may include coppice. Total area suggested by EFISCEN data (including coppice) reasonably consistent with UN-ECE but areas for age classes do not agree terribly well (base year difference?). EFISCEN data is for old base year but it is known that the UN-ECE data is of similar vintage. Use EFISCEN data as best available source.
Russia (European)	Yes	2005, 2010	2005, 2010	1998	Have to assume the UN-ECE is the most authoritative source but this represents the whole of Russia. EFISCEN data is for European Russia and is of greater relevance for this project. Use EFISCEN data as best available and most relevant source.
Slovakia	Yes	Yes	Yes	?	Have to assume the UN-ECE is the most authoritative source. Total area suggested by EFISCEN data reasonably consistent given unknown base year. Use UN-ECE data but allocate species based on EFISCEN data.
Slovenia	Yes	No	No	2000	Total area suggested by EFISCEN data is reasonably consistent with total area for 2005 UN-ECE data (i.e. including uneven aged stands). Use EFISCEN data as best available source.
Spain	No	No	No	No	Develop data set based on best available information (JRC tool and country report).
Sweden	Yes	Yes	Yes	1998	Total area suggested by EFISCEN data reasonably consistent with total area for UN-ECE data but somewhat higher and some inconsistencies across age classes. Have to assume the UN-ECE is the most authoritative source. Use UN-ECE data but allocate species based on EFISCEN data.

Table A9.7 (continued) Assessment of available data sources on forest areas

Country	Availability of data				Assessment
	UN-ECE (previous 2005 report, withdrawn)	UN-ECE (2010, forest area available for wood supply)	UN-ECE (2010, total forest area)	EFISCEN database (and base year)	
Ukraine	Yes	Yes	Yes	No	Use UN-ECE data and allocate species based on country report.
United Kingdom	Yes	Yes	Yes	Not downloaded	Use UN-ECE data for consistency with other countries and allocate species based on UK National Forest Inventory Report.

A9.4 Summary forest data for countries modelled in this project

The summary tables in this section show the processed data on forest areas, by tree species, growth rate and age class, with assigned characteristic rotations, referred to in the modelling of forests in this project.

The first table gives results for Estonia, following the example given in Section 9.3. This is followed by a series of table for other EU27 Member States. Three further tables show results for countries representing the CIS region. Two final tables show results for Canada and the USA.

Summary forest data for Estonia (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Norway spruce	NS	10-12	60-80	31.1	4.5	2.5	7.7	6.8	6.4	2.6	0.7	0.0	0.0
	NS	6-8	60-80	186.7	26.7	15.1	46.0	40.8	38.3	15.7	4.2	0.0	0.0
	NS	4	60-80	93.3	13.4	7.5	23.0	20.4	19.1	7.8	2.1	0.0	0.0
Scots pine	SP	6-8	80-100	66.0	5.8	3.4	11.8	18.5	15.3	8.1	2.8	0.3	0.0
	SP	4	80-100	330.0	28.8	17.2	58.9	92.6	76.7	40.3	13.9	1.6	0.0
	SP	2	80-100	44.0	3.8	2.3	7.9	12.3	10.2	5.4	1.9	0.2	0.0
Alders	SY	6-8	40-50	18.3	2.5	1.9	9.1	4.7	0.1	0.0	0.0	0.0	0.0
	SY	6-8	60-80	5.2	0.3	0.3	1.2	2.3	0.9	0.2	0.0	0.0	0.0
	SY	4	40-50	91.7	12.7	9.3	45.4	23.6	0.7	0.0	0.0	0.0	0.0
	SY	4	60-80	26.0	1.7	1.3	6.0	11.6	4.4	0.9	0.1	0.0	0.0
	SY	2	40-50	73.3	10.2	7.4	36.3	18.9	0.5	0.0	0.0	0.0	0.0
	SY	2	60-80	20.8	1.4	1.0	4.8	9.3	3.5	0.7	0.1	0.0	0.0
Birch	BI	6-8	60-80	56.4	7.3	4.4	14.0	20.8	8.7	1.2	0.1	0.0	0.0
	BI	4	60-80	282.2	36.3	21.9	69.8	104.2	43.7	5.9	0.3	0.0	0.0
	BI	2	60-80	225.8	29.1	17.5	55.8	83.4	35.0	4.7	0.3	0.0	0.0
Aspen	PO	6-8	60-80	9.6	1.7	0.7	1.4	3.8	1.7	0.3	0.0	0.0	0.0
	PO	4	60-80	48.1	8.3	3.5	7.1	18.8	8.7	1.6	0.1	0.0	0.0
	PO	2	60-80	38.5	6.6	2.8	5.7	15.1	7.0	1.3	0.1	0.0	0.0

Summary forest data for Austria (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce	NS	14-16	80-100	141.3	1.7	19.9	38.3	21.7	16.9	14.9	17.9	10.0	0.0
	NS	10-12	80-100	565.3	7.0	79.7	153.4	86.6	67.6	59.4	71.7	39.9	0.0
	NS	6-8	80-100	565.3	7.0	79.7	153.4	86.6	67.6	59.4	71.7	39.9	0.0
	NS	4	80-100	141.3	1.7	19.9	38.3	21.7	16.9	14.9	17.9	10.0	0.0
Pine	SP	6-8	80-100	188.4	2.3	26.6	51.1	28.9	22.5	19.8	23.9	13.3	0.0
	SP	4	80-100	235.5	2.9	33.2	63.9	36.1	28.1	24.8	29.9	16.6	0.0
	SP	2	80-100	47.1	0.6	6.6	12.8	7.2	5.6	5.0	6.0	3.3	0.0
Oak	OK	6-8	80-100	43.4	0.7	9.2	8.3	5.2	6.1	5.2	5.6	3.1	0.0
	OK	4	80-100	54.2	0.9	11.5	10.4	6.5	7.6	6.5	6.9	3.9	0.0
	OK	2	80-100	10.8	0.2	2.3	2.1	1.3	1.5	1.3	1.4	0.8	0.0
Beech	BE	6-8	80-100	216.9	3.6	46.0	41.6	26.0	30.4	26.0	27.8	15.6	0.0
	BE	4	80-100	271.1	4.5	57.5	51.9	32.6	38.0	32.5	34.7	19.5	0.0
	BE	2	80-100	54.2	0.9	11.5	10.4	6.5	7.6	6.5	6.9	3.9	0.0
Other broad-leaves	SY	6-8	80-100	57.7	1.0	12.2	11.1	6.9	8.1	6.9	7.4	4.1	0.0
	SY	4	80-100	72.1	1.2	15.3	13.8	8.7	10.1	8.6	9.2	5.2	0.0
	SY	2	80-100	14.4	0.2	3.1	2.8	1.7	2.0	1.7	1.8	1.0	0.0
	AH	6-8	80-100	57.7	1.0	12.2	11.1	6.9	8.1	6.9	7.4	4.1	0.0
	AH	4	80-100	72.1	1.2	15.3	13.8	8.7	10.1	8.6	9.2	5.2	0.0
	AH	2	80-100	14.4	0.2	3.1	2.8	1.7	2.0	1.7	1.8	1.0	0.0
	BI	6-8	80-100	58.1	1.0	12.3	11.1	7.0	8.1	7.0	7.4	4.2	0.0
	BI	4	80-100	72.7	1.2	15.4	13.9	8.7	10.2	8.7	9.3	5.2	0.0
	BI	2	80-100	14.5	0.2	3.1	2.8	1.7	2.0	1.7	1.9	1.0	0.0

Summary forest data for Belgium (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce	NS	14-16	60-80	18.4	2.6	2.8	5.9	4.2	2.2	0.6	0.2	0.0	0.0
	NS	10-12	60-80	110.6	15.4	16.9	35.3	25.1	13.0	3.6	1.4	0.0	0.0
	NS	6-8	60-80	55.3	7.7	8.4	17.6	12.6	6.5	1.8	0.7	0.0	0.0
Scots pine	SP	10-12	60-80	24.3	0.3	6.1	9.1	6.3	1.7	0.7	0.0	0.0	0.0
	SP	6-8	60-80	34.7	0.5	8.8	12.9	9.1	2.4	1.0	0.1	0.0	0.0
	SP	4	60-80	10.4	0.1	2.6	3.9	2.7	0.7	0.3	0.0	0.0	0.0
Corsican pine	CP	18-20	60-80	2.0	0.1	0.0	1.2	0.5	0.1	0.0	0.0	0.0	0.0
	CP	14-16	60-80	12.0	0.8	0.2	7.1	3.0	0.6	0.2	0.0	0.0	0.0
	CP	10-12	60-80	6.0	0.4	0.1	3.6	1.5	0.3	0.1	0.0	0.0	0.0
Larches	EL	10-12	60-80	3.8	0.2	0.3	2.4	0.7	0.0	0.0	0.0	0.0	0.0
	EL	6-8	60-80	5.4	0.3	0.4	3.5	1.0	0.1	0.0	0.1	0.0	0.0
	EL	4	60-80	1.6	0.1	0.1	1.0	0.3	0.0	0.0	0.0	0.0	0.0
Douglas fir	DF	18-20	60-80	3.3	1.6	0.9	0.7	0.0	0.1	0.0	0.0	0.0	0.0
	DF	14-16	60-80	6.6	3.2	1.8	1.3	0.0	0.2	0.0	0.0	0.0	0.0
	DF	10-12	60-80	1.1	0.5	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Oaks	OK	6-8	80-100	39.9	2.6	0.9	11.2	11.1	11.2	2.0	0.2	0.7	0.0
	OK	4	80-100	11.4	0.7	0.2	3.2	3.2	3.2	0.6	0.1	0.2	0.0
	OK	2	80-100	5.7	0.4	0.1	1.6	1.6	1.6	0.3	0.0	0.1	0.0
Beech	BE	10-12	80-100	2.5	0.1	0.2	0.2	0.6	0.7	0.6	0.1	0.0	0.0
	BE	6-8	80-100	15.2	0.3	1.1	1.5	3.8	3.9	3.8	0.6	0.1	0.0
	BE	4	80-100	5.1	0.1	0.4	0.5	1.3	1.3	1.3	0.2	0.0	0.0
	BE	2	80-100	2.5	0.1	0.2	0.2	0.6	0.7	0.6	0.1	0.0	0.0
Other broad-leaves	SY	10-12	80-100	5.2	1.1	0.4	2.3	0.9	0.2	0.3	0.0	0.0	0.0
	SY	6-8	80-100	31.0	6.8	2.3	13.5	5.3	1.3	1.6	0.0	0.3	0.0
	SY	4	80-100	10.3	2.3	0.8	4.5	1.8	0.4	0.5	0.0	0.1	0.0
	SY	2	80-100	5.2	1.1	0.4	2.3	0.9	0.2	0.3	0.0	0.0	0.0
Birches	BI	10-12	80-100	2.0	0.6	0.0	0.9	0.3	0.1	0.0	0.0	0.0	0.0
	BI	6-8	80-100	12.1	3.8	0.2	5.5	2.0	0.5	0.1	0.0	0.1	0.0
	BI	4	80-100	4.0	1.3	0.1	1.8	0.7	0.2	0.0	0.0	0.0	0.0
	BI	2	80-100	2.0	0.6	0.0	0.9	0.3	0.1	0.0	0.0	0.0	0.0
Poplars	PO	14-16	60-80	16.2	2.3	1.0	11.6	1.2	0.1	0.0	0.0	0.0	0.0
	PO	10-12	60-80	32.3	4.5	2.0	23.2	2.5	0.2	0.0	0.0	0.0	0.0
	PO	6-8	60-80	5.4	0.8	0.3	3.9	0.4	0.0	0.0	0.0	0.0	0.0

Summary forest data for Bulgaria (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce	NS	14-16	80-100	9.7	1.2	1.1	2.1	0.5	1.2	1.7	1.6	0.1	0.0
	NS	10-12	80-100	87.3	11.1	10.1	19.3	4.9	10.6	15.6	14.3	1.3	0.0
	NS	6-8	80-100	87.3	11.1	10.1	19.3	4.9	10.6	15.6	14.3	1.3	0.0
	NS	4	80-100	9.7	1.2	1.1	2.1	0.5	1.2	1.7	1.6	0.1	0.0
Pine	SP	10-12	80-100	162.7	22.2	25.8	64.2	14.4	15.9	14.2	5.9	0.1	0.0
	SP	6-8	80-100	298.2	40.6	47.3	117.7	26.4	29.2	26.0	10.7	0.3	0.0
	SP	4	80-100	81.3	11.1	12.9	32.1	7.2	8.0	7.1	2.9	0.1	0.0
Black pine	CP	10-12	80-100	88.3	15.3	16.0	44.5	6.9	2.4	1.6	1.5	0.2	0.0
	CP	6-8	80-100	162.0	28.0	29.3	81.5	12.6	4.4	3.0	2.8	0.3	0.0
	CP	4	80-100	44.2	7.6	8.0	22.2	3.4	1.2	0.8	0.8	0.1	0.0
Oak	OK	6-8	15-30	34.6	1.7	1.3	9.5	18.5	3.7	0.0	0.0	0.0	0.0
	OK	6-8	> 100	42.3	3.7	4.0	10.4	9.9	4.5	3.9	5.0	1.0	0.0
	OK	4	15-30	173.2	8.6	6.4	47.4	92.5	18.3	0.0	0.0	0.0	0.0
	OK	4	> 100	211.5	18.4	19.8	51.9	49.5	22.6	19.3	25.0	5.1	0.0
	OK	2	15-30	138.5	6.9	5.1	37.9	74.0	14.7	0.0	0.0	0.0	0.0
	OK	2	> 100	169.2	14.7	15.8	41.5	39.6	18.1	15.4	20.0	4.1	0.0
Beech/ horn-beam	BE	6-8	15-30	30.2	1.3	1.3	7.7	15.5	4.5	0.0	0.0	0.0	0.0
	BE	6-8	30-40	96.7	32.3	21.2	25.4	16.7	1.3	0.0	0.0	0.0	0.0
	BE	6-8	> 100	48.6	2.8	3.2	8.3	5.4	5.5	8.1	11.7	3.6	0.0
	BE	4	15-30	242.0	10.0	10.3	61.7	124.0	35.9	0.0	0.0	0.0	0.0
	BE	4	30-40	41.5	13.8	9.1	10.9	7.1	0.5	0.0	0.0	0.0	0.0
	BE	4	> 100	388.6	22.5	25.6	66.4	42.8	43.6	65.2	93.7	28.7	0.0
	BE	2	15-30	30.2	1.3	1.3	7.7	15.5	4.5	0.0	0.0	0.0	0.0
	BE	2	> 100	48.6	2.8	3.2	8.3	5.4	5.5	8.1	11.7	3.6	0.0
Other broad-leaves	SY	6-8	15-30	2.2	0.8	0.7	0.7	0.1	0.0	0.0	0.0	0.0	0.0
	SY	6-8	30-40	19.9	1.3	1.1	5.3	11.0	1.1	0.0	0.0	0.0	0.0
	SY	6-8	40-50	21.4	4.5	3.8	6.3	3.1	1.1	0.8	1.5	0.4	0.0
	SY	4	15-30	17.6	6.3	5.6	5.2	0.5	0.0	0.0	0.0	0.0	0.0
	SY	4	30-40	158.9	10.5	9.1	42.8	87.7	8.9	0.0	0.0	0.0	0.0
	SY	4	40-50	171.6	35.6	30.5	50.2	25.0	8.6	6.3	12.0	3.3	0.0
	SY	2	15-30	2.2	0.8	0.7	0.7	0.1	0.0	0.0	0.0	0.0	0.0
	SY	2	30-40	19.9	1.3	1.1	5.3	11.0	1.1	0.0	0.0	0.0	0.0
	SY	2	40-50	21.4	4.5	3.8	6.3	3.1	1.1	0.8	1.5	0.4	0.0
	AH	6-8	15-30	2.1	0.0	0.0	0.4	1.2	0.5	0.0	0.0	0.0	0.0
	AH	6-8	80-100	18.2	1.1	1.6	6.5	6.8	1.2	0.5	0.4	0.0	0.0
	AH	4	15-30	16.4	0.3	0.4	2.8	9.3	3.7	0.0	0.0	0.0	0.0
	AH	4	80-100	145.7	8.5	12.9	51.9	54.7	9.9	4.2	3.2	0.3	0.0
	AH	2	15-30	2.1	0.0	0.0	0.4	1.2	0.5	0.0	0.0	0.0	0.0
	AH	2	80-100	18.2	1.1	1.6	6.5	6.8	1.2	0.5	0.4	0.0	0.0

Summary forest data for Czech Republic (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce	NS	14-16	80-100	68.5	7.6	5.8	10.5	9.4	13.5	13.0	8.2	0.6	0.0
	NS	10-12	80-100	616.4	68.2	51.8	94.6	84.7	121.5	116.8	73.9	5.0	0.0
	NS	6-8	80-100	616.4	68.2	51.8	94.6	84.7	121.5	116.8	73.9	5.0	0.0
	NS	4	80-100	68.5	7.6	5.8	10.5	9.4	13.5	13.0	8.2	0.6	0.0
Pine	SP	6-8	> 100	220.4	19.1	16.4	28.5	27.0	39.4	43.6	43.5	2.8	0.0
	SP	4	> 100	132.2	11.5	9.8	17.1	16.2	23.6	26.2	26.1	1.7	0.0
	SP	2	> 100	88.2	7.7	6.5	11.4	10.8	15.8	17.4	17.4	1.1	0.0
Larch	EL	10-12	80-100	19.4	2.7	1.8	3.7	2.8	3.5	3.0	1.9	0.1	0.0
	EL	6-8	80-100	58.2	8.1	5.3	11.2	8.3	10.4	8.9	5.7	0.3	0.0
	EL	4	80-100	14.5	2.0	1.3	2.8	2.1	2.6	2.2	1.4	0.1	0.0
	EL	2	80-100	4.8	0.7	0.4	0.9	0.7	0.9	0.7	0.5	0.0	0.0
Fir	NF	14-16	80-100	1.1	0.1	0.1	0.1	0.1	0.2	0.3	0.2	0.0	0.0
	NF	10-12	80-100	10.2	0.7	0.5	1.2	0.8	2.0	2.4	2.2	0.3	0.0
	NF	6-8	80-100	10.2	0.7	0.5	1.2	0.8	2.0	2.4	2.2	0.3	0.0
	NF	4	80-100	1.1	0.1	0.1	0.1	0.1	0.2	0.3	0.2	0.0	0.0
Oak	OK	6-8	> 100	16.1	1.3	0.8	2.3	2.5	3.5	2.7	2.7	0.4	0.0
	OK	4	> 100	129.0	10.3	6.6	18.5	19.7	27.9	21.3	21.9	2.8	0.0
	OK	2	> 100	16.1	1.3	0.8	2.3	2.5	3.5	2.7	2.7	0.4	0.0
Beech	BE	6-8	> 100	75.7	7.7	4.6	10.9	10.0	10.5	10.7	16.1	5.2	0.0
	BE	4	> 100	45.4	4.6	2.7	6.6	6.0	6.3	6.4	9.7	3.1	0.0
	BE	2	> 100	30.3	3.1	1.8	4.4	4.0	4.2	4.3	6.4	2.1	0.0
Maple	SY	6-8	80-100	111.2	9.7	9.9	26.9	31.0	20.3	7.9	4.8	0.8	0.0
	SY	4	80-100	66.7	5.8	5.9	16.1	18.6	12.2	4.7	2.9	0.5	0.0
	SY	2	80-100	44.5	3.9	3.9	10.7	12.4	8.1	3.1	1.9	0.3	0.0
Ash	AH	6-8	80-100	14.0	1.1	0.9	2.6	3.3	3.2	1.7	1.1	0.1	0.0
	AH	4	80-100	8.4	0.7	0.5	1.6	2.0	1.9	1.0	0.7	0.1	0.0
	AH	2	80-100	5.6	0.5	0.4	1.0	1.3	1.3	0.7	0.4	0.0	0.0

Summary forest data for Denmark (base year 2005)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce	NS	14-16	40-50	31.0	5.5	7.3	9.6	7.7	0.5	0.2	0.2	0.0	0.0
	NS	14-16	50-60	7.6	0.6	1.6	2.8	2.3	0.2	0.0	0.0	0.0	0.0
	NS	10-12	40-50	25.8	2.0	4.8	9.2	7.9	1.1	0.4	0.3	0.0	0.0
	NS	10-12	50-60	86.2	8.5	16.0	27.3	28.1	4.0	1.7	0.5	0.0	0.0
	NS	6-8	50-60	35.5	3.6	5.5	11.0	11.5	2.2	1.2	0.4	0.0	0.0
	NS	6-8	60-80	48.3	4.0	8.5	15.4	12.0	6.6	1.6	0.1	0.0	0.0
Pine	SP	4	80-100	24.0	0.9	2.9	7.0	7.8	4.4	0.9	0.1	0.0	0.0
	SP	2	80-100	24.0	0.9	2.9	7.0	7.8	4.4	0.9	0.1	0.0	0.0
Fir	GF	14-16	40-50	4.2	1.1	1.3	1.0	0.6	0.2	0.0	0.0	0.0	0.0
	GF	10-12	40-50	20.5	4.1	6.2	6.1	2.7	1.1	0.3	0.0	0.0	0.0
	GF	6-8	40-50	5.3	1.0	1.8	1.7	0.5	0.2	0.1	0.0	0.0	0.0
Oak	OK	6-8	60-80	16.3	0.9	1.8	3.5	4.6	3.1	0.7	1.2	0.6	0.0
	OK	6-8	> 100	3.6	0.2	0.4	1.0	0.9	0.5	0.2	0.4	0.1	0.0
	OK	4	> 100	7.9	0.7	1.1	2.3	1.5	1.0	0.4	0.6	0.2	0.0
	OK	2	> 100	1.6	0.4	0.3	0.5	0.1	0.1	0.1	0.1	0.0	0.0
Beech	BE	10-12	> 100	2.4	0.1	0.2	0.3	0.5	0.4	0.4	0.5	0.1	0.0
	BE	6-8	> 100	53.1	2.4	4.1	9.1	11.9	8.3	7.3	8.0	2.1	0.0
	BE	4	> 100	16.1	0.6	1.3	2.7	2.9	2.0	1.7	3.5	1.5	0.0
	BE	2	> 100	1.0	0.1	0.2	0.3	0.2	0.0	0.0	0.1	0.0	0.0
Other broad-leaves	SY	6-8	80-100	7.6	0.7	1.3	2.4	2.3	0.6	0.2	0.1	0.0	0.0
	SY	4	80-100	22.9	2.0	3.9	7.3	6.9	1.9	0.6	0.4	0.1	0.0

Summary forest data for Finland (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce	NS	6-8	80-100	5203.4	282.3	290.8	564.8	807.2	1021.3	979.6	767.7	489.7	0.0
Pine	SP	6-8	80-100	342.4	40.5	41.7	57.1	64.1	66.7	47.0	22.2	3.0	0.0
	SP	4	80-100	8403.0	991.0	1021.2	1547.0	1164.3	1270.1	965.5	941.1	502.8	0.0
	SP	2	80-100	4644.5	319.1	328.8	907.8	900.1	843.5	521.8	508.7	314.9	0.0
Other broad-leaves	SY	4	60-80	125.5	7.5	7.7	70.9	26.5	9.2	2.2	0.8	0.8	0.0
	SY	2	60-80	16.3	0.8	0.9	9.1	3.1	1.0	0.5	0.8	0.1	0.0
Birch	BI	4	80-100	1116.8	61.1	62.9	396.0	283.8	179.7	90.0	37.2	6.1	0.0
	BI	2	80-100	465.2	24.4	25.1	161.6	113.7	73.5	40.5	21.8	4.7	0.0

Summary forest data for France (base year 2000)

NFI species	Model species	Productivity class ($m^3\ ha^{-1}\ yr^{-1}$)	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Fir and spruce	NS	14-16	50-60	58.8	11.1	10.1	19.3	11.8	4.8	1.2	0.4	0.0	0.0
	NS	14-16	80-100	251.3	12.5	35.2	95.9	29.1	20.4	17.8	20.1	15.5	4.9
	NS	10-12	50-60	117.5	22.1	20.3	38.5	23.7	9.7	2.4	0.8	0.0	0.0
	NS	10-12	80-100	502.6	24.9	70.4	191.9	58.2	40.7	35.5	40.2	31.0	9.8
	NS	6-8	50-60	58.8	11.1	10.1	19.3	11.8	4.8	1.2	0.4	0.0	0.0
	NS	6-8	80-100	251.3	12.5	35.2	95.9	29.1	20.4	17.8	20.1	15.5	4.9
Scots pine	SP	10-12	80-100	132.6	5.4	6.7	42.7	35.8	20.3	10.1	7.3	3.9	0.4
	SP	6-8	80-100	371.3	15.2	18.8	119.5	100.4	57.0	28.2	20.4	10.8	1.1
	SP	4	80-100	26.5	1.1	1.3	8.5	7.2	4.1	2.0	1.5	0.8	0.1
Maritime pine	LP	14-16	40-50	87.5	7.4	11.9	31.9	26.2	7.8	1.9	0.4	0.0	0.0
	LP	10-12	40-50	245.0	20.7	33.4	89.3	73.4	21.9	5.3	1.0	0.1	0.0
	LP	6-8	40-50	17.5	1.5	2.4	6.4	5.2	1.6	0.4	0.1	0.0	0.0
Douglas fir	DF	> 20	80-100	10.9	2.2	3.8	4.6	0.3	0.1	0.0	0.0	0.0	0.0
	DF	18-20	80-100	152.9	30.5	52.7	63.9	3.9	1.4	0.3	0.1	0.1	0.0
	DF	14-16	80-100	54.6	10.9	18.8	22.8	1.4	0.5	0.1	0.0	0.0	0.0
Oak	OK	6-8	> 100	3323.7	236.7	183.2	398.3	690.0	593.1	426.7	506.4	237.8	51.5
	OK	4	> 100	1107.9	78.9	61.1	132.8	230.0	197.7	142.2	168.8	79.3	17.2
Beech	BE	10-12	50-60	46.3	9.2	9.1	13.3	11.1	2.6	0.3	0.4	0.2	0.1
	BE	6-8	50-60	138.9	27.7	27.3	39.8	33.2	7.8	0.8	1.1	0.7	0.4
	BE	6-8	> 100	767.0	48.4	34.9	67.9	73.9	107.6	130.7	184.5	106.0	13.1
	BE	4	> 100	255.7	16.1	11.6	22.6	24.6	35.9	43.6	61.5	35.3	4.4
Other broad-leaves	SY	6-8	80-100	1170.3	127.9	162.0	321.0	314.7	153.0	58.1	27.7	5.0	1.0
	SY	4	80-100	390.1	42.6	54.0	107.0	104.9	51.0	19.4	9.2	1.7	0.3

Summary forest data for Germany (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce	NS	14-16	> 100	791.3	60.1	60.1	156.5	174.3	144.0	107.9	77.3	11.1	0.1
	NS	10-12	> 100	1549.6	117.7	117.7	306.4	341.3	282.0	211.2	151.4	21.7	0.1
	NS	6-8	> 100	956.2	72.6	72.6	189.1	210.6	174.0	130.3	93.4	13.4	0.1
Pine	SP	6-8	> 100	874.7	43.6	43.6	159.7	204.8	147.9	138.7	117.6	18.6	0.2
	SP	4	> 100	1457.9	72.7	72.7	266.1	341.3	246.5	231.2	195.9	31.0	0.4
	SP	2	> 100	583.1	29.1	29.1	106.4	136.5	98.6	92.5	78.4	12.4	0.1
Larch	EL	10-12	> 100	72.5	6.5	6.5	28.4	16.1	5.5	3.8	4.4	1.2	0.0
	EL	6-8	> 100	203.1	18.3	18.3	79.5	45.0	15.5	10.7	12.3	3.5	0.0
	EL	4	> 100	14.5	1.3	1.3	5.7	3.2	1.1	0.8	0.9	0.2	0.0
Douglas fir	DF	14-16	> 100	29.3	7.1	7.1	9.8	2.7	1.7	0.8	0.2	0.0	0.0
	DF	10-12	> 100	57.3	13.8	13.8	19.2	5.3	3.3	1.5	0.4	0.0	0.0
	DF	6-8	> 100	35.4	8.5	8.5	11.9	3.2	2.0	1.0	0.3	0.0	0.0
Fir	GF	14-16	> 100	35.3	1.5	1.5	2.0	4.5	5.1	7.0	10.6	3.1	0.0
	GF	10-12	> 100	69.1	2.9	2.9	4.0	8.8	10.1	13.8	20.7	6.0	0.0
	GF	6-8	> 100	42.6	1.8	1.8	2.5	5.4	6.2	8.5	12.8	3.7	0.0
Oak	OK	6-8	> 100	252.5	8.6	8.6	20.4	36.8	27.9	38.0	71.2	39.9	1.0
	OK	4	> 100	505.0	17.2	17.2	40.8	73.7	55.8	76.1	142.4	79.8	2.0
	OK	2	> 100	252.5	8.6	8.6	20.4	36.8	27.9	38.0	71.2	39.9	1.0
Beech	BE	6-8	> 100	820.3	21.3	21.3	59.8	112.3	98.7	119.1	242.7	142.0	3.0
	BE	4	> 100	820.3	21.3	21.3	59.8	112.3	98.7	119.1	242.7	142.0	3.0
Other broad-leaved h'woods	SY	6-8	80-100	111.7	10.2	10.2	18.1	30.5	15.6	11.3	11.5	4.2	0.0
	SY	4	80-100	223.5	20.4	20.4	36.2	61.1	31.1	22.6	23.1	8.5	0.1
	SY	2	80-100	111.7	10.2	10.2	18.1	30.5	15.6	11.3	11.5	4.2	0.0
Other broad-leaved s'woods	PO	14-16	50-60	174.6	20.7	20.7	50.0	53.6	15.8	7.2	5.7	0.9	0.0
	PO	10-12	50-60	488.9	58.0	58.0	139.9	150.1	44.2	20.3	15.8	2.4	0.0
	PO	6- 8	50-60	34.9	4.1	4.1	10.0	10.7	3.2	1.4	1.1	0.2	0.0

Summary forest data for Greece (base year 2009)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years) 0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce	NS	14-16	60-80	24.7	4.8	3.5	4.2	4.2	4.2	3.9	0.0	0.0	0.0
	NS	10-12	60-80	222.7	43.4	31.6	37.4	37.4	37.4	35.5	0.0	0.0	0.0
	NS	6-8	60-80	222.7	43.4	31.6	37.4	37.4	37.4	35.5	0.0	0.0	0.0
	NS	4	60-80	24.7	4.8	3.5	4.2	4.2	4.2	3.9	0.0	0.0	0.0
Pine	SP	6-8	60-80	403.8	78.6	57.3	67.8	67.8	67.8	64.4	0.0	0.0	0.0
	SP	4	60-80	323.0	62.9	45.9	54.3	54.3	54.3	51.5	0.0	0.0	0.0
	SP	2	60-80	80.8	15.7	11.5	13.6	13.6	13.6	12.9	0.0	0.0	0.0
Oak	OK	4	80-100	1980.0	385.4	281.2	332.5	332.5	332.5	315.9	0.0	0.0	0.0
	OK	2	80-100	1980.0	385.4	281.2	332.5	332.5	332.5	315.9	0.0	0.0	0.0
Beech	BE	6-8	80-100	247.5	48.2	35.1	41.6	41.6	41.6	39.5	0.0	0.0	0.0
	BE	4	80-100	495.0	96.3	70.3	83.1	83.1	83.1	79.0	0.0	0.0	0.0
	BE	2	80-100	247.5	48.2	35.1	41.6	41.6	41.6	39.5	0.0	0.0	0.0
Other broad-leaves	SY	6-8	80-100	65.1	12.7	9.2	10.9	10.9	10.9	10.4	0.0	0.0	0.0
	SY	4	80-100	130.3	25.4	18.5	21.9	21.9	21.9	20.8	0.0	0.0	0.0
	SY	2	80-100	65.1	12.7	9.2	10.9	10.9	10.9	10.4	0.0	0.0	0.0

Summary forest data for Hungary (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years) 0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Conifers	SP	10-12	40-50	116.1	11.1	16.0	58.5	21.6	6.3	2.3	0.3	0.0	0.0
	SP	6-8	40-50	78.8	9.0	15.4	39.0	11.2	2.8	1.2	0.2	0.0	0.0
	SP	6-8	60-80	15.8	0.8	0.9	9.9	2.6	1.0	0.5	0.1	0.0	0.0
Oak	OK	6-8	80-100	115.6	7.9	11.0	24.8	29.7	20.7	17.5	3.8	0.1	0.0
	OK	4	> 100	235.2	48.8	68.3	29.8	30.0	35.0	18.9	4.3	0.1	0.0
	OK	2	> 100	41.7	4.0	18.6	3.1	3.3	5.7	4.4	2.4	0.1	0.0
Other broad-leaved h'woods	BE	14-16	50-60	39.7	0.7	3.4	27.6	7.6	0.4	0.0	0.0	0.0	0.0
	BE	10-12	50-60	170.2	24.5	36.5	85.9	22.3	1.0	0.1	0.0	0.0	0.0
	SY	6-8	> 100	151.3	2.7	7.8	27.8	40.4	43.3	22.0	7.2	0.2	0.0
	SY	4	80-100	165.1	7.8	14.7	32.6	36.8	44.4	22.1	6.5	0.2	0.0
	SY	2	> 100	39.2	0.4	1.9	9.3	8.7	10.3	6.2	2.3	0.1	0.0
Poplar, Other broad-leaved s'woods	PO	14-16	15-30	32.8	10.0	15.4	6.8	0.5	0.0	0.0	0.0	0.0	0.0
	PO	14-16	40-50	53.3	6.8	19.7	15.8	8.4	1.9	0.6	0.1	0.0	0.0
	PO	10-12	15-30	424.2	150.8	268.7	3.3	0.9	0.3	0.1	0.0	0.0	0.0
	PO	10-12	30-40	66.0	10.8	17.8	32.6	4.3	0.5	0.0	0.0	0.0	0.0
	PO	10-12	60-80	41.6	1.0	4.3	21.8	11.0	2.6	0.7	0.2	0.0	0.0

Summary forest data for Ireland (base year 1992)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Norway spruce	NS	> 20	30-40	3.3	0.4	0.5	1.8	0.6	0.0	0.0	0.0	0.0	0.0
	NS	14-16	40-50	11.6	2.9	1.7	5.0	2.0	0.0	0.0	0.0	0.0	0.0
	NS	10-12	50-60	11.6	2.9	1.7	5.0	2.0	0.0	0.0	0.0	0.0	0.0
	NS	4	60-80	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Sitka spruce	SS	> 20	30-40	97.7	45.9	32.4	18.2	1.1	0.0	0.0	0.0	0.0	0.0
	SS	14-16	40-50	158.0	65.0	56.0	34.1	2.9	0.0	0.0	0.0	0.0	0.0
	SS	10-12	50-60	54.5	15.3	18.7	18.5	2.0	0.0	0.0	0.0	0.0	0.0
	SS	4	60-80	4.0	0.5	0.9	2.2	0.4	0.0	0.0	0.0	0.0	0.0
Scots pine	SP	14-16	40-50	0.6	0.0	0.0	0.2	0.3	0.1	0.0	0.0	0.0	0.0
	SP	10-12	50-60	7.2	0.1	0.4	3.0	2.8	0.8	0.0	0.0	0.0	0.0
	SP	4	60-80	0.9	0.0	0.0	0.2	0.3	0.3	0.1	0.0	0.0	0.0
Lodgepole pine	LP	14-16	40-50	24.7	3.7	12.1	8.8	0.1	0.0	0.0	0.0	0.0	0.0
	LP	10-12	50-60	60.7	17.3	23.6	18.2	1.6	0.0	0.0	0.0	0.0	0.0
	LP	4	60-80	17.0	4.1	4.3	6.7	1.9	0.0	0.0	0.0	0.0	0.0
Larch	JL	14-16	40-50	0.7	0.3	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
	JL	10-12	50-60	7.2	1.7	2.1	2.4	0.8	0.1	0.0	0.0	0.0	0.0
	JL	4	60-80	2.5	0.6	0.7	0.8	0.3	0.1	0.0	0.0	0.0	0.0
Douglas fir	DF	> 20	30-40	3.0	1.2	1.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0
	DF	14-16	40-50	8.0	3.0	2.7	2.1	0.1	0.1	0.0	0.0	0.0	0.0
	DF	10-12	50-60	1.0	0.1	0.2	0.5	0.1	0.0	0.0	0.0	0.0	0.0
	DF	4	60-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other conifers	GF	> 20	30-40	0.9	0.1	0.2	0.4	0.1	0.0	0.0	0.0	0.0	0.0
	GF	14-16	40-50	2.3	0.5	0.6	1.0	0.2	0.0	0.0	0.0	0.0	0.0
	GF	10-12	50-60	2.9	0.6	0.7	1.3	0.3	0.0	0.0	0.0	0.0	0.0
	GF	4	60-80	0.7	0.1	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0
Other broad-leaves	OK	4	> 100	5.6	1.9	0.4	0.2	0.6	0.2	1.7	0.2	0.4	0.0
	SY	4	80-100	50.0	29.0	6.0	3.6	8.5	2.9	0.0	0.0	0.0	0.0

Summary forest data for Italy (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce	NS	10-12	50-60	25.8	2.6	4.7	13.3	3.8	1.5	0.0	0.0	0.0	0.0
	NS	10-12	60-80	109.4	1.8	1.5	5.9	40.4	25.4	8.6	17.4	8.3	0.0
	NS	6-8	50-60	72.3	7.2	13.1	37.1	10.7	4.1	0.1	0.1	0.0	0.0
	NS	6-8	60-80	306.4	5.2	4.2	16.6	113.2	71.2	24.0	48.6	23.2	0.0
	NS	4	50-60	5.2	0.5	0.9	2.7	0.8	0.3	0.0	0.0	0.0	0.0
	NS	4	60-80	21.9	0.4	0.3	1.2	8.1	5.1	1.7	3.5	1.7	0.0
Mountain pine	SP	10-12	50-60	94.3	4.7	3.8	10.1	44.2	20.2	4.9	5.3	1.0	0.0
	SP	6-8	50-60	264.2	13.1	10.7	28.4	123.8	56.7	13.7	15.0	2.9	0.0
	SP	4	50-60	18.9	0.9	0.8	2.0	8.8	4.0	1.0	1.1	0.2	0.0
Maritime pine	LP	10-12	60-80	32.0	3.2	2.6	6.0	15.4	4.0	0.5	0.4	0.0	0.0
	LP	6-8	60-80	89.7	8.9	7.2	16.8	43.2	11.2	1.4	1.0	0.0	0.0
	LP	4	60-80	6.4	0.6	0.5	1.2	3.1	0.8	0.1	0.1	0.0	0.0
Larch	EL	10-12	60-80	51.6	1.2	1.0	3.4	19.8	12.4	4.0	6.8	3.0	0.0
	EL	6-8	60-80	144.6	3.4	2.8	9.6	55.4	34.9	11.1	18.9	8.5	0.0
	EL	4	60-80	10.3	0.2	0.2	0.7	4.0	2.5	0.8	1.4	0.6	0.0
Fir	GF	10-12	60-80	19.7	0.1	0.1	0.9	8.8	5.6	1.5	2.1	0.7	0.0
	GF	6-8	60-80	55.3	0.3	0.3	2.4	24.7	15.6	4.3	5.8	1.9	0.0
	GF	4	60-80	3.9	0.0	0.0	0.2	1.8	1.1	0.3	0.4	0.1	0.0
Oak	OK	6-8	60-80	214.9	16.7	51.6	96.6	29.9	12.9	3.1	3.6	0.5	0.0
	OK	4	60-80	429.9	33.5	103.3	193.2	59.7	25.8	6.2	7.2	1.0	0.0
	OK	2	60-80	214.9	16.7	51.6	96.6	29.9	12.9	3.1	3.6	0.5	0.0
Beech, Hornbeam	BE	6-8	30-40	203.4	23.3	53.8	126.3	0.0	0.0	0.0	0.0	0.0	0.0
	BE	6-8	> 100	197.4	3.0	10.5	82.4	53.1	28.7	8.0	9.5	2.2	0.0
	BE	4	30-40	406.8	46.6	107.6	252.6	0.0	0.0	0.0	0.0	0.0	0.0
	BE	4	> 100	394.7	6.0	21.0	164.9	106.2	57.3	15.9	19.1	4.3	0.0
	BE	2	30-40	203.4	23.3	53.8	126.3	0.0	0.0	0.0	0.0	0.0	0.0
	BE	2	> 100	197.4	3.0	10.5	82.4	53.1	28.7	8.0	9.5	2.2	0.0
Chestnut	SY	6-8	50-60	184.9	20.2	42.0	85.8	25.4	7.4	1.9	1.9	0.3	0.0
	SY	4	50-60	369.7	40.4	84.0	171.6	50.7	14.8	3.9	3.8	0.6	0.0
	SY	2	50-60	184.9	20.2	42.0	85.8	25.4	7.4	1.9	1.9	0.3	0.0
Poplar	PO	6-8	30-40	24.2	20.7	1.3	2.2	0.0	0.0	0.0	0.0	0.0	0.0
	PO	4	30-40	48.3	41.4	2.6	4.3	0.0	0.0	0.0	0.0	0.0	0.0
	PO	2	30-40	24.2	20.7	1.3	2.2	0.0	0.0	0.0	0.0	0.0	0.0

Summary forest data for Latvia (base year 2005)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce, other conifers	NS	10-12	80-100	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	NS	6- 8	80-100	175.6	19.8	17.9	68.7	23.7	16.5	16.1	11.3	1.6	0.0
	NS	4	80-100	340.4	55.1	46.6	67.0	28.8	55.8	63.3	22.7	1.0	0.0
	NS	2	80-100	15.0	1.9	2.4	4.1	2.2	2.7	1.3	0.2	0.0	0.0
Pine	SP	10-12	80-100	2.4	0.0	0.0	0.1	0.5	0.9	0.5	0.3	0.2	0.0
	SP	6- 8	80-100	578.2	26.5	12.1	37.6	97.9	134.0	111.5	126.7	32.0	0.0
	SP	4	80-100	418.7	20.7	6.4	17.3	83.1	127.4	95.8	62.9	5.1	0.0
	SP	2	80-100	12.5	0.3	0.0	0.9	5.5	4.0	1.3	0.3	0.1	0.0
Oak	OK	10-12	> 100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	OK	6- 8	> 100	5.4	0.1	0.1	0.2	0.3	0.5	1.2	1.9	1.0	0.0
	OK	4	> 100	4.3	0.1	0.0	0.2	0.5	0.8	1.2	1.2	0.2	0.0
	OK	2	> 100	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alders	SY	10-12	40-50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SY	10-12	60-80	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SY	6- 8	40-50	33.5	1.2	3.0	15.5	13.5	0.4	0.0	0.0	0.0	0.0
	SY	6- 8	50-60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SY	6- 8	60-80	34.9	1.3	1.5	5.5	11.8	9.6	4.0	1.2	0.0	0.0
	SY	4	40-50	116.4	9.9	15.8	65.4	25.1	0.3	0.0	0.0	0.0	0.0
	SY	4	60-80	34.5	3.5	2.5	4.3	10.3	9.8	3.2	0.9	0.1	0.0
	SY	2	40-50	17.4	1.3	5.3	10.2	0.6	0.0	0.0	0.0	0.0	0.0
	SY	2	60-80	0.6	0.1	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.0
Ash	AH	6- 8	> 100	2.3	0.4	0.2	0.4	0.3	0.2	0.3	0.3	0.1	0.0
	AH	4	> 100	16.5	3.1	2.8	2.8	3.2	2.6	1.3	0.6	0.1	0.0
	AH	2	> 100	2.9	0.0	0.0	0.6	1.2	0.8	0.3	0.0	0.0	0.0
Birch	BI	10-12	60-80	0.7	0.0	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0
	BI	6- 8	60-80	301.5	18.2	15.1	62.7	121.2	58.2	22.8	3.3	0.0	0.0
	BI	4	60-80	433.4	29.3	12.0	42.1	170.8	126.2	48.6	4.4	0.0	0.0
	BI	2	60-80	24.7	3.6	1.4	2.2	8.7	6.5	2.2	0.2	0.0	0.0
Aspen	PO	10-12	60-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	PO	6- 8	60-80	5.8	0.8	0.6	1.4	2.0	0.6	0.3	0.0	0.0	0.0
	PO	4	60-80	66.0	13.4	3.1	6.5	20.3	17.3	4.8	0.5	0.0	0.0
	PO	2	60-80	11.0	1.7	0.5	1.2	3.7	3.2	0.6	0.1	0.0	0.0

Summary forest data for Lithuania (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce	NS	10-12	80-100	8.4	1.0	0.9	1.7	1.2	2.0	1.1	0.4	0.0	0.0
	NS	6-8	80-100	309.1	38.8	34.1	48.1	48.4	90.7	40.1	8.9	0.1	0.0
	NS	4	80-100	94.7	11.9	10.4	14.3	14.9	28.2	12.2	2.6	0.0	0.0
Pine	SP	10-12	> 100	5.4	0.0	0.0	0.2	1.3	1.9	1.3	0.6	0.1	0.0
	SP	6-8	> 100	311.2	8.5	9.1	46.2	94.1	73.8	56.8	21.5	1.3	0.0
	SP	4	> 100	220.0	6.6	7.1	35.8	68.5	48.9	38.6	13.8	0.7	0.0
	SP	2	> 100	53.7	1.6	1.8	8.9	16.8	11.8	9.3	3.3	0.2	0.0
Oak	OK	6-8	> 100	2.6	0.0	0.0	0.2	0.5	0.6	0.5	0.5	0.3	0.0
	OK	4	> 100	19.7	0.2	0.2	1.1	4.3	4.4	3.7	3.8	2.0	0.0
	OK	2	> 100	2.5	0.0	0.0	0.1	0.5	0.6	0.5	0.5	0.2	0.0
Beech and oak	BE	6-8	80-100	126.7	3.7	4.2	25.3	59.0	29.7	4.6	0.2	0.0	0.0
	BE	4	80-100	208.3	5.2	5.8	35.1	105.9	47.4	8.8	0.2	0.0	0.0
	BE	2	80-100	24.6	0.6	0.7	4.1	12.6	5.6	1.0	0.0	0.0	0.0
Alders	SY	6-8	60-80	16.3	1.3	1.6	10.2	3.2	0.1	0.0	0.0	0.0	0.0
	SY	6-8	80-100	75.6	4.0	4.0	16.0	27.6	19.5	4.3	0.3	0.0	0.0
	SY	6-8	> 100	0.3	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0
	SY	4	60-80	77.5	5.3	6.8	48.3	16.9	0.3	0.0	0.0	0.0	0.0
	SY	4	80-100	25.9	1.7	1.7	6.6	9.6	5.3	0.9	0.1	0.0	0.0
	SY	4	> 100	2.5	0.0	0.0	0.3	1.2	0.7	0.2	0.1	0.0	0.0
	SY	2	60-80	9.6	0.7	0.8	6.0	2.1	0.0	0.0	0.0	0.0	0.0
	SY	2	80-100	2.2	0.2	0.2	0.6	0.8	0.4	0.0	0.0	0.0	0.0
	SY	2	> 100	0.3	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0
Ash	AH	6-8	80-100	7.2	0.5	0.5	1.6	2.2	1.5	0.6	0.2	0.0	0.0
	AH	4	80-100	36.6	1.9	1.9	7.1	12.1	8.8	3.7	1.0	0.0	0.0
	AH	2	80-100	4.5	0.2	0.2	0.9	1.5	1.1	0.5	0.1	0.0	0.0
Aspen, other broad-leaved s'woods	PO	6-8	80-100	6.5	0.4	0.4	0.9	3.0	1.6	0.2	0.0	0.0	0.0
	PO	4	80-100	41.3	2.3	2.1	5.9	19.7	10.0	1.2	0.0	0.0	0.0
	PO	2	80-100	5.1	0.3	0.3	0.7	2.5	1.2	0.2	0.0	0.0	0.0

Summary forest data for Luxembourg (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce, Douglas fir, other conifers	NS	14-16	50-60	5.1	0.8	1.2	2.0	0.8	0.2	0.1	0.0	0.0	0.0
	NS	10-12	50-60	10.1	1.5	2.4	4.1	1.5	0.4	0.1	0.0	0.0	0.0
	NS	6- 8	50-60	10.1	1.5	2.4	4.1	1.5	0.4	0.1	0.0	0.0	0.0
Aleppo, Calabrian pine	SP	6- 8	50-60	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	SP	6- 8	> 100	1.1	0.1	0.1	0.4	0.2	0.1	0.2	0.1	0.0	0.0
	SP	4	50-60	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	SP	4	> 100	0.9	0.0	0.1	0.3	0.1	0.1	0.1	0.0	0.0	0.0
	SP	2	50-60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SP	2	> 100	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Oak	OK	6- 8	80-100	17.2	0.2	0.3	0.1	0.1	0.1	0.2	1.0	15.1	0.0
	OK	4	80-100	17.2	0.2	0.3	0.1	0.1	0.1	0.2	1.0	15.1	0.0
Beech	BE	6- 8	60-80	22.3	0.3	0.4	0.4	0.2	0.4	0.9	4.3	15.4	0.0
	BE	4	60-80	22.3	0.3	0.4	0.4	0.2	0.4	0.9	4.3	15.4	0.0
Other broadleaves	SY	6- 8	50-60	1.1	0.2	0.3	0.3	0.2	0.1	0.0	0.0	0.0	0.0
	SY	4	50-60	1.1	0.2	0.3	0.3	0.2	0.1	0.0	0.0	0.0	0.0

Summary forest data for Netherlands (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruces	NS	14-16	60-80	2.1	0.1	0.2	1.0	0.7	0.2	0.0	0.0	0.0	0.0
	NS	10-12	60-80	4.3	0.2	0.3	2.0	1.3	0.4	0.0	0.0	0.0	0.0
	NS	6-8	60-80	3.2	0.2	0.2	1.5	1.0	0.3	0.0	0.0	0.0	0.0
	NS	4	60-80	1.1	0.1	0.1	0.5	0.3	0.1	0.0	0.0	0.0	0.0
Scots pine	SP	6-8	60-80	0.8	0.0	0.0	0.3	0.2	0.1	0.0	0.0	0.0	0.0
	SP	6-8	> 100	36.5	1.7	2.1	4.5	10.8	10.9	4.8	1.6	0.1	0.0
	SP	4	60-80	0.8	0.0	0.0	0.3	0.2	0.1	0.0	0.0	0.0	0.0
	SP	4	> 100	36.5	1.7	2.1	4.5	10.8	10.9	4.8	1.6	0.1	0.0
Pinus nigra	CP	10-12	60-80	2.7	0.2	0.2	0.9	1.0	0.4	0.0	0.0	0.0	0.0
	CP	6-8	60-80	8.0	0.5	0.6	2.7	2.9	1.2	0.1	0.0	0.0	0.0
Larches	EL	10-12	60-80	2.2	0.1	0.1	0.3	1.4	0.4	0.0	0.0	0.0	0.0
	EL	6-8	60-80	6.6	0.2	0.3	0.8	4.1	1.2	0.0	0.0	0.0	0.0
	EL	4	60-80	2.2	0.1	0.1	0.3	1.4	0.4	0.0	0.0	0.0	0.0
Douglas fir	DF	18-20	60-80	0.6	0.1	0.1	0.2	0.2	0.1	0.0	0.0	0.0	0.0
	DF	14-16	60-80	9.1	0.8	1.0	2.9	3.3	0.9	0.1	0.0	0.0	0.0
	DF	10-12	60-80	3.2	0.3	0.4	1.0	1.2	0.3	0.1	0.0	0.0	0.0
Oaks, red oak	OK	6-8	80-100	3.2	0.0	0.1	0.5	1.3	1.1	0.2	0.0	0.0	0.0
	OK	6-8	> 100	29.9	2.3	2.9	4.9	6.0	5.8	4.6	2.3	1.0	0.0
	OK	4	80-100	1.1	0.0	0.0	0.2	0.4	0.4	0.1	0.0	0.0	0.0
	OK	4	> 100	10.0	0.8	1.0	1.6	2.0	1.9	1.5	0.8	0.3	0.0
Beech	BE	6-8	> 100	11.3	0.5	0.6	1.1	0.9	1.3	1.7	1.8	3.6	0.0
	BE	4	> 100	3.8	0.2	0.2	0.4	0.3	0.4	0.6	0.6	1.2	0.0
Other broad-leaves	SY	6-8	60-80	12.3	1.0	1.2	5.2	3.9	0.6	0.2	0.2	0.0	0.0
	SY	4	60-80	4.1	0.3	0.4	1.7	1.3	0.2	0.1	0.1	0.0	0.0
Birches	BI	6-8	60-80	12.2	1.2	1.5	4.5	3.3	1.2	0.1	0.5	0.0	0.0
	BI	4	60-80	4.1	0.4	0.5	1.5	1.1	0.4	0.0	0.2	0.0	0.0
Poplar, willow	PO	14-16	50-60	4.1	0.7	0.9	1.8	0.6	0.0	0.0	0.0	0.0	0.0
	PO	10-12	50-60	11.5	2.0	2.5	5.1	1.8	0.0	0.0	0.0	0.0	0.0
	PO	6-8	50-60	0.8	0.1	0.2	0.4	0.1	0.0	0.0	0.0	0.0	0.0

Summary forest data for Poland (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce	NS	10-12	> 100	22.5	1.0	1.7	5.2	4.3	5.1	3.4	1.6	0.4	0.0
	NS	6-8	> 100	405.0	17.4	30.1	93.5	77.0	91.1	60.8	28.4	6.7	0.0
	NS	4	> 100	22.5	1.0	1.7	5.2	4.3	5.1	3.4	1.6	0.4	0.0
Pine	SP	6-8	> 100	4577.2	323.8	285.0	1106.2	1165.8	888.6	545.5	247.2	15.4	0.0
	SP	4	> 100	1525.7	107.9	95.0	368.7	388.6	296.2	181.8	82.4	5.1	0.0
Fir	NF	10-12	> 100	9.9	0.8	0.1	1.2	2.4	2.2	1.9	1.1	0.3	0.0
	NF	6-8	> 100	178.4	14.6	1.9	21.2	42.9	38.9	33.5	19.6	5.8	0.0
	NF	4	> 100	9.9	0.8	0.1	1.2	2.4	2.2	1.9	1.1	0.3	0.0
Oak	OK	6-8	> 100	135.0	14.3	11.5	23.3	25.9	20.3	16.3	22.2	1.1	0.0
	OK	4	> 100	269.9	28.6	23.1	46.5	51.8	40.6	32.6	44.5	2.2	0.0
	OK	2	> 100	135.0	14.3	11.5	23.3	25.9	20.3	16.3	22.2	1.1	0.0
Beech, hornbeam	BE	6-8	> 100	94.4	4.8	3.0	12.5	19.8	20.0	17.8	12.2	4.2	0.0
	BE	4	> 100	188.8	9.6	6.1	25.0	39.7	40.1	35.6	24.3	8.5	0.0
	BE	2	> 100	94.4	4.8	3.0	12.5	19.8	20.0	17.8	12.2	4.2	0.0
Alder	SY	6-8	60-80	116.5	14.9	8.3	34.7	32.5	17.4	6.4	1.5	0.8	0.0
	SY	4	60-80	233.1	29.9	16.6	69.4	65.0	34.7	12.8	3.0	1.6	0.0
	SY	2	60-80	116.5	14.9	8.3	34.7	32.5	17.4	6.4	1.5	0.8	0.0
Birch	BI	6-8	80-100	131.8	3.5	9.5	41.3	52.7	19.4	4.3	0.4	0.7	0.0
	BI	4	80-100	263.6	7.0	19.1	82.6	105.5	38.8	8.5	0.7	1.4	0.0
	BI	2	80-100	131.8	3.5	9.5	41.3	52.7	19.4	4.3	0.4	0.7	0.0
Poplar, Aspen	PO	6-8	40-50	3.7	0.2	0.5	2.1	0.5	0.1	0.0	0.0	0.2	0.0
	PO	6-8	80-100	7.9	0.5	0.5	3.0	2.1	1.0	0.4	0.3	0.1	0.0
	PO	4	40-50	7.3	0.4	1.0	4.3	1.1	0.2	0.0	0.0	0.3	0.0
	PO	4	80-100	15.7	0.9	1.0	6.1	4.1	2.0	0.8	0.5	0.2	0.0
	PO	2	40-50	3.7	0.2	0.5	2.1	0.5	0.1	0.0	0.0	0.2	0.0
	PO	2	80-100	7.9	0.5	0.5	3.0	2.1	1.0	0.4	0.3	0.1	0.0

Summary forest data for Portugal (base year 1998)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Stone pine	SP	6-8	60-80	61.3	9.9	8.2	11.8	12.1	19.3	0.0	0.0	0.0	0.0
	SP	6-8	80-100	21.6	2.8	2.5	5.1	5.1	5.1	1.0	0.0	0.0	0.0
	SP	4	60-80	20.4	3.3	2.7	3.9	4.0	6.4	0.0	0.0	0.0	0.0
	SP	4	80-100	7.2	0.9	0.8	1.7	1.7	1.7	0.3	0.0	0.0	0.0
Maritime pine	LP	10-12	60-80	256.9	48.9	39.5	55.2	73.4	40.0	0.0	0.0	0.0	0.0
	LP	6-8	60-80	770.6	146.6	118.4	165.5	220.1	120.0	0.0	0.0	0.0	0.0
Oaks	OK	4	60-80	68.9	1.1	3.9	32.8	16.9	14.2	0.0	0.0	0.0	0.0
	OK	2	60-80	68.9	1.1	3.9	32.8	16.9	14.2	0.0	0.0	0.0	0.0
Chestnut	BE	10-12	60-80	10.7	0.5	0.7	2.7	2.0	4.7	0.0	0.0	0.0	0.0
	BE	6-8	60-80	32.0	1.5	2.1	8.1	6.1	14.2	0.0	0.0	0.0	0.0
Eucalyptus	SY	> 20	15-30	707.6	592.8	114.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other broad-leaves	SY	6-8	60-80	26.9	0.3	1.1	8.5	14.2	2.8	0.0	0.0	0.0	0.0
	SY	4	60-80	53.7	0.5	2.2	17.0	28.3	5.7	0.0	0.0	0.0	0.0
	SY	2	60-80	26.9	0.3	1.1	8.5	14.2	2.8	0.0	0.0	0.0	0.0

Summary forest data for Romania (base year 1982)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce	NS	10-12	50-60	615.6	73.9	61.6	98.5	117.0	98.5	73.8	92.3	0.0	0.0
	NS	10-12	60-80	360.8	43.3	36.1	57.8	68.5	57.7	43.3	54.1	0.0	0.0
	NS	6-8	60-80	481.8	57.8	48.2	77.2	91.5	77.2	57.8	72.2	0.0	0.0
	NS	6-8	> 100	18.0	2.2	1.8	2.9	3.4	2.9	2.2	2.7	0.0	0.0
	NS	4	> 100	18.0	2.2	1.8	2.9	3.4	2.9	2.2	2.7	0.0	0.0
Fir	NF	10-12	60-80	172.7	20.7	17.2	27.7	32.9	27.7	20.7	25.8	0.0	0.0
	NF	6-8	60-80	172.7	20.7	17.2	27.7	32.9	27.7	20.7	25.8	0.0	0.0
Oak	OK	6-8	30-40	53.4	20.8	15.9	14.9	1.7	0.0	0.0	0.0	0.0	0.0
	OK	6-8	60-80	804.4	94.2	98.8	233.3	144.8	88.5	64.3	80.5	0.0	0.0
	OK	6-8	> 100	133.7	15.7	16.4	38.8	24.1	14.7	10.7	13.4	0.0	0.0
	OK	4	30-40	106.8	41.6	31.9	29.8	3.4	0.0	0.0	0.0	0.0	0.0
	OK	4	> 100	93.7	11.0	11.5	27.2	16.9	10.3	7.5	9.3	0.0	0.0
	OK	2	30-40	53.4	20.8	15.9	14.9	1.7	0.0	0.0	0.0	0.0	0.0
	OK	2	> 100	49.2	5.8	6.0	14.2	8.8	5.4	3.9	4.9	0.0	0.0
Beech	BE	6-8	15-30	74.7	29.1	22.3	20.8	2.4	0.0	0.0	0.0	0.0	0.0
	BE	6-8	80-100	1517.1	81.5	87.1	245.2	245.2	199.2	168.6	490.4	0.0	0.0
	BE	4	15-30	149.5	58.3	44.7	41.7	4.9	0.0	0.0	0.0	0.0	0.0
	BE	4	80-100	93.0	5.0	5.3	15.1	15.0	12.2	10.3	30.1	0.0	0.0
	BE	2	15-30	74.7	29.1	22.3	20.8	2.4	0.0	0.0	0.0	0.0	0.0
	BE	2	80-100	37.0	2.0	2.1	6.0	6.0	4.8	4.1	12.0	0.0	0.0
Other broad-leaves	SY	6-8	50-60	752.7	123.2	117.7	240.9	135.5	60.2	37.6	37.6	0.0	0.0
Poplar, willow	PO	10-12	15-30	14.0	5.5	4.3	4.2	0.0	0.0	0.0	0.0	0.0	0.0
	PO	10-12	40-50	80.6	14.6	14.6	31.1	11.7	4.3	2.4	1.9	0.0	0.0
	PO	6-8	15-30	42.1	16.6	12.8	12.7	0.0	0.0	0.0	0.0	0.0	0.0
	PO	6-8	40-50	241.8	43.8	43.8	93.2	35.2	12.9	7.3	5.6	0.0	0.0

Summary forest data for Slovakia (base year 2000)

NFI species	Model species	Productivity class ($m^3\ ha^{-1}\ yr^{-1}$)	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce, other conifers	NS	14-16	80-100	26.6	2.4	2.7	4.0	4.7	5.3	4.6	2.3	0.6	0.0
	NS	10-12	80-100	239.3	21.7	24.4	35.8	42.1	48.0	41.2	20.8	5.5	0.0
	NS	6-8	80-100	239.3	21.7	24.4	35.8	42.1	48.0	41.2	20.8	5.5	0.0
	NS	4	80-100	26.6	2.4	2.7	4.0	4.7	5.3	4.6	2.3	0.6	0.0
Pine	SP	6-8	80-100	66.9	5.9	6.8	13.0	11.2	13.2	12.1	4.3	0.4	0.0
	SP	4	80-100	53.5	4.7	5.5	10.4	8.9	10.6	9.7	3.4	0.3	0.0
	SP	2	80-100	13.4	1.2	1.4	2.6	2.2	2.6	2.4	0.9	0.1	0.0
Fir	NF	14-16	80-100	3.7	0.4	0.3	0.3	0.3	0.7	1.0	0.6	0.1	0.0
	NF	10-12	80-100	33.2	3.2	2.7	3.0	3.0	6.4	9.1	5.2	0.8	0.0
	NF	6-8	80-100	33.2	3.2	2.7	3.0	3.0	6.4	9.1	5.2	0.8	0.0
	NF	4	80-100	3.7	0.4	0.3	0.3	0.3	0.7	1.0	0.6	0.1	0.0
Oak	OK	6-8	> 100	49.3	2.4	2.4	3.4	11.9	14.1	10.0	4.6	0.5	0.0
	OK	4	> 100	98.5	4.8	4.8	6.8	23.8	28.3	20.0	9.1	0.9	0.0
	OK	2	> 100	49.3	2.4	2.4	3.4	11.9	14.1	10.0	4.6	0.5	0.0
Beech, hornbeam	BE	6-8	80-100	158.1	10.5	13.2	20.5	32.1	34.2	28.2	16.7	2.8	0.0
	BE	4	80-100	316.3	21.0	26.3	41.0	64.2	68.4	56.4	33.3	5.6	0.0
	BE	2	80-100	158.1	10.5	13.2	20.5	32.1	34.2	28.2	16.7	2.8	0.0
Other broad-leaves	SY	6-8	60-80	49.5	5.1	5.8	11.1	13.7	8.2	3.4	1.9	0.3	0.0
	SY	4	60-80	99.0	10.3	11.6	22.2	27.3	16.4	6.8	3.7	0.7	0.0
	SY	2	60-80	49.5	5.1	5.8	11.1	13.7	8.2	3.4	1.9	0.3	0.0

Summary forest data for Slovenia (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Conifers (pro-rata)	NS	14-16	80-100	21.9	0.2	0.3	1.3	3.9	3.0	6.5	5.9	0.8	0.0
	NS	10-12	80-100	197.2	1.7	2.3	12.1	35.4	26.9	58.5	53.3	6.8	0.0
	NS	6-8	80-100	197.2	1.7	2.3	12.1	35.4	26.9	58.5	53.3	6.8	0.0
	NS	4	80-100	21.9	0.2	0.3	1.3	3.9	3.0	6.5	5.9	0.8	0.0
	LP	6-8	80-100	32.7	0.3	0.4	2.0	5.9	4.5	9.7	8.9	1.1	0.0
	LP	4	80-100	26.2	0.2	0.3	1.6	4.7	3.6	7.8	7.1	0.9	0.0
	LP	2	80-100	6.5	0.1	0.1	0.4	1.2	0.9	1.9	1.8	0.2	0.0
Broad-leaves (pro-rata)	OK	6-8	> 100	16.2	0.1	0.4	2.0	3.3	3.6	2.3	4.1	0.5	0.0
	OK	4	> 100	32.4	0.3	0.8	4.1	6.5	7.3	4.5	8.1	0.9	0.0
	OK	2	> 100	16.2	0.1	0.4	2.0	3.3	3.6	2.3	4.1	0.5	0.0
	SY	6-8	> 100	145.9	1.1	3.5	18.3	29.3	32.7	20.3	36.5	4.2	0.0
	SY	4	> 100	291.7	2.3	6.9	36.7	58.6	65.3	40.7	72.9	8.4	0.0
	SY	2	> 100	145.9	1.1	3.5	18.3	29.3	32.7	20.3	36.5	4.2	0.0

Summary forest data for Spain (base year 2005)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Pines	SP	10-12	60-80	595.9	84.4	47.3	107.1	123.8	110.7	55.4	31.5	23.7	11.9
	SP	6-8	60-80	1787.6	253.3	142.0	321.3	371.4	332.1	166.2	94.5	71.2	35.6
	CP	14-16	60-80	442.6	62.7	35.2	79.6	92.0	82.2	41.1	23.4	17.6	8.8
	CP	10-12	60-80	1328.0	188.2	105.5	238.7	275.9	246.7	123.4	70.2	52.9	26.4
	LP	10-12	60-80	664.0	94.1	52.7	119.3	138.0	123.3	61.7	35.1	26.5	13.2
	LP	6-8	60-80	1991.9	282.3	158.2	358.0	413.9	370.0	185.2	105.3	79.4	39.7
Oak	OK	4	80-100	314.0	69.0	14.8	30.9	30.9	29.7	25.1	26.7	53.9	33.0
	OK	2	80-100	314.0	69.0	14.8	30.9	30.9	29.7	25.1	26.7	53.9	33.0
Beech	BE	6-8	80-100	56.1	12.3	2.6	5.5	5.5	5.3	4.5	4.8	9.6	5.9
	BE	4	80-100	112.1	24.6	5.3	11.1	11.0	10.6	9.0	9.5	19.3	11.8
	BE	2	80-100	56.1	12.3	2.6	5.5	5.5	5.3	4.5	4.8	9.6	5.9
Other broad-leaves	SY	6-8	80-100	897.2	197.0	42.2	88.4	88.2	85.0	71.8	76.2	154.1	94.3
	SY	4	80-100	1794.4	394.0	84.4	176.8	176.4	170.0	143.6	152.4	308.3	188.5
	SY	2	80-100	897.2	197.0	42.2	88.4	88.2	85.0	71.8	76.2	154.1	94.3
Poplar	PO	14-16	80-100	4.5	1.0	0.2	0.4	0.4	0.4	0.4	0.4	0.8	0.5
	PO	10-12	80-100	26.9	5.9	1.3	2.7	2.6	2.5	2.2	2.3	4.6	2.8
	PO	6-8	80-100	13.5	3.0	0.6	1.3	1.3	1.3	1.1	1.1	2.3	1.4

Summary forest data for Sweden (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce, mixed conifers	NS	10-12	60-80	282.3	42.9	27.1	72.7	50.5	49.8	27.0	11.3	0.9	0.0
	NS	6-8	60-80	1693.9	257.7	162.5	436.3	303.0	298.7	162.2	67.9	5.7	0.0
	NS	6-8	80-100	2145.9	321.4	172.1	330.7	252.8	244.6	305.9	356.9	161.4	0.0
	NS	6-8	> 100	163.7	12.5	11.7	21.2	14.2	13.6	18.2	36.9	35.4	0.0
	NS	4	60-80	847.0	128.8	81.3	218.1	151.5	149.4	81.1	34.0	2.8	0.0
	NS	4	80-100	715.3	107.1	57.4	110.2	84.3	81.5	102.0	119.0	53.8	0.0
	NS	4	> 100	1145.6	87.3	82.2	148.2	99.4	95.5	127.5	258.0	247.7	0.0
	NS	2	> 100	327.3	24.9	23.5	42.3	28.4	27.3	36.4	73.7	70.8	0.0
Pine	SP	10-12	80-100	37.3	4.5	3.1	15.9	7.4	3.6	1.9	0.8	0.1	0.0
	SP	6-8	80-100	1250.9	185.7	148.8	346.0	205.9	96.5	86.8	131.4	49.8	0.0
	SP	6-8	> 100	268.1	34.7	35.1	43.5	34.4	24.7	22.4	48.8	24.4	0.0
	SP	4	80-100	2019.3	308.3	251.4	512.7	322.1	149.7	145.3	237.9	91.7	0.0
	SP	4	> 100	1340.5	173.7	175.4	217.7	172.0	123.4	112.1	243.9	122.2	0.0
	SP	2	> 100	1072.4	139.0	140.3	174.2	137.6	98.8	89.7	195.1	97.8	0.0
Broad-leaved	SY	6-8	60-80	1229.8	119.8	130.6	363.5	325.7	170.9	74.1	36.7	8.4	0.0
	SY	6-8	80-100	90.4	4.7	7.5	19.2	20.1	11.3	10.7	10.6	6.2	0.0
	SY	4	60-80	449.3	45.2	54.4	122.7	96.5	61.1	35.6	26.5	7.3	0.0
	SY	4	80-100	451.9	23.6	37.7	95.8	100.5	56.7	53.5	53.0	31.2	0.0
	SY	2	80-100	361.6	18.9	30.2	76.6	80.4	45.4	42.8	42.4	24.9	0.0
Mixed conifer & b'leaf	BI	6-8	60-80	609.5	62.1	45.6	177.1	189.4	77.5	37.9	18.4	1.5	0.0
	BI	4	60-80	157.5	16.7	15.5	55.1	52.0	14.4	2.9	0.9	0.0	0.0
	BI	2	60-80	54.5	5.0	4.5	20.0	16.9	6.8	1.1	0.2	0.0	0.0

Summary forest data for the UK (base year 2005)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruces, other conifers	NS	10-12	50-60	83.0	9.0	12.3	35.0	16.8	6.3	1.8	1.3	0.5	0.1
	NS	6-8	50-60	83.0	9.0	12.3	35.0	16.8	6.3	1.8	1.3	0.5	0.1
	SS	> 20	30-40	24.9	2.7	3.7	10.5	5.0	1.9	0.5	0.4	0.1	0.0
	SS	> 20	50-60	53.1	5.7	7.9	22.4	10.7	4.0	1.1	0.8	0.3	0.1
	SS	18-20	30-40	37.4	4.0	5.6	15.7	7.6	2.8	0.8	0.6	0.2	0.0
	SS	18-20	50-60	79.7	8.6	11.8	33.6	16.1	6.1	1.7	1.3	0.4	0.1
	SS	14-16	30-40	49.8	5.4	7.4	21.0	10.1	3.8	1.1	0.8	0.3	0.1
	SS	14-16	50-60	106.2	11.5	15.8	44.8	21.5	8.1	2.3	1.7	0.6	0.1
	SS	10-12	30-40	99.6	10.8	14.8	42.0	20.1	7.6	2.1	1.6	0.6	0.1
	SS	10-12	50-60	212.5	23.0	31.6	89.5	43.0	16.1	4.5	3.4	1.2	0.3
	SS	6-8	30-40	37.4	4.0	5.6	15.7	7.6	2.8	0.8	0.6	0.2	0.0
	SS	6-8	50-60	79.7	8.6	11.8	33.6	16.1	6.1	1.7	1.3	0.4	0.1
Pines	SP	10-12	50-60	28.2	3.0	4.2	11.9	5.7	2.1	0.6	0.4	0.2	0.0
	SP	6-8	50-60	225.8	24.4	33.6	95.1	45.7	17.1	4.8	3.6	1.2	0.3
	SP	4	50-60	28.2	3.0	4.2	11.9	5.7	2.1	0.6	0.4	0.2	0.0
	CP	> 20	50-60	10.0	1.1	1.5	4.2	2.0	0.8	0.2	0.2	0.1	0.0
	CP	18-20	50-60	13.3	1.4	2.0	5.6	2.7	1.0	0.3	0.2	0.1	0.0
	CP	14-16	50-60	19.9	2.2	3.0	8.4	4.0	1.5	0.4	0.3	0.1	0.0
	CP	10-12	50-60	19.9	2.2	3.0	8.4	4.0	1.5	0.4	0.3	0.1	0.0
	CP	6-8	50-60	3.3	0.4	0.5	1.4	0.7	0.3	0.1	0.1	0.0	0.0
	LP	10-12	50-60	14.9	1.6	2.2	6.3	3.0	1.1	0.3	0.2	0.1	0.0
	LP	6-8	50-60	119.5	12.9	17.8	50.3	24.2	9.1	2.5	1.9	0.7	0.1
	LP	4	50-60	14.9	1.6	2.2	6.3	3.0	1.1	0.3	0.2	0.1	0.0
Other conifers	JL	10-12	50-60	14.9	1.6	2.2	6.3	3.0	1.1	0.3	0.2	0.1	0.0
	JL	6-8	50-60	119.5	12.9	17.8	50.3	24.2	9.1	2.5	1.9	0.7	0.1
	JL	4	50-60	14.9	1.6	2.2	6.3	3.0	1.1	0.3	0.2	0.1	0.0
Other conifers	DF	> 20	50-60	10.0	1.1	1.5	4.2	2.0	0.8	0.2	0.2	0.1	0.0
	DF	18-20	50-60	13.3	1.4	2.0	5.6	2.7	1.0	0.3	0.2	0.1	0.0
	DF	14-16	50-60	19.9	2.2	3.0	8.4	4.0	1.5	0.4	0.3	0.1	0.0
	DF	10-12	50-60	19.9	2.2	3.0	8.4	4.0	1.5	0.4	0.3	0.1	0.0
	DF	6-8	50-60	3.3	0.4	0.5	1.4	0.7	0.3	0.1	0.1	0.0	0.0
Oak	OK	6-8	> 100	130.3	12.9	9.6	18.8	27.1	22.9	14.0	17.6	5.1	2.3
	OK	4	> 100	104.3	10.3	7.7	15.0	21.7	18.3	11.2	14.1	4.1	1.8
	OK	2	> 100	26.1	2.6	1.9	3.8	5.4	4.6	2.8	3.5	1.0	0.5
Beech	BE	10-12	> 100	9.5	0.9	0.7	1.4	2.0	1.7	1.0	1.3	0.4	0.2
	BE	6-8	> 100	47.4	4.7	3.5	6.8	9.8	8.3	5.1	6.4	1.9	0.8
	BE	4	> 100	28.4	2.8	2.1	4.1	5.9	5.0	3.1	3.8	1.1	0.5
	BE	2	> 100	9.5	0.9	0.7	1.4	2.0	1.7	1.0	1.3	0.4	0.2

Summary forest data for the UK (continued)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Sycamore ash, birch, other broad-leaves	SY	10-12	60-80	35.5	3.5	2.6	5.1	7.4	6.3	3.8	4.8	1.4	0.6
	SY	6-8	60-80	59.2	5.9	4.4	8.5	12.3	10.4	6.4	8.0	2.3	1.0
	SY	4	60-80	23.7	2.3	1.7	3.4	4.9	4.2	2.6	3.2	0.9	0.4
	AH	10-12	60-80	152.9	15.1	11.3	22.0	31.7	26.9	16.5	20.6	6.0	2.7
	AH	6-8	60-80	254.8	25.2	18.8	36.7	52.9	44.8	27.5	34.4	10.0	4.5
	AH	4	60-80	101.9	10.1	7.5	14.7	21.2	17.9	11.0	13.7	4.0	1.8
	BI	10-12	60-80	60.4	6.0	4.5	8.7	12.5	10.6	6.5	8.1	2.4	1.1
	BI	6-8	60-80	100.7	10.0	7.4	14.5	20.9	17.7	10.9	13.6	4.0	1.8
	BI	4	60-80	40.3	4.0	3.0	5.8	8.4	7.1	4.3	5.4	1.6	0.7

Summary forest data for Belarus (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Norway spruce	NS	10-12	80-100	36.3	2.0	3.6	6.4	13.2	10.3	0.9	0.0	0.0	0.0
	NS	6-8	80-100	253.9	13.7	25.3	44.6	92.4	71.8	6.2	0.0	0.0	0.0
	NS	4	80-100	290.2	15.6	28.9	50.9	105.6	82.1	7.1	0.0	0.0	0.0
	NS	2	80-100	145.1	7.8	14.4	25.5	52.8	41.0	3.6	0.0	0.0	0.0
Scots pine	SP	14-16	80-100	338.8	8.3	15.3	69.7	137.1	96.6	11.7	0.0	0.0	0.0
	SP	10-12	80-100	677.6	16.6	30.6	139.5	274.2	193.3	23.4	0.0	0.0	0.0
	SP	6-8	80-100	2032.7	49.8	91.9	418.4	822.7	579.9	70.1	0.0	0.0	0.0
	SP	4	80-100	338.8	8.3	15.3	69.7	137.1	96.6	11.7	0.0	0.0	0.0
Oak	OK	6-8	80-100	52.8	2.4	4.4	10.4	11.0	15.6	4.5	4.4	0.0	0.0
	OK	4	80-100	105.7	4.8	8.9	20.8	22.1	31.1	9.0	8.9	0.0	0.0
	OK	2	80-100	52.8	2.4	4.4	10.4	11.0	15.6	4.5	4.4	0.0	0.0
Ash	AH	6-8	80-100	9.2	0.3	0.6	1.2	3.4	3.4	0.2	0.1	0.0	0.0
	AH	4	80-100	18.4	0.7	1.2	2.4	6.7	6.8	0.5	0.1	0.0	0.0
	AH	2	80-100	9.2	0.3	0.6	1.2	3.4	3.4	0.2	0.1	0.0	0.0
Birch	BI	6-8	60-80	334.5	27.0	54.9	115.0	110.4	27.3	0.0	0.0	0.0	0.0
	BI	4	60-80	668.9	53.9	109.7	230.0	220.7	54.6	0.0	0.0	0.0	0.0
	BI	2	60-80	334.5	27.0	54.9	115.0	110.4	27.3	0.0	0.0	0.0	0.0
Poplar	PO	6-8	50-60	35.2	3.2	8.1	12.7	11.1	0.0	0.0	0.0	0.0	0.0
	PO	4	50-60	70.4	6.4	16.3	25.3	22.3	0.0	0.0	0.0	0.0	0.0
	PO	2	50-60	35.2	3.2	8.1	12.7	11.1	0.0	0.0	0.0	0.0	0.0

Summary forest data for European Russia (base year 1998)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Pine/ spruce	SP	10-12	> 100	3702.9	273.5	249.0	497.7	418.4	418.4	172.1	903.1	770.6	0.0
	SP	6-8	> 100	29623.4	2188.4	1992.3	3981.6	3347.1	3347.1	1376.9	7225.1	6164.9	0.0
	SP	4	> 100	33326.3	2461.9	2241.4	4479.3	3765.5	3765.5	1549.1	8128.2	6935.5	0.0
	SP	2	> 100	7405.9	547.1	498.1	995.4	836.8	836.8	344.2	1806.3	1541.2	0.0
Oak/ beech/ maple	OK	6-8	> 100	97.8	8.3	7.6	15.1	16.1	16.1	11.8	22.4	0.5	0.0
	OK	4	> 100	635.4	54.1	49.2	98.4	104.5	104.5	76.4	145.3	3.1	0.0
	OK	2	> 100	244.4	20.8	18.9	37.8	40.2	40.2	29.4	55.9	1.2	0.0
Birch/ aspen/ lime	BI	6-8	80-100	4077.2	691.3	530.5	556.1	556.1	676.0	1067.1	0.0	0.0	0.0
	BI	4	80-100	26501.5	4493.5	3448.5	3614.6	3614.6	4394.2	6936.0	0.0	0.0	0.0
	BI	2	80-100	10192.9	1728.3	1326.4	1390.2	1390.2	1690.1	2667.7	0.0	0.0	0.0

Summary forest data for Ukraine (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
Spruce	NS	10-12	60-80	121.5	2.7	7.6	25.9	41.2	30.1	9.6	3.8	0.6	0.0
	NS	6-8	60-80	364.5	8.0	22.8	77.6	123.5	90.3	28.8	11.5	1.9	0.0
Pine	SP	10-12	60-80	457.0	10.0	28.5	97.4	154.9	113.2	36.1	14.5	2.4	0.0
	SP	6-8	60-80	1371.1	30.1	85.6	292.1	464.6	339.6	108.4	43.4	7.2	0.0
Oak	OK	6-8	80-100	375.2	8.4	21.8	71.6	99.8	86.9	52.1	29.3	5.4	0.0
	OK	4	80-100	750.5	16.7	43.5	143.1	199.5	173.9	104.2	58.7	10.8	0.0
	OK	2	80-100	375.2	8.4	21.8	71.6	99.8	86.9	52.1	29.3	5.4	0.0
Beech	BE	6-8	80-100	166.8	3.7	9.7	31.8	44.3	38.6	23.2	13.0	2.4	0.0
	BE	4	80-100	333.5	7.4	19.4	63.6	88.7	77.3	46.3	26.1	4.8	0.0
	BE	2	80-100	166.8	3.7	9.7	31.8	44.3	38.6	23.2	13.0	2.4	0.0
Birch	BI	6-8	60-80	291.8	6.5	16.9	55.7	77.6	67.6	40.5	22.8	4.2	0.0
	BI	4	60-80	583.7	13.0	33.9	111.3	155.2	135.2	81.0	45.6	8.4	0.0
	BI	2	60-80	291.8	6.5	16.9	55.7	77.6	67.6	40.5	22.8	4.2	0.0

Summary forest data for Canada (base year 2000)

NFI species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
See Table A9.5	NS	'10-12	' 80-100	19384.2	173.8	232.5	929.2	1434.3	2621.7	6622	6385.2	563.3	422.2
	NS	' 6- 8	' 80-100	96921.1	869	1162.5	4645.8	7171.6	13108.6	33110.3	31926	2816.6	2110.8
	NS	' 4- 4	' 80-100	61956.8	2089.5	1968.6	3678.7	4372.2	7869.2	19866.6	19155.6	1690	1266.5
	NS	' 2- 2	' 80-100	23188.4	1741.9	1503.6	1820.4	1503.6	2625.8	6622.5	6385.2	563.3	422.2
	SP	' 6- 8	> 100	7074	488.9	420	814	912.9	1271.7	1287.9	1205.5	461.8	211.2
	SP	' 4- 4	> 100	15916.5	1100.1	945.1	1831.6	2054	2861.4	2897.8	2712.3	1039.1	475.2
	SP	' 2- 2	> 100	12379.5	855.6	735.1	1424.6	1597.5	2225.5	2253.8	2109.6	808.2	369.6
	EL	' 6- 8	' 80-100	3377.3	317.8	230.2	254	490.6	673.9	676.9	520	163.5	50.3
	EL	' 4- 4	' 80-100	2251.5	211.8	153.5	169.4	327.1	449.3	451.3	346.7	109	33.5
	DF	'10-12	' 80-100	2493.9	5.6	21.9	169.2	205.6	307.4	353.7	720.4	295.3	414.8
	DF	' 6- 8	' 80-100	2493.9	5.6	21.9	169.2	205.6	307.4	353.7	720.4	295.3	414.8
	NF	'10-12	' 80-100	2190.3	57.1	66.1	217.9	312.3	293.8	294	227.2	164.6	557.4
	NF	' 6- 8	' 80-100	19712.3	513.6	594.8	1960.7	2810.7	2644.2	2646.4	2044.4	1481	5016.6
	RC	'10-12	' 80-100	1211.7	11	17.3	92.2	122.7	100.1	113.3	96.1	39.7	619.3
	RC	' 6- 8	' 80-100	2827.4	25.7	40.4	215.2	286.4	233.5	264.3	224.3	92.8	1445
	WH	'10-12	' 80-100	1722	2.1	8.7	133.5	108.7	107.6	77.7	116.7	72.8	1094.4
	WH	' 6- 8	' 80-100	4018.1	5	20.2	311.4	253.6	251	181.3	272.2	169.8	2553.7
	SY	' 6- 8	' 80-100	190.4	16.9	16.2	35.8	42.2	43.8	21.4	13.4	0.8	0
	SY	' 6- 8	> 100	1004.2	41.8	30.2	69.5	357.8	180.8	230.8	74.6	16.4	2.3
	SY	' 4- 4	' 80-100	1687.7	497.8	326.1	247.2	218.8	220.2	106.8	67	3.8	0
	SY	' 4- 4	> 100	5020.9	209.1	151	347.4	1788.8	904.1	1154	373	82.1	11.3
	SY	' 2- 2	' 80-100	1497.2	480.9	309.9	211.5	176.6	176.3	85.4	53.6	3	0
	SY	' 2- 2	> 100	4016.7	167.3	120.8	277.9	1431	723.3	923.2	298.4	65.7	9
	BI	' 6- 8	' 80-100	1423	41.8	48.7	182.1	408.3	384.6	281.9	71.9	3.4	0.4
	BI	' 4- 4	' 80-100	7115.1	208.9	243.3	910.3	2041.7	1922.9	1409.4	359.5	17.1	1.9
	BI	' 2- 2	' 80-100	5692.1	167.2	194.6	728.2	1633.4	1538.3	1127.5	287.6	13.7	1.5
	PO	' 6- 8	' 60- 80	31430.4	1099.8	1056.3	2874.9	6615.2	10346.8	6968.3	2248.6	167	53.5
	PO	' 4- 4	' 60- 80	10476.8	366.6	352.1	958.3	2205.1	3448.9	2322.8	749.5	55.7	17.8

Summary forest data for the USA (base year 2013, adjusted to 2006 for the purposes of modelling)

FIA species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
See Table A9.6	NS	'18-20	' 80-100	7.1	0	0	2.4	2.2	1.7	0	0.6	0.2	0
	NS	'14-16	' 80-100	110	0.2	10.4	35.2	20.8	20.3	9.3	11.2	2.8	0
	NS	'10-12	' 80-100	698.3	23.5	53.5	95.3	95.2	134.7	107.2	150.9	38	0
	NS	' 6- 8	' 80-100	2907.5	98.6	162.1	141	203.3	468.4	551.6	1039.7	242.7	0
	NS	' 4- 4	' 80-100	2495.3	60.6	155	99.9	109.4	242.1	424.4	1126.3	277.5	0
	NS	' 2- 2	' 80-100	2358	73.7	150.6	117.6	51	165	459.3	1073.6	267.1	0
	SS	'18-20	' 60- 80	0.2	0	0	0.2	0	0	0	0	0	0
	SS	'18-20	' 80-100	249.3	27.8	15.9	96.3	61	21.4	10.4	13.2	3.3	0
	SS	'14-16	' 60- 80	0.8	0	0	0.8	0	0	0	0	0	0
	SS	'14-16	' 80-100	317	24.1	14.9	90.6	90	36.8	17.5	34.4	8.6	0
	SS	'10-12	' 60- 80	86.9	3.5	2	18.7	37.8	11.8	8.8	3.5	0.9	0
	SS	'10-12	' 80-100	545.2	29.1	36.6	89.9	96.9	84.1	42.5	133.1	33.1	0
	SS	' 6- 8	' 60- 80	1398.7	25.7	81.6	401.4	328.2	302.6	165.6	76	17.7	0
	SS	' 6- 8	' 80-100	1030.5	44.6	59.3	102.9	70	109.7	89.5	446.8	107.7	0
	SS	' 4- 4	' 60- 80	1838.7	38.3	106.2	408.1	377	415.9	289.5	162.5	41.2	0
	SS	' 4- 4	' 80-100	733.6	25.2	35	50.7	24.5	31.7	45.8	418	102.6	0
	SS	' 2- 2	' 60- 80	2281.2	41.4	107.8	287.1	407.8	623	439.6	299.7	74.8	0
	SS	' 2- 2	' 80-100	616	14.6	18.6	32.6	15.7	8.5	26.5	400.4	99	0
	SP	'18-20	' 15- 30	32.1	4.1	1.8	6.9	10.5	5	1.2	2	0.5	0
	SP	'14-16	' 15- 30	438.8	45.7	56.1	118.8	82.2	69.9	36	24.2	5.8	0
	SP	'10-12	' 40- 50	23.2	0.8	1.1	7.1	12.3	1.2	0.6	0	0	0
	SP	'10-12	' 60- 80	1002.1	31.6	40.3	152.9	196.6	200.6	142.7	189.6	47.8	0
	SP	'10-12	' 80-100	0.6	0	0	0	0	0	0	0.5	0.1	0
	SP	'10-12	> 100	1174.5	158.2	144	347.2	297.5	174.1	48.9	3.7	0.9	0
	SP	' 6- 8	' 40- 50	101.2	2.8	16.3	26.9	40.5	14	0.7	0	0	0
	SP	' 6- 8	' 60- 80	2883.9	58.7	113.1	254	618	704.4	499.5	533	103.2	0
	SP	' 6- 8	' 80-100	0.1	0	0	0	0	0	0	0.1	0	0
	SP	' 6- 8	> 100	5021.7	886.5	609.5	1048.5	1312.5	892.7	244.6	22.8	4.8	0
	SP	' 4- 4	' 40- 50	74.4	2.6	8.9	25.6	24.4	11.1	1.8	0	0	0
	SP	' 4- 4	' 60- 80	1442.2	27.8	60.6	131.5	283.8	359.2	272	246	61.3	0
	SP	' 4- 4	' 80-100	12.5	0	0	0.8	2.3	5	3.3	0.8	0.2	0
	SP	' 4- 4	> 100	3155.9	483.1	375.1	615.8	798.5	651.6	195.6	29.9	6.4	0
	SP	' 2- 2	' 40- 50	60.8	1.5	9.6	16.8	18	12	2.7	0	0	0
	SP	' 2- 2	' 60- 80	691.2	21.8	68.1	125.2	142.5	133.7	102.4	78.6	19	0
	SP	' 2- 2	' 80-100	40	0	0	2.6	7.4	16.1	10.6	2.7	0.7	0
	SP	' 2- 2	> 100	1365.6	87.3	112.5	260.1	410.9	341.6	114.4	32.1	6.9	0

Summary forest data for the USA (continued)

FIA species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
	CP	'18-20	' 15- 30	39.6	11.3	12.7	4.6	7.5	0.5	2.6	0.4	0.1	0
	CP	'14-16	' 15- 30	1714.9	135.3	665.1	745.6	108.1	40.4	13.9	5.4	1.3	0
	CP	'10-12	' 50- 60	5648.6	672	1586.3	2462.3	565.7	323.1	32	5.9	1.3	0
	CP	'10-12	' 60- 80	242	24.1	35.9	34.2	42	38.1	32.8	28.1	6.8	0
	CP	' 6- 8	' 50- 60	14187.1	2989.9	3441.5	4901.6	1764.8	924.1	147.4	14.2	3.5	0
	CP	' 6- 8	' 60- 80	1829.2	81.2	90.4	273.5	272.6	367.7	370	311.6	62.2	0
	CP	' 4- 4	' 50- 60	5772.4	1308.3	1293.1	1658.5	855.9	525.6	112.5	15	3.5	0
	CP	' 4- 4	' 60- 80	3046	102.3	120.6	301.5	373.2	621.3	780.6	627.7	118.9	0
	CP	' 2- 2	' 50- 60	1235.1	123.6	148.8	339.4	298.8	211.4	86.2	21.6	5.2	0
	CP	' 2- 2	' 60- 80	4561.3	157.9	170.6	274.3	396.5	893.4	1416.1	1029	223.5	0
	LP	'14-16	' 15- 30	2.9	0	0.4	0.5	1.5	0.5	0	0	0	0
	LP	'10-12	' 80-100	64.4	6.3	15	8.1	9.5	16.5	3.6	4.4	1	0
	LP	' 6- 8	' 80-100	496.8	34.1	47.3	52.9	64.1	120.9	103.6	59.8	14.2	0
	LP	' 4- 4	' 80-100	1222.7	82.4	115.7	123.9	110.9	204.6	273.5	252.1	59.6	0
See Table A9.6	LP	' 2- 2	' 80-100	2264.2	153.7	246.9	196.9	163.8	296.2	496.5	582.7	127.5	0
	JL	'18-20	' 80-100	0.6	0	0	0.6	0	0	0	0	0	0
	JL	'14-16	' 80-100	6.4	0	1.6	2.7	0.5	0.4	0	0.9	0.2	0
	JL	'10-12	' 80-100	45.2	3.1	4.3	13	2.6	11.3	0.2	8.5	2.1	0
	JL	' 6- 8	' 80-100	288	23.3	21.5	26	34.8	69.5	51.2	48.6	13	0
	JL	' 4- 4	' 80-100	215.3	24.1	17.6	6	16.7	33.5	40.7	61.4	15.2	0
	JL	' 2- 2	' 80-100	71.2	14.8	6.9	0.7	2.3	2.6	5.9	30.5	7.6	0
	DF	'18-20	' 80-100	101.5	31.7	28.1	22.4	9.8	2.1	2.3	4	1	0
	DF	'14-16	' 80-100	1104.2	134.4	151.2	411.4	175.8	112.1	33.8	68.5	17	0
	DF	'10-12	' 80-100	2774	298.8	400.4	810	456.8	255.9	161	314.8	76.3	0
	DF	' 6- 8	' 80-100	3647.5	179.4	252	498.3	477	568.7	624	838.5	209.6	0
	DF	' 4- 4	' 80-100	2768.7	98.1	149.8	141.4	192	425.2	648.9	898.4	214.7	0
	DF	' 2- 2	' 80-100	3121.4	112.6	187.9	116.8	172.2	401.4	732.1	1133.8	264.6	0
	GF	'18-20	' 80-100	54.2	2.2	6.5	8.6	9.1	7.5	11.4	7.3	1.8	0
	GF	'14-16	' 80-100	82.2	3.7	5.6	14.4	13.7	13.6	23.2	6.7	1.2	0
	GF	'10-12	' 80-100	87.4	1.6	7.2	9.1	24.4	15.2	13.6	13.5	2.9	0
	GF	' 6- 8	' 80-100	32.1	0	1.3	0.7	4.4	10.5	1	11.3	2.8	0

Summary forest data for the USA (continued)

FIA species	Model species	Productivity class (m^3 ha^{-1} yr^{-1})	Basic rotation (years)	Total area (kha)	Area (kha) by age (years)								
					0-10	11-20	21-40	41-60	61-80	81-100	101-140	141-180	> 180
See Table A9.6	OK	'18-20	' 80-100	3	0.5	0	0	1.7	0	0	0.6	0.2	0
	OK	'18-20	> 100	101.3	12.2	10	19.7	24.3	25.5	9.6	0	0	0
	OK	'14-16	' 80-100	16.7	2.1	3	4.7	2.5	0	3.7	0.6	0.2	0
	OK	'14-16	> 100	656.2	93.6	72.2	123.2	170.7	151.6	39.7	4.3	1.1	0
	OK	'10-12	' 80-100	155.8	34.3	15.7	38.2	24.9	22	10.9	7.8	2	0
	OK	'10-12	> 100	3818.5	372.4	281	742.9	1155.7	964.7	237.6	52.2	12	0
	OK	' 6- 8	' 80-100	482.9	40.5	52.6	93.1	124.6	88.2	55.9	23.6	4.5	0
	OK	' 6- 8	> 100	26733.1	2367.4	1711.2	3993.1	7781.7	7461	2674.5	607.5	136.6	0
	OK	' 4- 4	' 80-100	462.9	42.1	50.9	87.6	97.9	99.9	58.9	21.3	4.3	0
	OK	' 4- 4	> 100	22024.8	1638.3	1256.3	2725.7	5641.6	6759.9	3064.3	757.5	181.3	0
	OK	' 2- 2	' 80-100	454.8	49.9	55	105.2	78.8	88.5	57.7	16	3.6	0
	OK	' 2- 2	> 100	12980.9	601	622.8	1395.9	2784.5	4067.8	2502.5	810.3	196.2	0
	SY	'18-20	' 30- 40	1.8	1.8	0	0	0	0	0	0	0	0
	SY	'18-20	' 80-100	61.1	7.2	5.3	12.3	24	9.3	1.5	1.4	0.2	0
	SY	'14-16	' 30- 40	5.9	2.3	2.3	0	1.3	0	0	0	0	0
	SY	'14-16	' 80-100	254.1	35.3	52.6	56.1	55.1	33.5	10.8	8.6	2	0
	SY	'10-12	' 30- 40	45.4	22.6	5.9	6.9	10	0	0	0	0	0
	SY	'10-12	' 80-100	507.1	55.9	83.9	130.6	120.5	76.9	24.1	12.6	2.4	0
	SY	' 6- 8	' 30- 40	209.3	82.9	47.7	43.4	27.8	7.2	0.2	0	0	0
	SY	' 6- 8	' 80-100	261	14.2	31.2	78.3	64	37.7	23.2	10.2	2.1	0
	SY	' 4- 4	' 30- 40	155.8	48.4	36.7	35.1	26.4	8.3	0.7	0.1	0	0
	SY	' 4- 4	' 80-100	45.2	3	4.6	16.3	13.3	2.6	3.2	1.7	0.4	0
	SY	' 2- 2	' 30- 40	100.5	18.9	22.6	21.5	29.3	6.8	0.9	0.4	0.1	0
	SY	' 2- 2	' 80-100	16	1.4	2.1	7.3	4.2	0	0	0.8	0.2	0
	AH	'18-20	' 80-100	31.4	0	4.1	9.1	13.2	3.2	1.7	0	0	0
	AH	'14-16	' 80-100	80.2	7.9	8.4	18.8	26.3	16.6	2.3	0	0	0
	AH	'10-12	' 80-100	504.7	47.8	41.1	110.5	179	102.7	15.8	6.2	1.6	0
	AH	' 6- 8	' 80-100	3727.6	292.9	318.2	757.5	1282	840.8	188.3	38.8	9.1	0
	AH	' 4- 4	' 80-100	2952.7	208	212.6	581.6	976.2	696.7	208.8	55.3	13.3	0
	AH	' 2- 2	' 80-100	2541.9	120.1	169	436.2	760.3	659.9	286.7	88.5	21.3	0
	BI	'18-20	' 80-100	3.2	0	0	1.6	0	1.6	0	0	0	0
	BI	'14-16	' 80-100	20.4	2.5	2.1	6.7	2.4	6.6	0	0	0	0
	BI	'10-12	' 80-100	163.5	12.5	19.5	57	41.9	26	4.4	1.8	0.4	0
	BI	' 6- 8	' 80-100	3026.6	267.1	308.5	897.4	817.7	509.1	153.1	59.4	14.4	0
	BI	' 4- 4	' 80-100	2849.8	275.4	378.1	572.8	589.5	572	279.2	146.9	35.9	0
	BI	' 2- 2	' 80-100	2692.1	333.2	403.5	330.9	420.2	555.5	377.9	217.2	53.5	0

Appendix 10 Assessment of solutions of CARBINE model baseline simulations for countries represented in this project

The assessment in the table below refers to stages in the forest modelling optimisation process for baseline simulations, as illustrated in Figure 4.12, Section 4.8.1 of the main project report.

Country	Simple solution	Solution based on optimised rotations	Solution based on introducing additional harvesting	Solution possible
EU27				
Austria	NO	NO	YES	YES
Belgium	NO	NO	YES	YES
Bulgaria	YES	NO	NO	YES
Czech	NO	NO	YES	YES
Denmark	YES	NO	NO	YES
Estonia	NO	YES	NO	YES
Finland	YES	NO	NO	YES
France	NO	NO	YES	YES
Germany	NO	NO	YES	YES
Greece	YES	NO	NO	YES
Hungary	YES	NO	NO	YES
Ireland	YES	NO	NO	YES
Italy	YES	NO	NO	YES
Latvia	NO	NO	YES	YES
Lithuania	NO	YES	NO	YES
Luxembourg	NO	YES	NO	YES
Netherlands	NO	YES	NO	YES
Poland	NO	YES	NO	YES
Portugal	NO	YES	NO	YES
Romania	YES	NO	NO	YES
Slovakia	NO	NO	YES	YES
Slovenia	YES	NO	NO	YES
Spain	YES	NO	NO	YES
Sweden	NO	NO	YES	YES
UK	YES	NO	NO	YES
CIS				
Belarus	YES	NO	NO	YES
Russia	YES	NO	NO	YES
Ukraine	YES	NO	NO	YES
Canada	YES	NO	NO	YES
USA	NO	YES	NO	YES

Appendix 11 Results of CARBINE model simulations for forest bioenergy supply to the EU

A11.1 Introduction

This appendix contains a complete set of results, for all the scenarios developed in this project, based on outputs of the CARBINE forest sector carbon accounting model, representing the development over time of:

- Areas of forest, classified as recently afforested, not under management for production, managed for production etc.
- Levels of wood supply for bioenergy and material wood products
- Forest carbon stocks and carbon sequestration
- Very approximate biogenic carbon emissions factors for forest bioenergy.

Different scenarios developed in this project explicitly recognised that forest biomass could be produced within the EU region and also imported from other countries. It was, therefore, necessary to represent the potential contributions due to forestry in a wide range of relevant regions and countries.

Table A11.1, which is an abbreviated version of Table 1.1 in Section 1.4 of the main final project report, shows how the countries of key regions potentially supplying the EU with forest bioenergy have been represented.

Table A11.1 Representation of countries in regions supplying forest bioenergy to the EU

Region	Representation
EU27	Forests, forest management and wood production in each EU27 Member State were modelled individually. Cyprus and Malta were excluded due to their small forest areas.
CIS	Forests, forest management and wood production were modelled individually for Belarus, European Russia (effectively west of the Urals) and Ukraine
Canada	Forests, forest management and wood production were modelled individually for six ecological zones represented in the Canadian National Forest Inventory
USA	Forests, forest management and wood production were modelled individually for each of the conterminous States of the USA
LAM	Forest bioenergy supplied from the LAM region was assumed to be restricted to production from purpose-grown plantation forests established on abandoned and degraded agricultural land in Brazil. Contributions from Brazil to forest bioenergy supply were not included in all scenarios.

Each page of results in this appendix consists of a matrix of 2 columns by 3 rows of individual graphs of CARBINE model results, as indicated in Table A11.2.

Two sets of results are shown for each combination of scenario and supplying region, one based on the two contrasting possible approaches to forest management and wood use, as developed in this project, referred to as the ‘Precautionary’ approach and the

'Synergistic' approach. Further details are given in Section 4.8 of the main final project report.

It should be noted that:

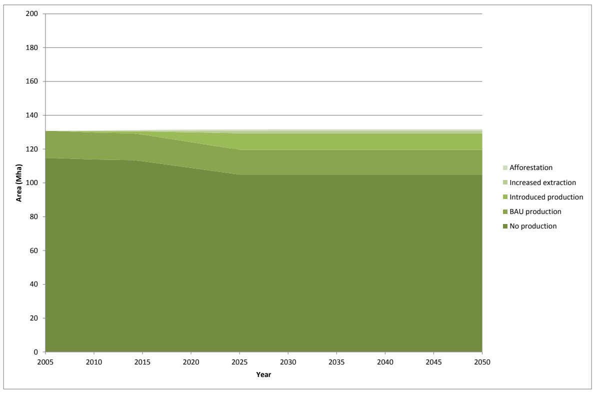
There are no results for forest biomass supply to the EU region from the LAM region under the 'Precautionary' approach to forest management and wood use. As explained in Sections 4.7.2 and 4.8.2, the assumptions developed for the 'Precautionary' approach do not include the supply of forest bioenergy from the LAM region to the EU region for use of energy.

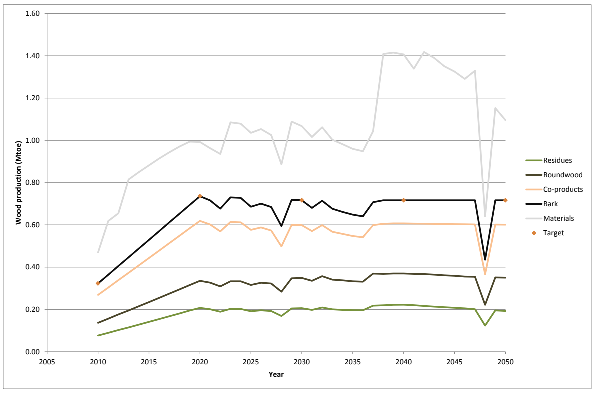
Under the 'Synergistic' approach to forest management and wood use, results are reported for forest biomass supply to the EU region from the LAM region. However, there are no results for the marginal impacts on the supply of material wood products, as a consequence of changes in forestry practice and patterns of wood use in response to increased requirements for forest bioenergy in the EU region. This is because, as explained in Section 4.8.3 of the main final report, the modelling of forest bioenergy supply to the EU region from the LAM region assumed this would involve the establishment of high-productivity plantations dedicated to bioenergy production on formerly degraded agricultural land. Biomass production from these plantations was assumed to be entirely for use of energy, with no impacts on the supply of material wood products.

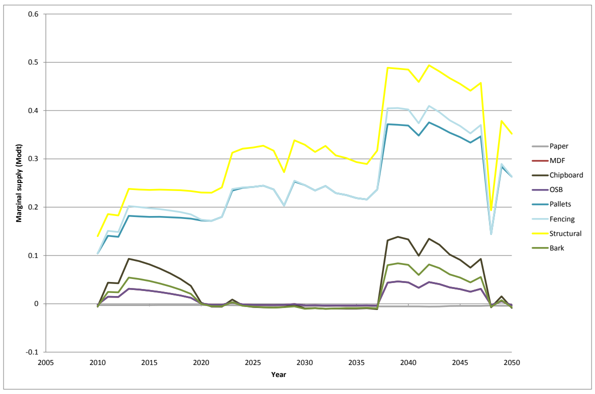
Table A11.2 Representation of countries in regions supplying forest bioenergy to the EU

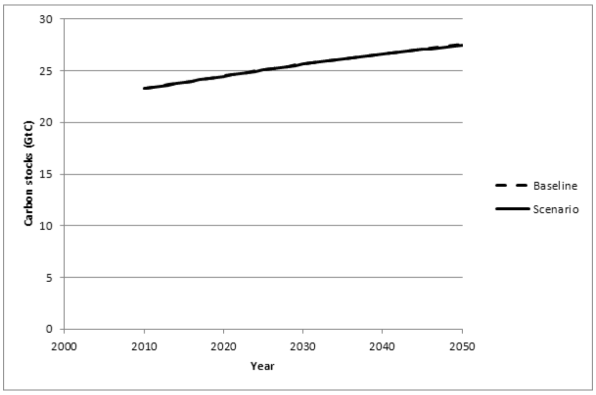
Position in matrix of results	
The projected development of forest areas over time, classified as recently afforested, not under management for production, managed for production etc. (See Section 4.10.1.)	The projected supply of forest bioenergy over time to the EU region. The simulated forest bioenergy supply is broken down into the woody biomass categories of: • Harvest residues (abbreviated to 'Residues' in the figures) • Small roundwood (abbreviated to 'Roundwood' in the figures) • Sawmill co-products (abbreviated to 'Co-products' in the figures) • Bark. (See Section 4.10.2.)
The projected marginal impacts on the supply of material wood products, as a consequence of changes in forestry practice and patterns of wood use in response to increased requirements for forest bioenergy. The simulated marginal supply is broken down into the categories of finished material wood products of woody biomass categories of: • Paper • Three categories of wood-based panels, medium density fibreboard (MDF), chipboard and oriented strand board (OSB) • Pallets (may also include some wood used for packaging) • Fencing (may also include some wood used for joinery) • Structural timber • Bark. (See Section 4.10.3.)	The projected development of carbon stocks in forests in the EU27 region, as a consequence of changes in forestry practice and patterns of wood use in response to increased requirements for forest bioenergy. For comparison, the figures also show the projected development of forest carbon stocks under the baseline or counterfactual scenario. The example in Figure 4.35 is based on results for Scenario A ('Reference') and the 'Precautionary' approach to forest management and patterns of wood use (see Section 4.8.3). Figure 4.36 is also based on Scenario A but involves the 'Synergistic' approach. The simulated result for development of carbon stocks include contributions from: • Tree biomass • Litter • Soil organic matter. The results are in units of GtC. (See Section 4.10.5.)
The projected development of very approximate estimates of **annual** biogenic carbon emissions factors for forest bioenergy, as supplied from different sources under the scenarios developed in this project. (See Section 4.10.6.)	The projected development of very approximate estimates of **cumulative** biogenic carbon emissions factors for forest bioenergy, as supplied from different sources under the scenarios developed in this project. (See Section 4.10.6.)

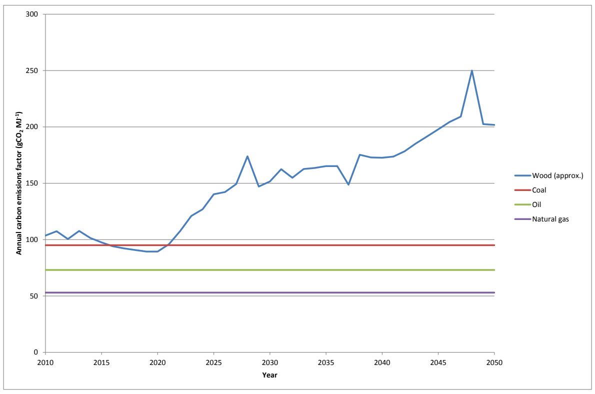
All scenarios, ‘Precautionary’ & ‘Synergistic’ approaches, CIS

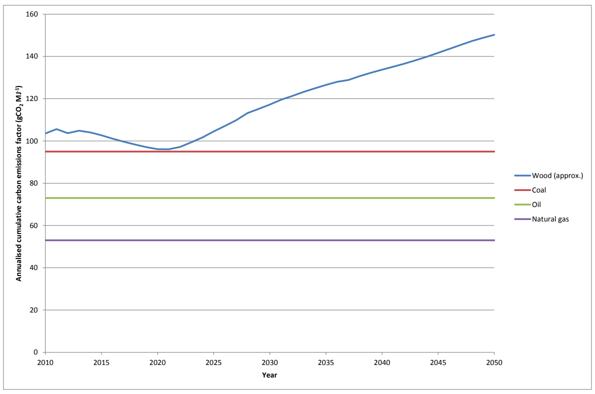




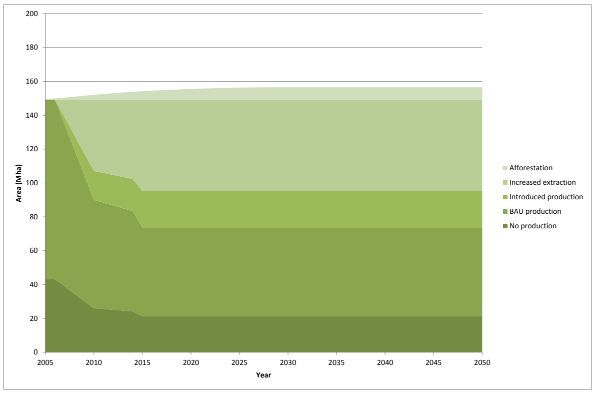


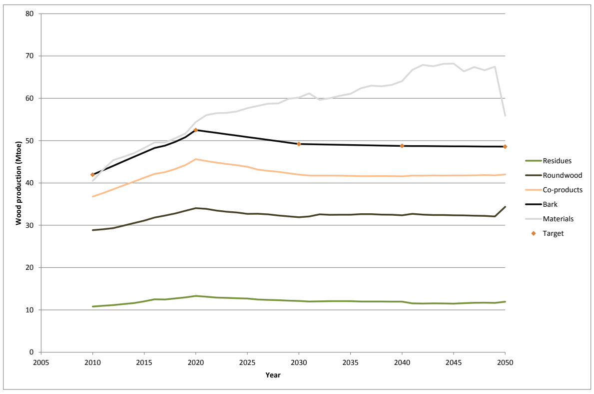


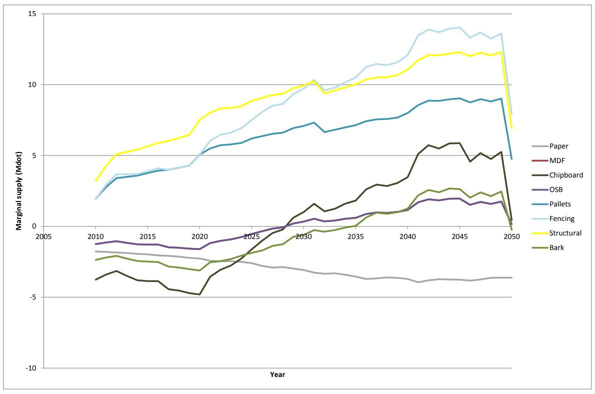


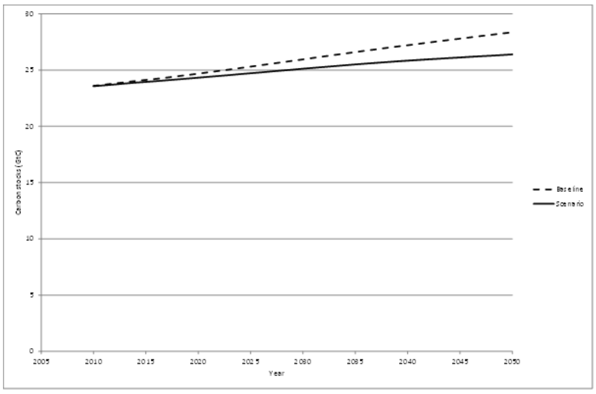


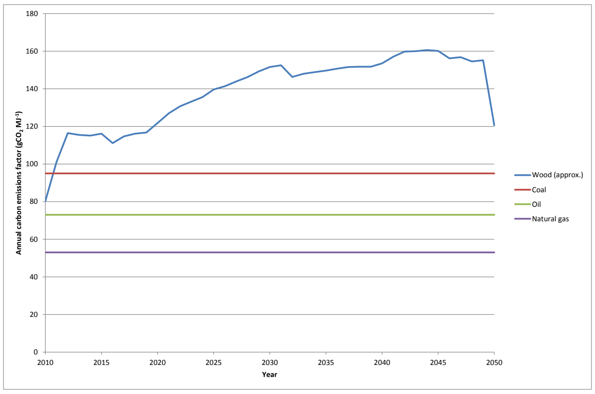
Scenario A, 'Precautionary' approach, EU27

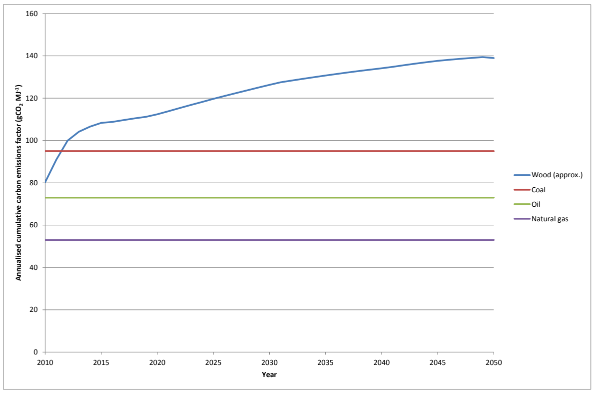




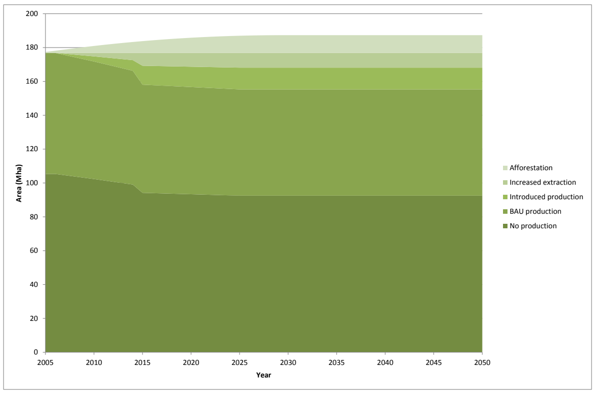


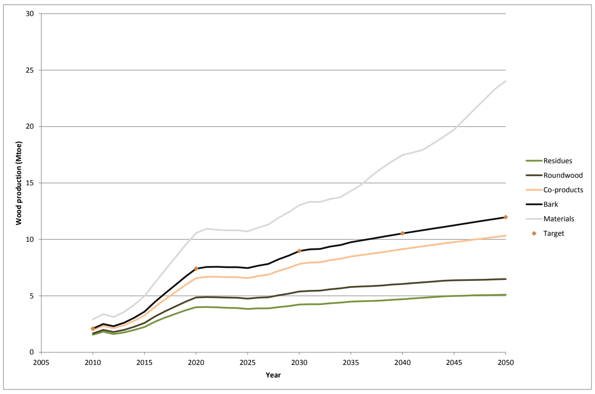


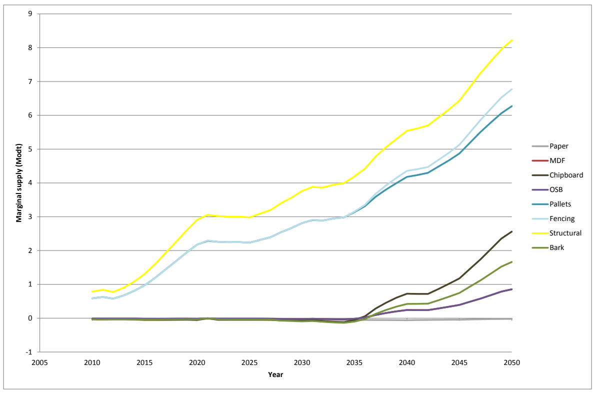


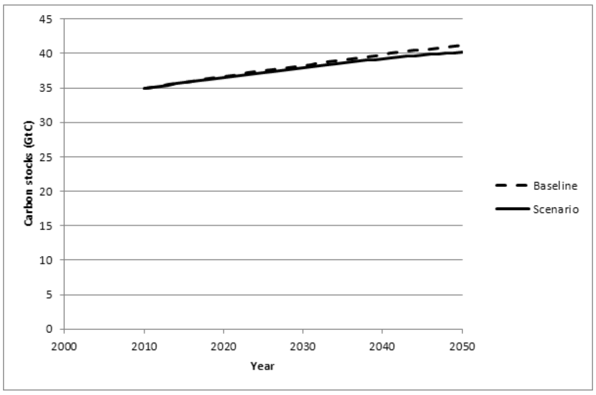


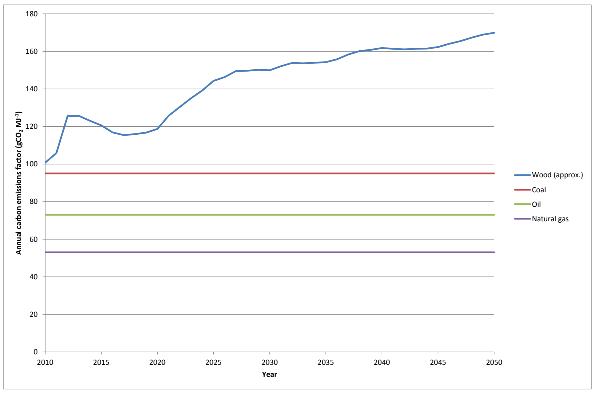
Scenario A, ‘Precautionary’ approach, USA

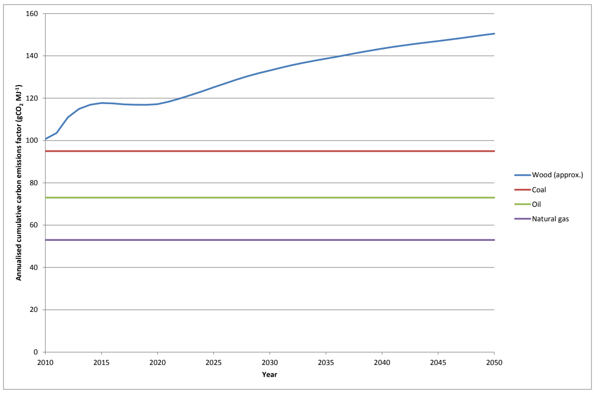




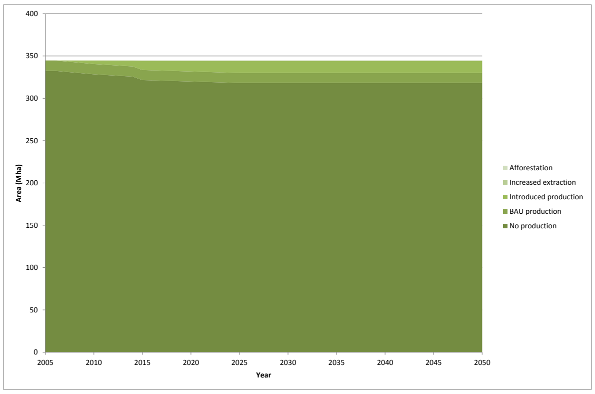


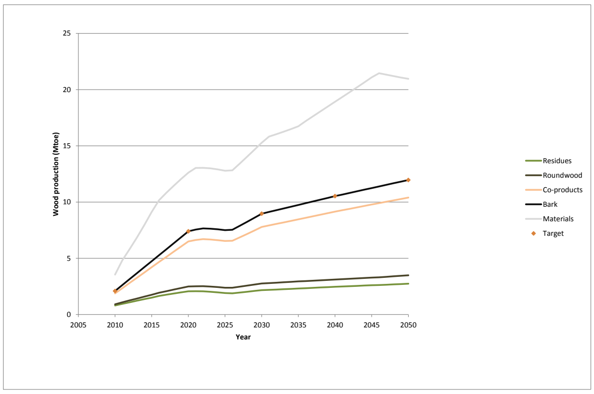


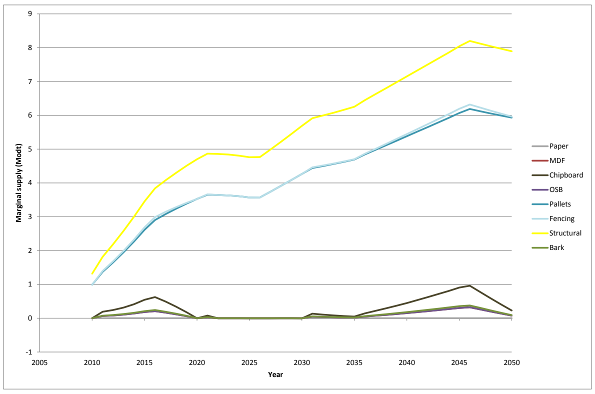


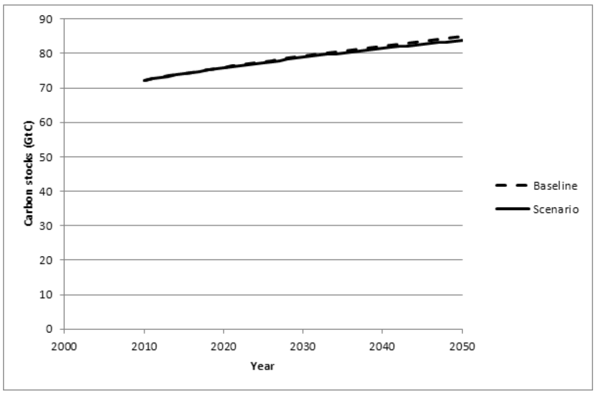


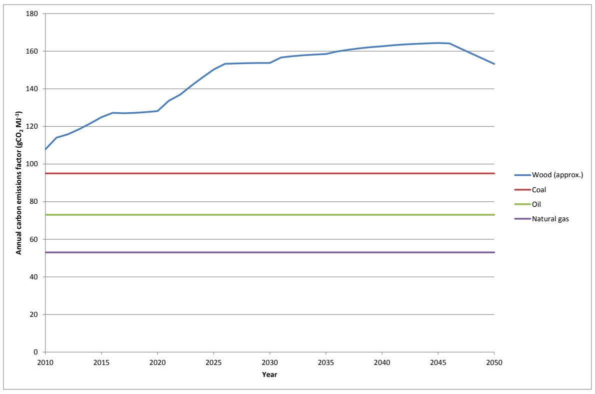
Scenario A, 'Precautionary' approach, Canada

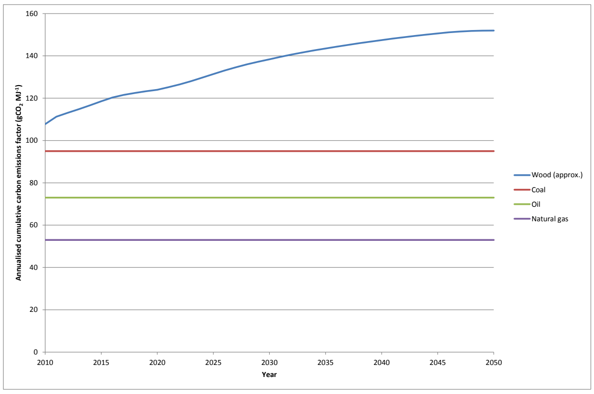




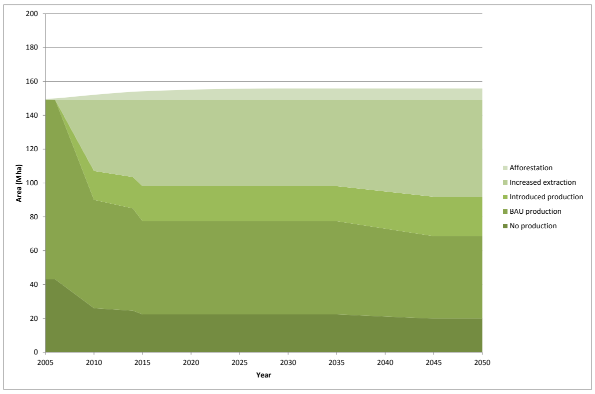


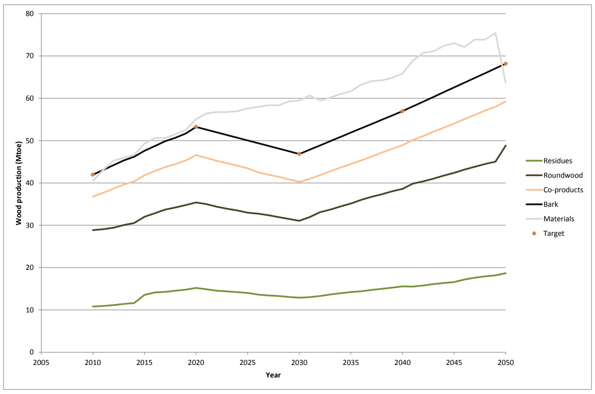


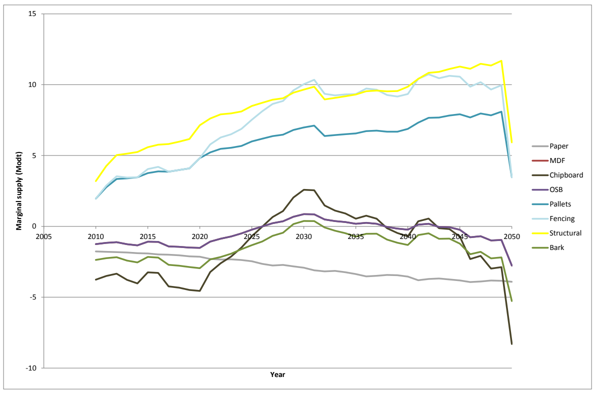


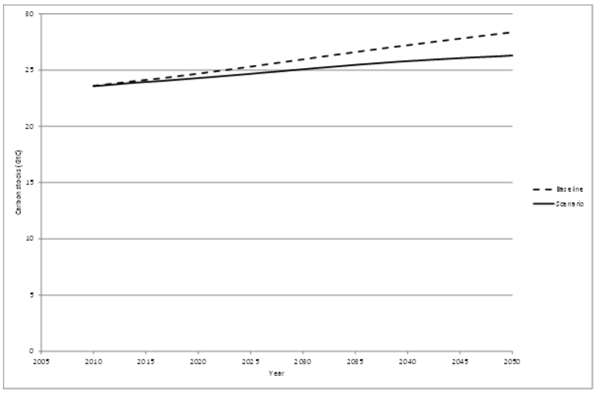


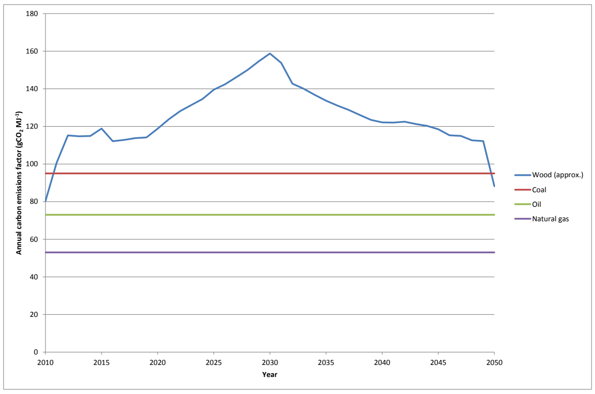
Scenario B, 'Precautionary' approach, EU27

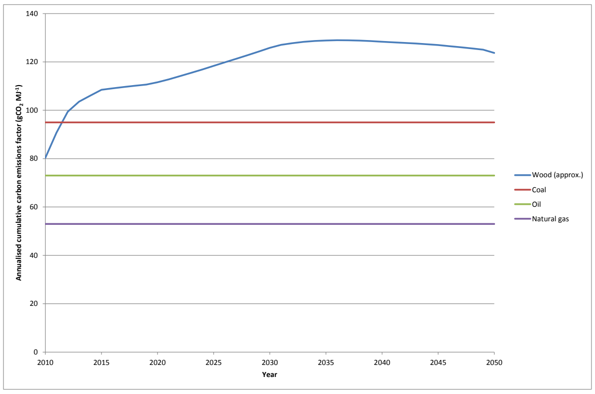




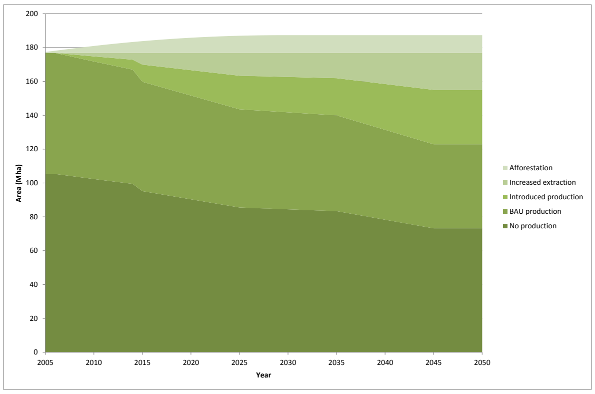


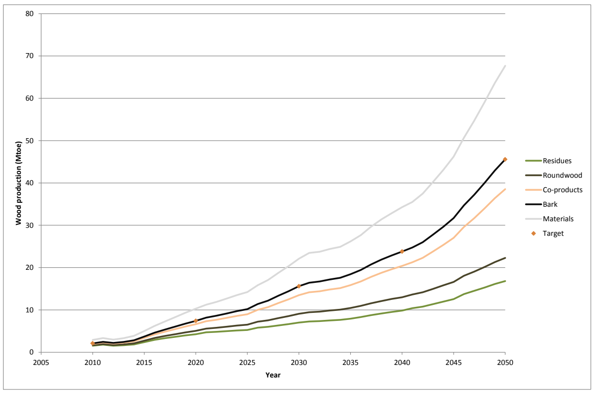


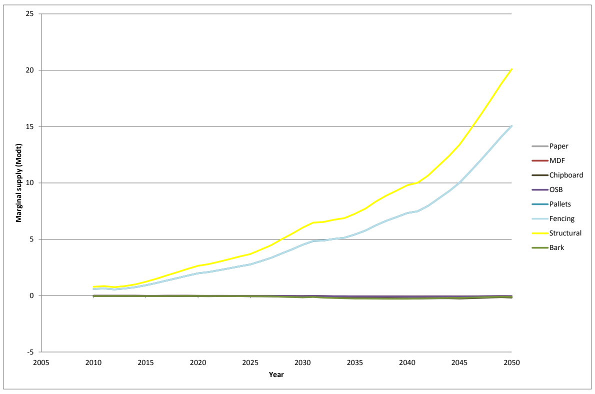


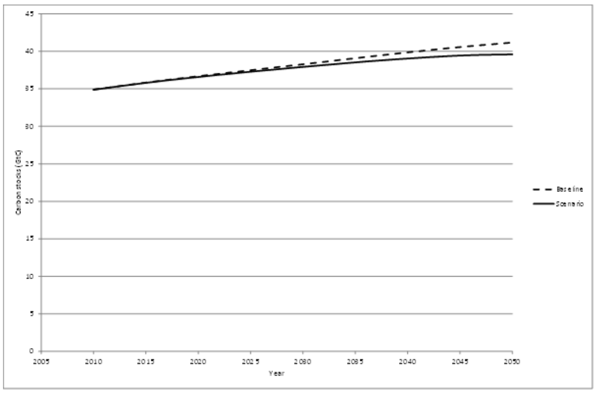


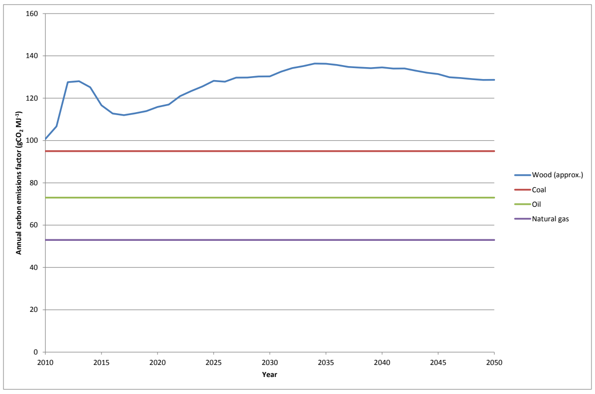
Scenario B, 'Precautionary' approach, USA

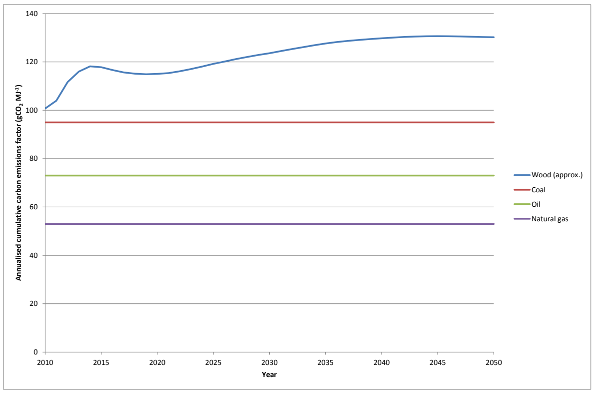




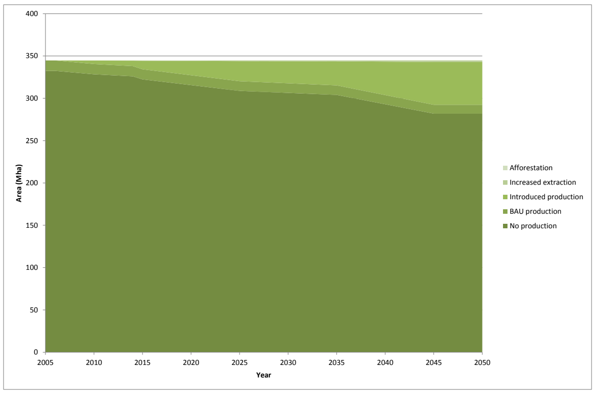


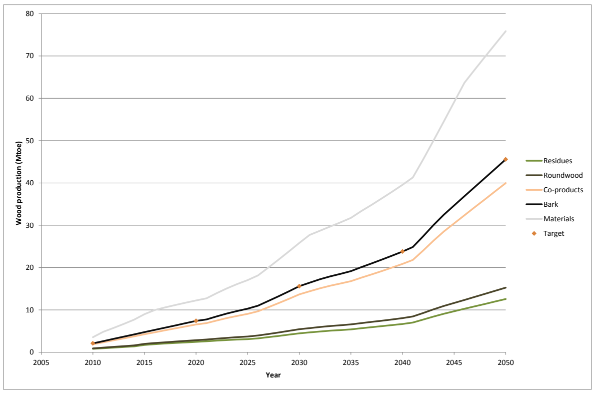


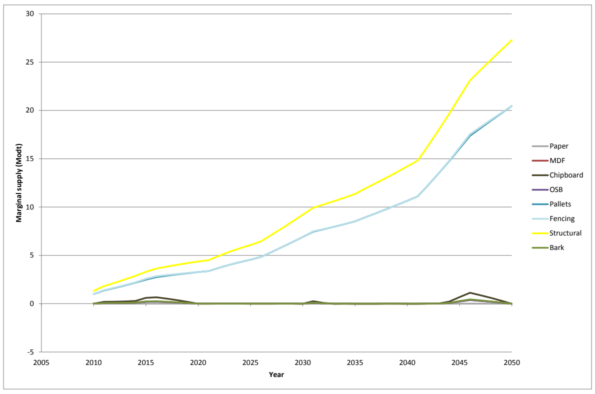


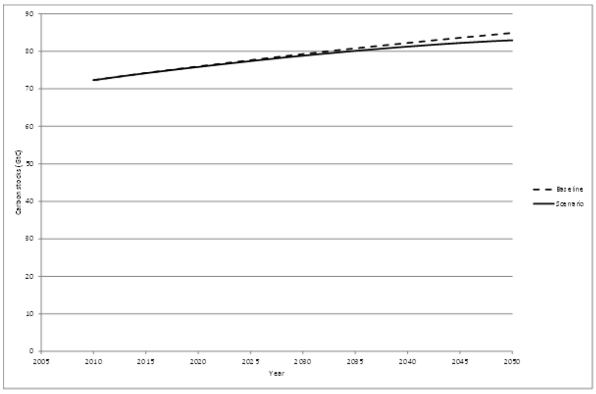


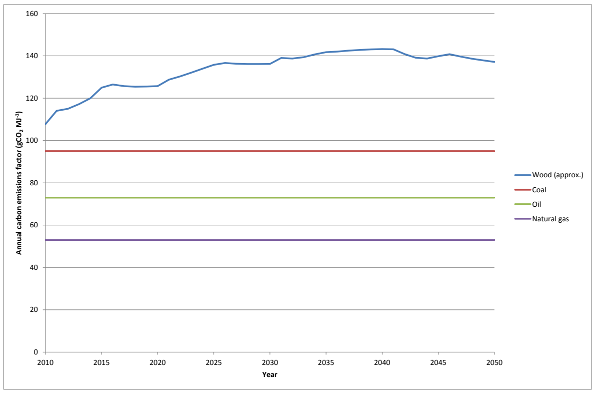
Scenario B, 'Precautionary' approach, Canada

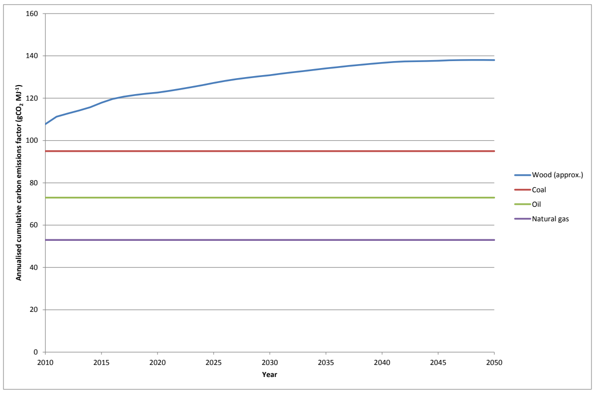




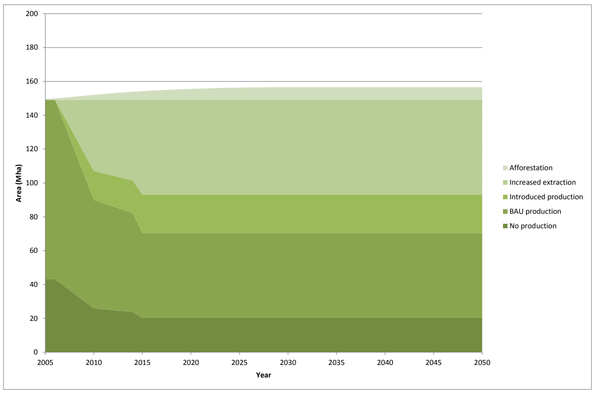


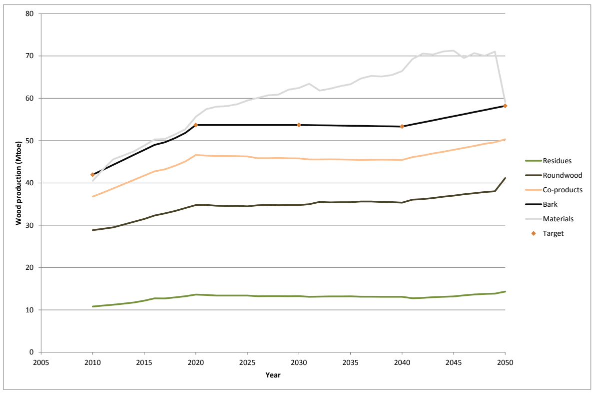


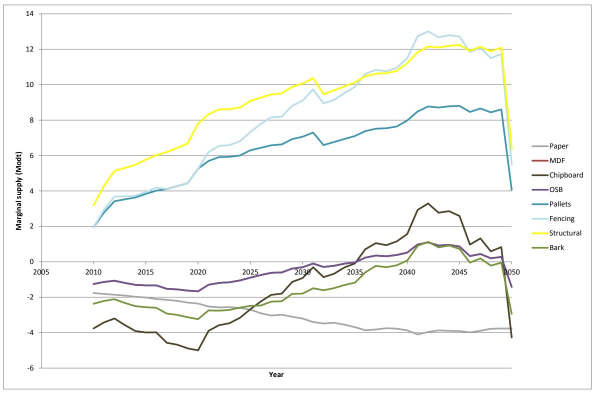


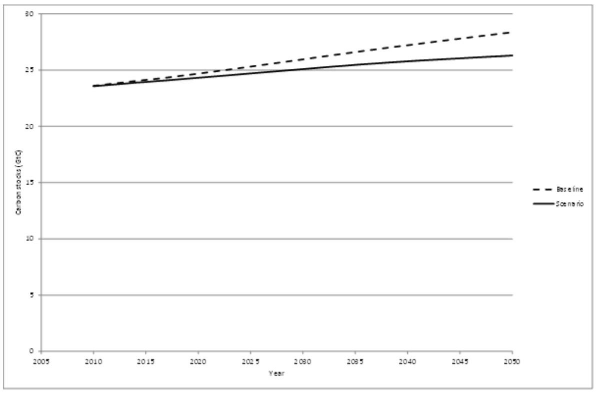


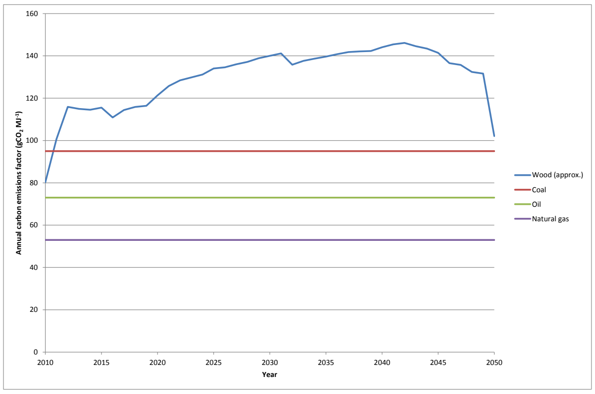
Scenario C1, 'Precautionary' approach, EU27

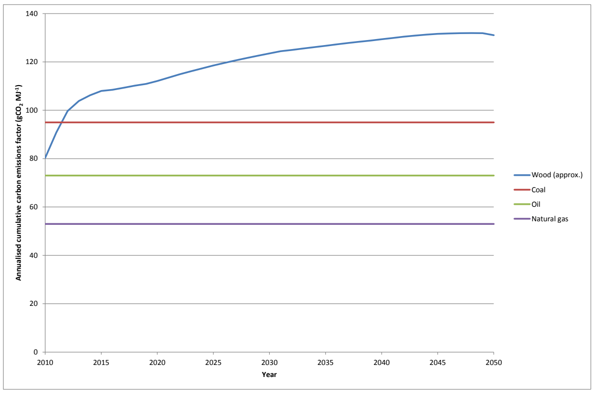




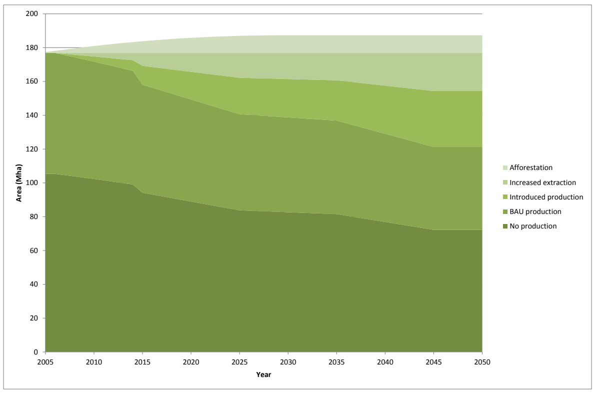


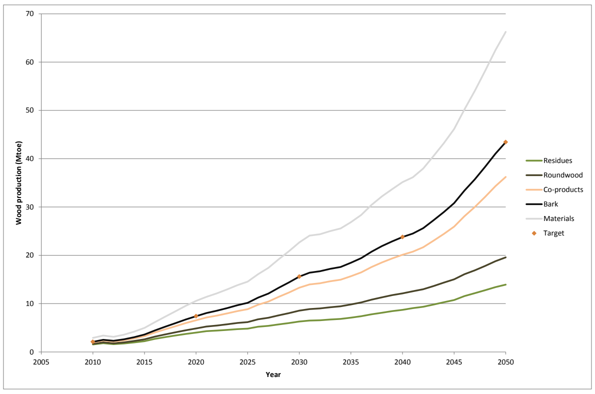


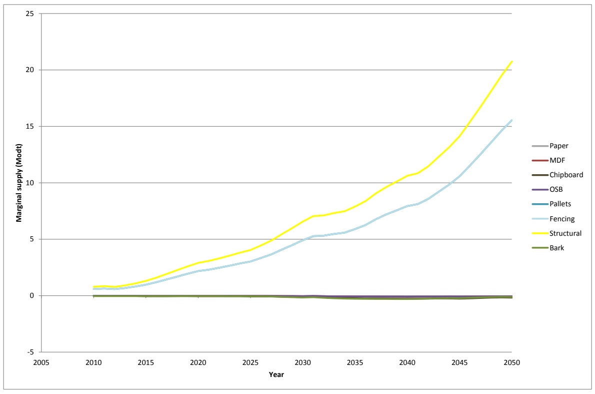


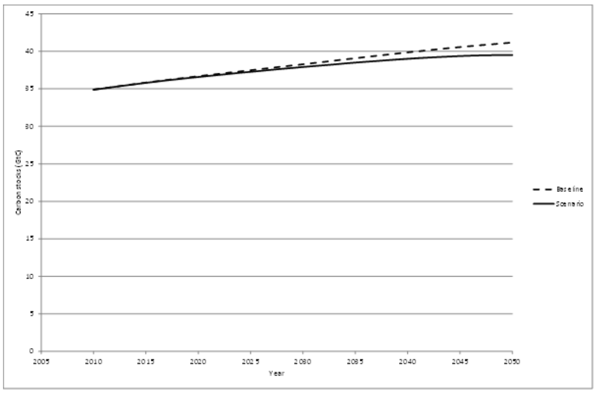


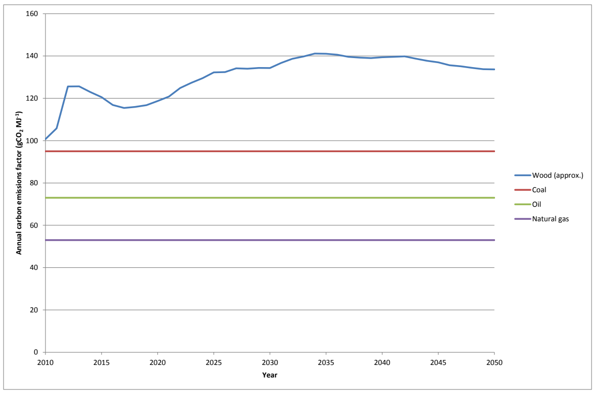
Scenario C1, 'Precautionary' approach, USA

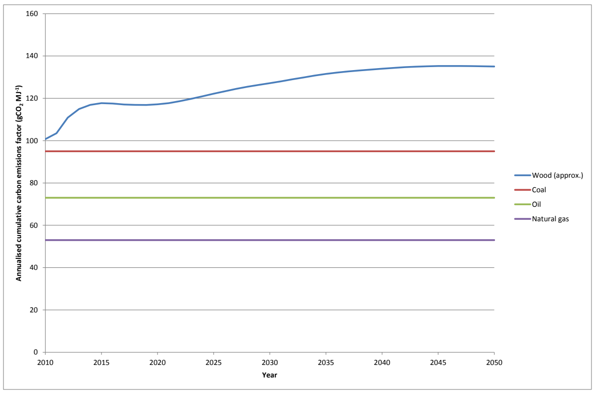




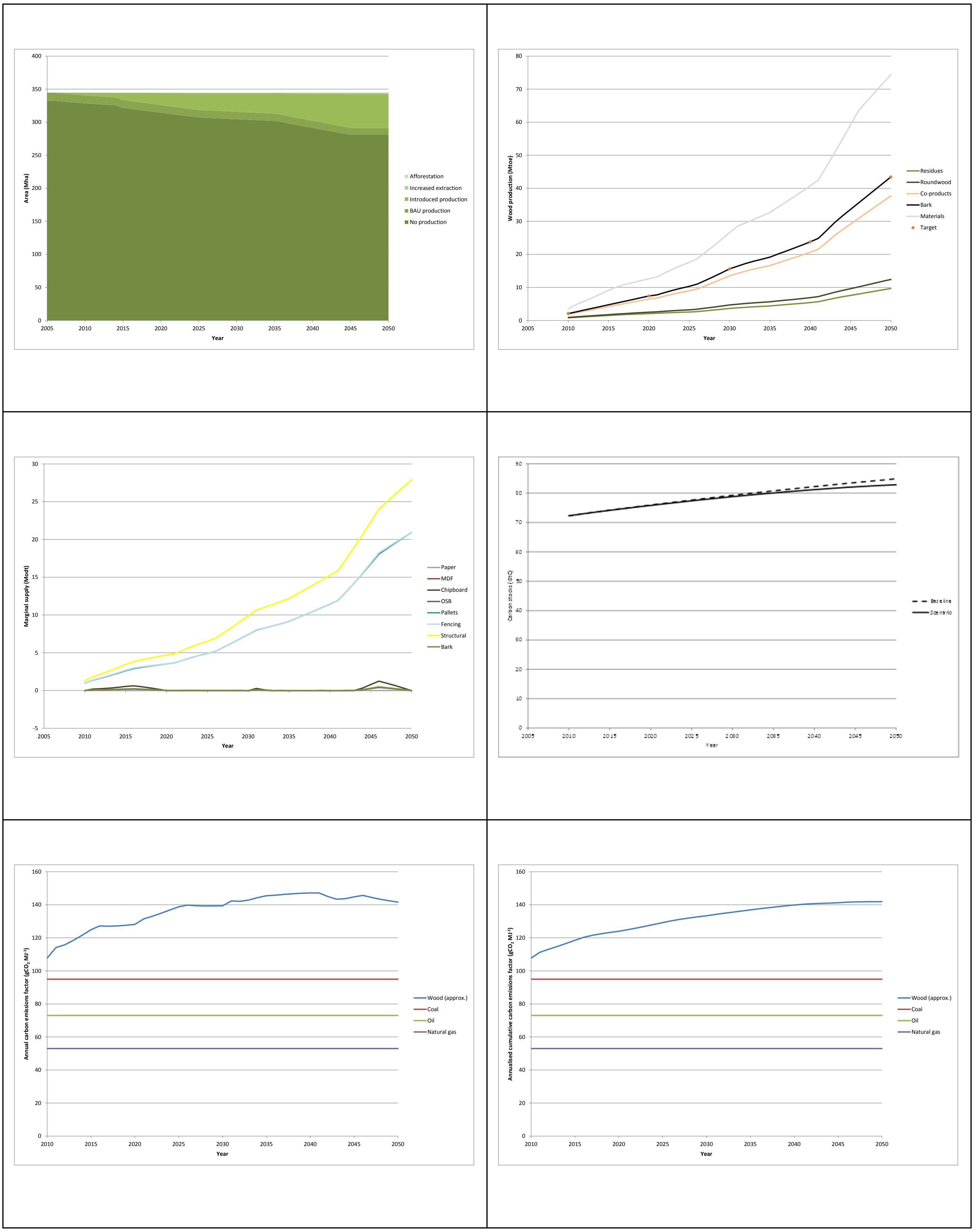




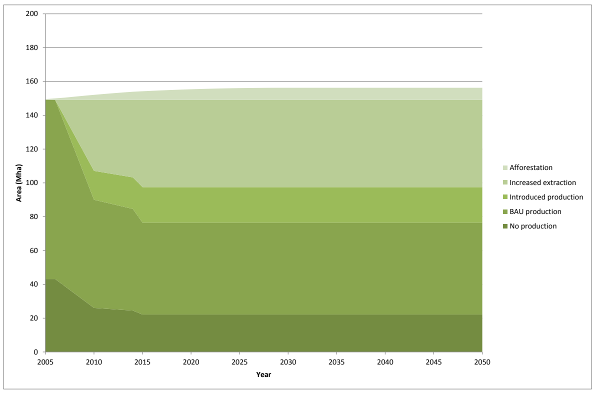


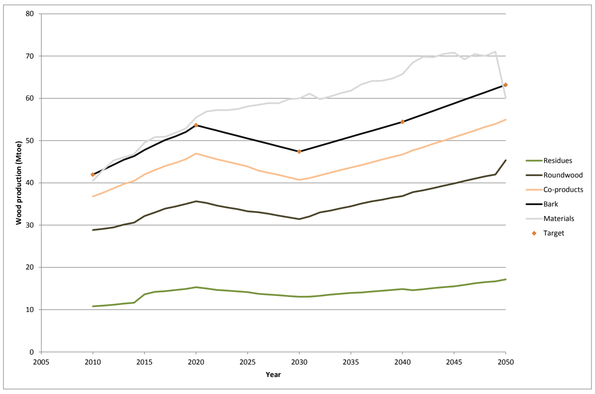


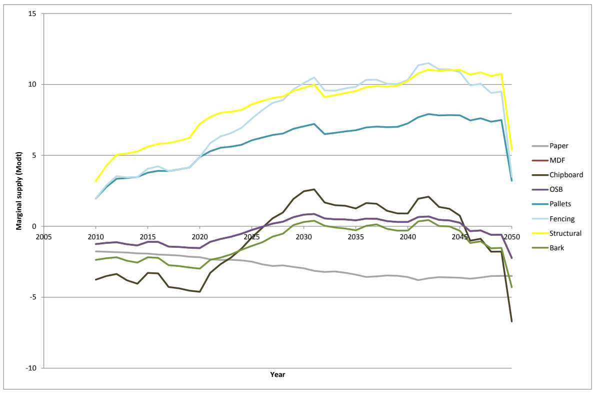
Scenario C1, 'Precautionary' approach, Canada

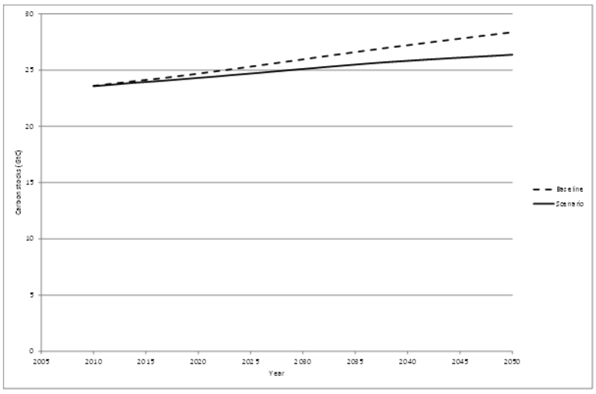


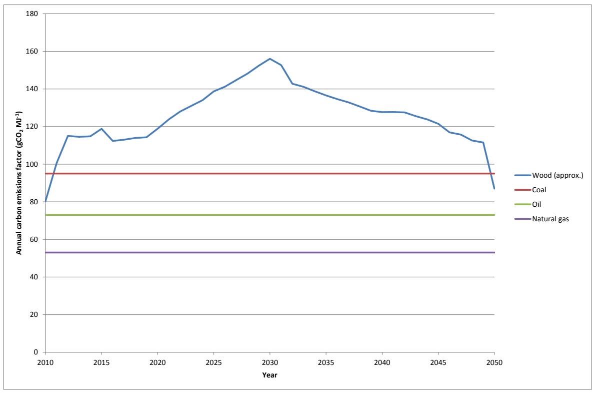
Scenario C2, 'Precautionary' approach, EU27

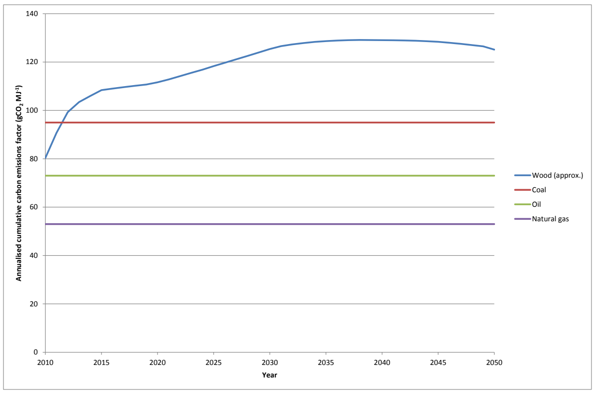




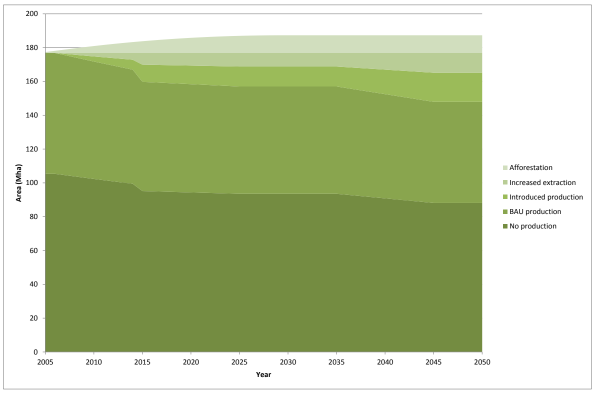


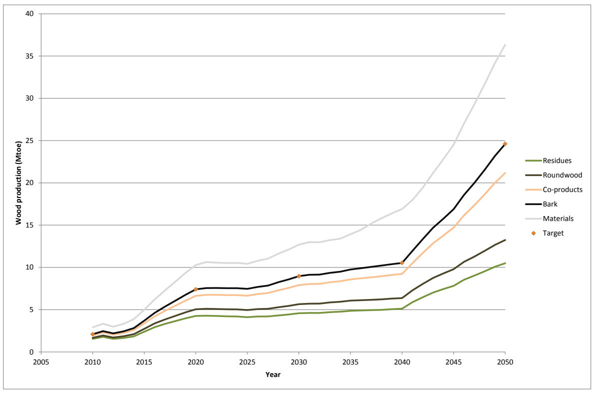


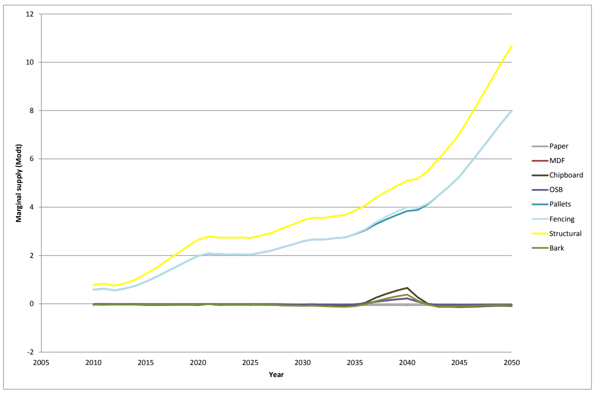


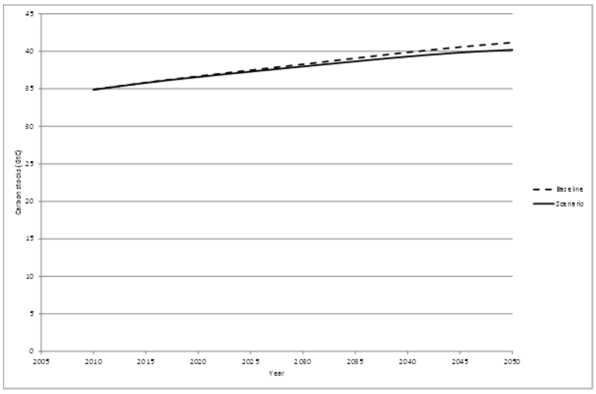


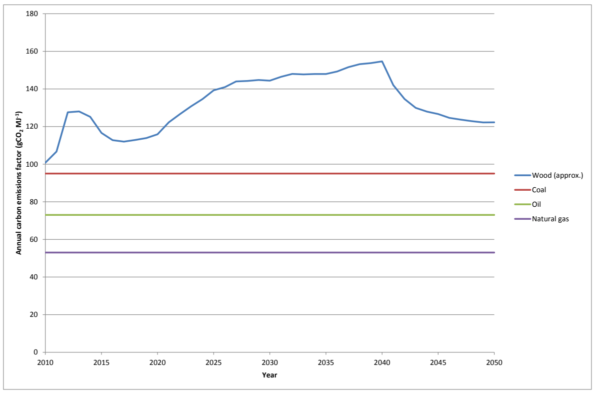
Scenario C2, 'Precautionary' approach, USA

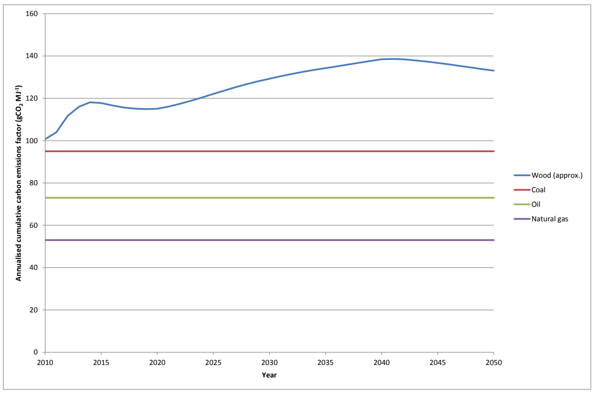




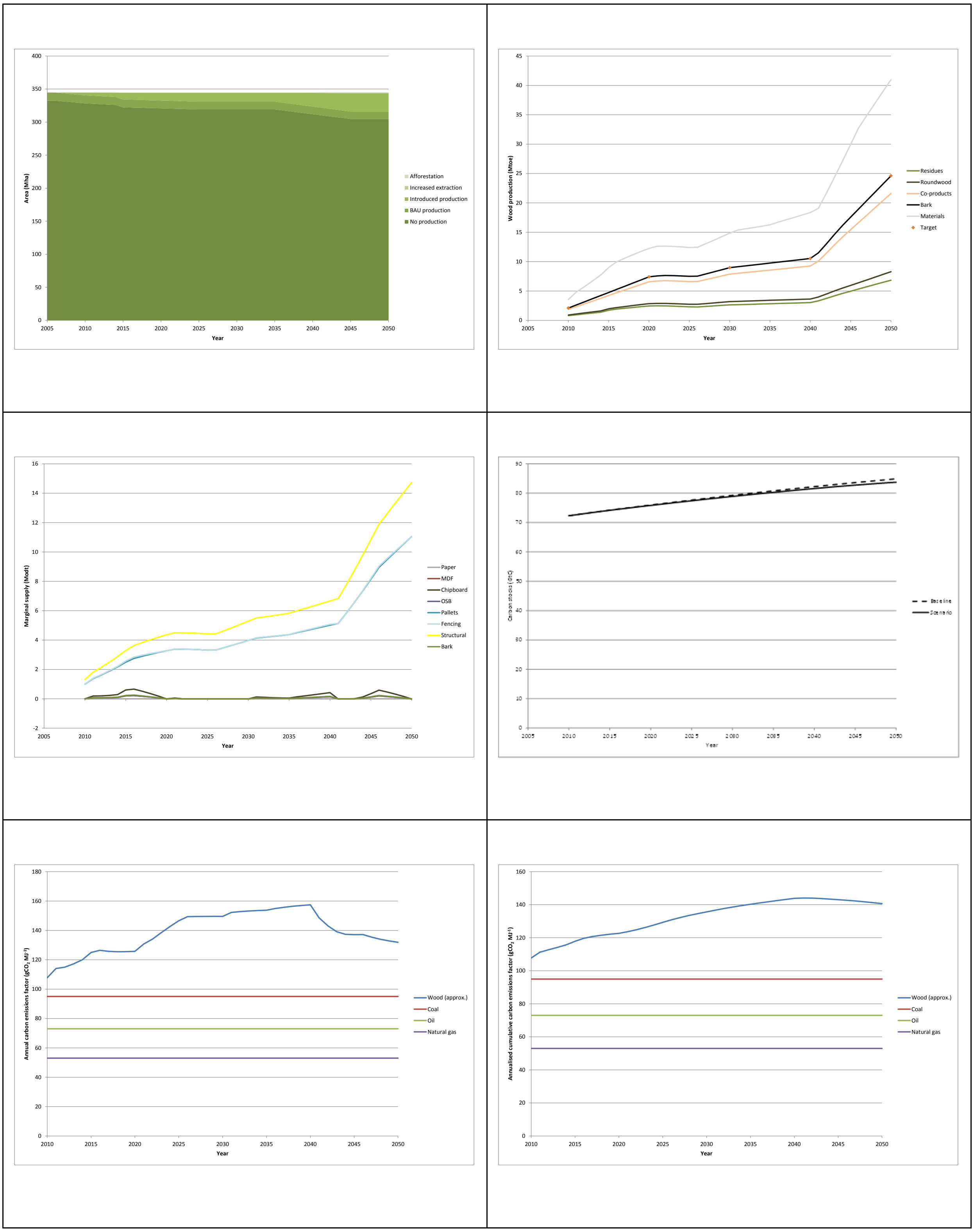




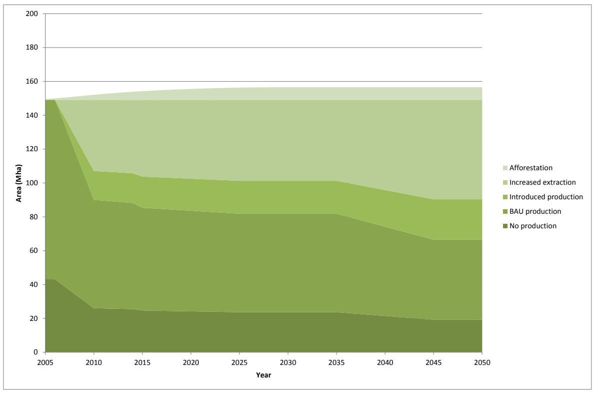


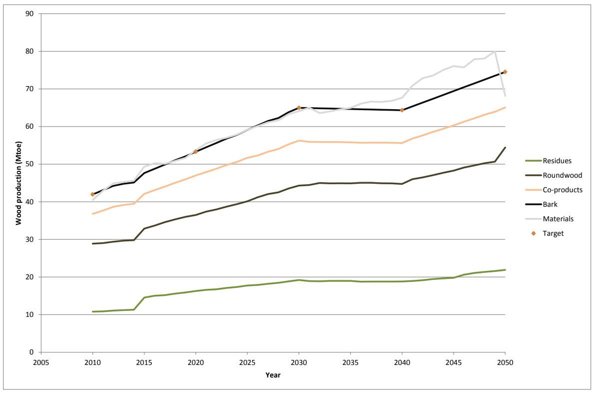


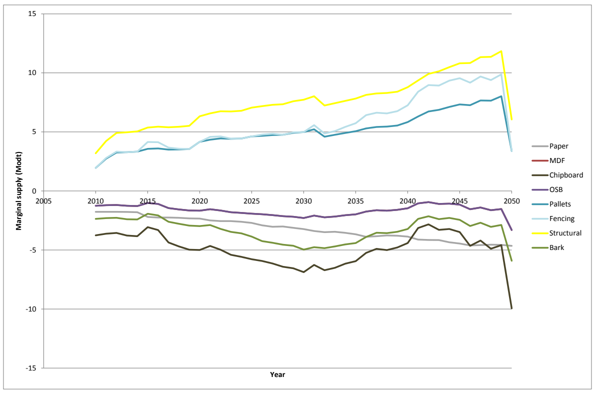
Scenario C2, 'Precautionary' approach, Canada

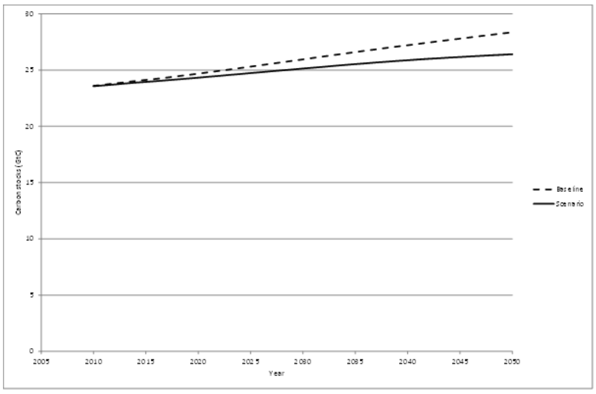


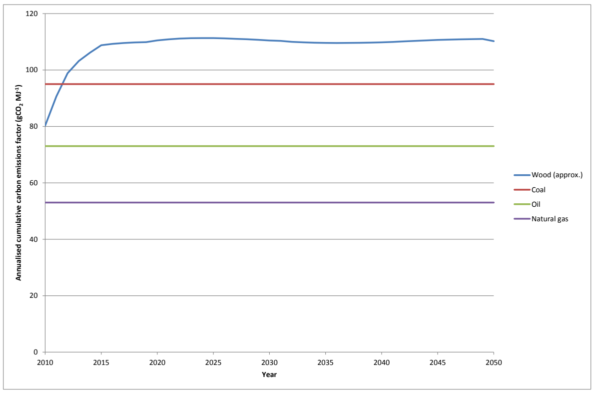
Scenario C3, 'Precautionary' approach, EU27



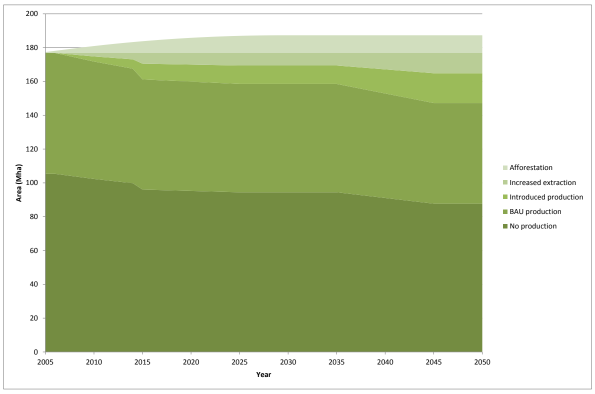


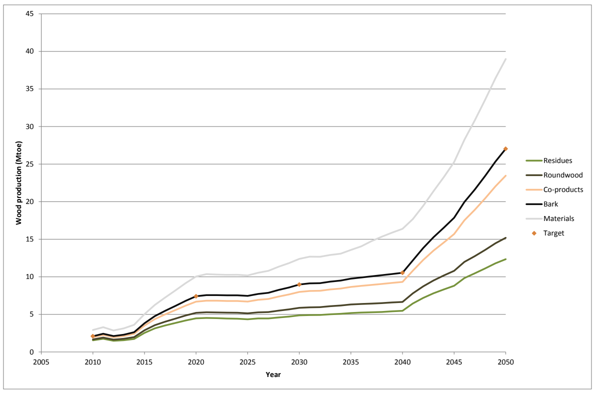


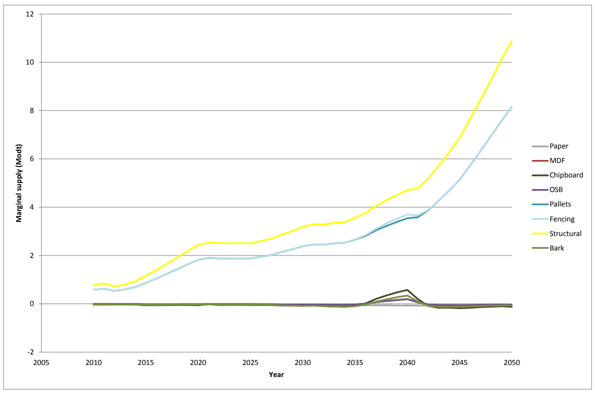


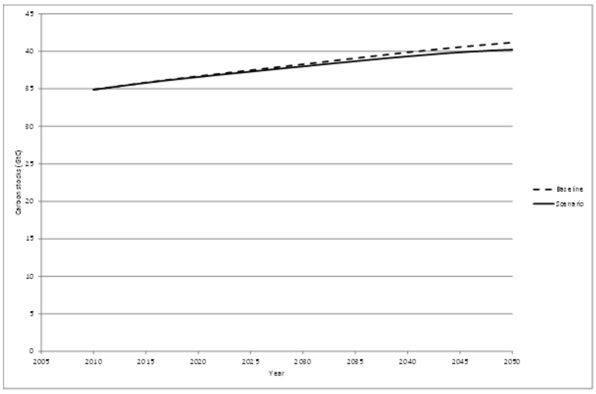


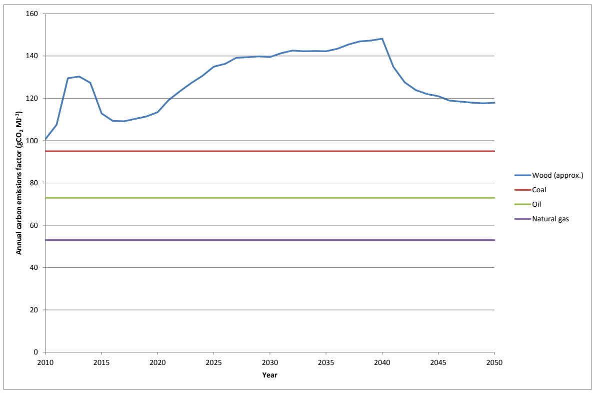
Scenario C3, 'Precautionary' approach, USA

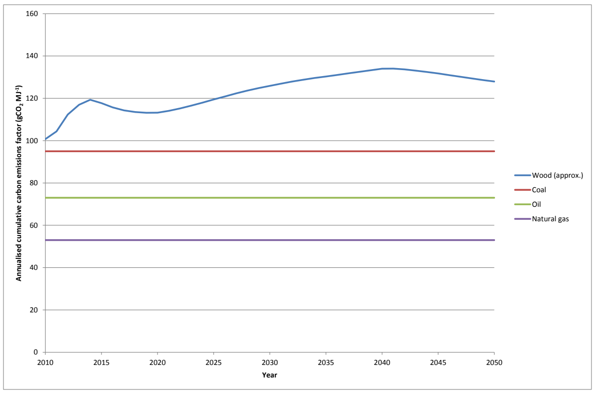




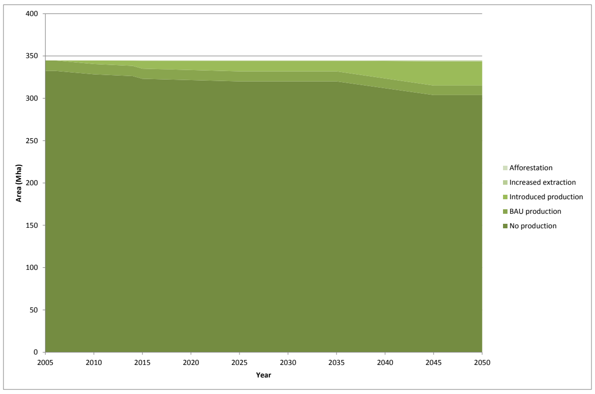


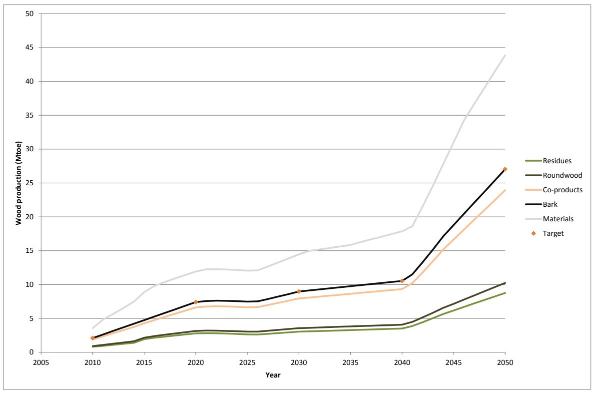


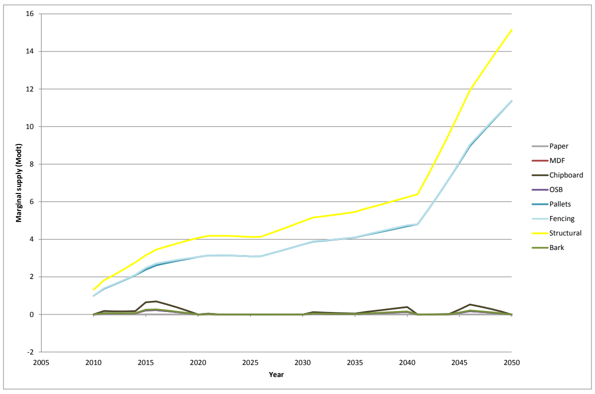


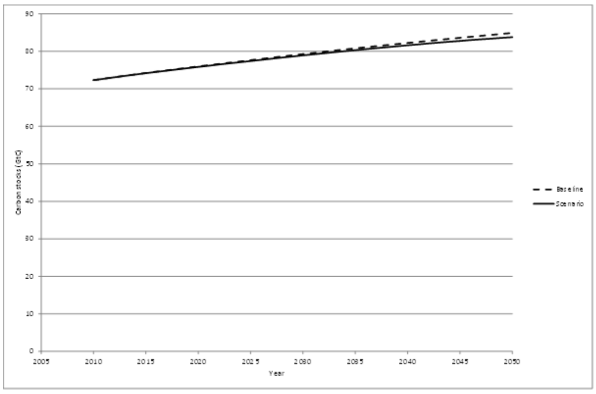


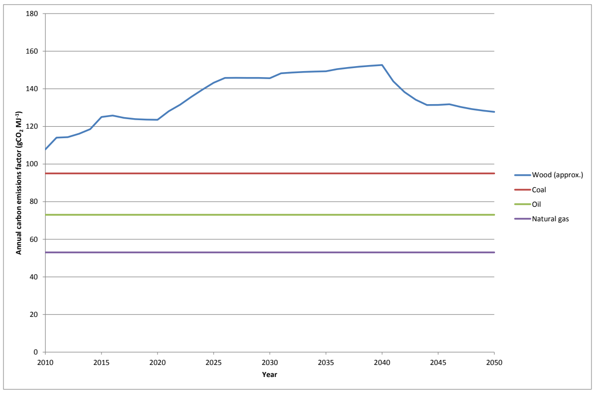
Scenario C3, 'Precautionary' approach, Canada

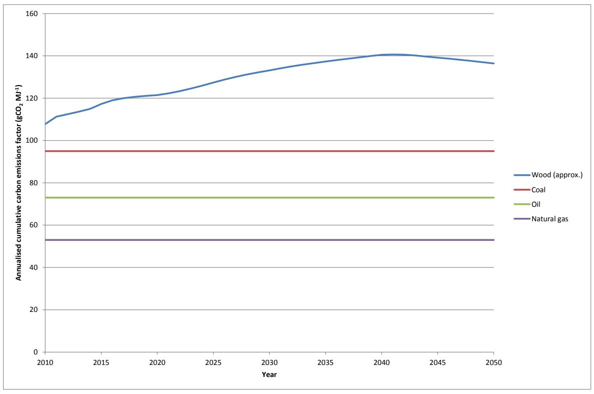




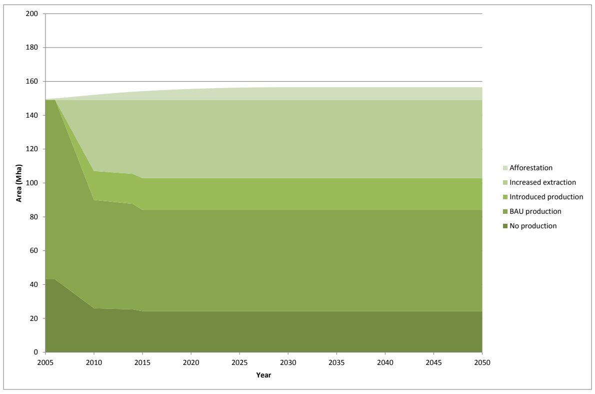


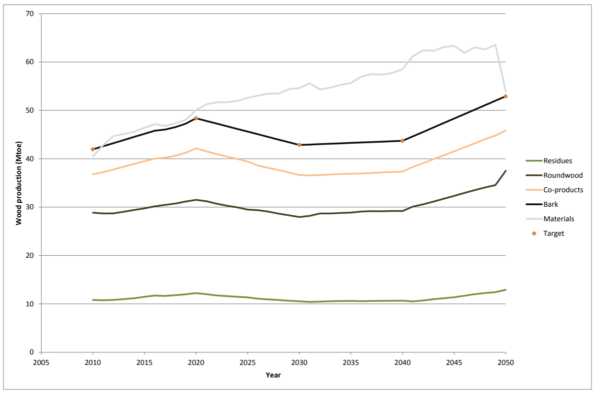


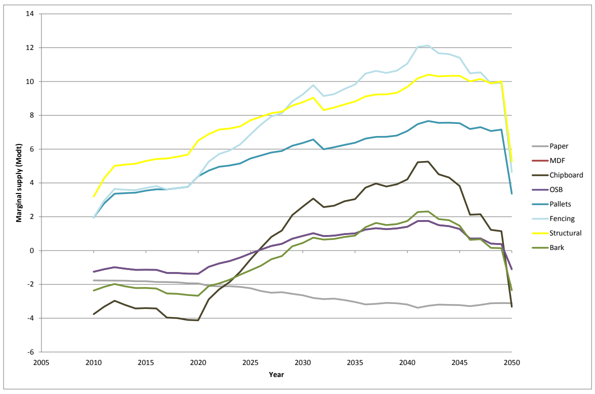


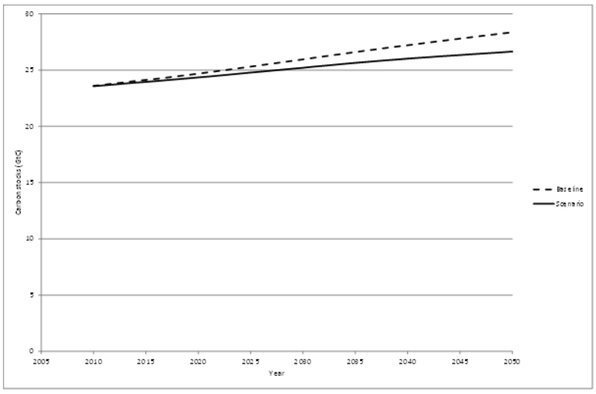


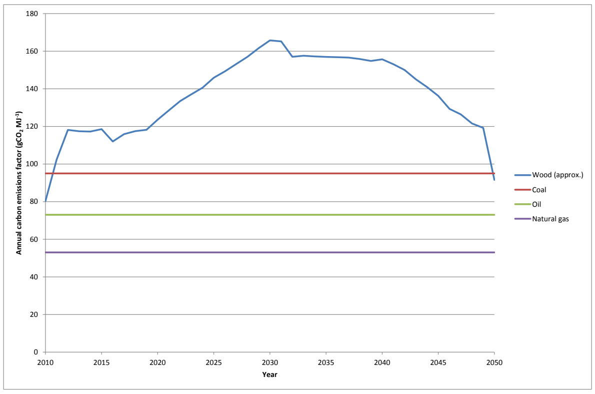
Scenario D, 'Precautionary' approach, EU27

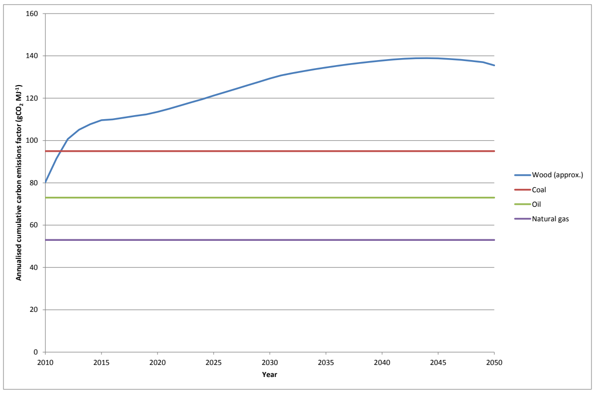




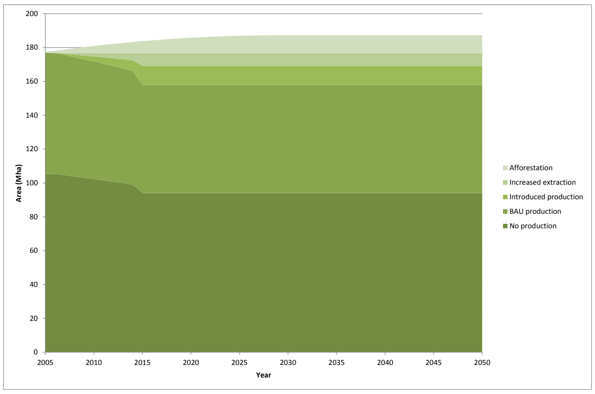


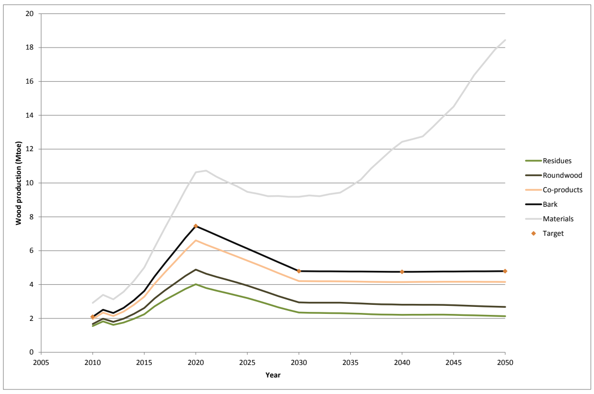


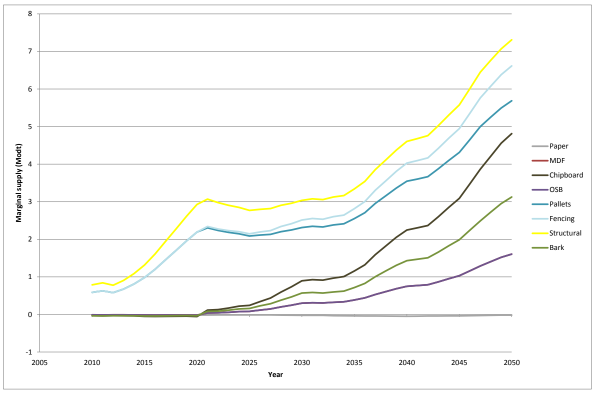


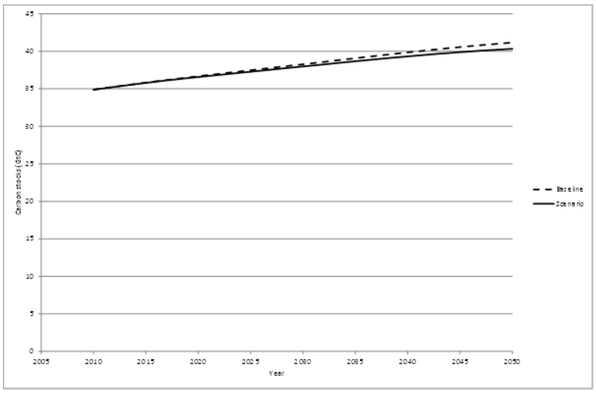


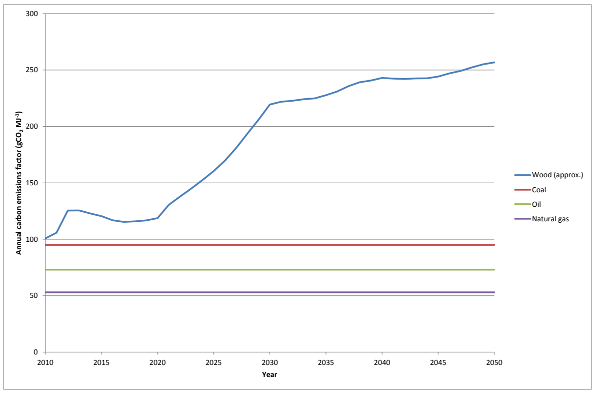
Scenario D, ‘Precautionary’ approach, USA

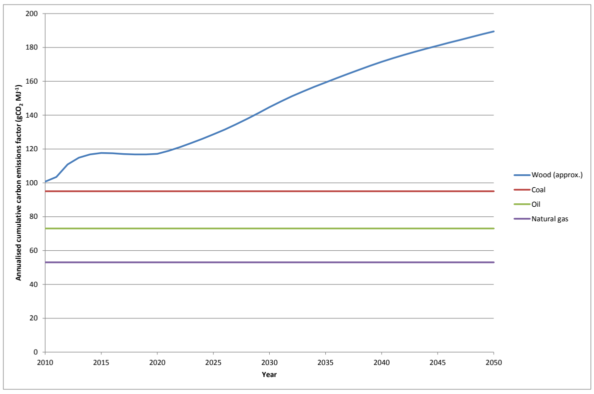




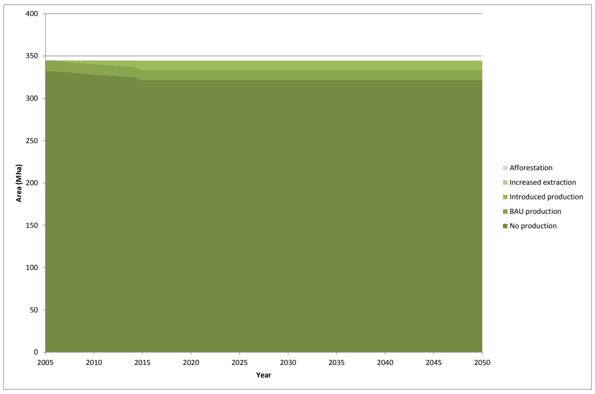


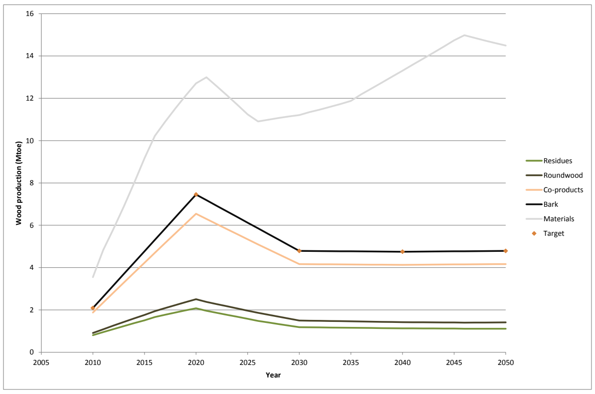


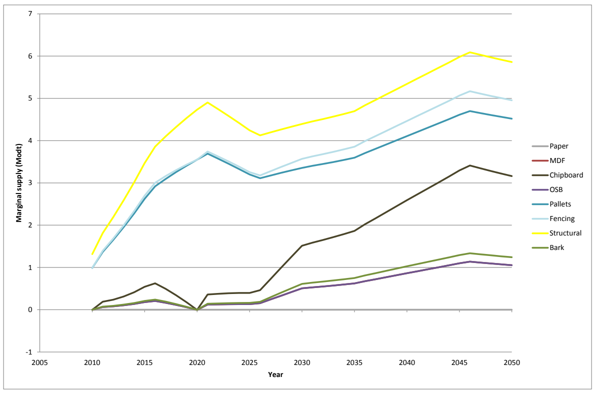


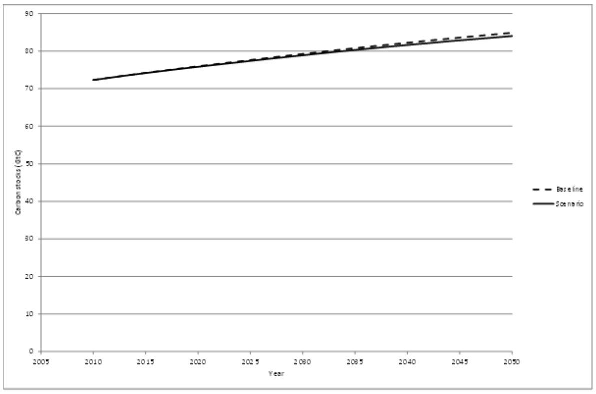


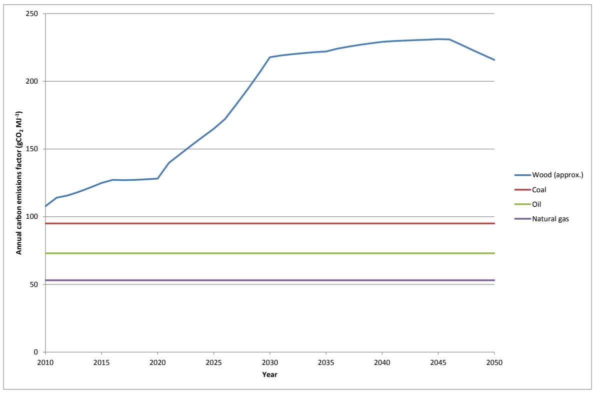
Scenario D, 'Precautionary' approach, Canada

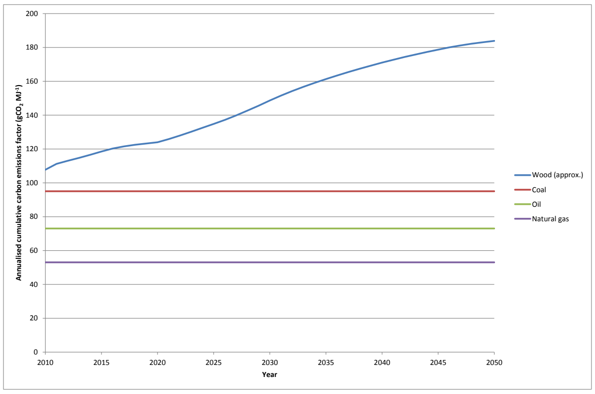




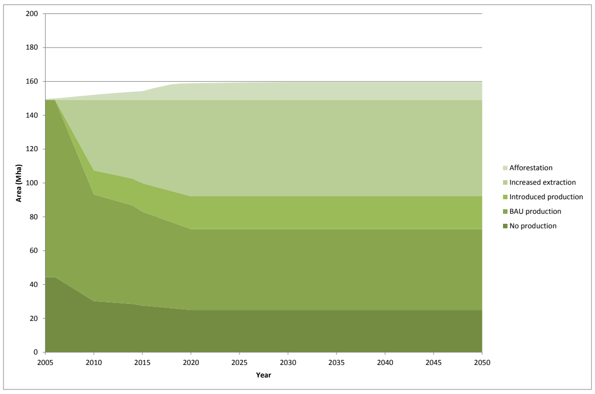


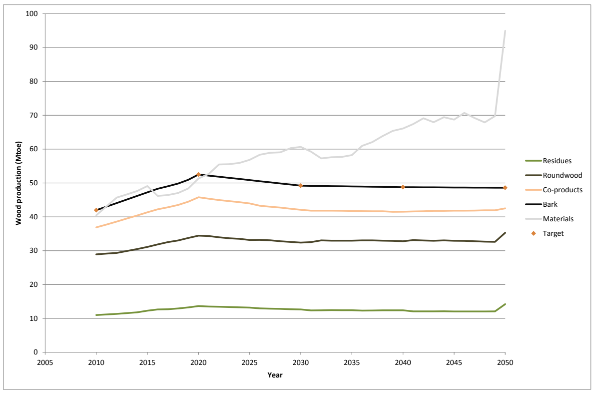


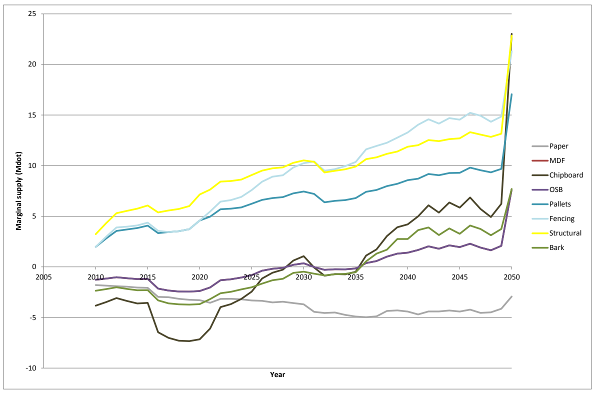


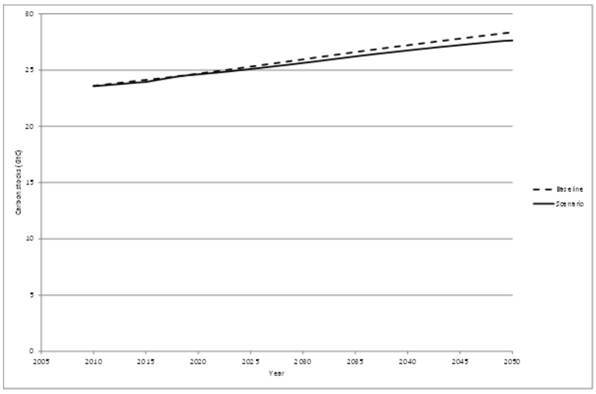


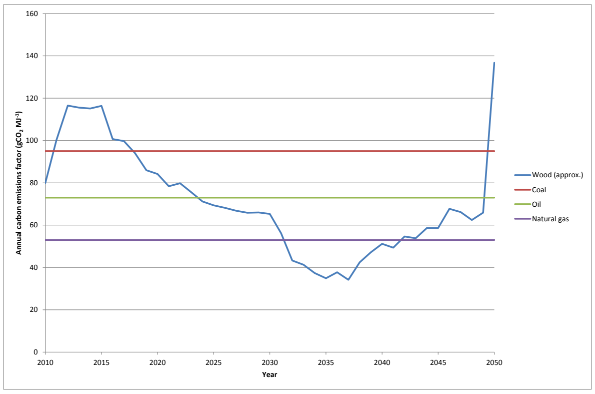
Scenario A, 'Synergistic' approach, EU27

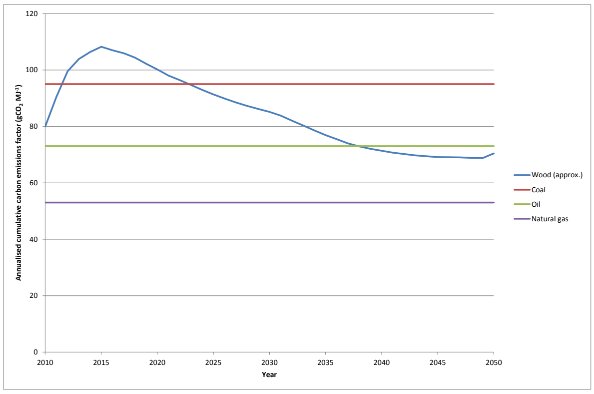




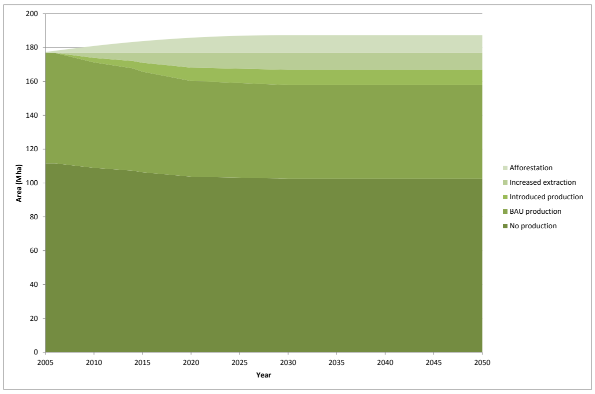


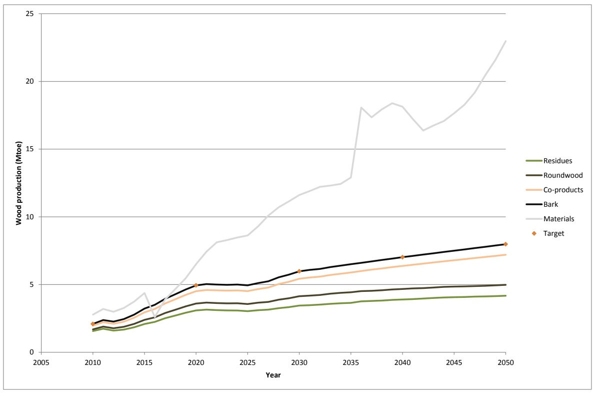


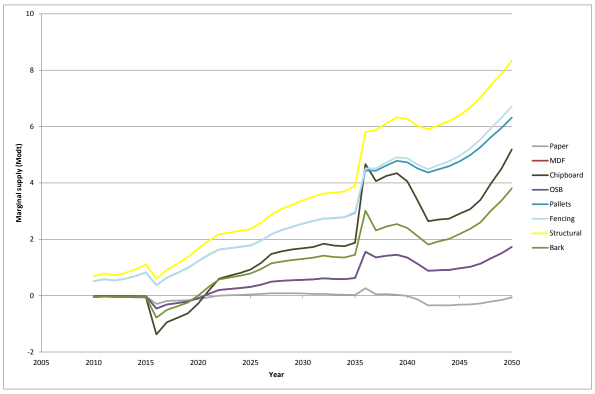


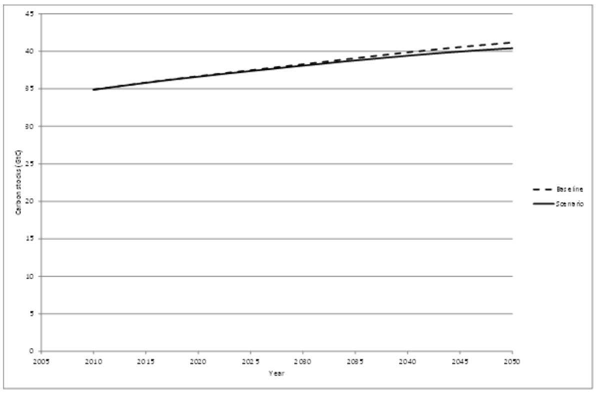


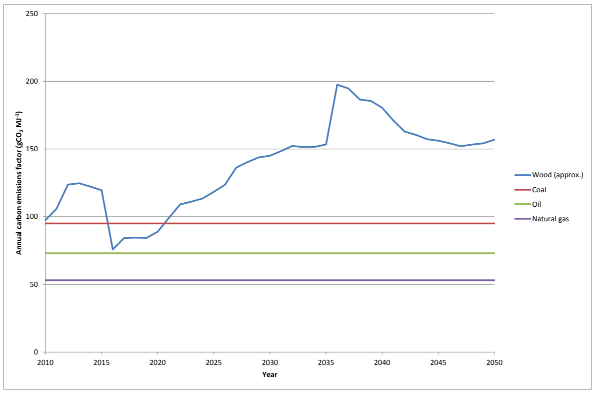
Scenario A, 'Synergistic' approach, USA

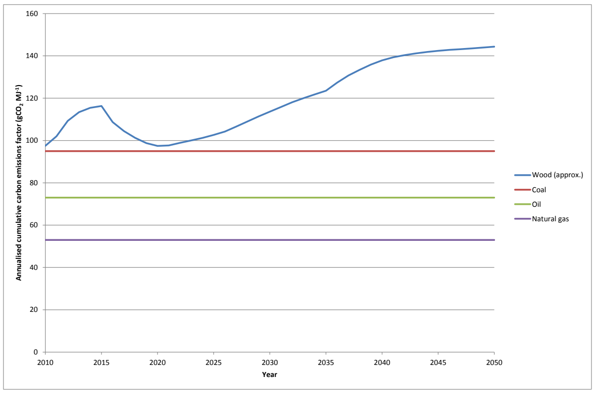




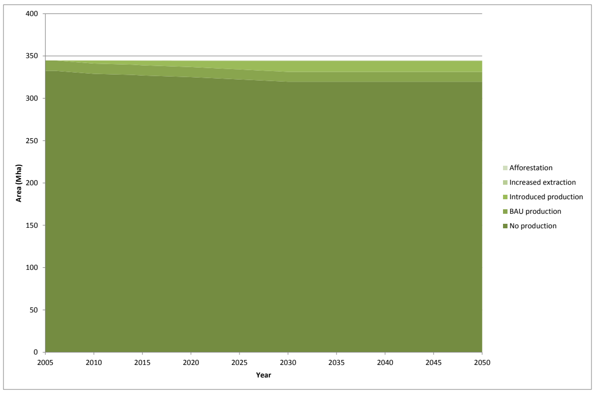


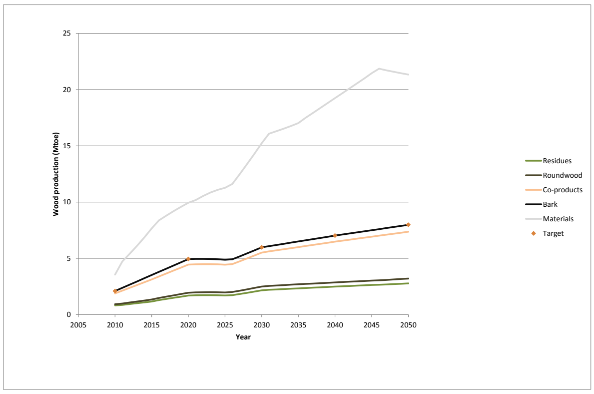


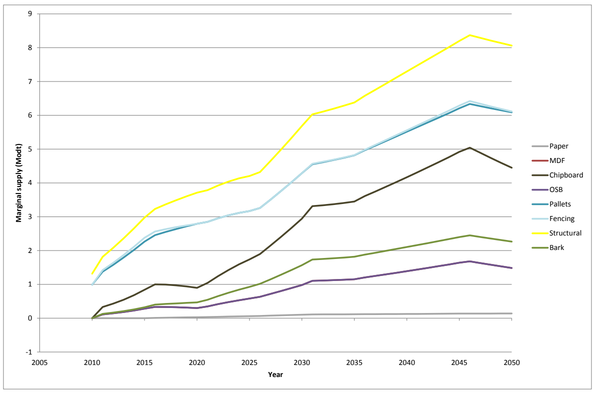


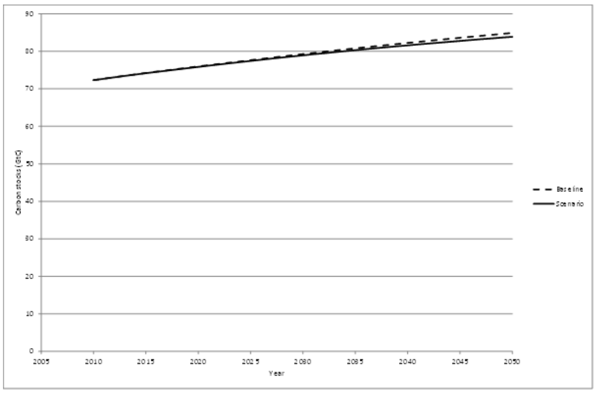


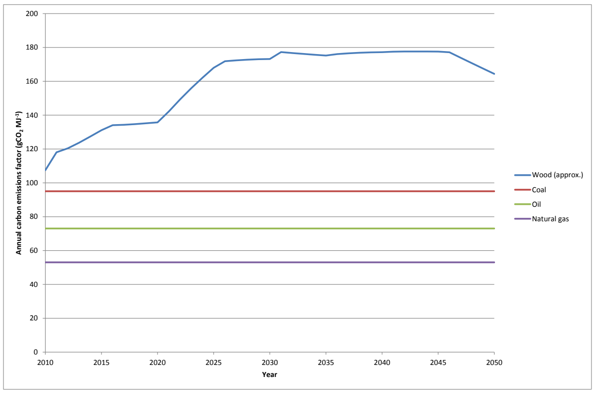
Scenario A, 'Synergistic' approach, Canada

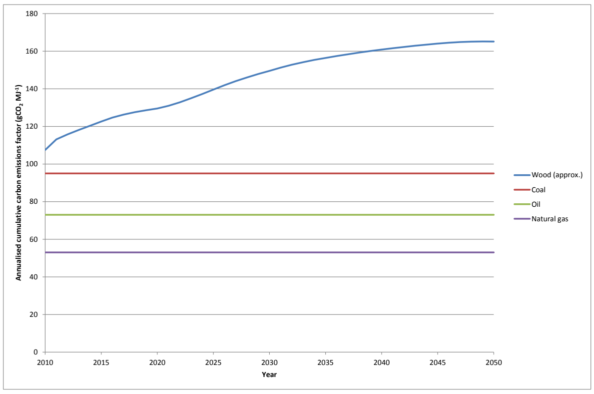




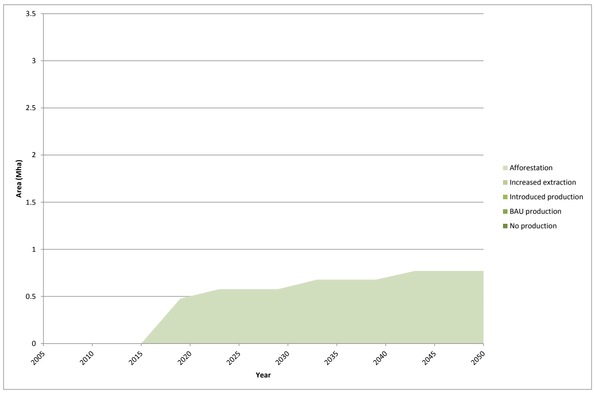


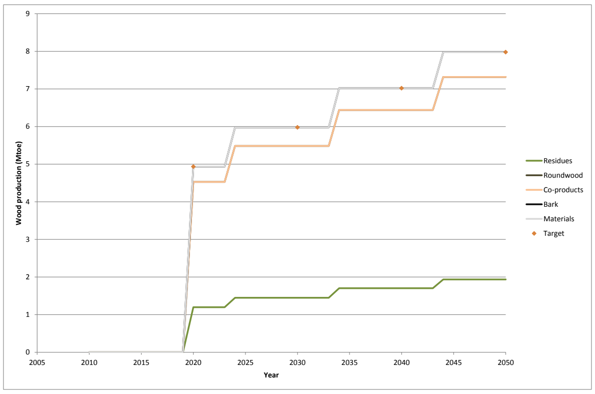


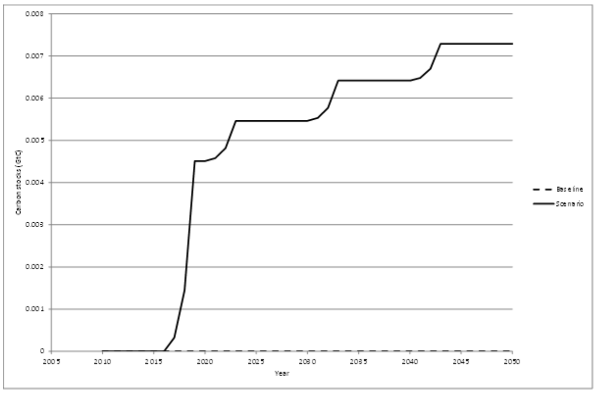


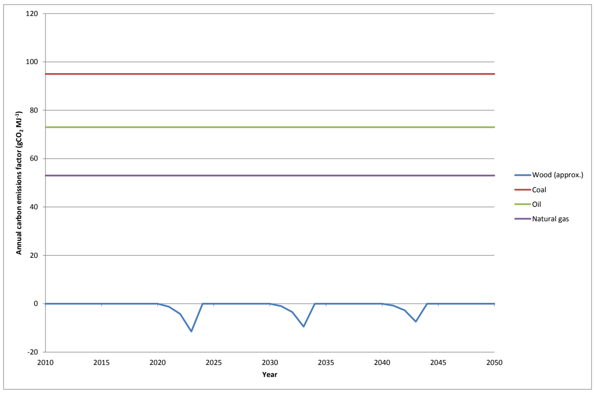


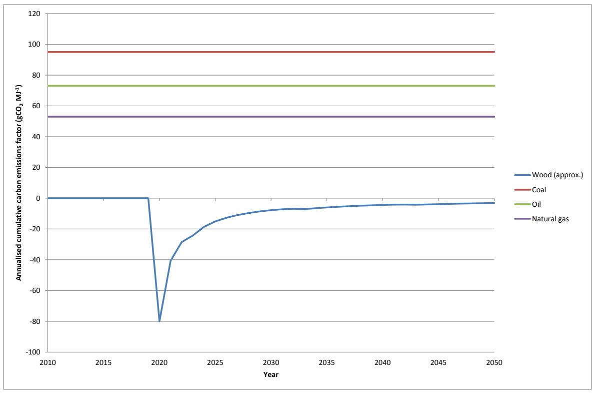
Scenario A, 'Synergistic' approach, LAM



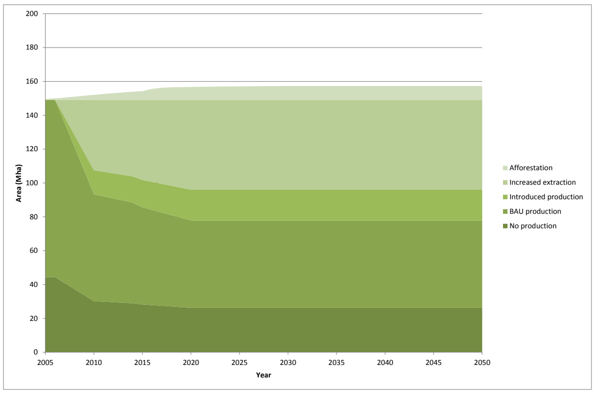


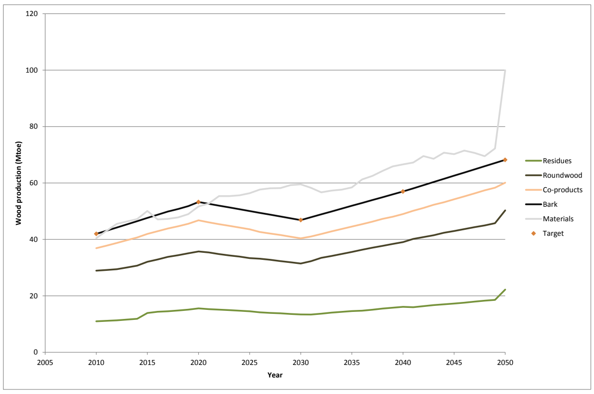


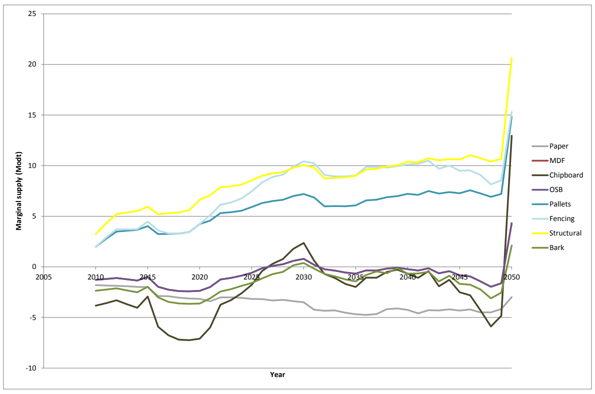


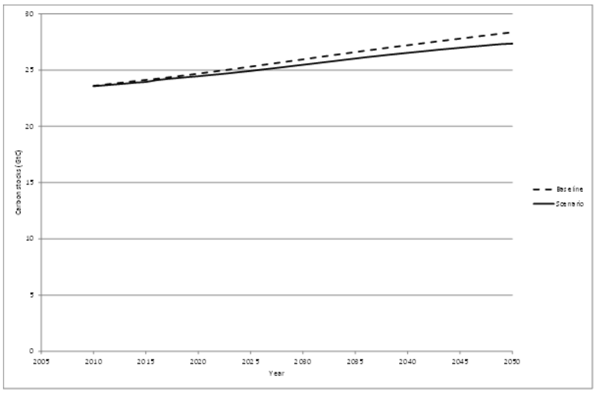


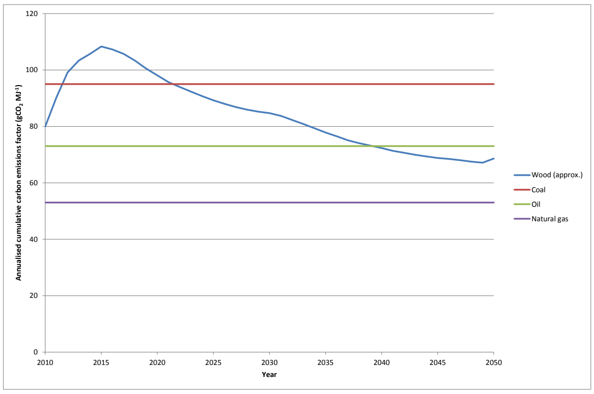
Scenario B, 'Synergistic' approach, EU27



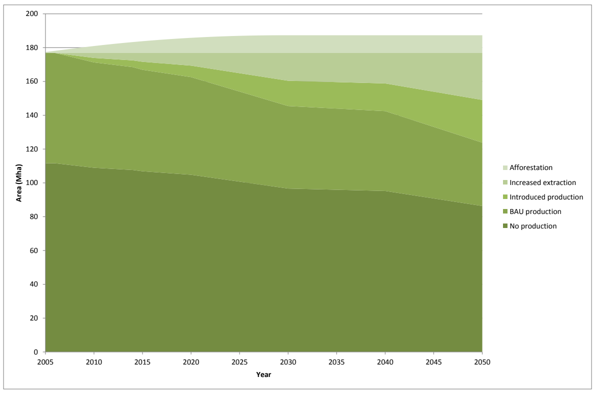


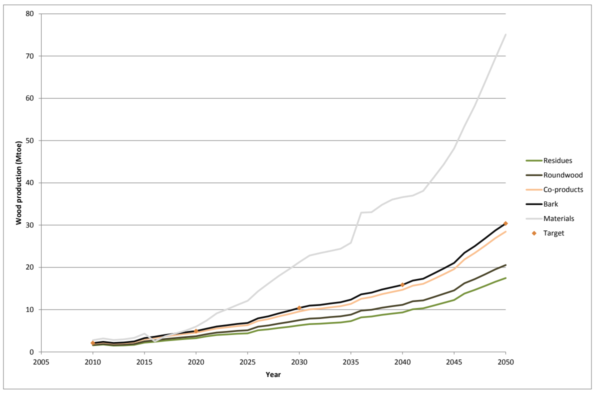


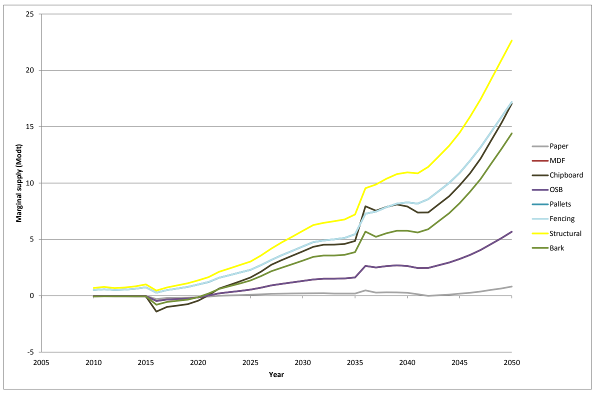


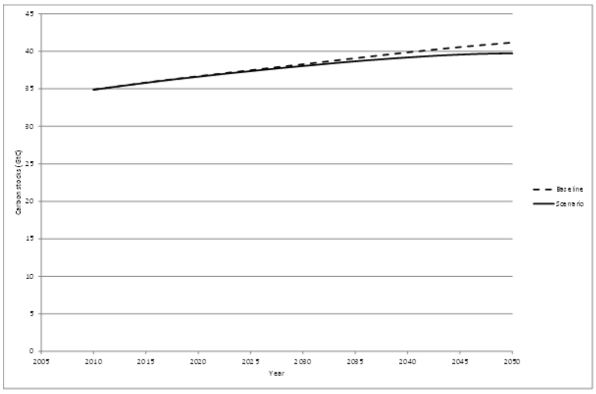


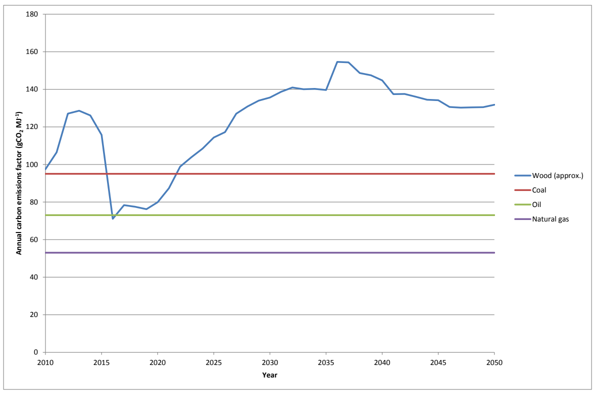
Scenario B, 'Synergistic' approach, USA

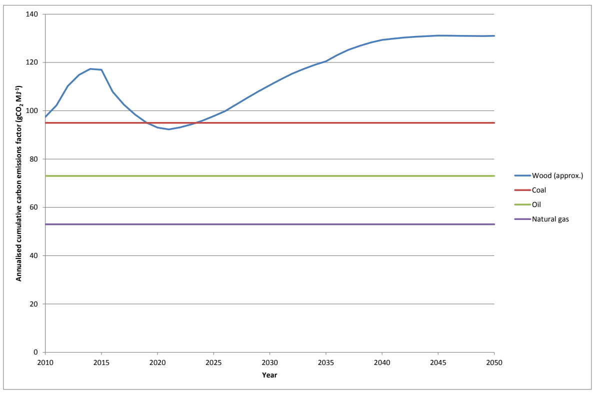




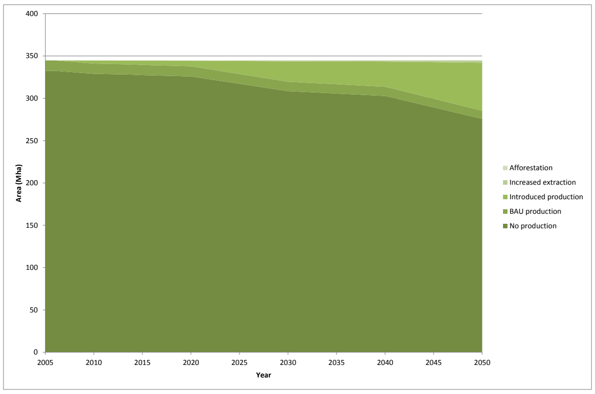


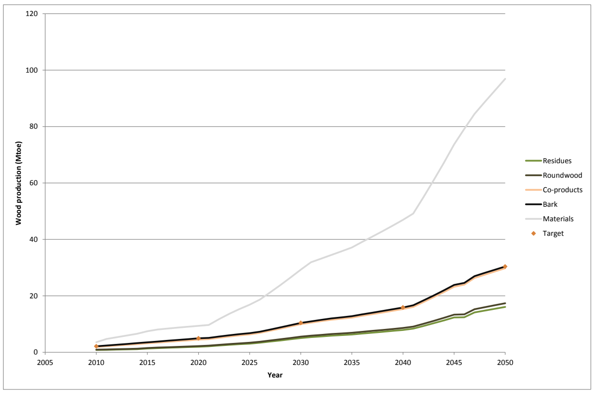


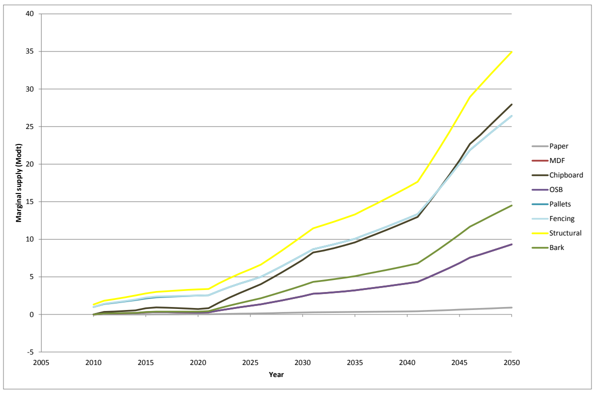


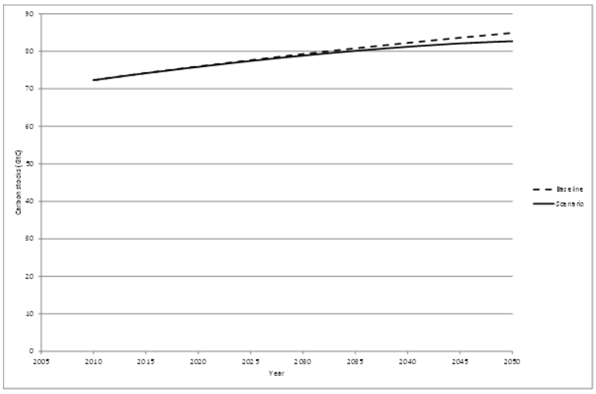


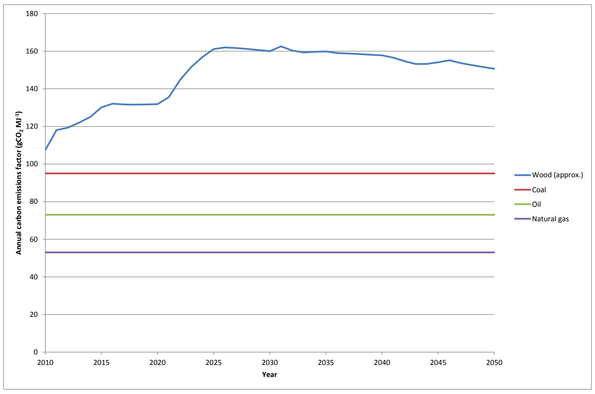
Scenario B, ‘Synergistic’ approach, Canada

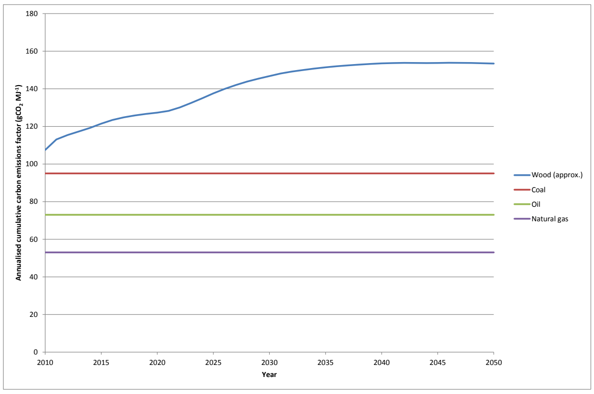




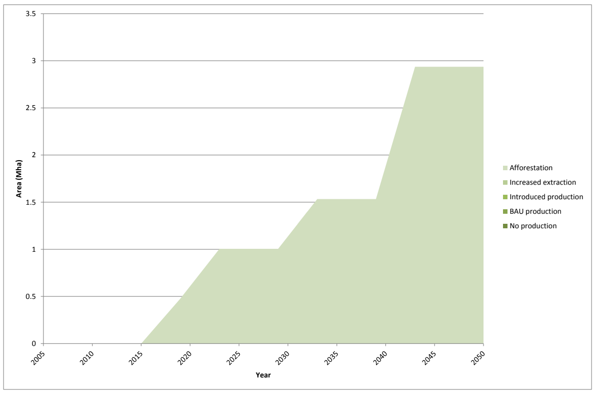


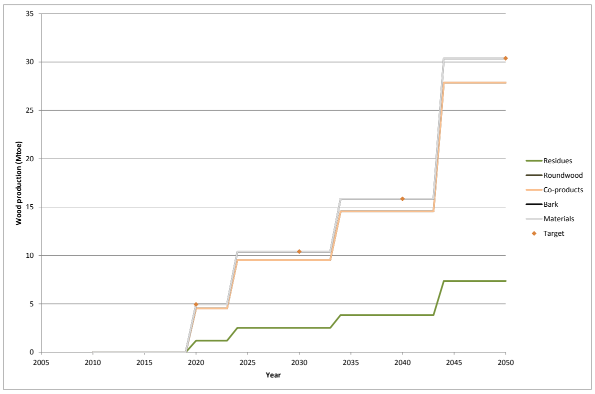


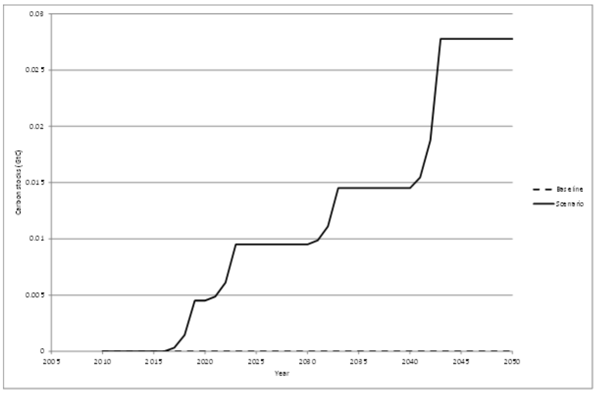


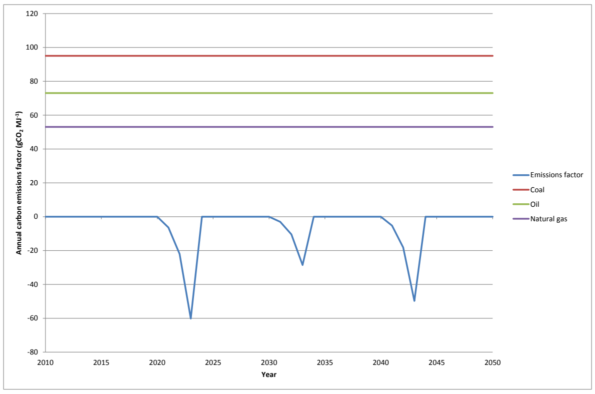


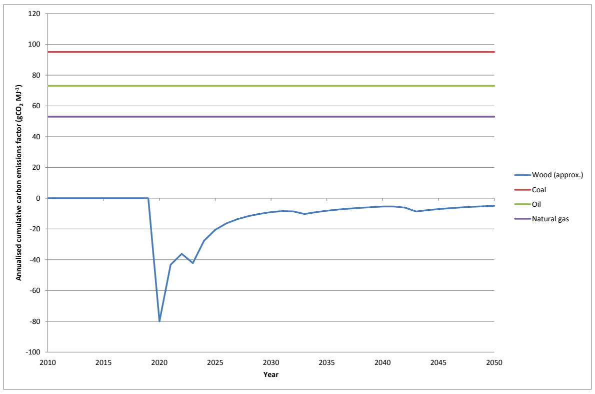
Scenario B, 'Synergistic' approach, LAM



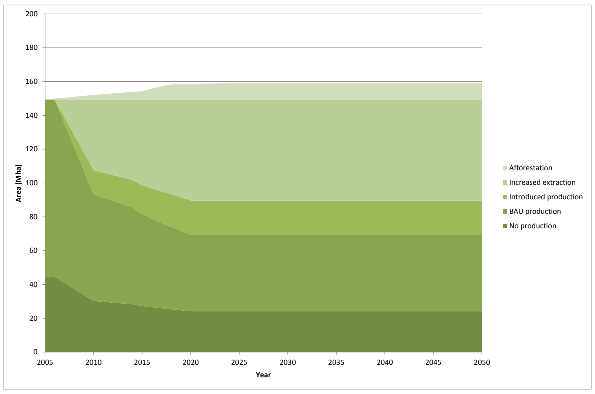


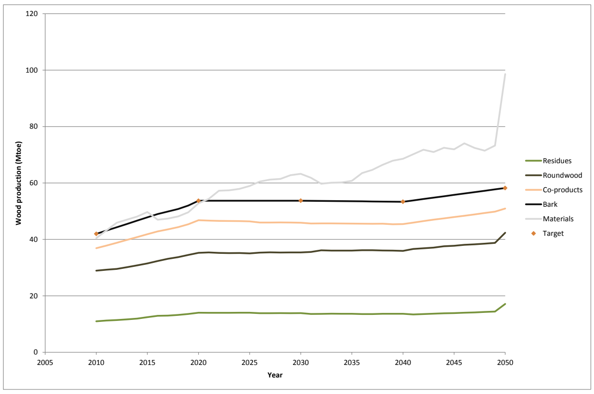


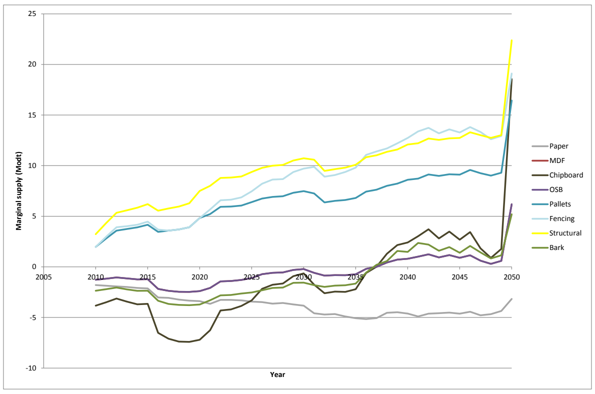


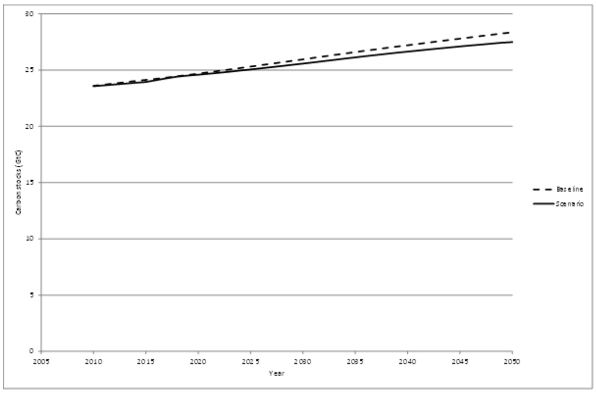


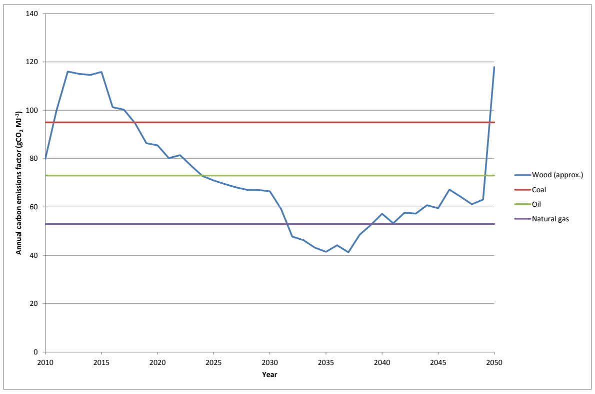
Scenario C1, 'Synergistic' approach, EU27

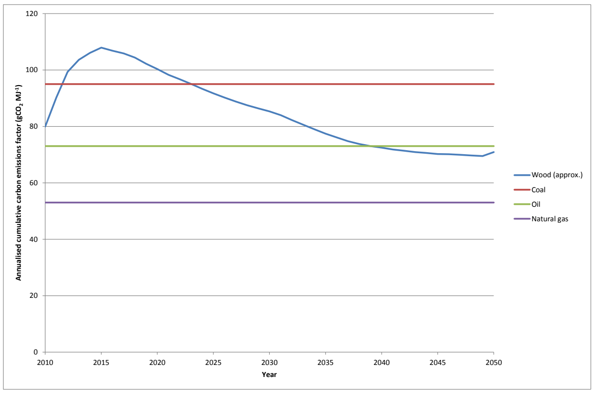




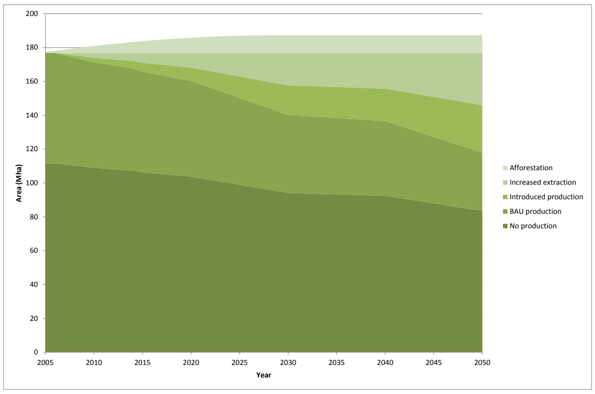


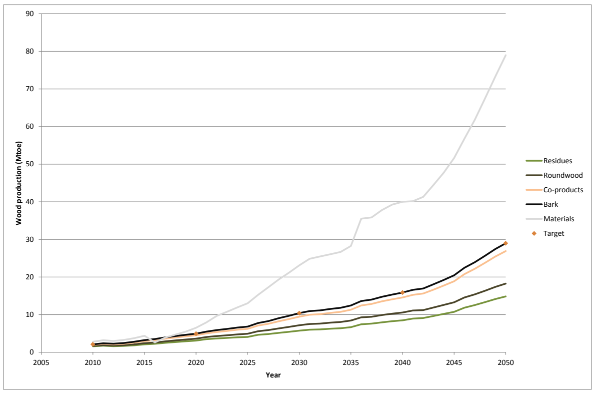


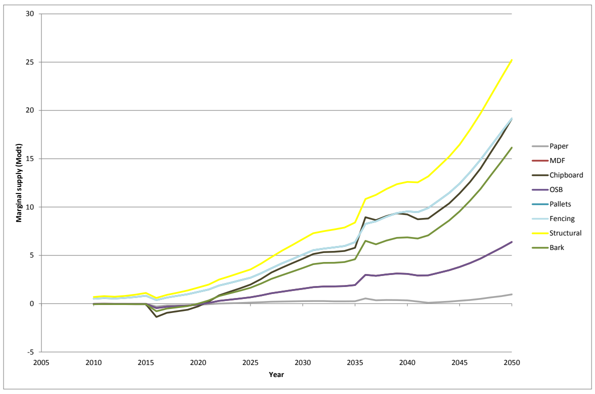


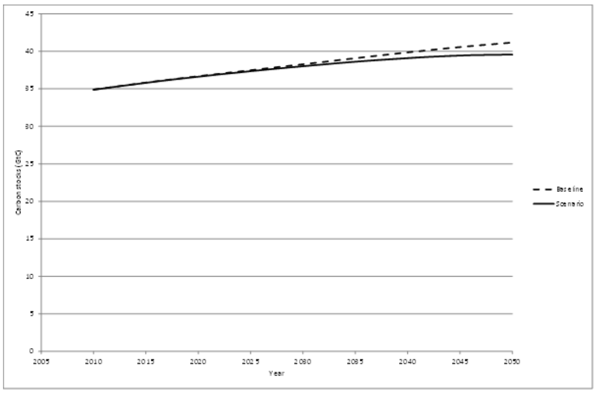


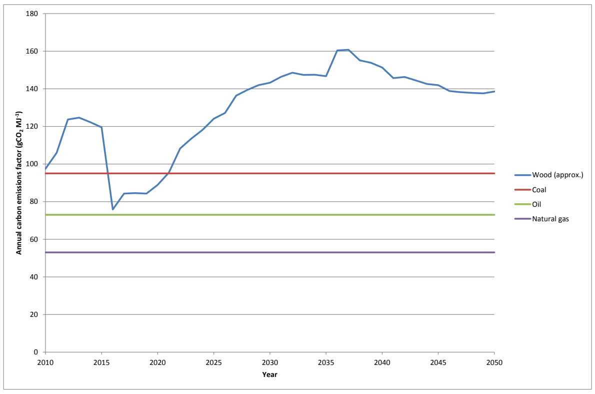
Scenario C1, ‘Synergistic’ approach, USA

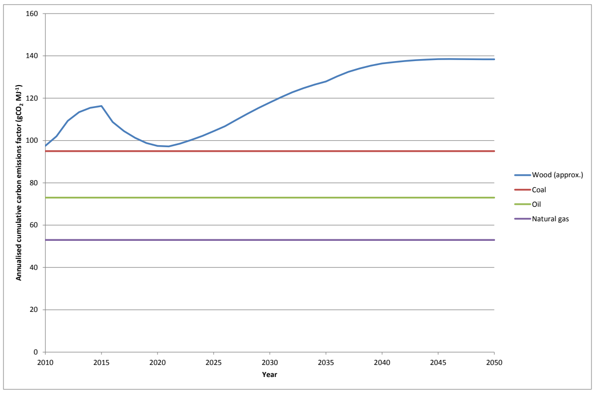




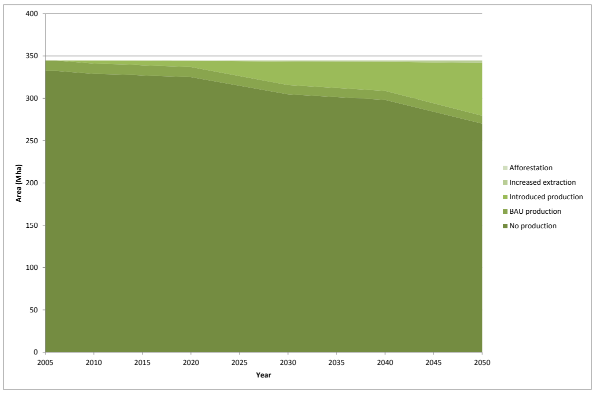


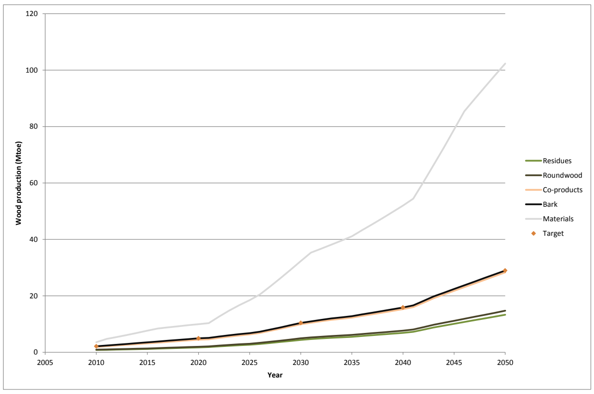


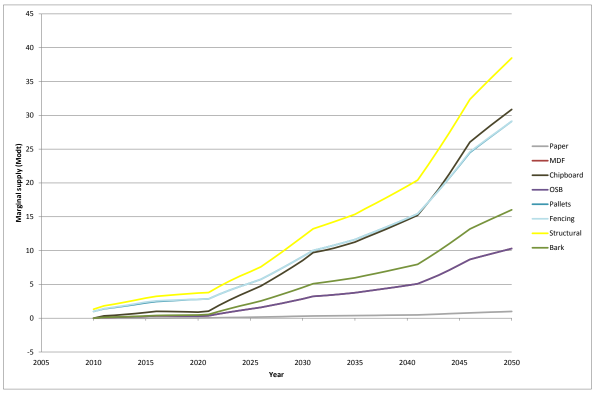


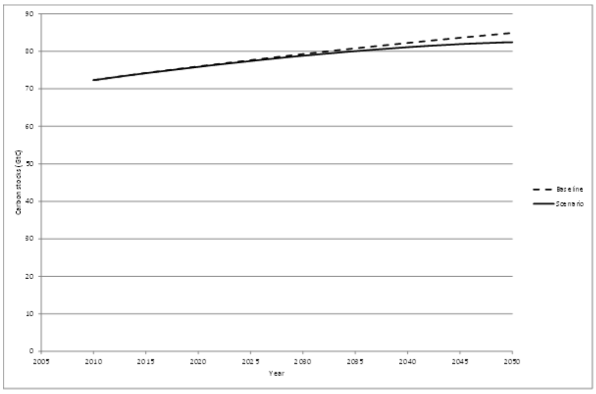


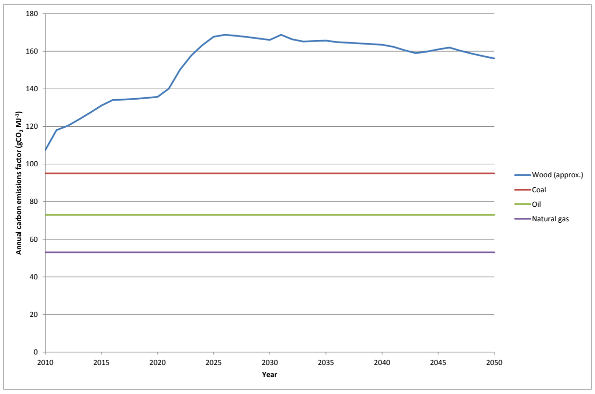
Scenario C1, 'Synergistic' approach, Canada

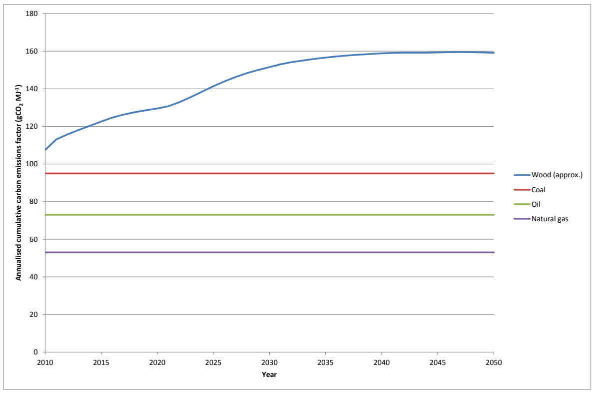




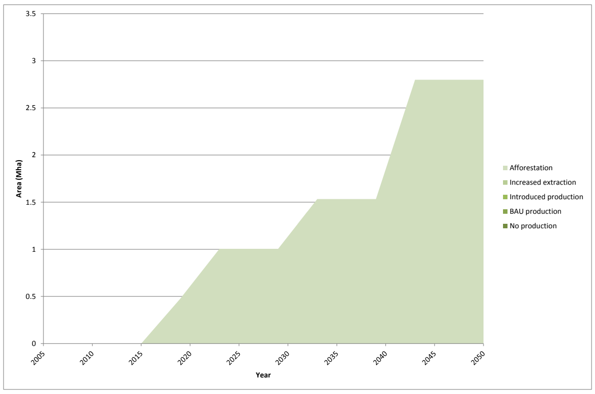


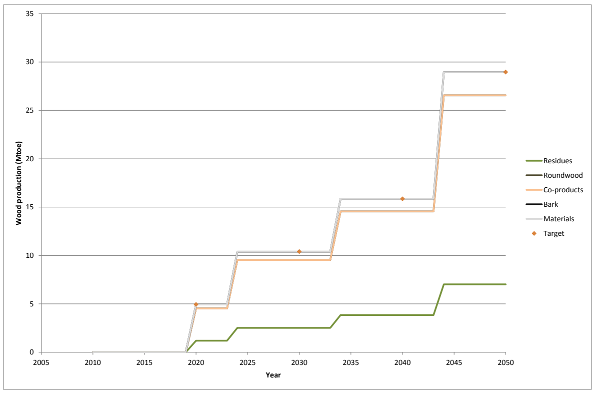


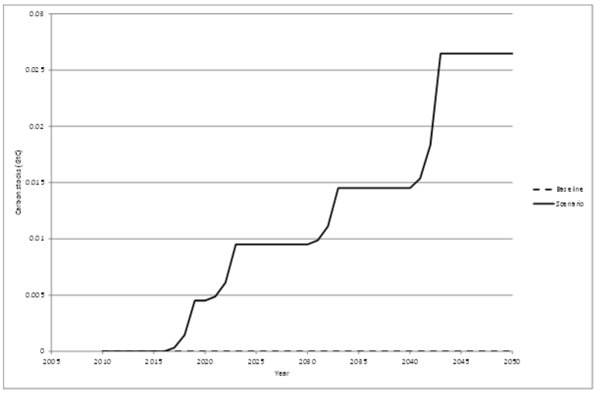


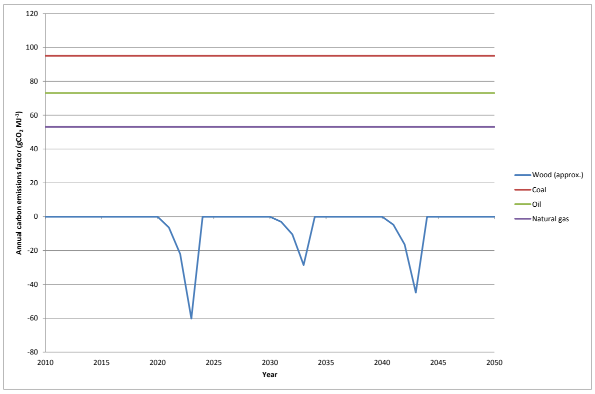


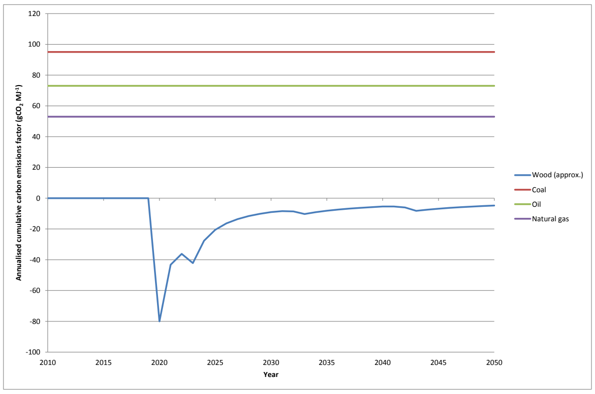
Scenario C1, 'Synergistic' approach, LAM



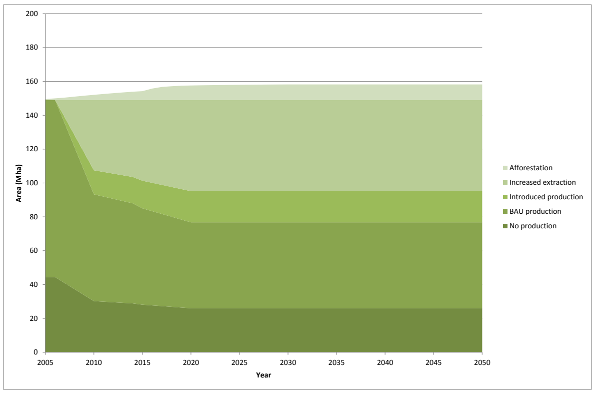


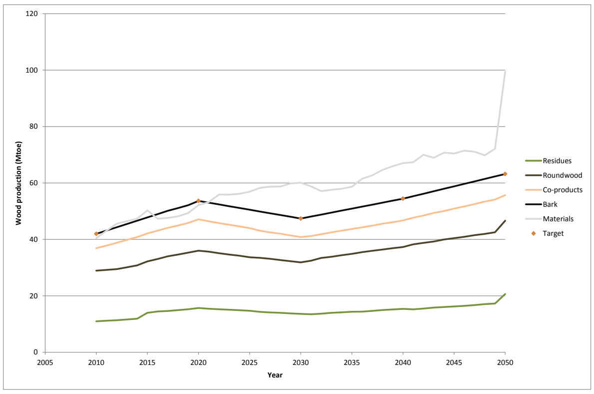


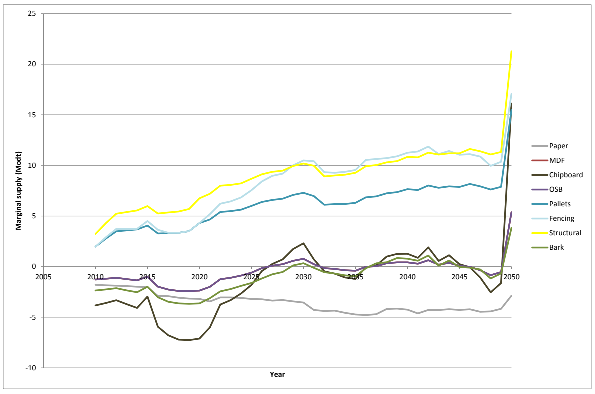


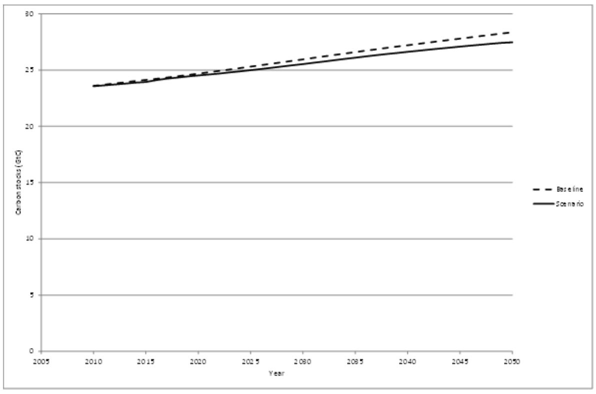


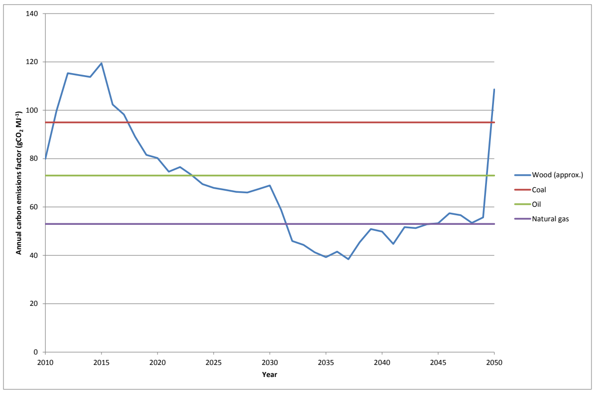
Scenario C2, 'Synergistic' approach, EU27

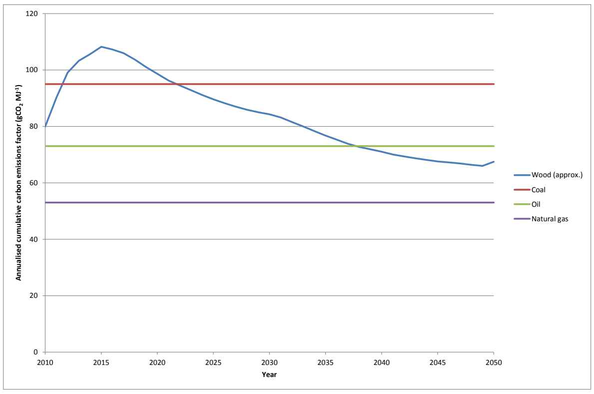




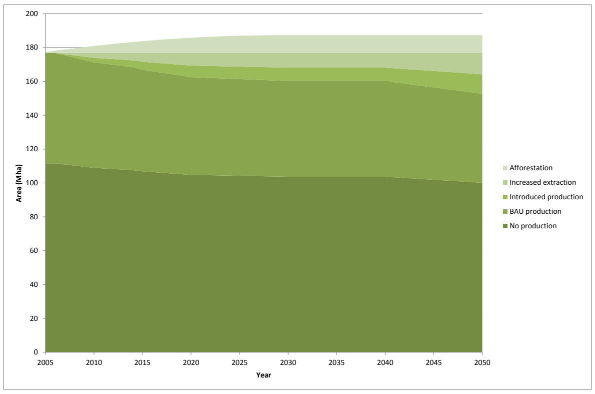


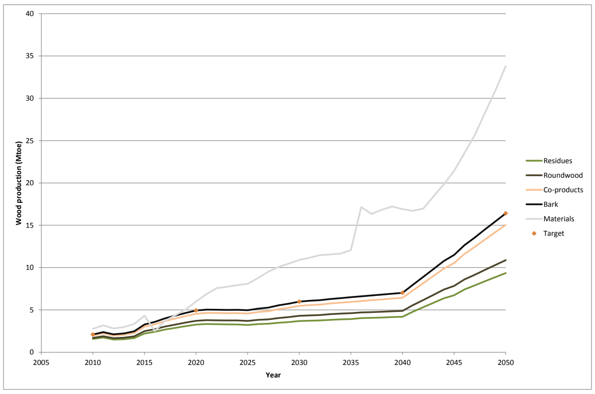


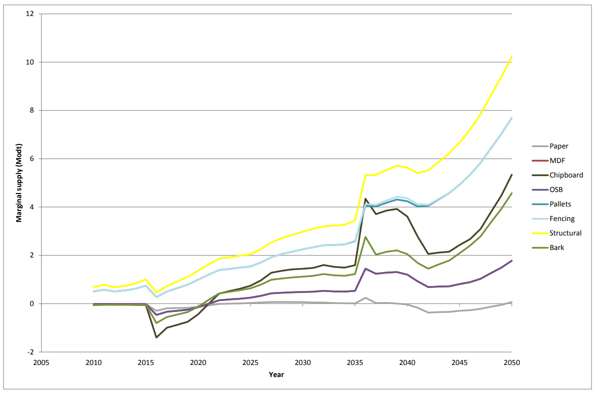


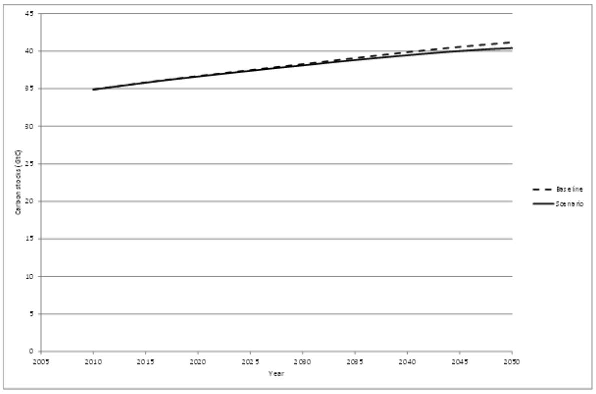


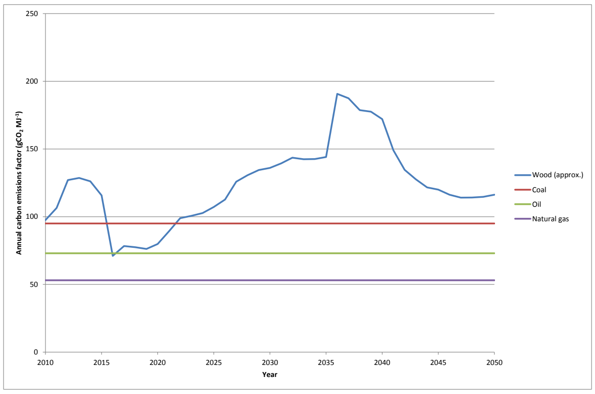
Scenario C2, 'Synergistic' approach, USA

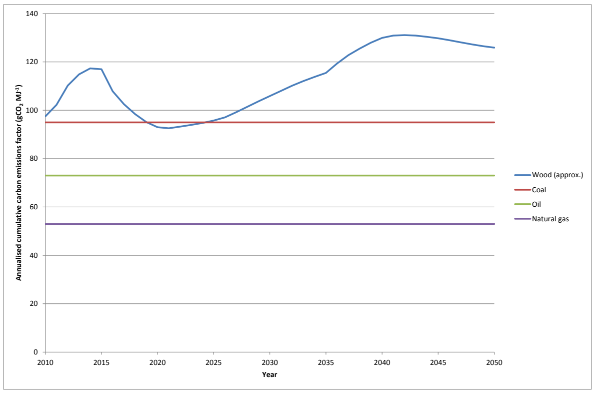




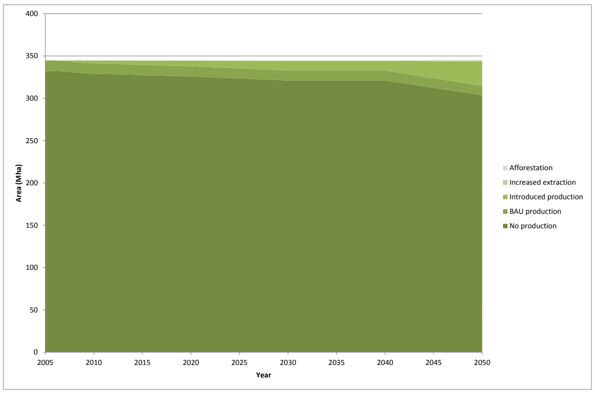


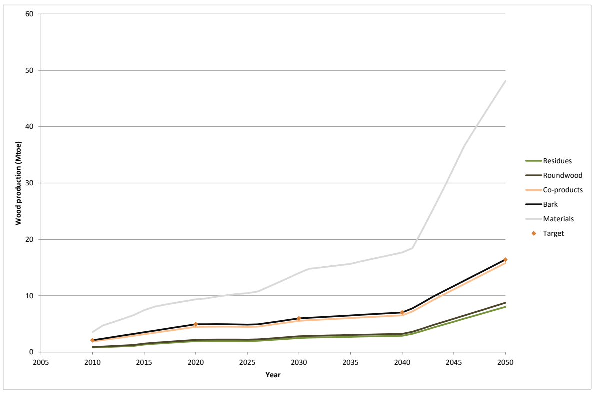


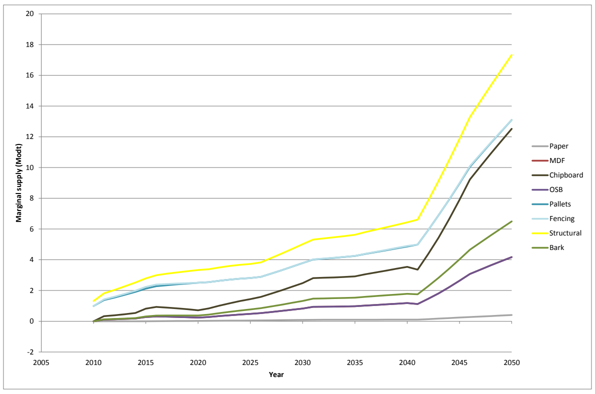


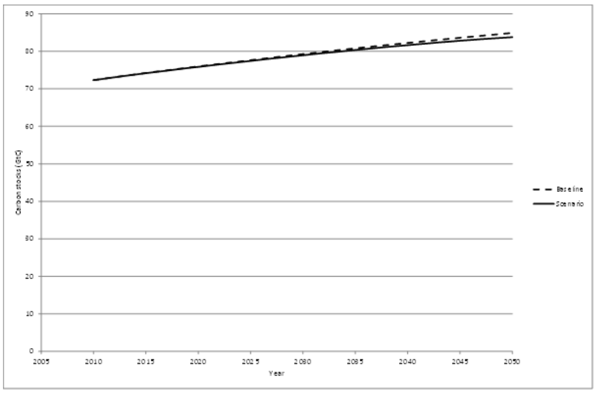


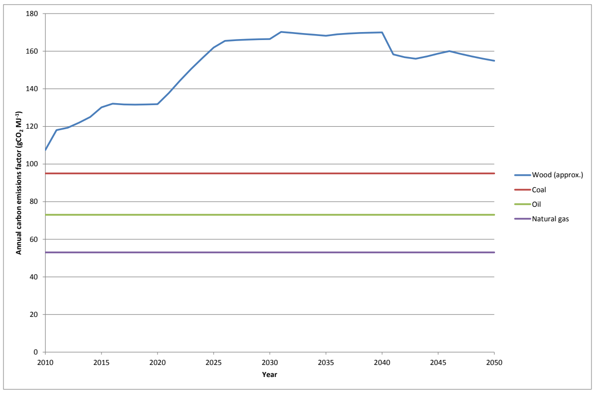
Scenario C2, 'Synergistic' approach, Canada

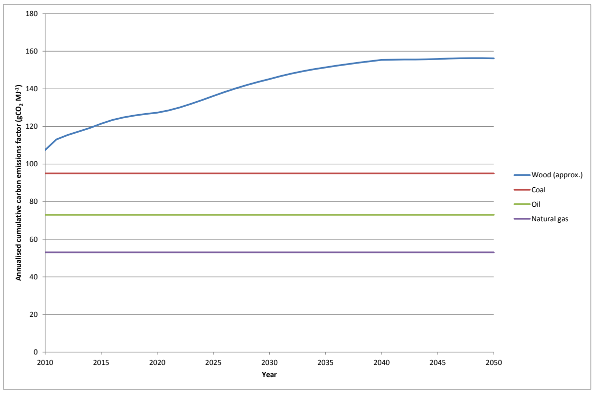




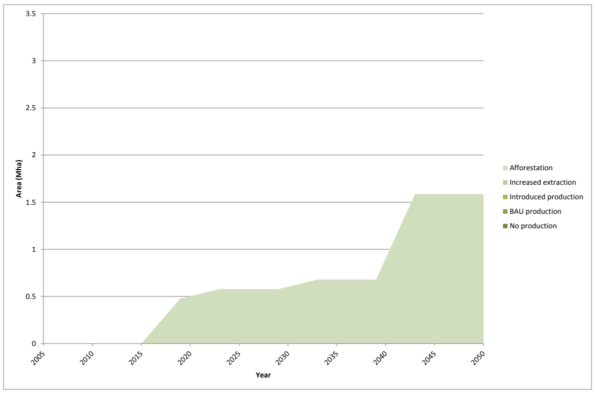


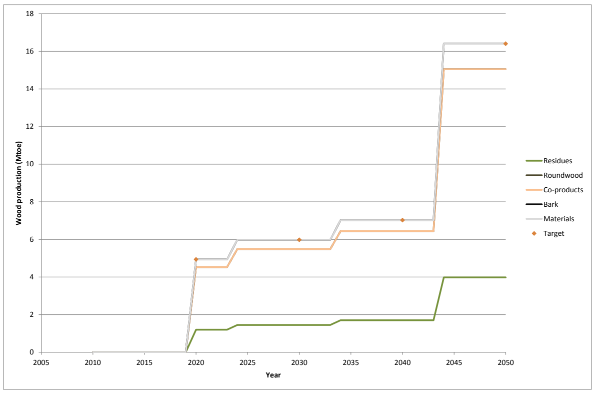


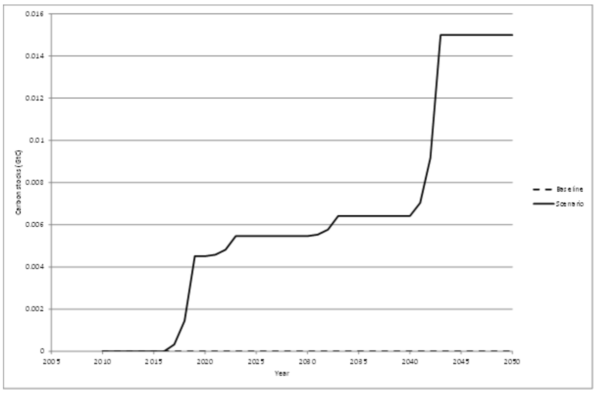


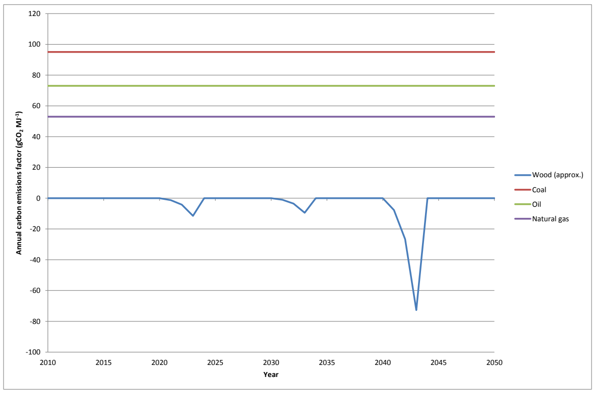


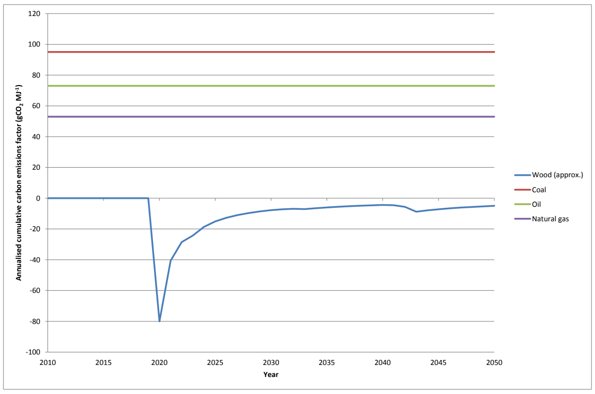
Scenario C2, ‘Synergistic’ approach, LAM



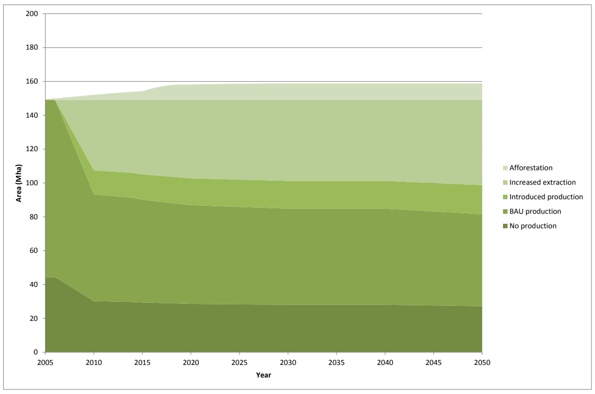


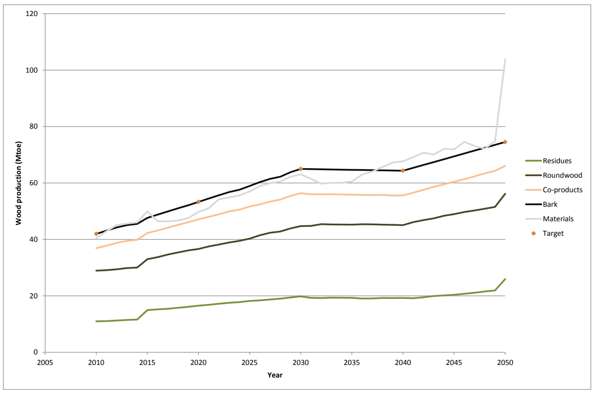


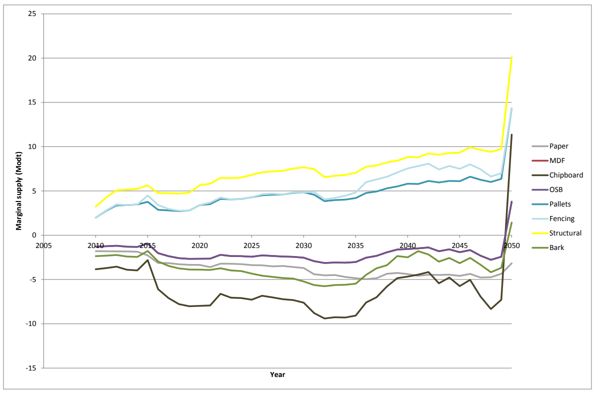


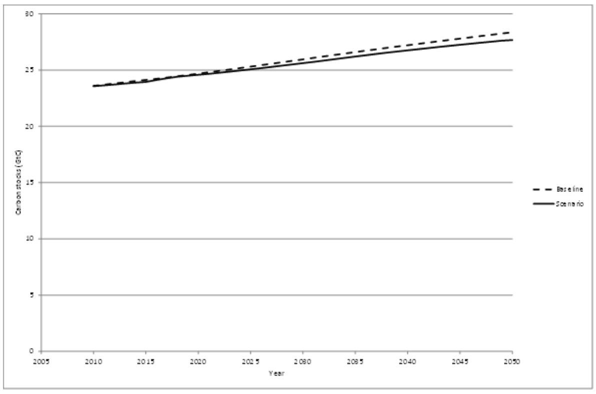


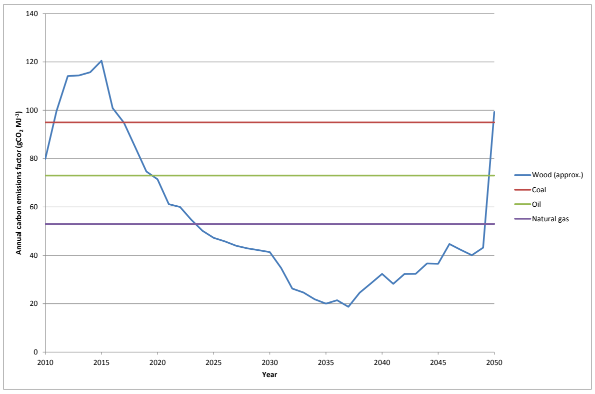
Scenario C3, ‘Synergistic’ approach, EU27

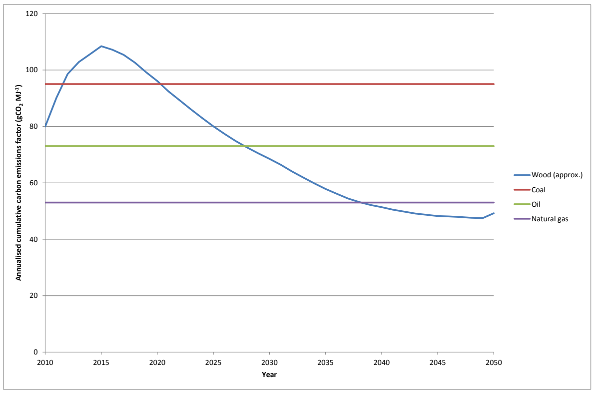




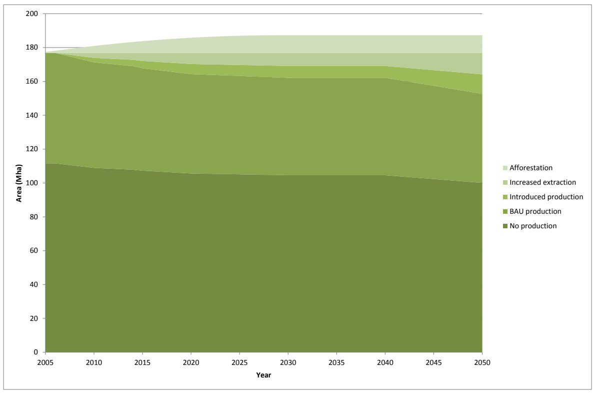


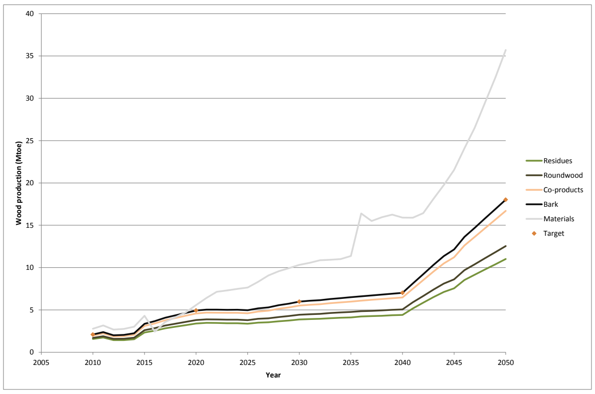


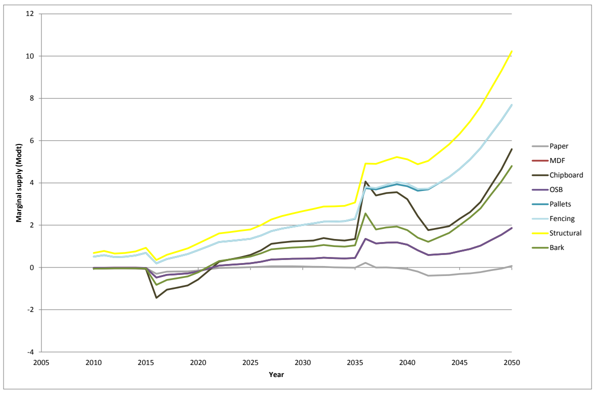


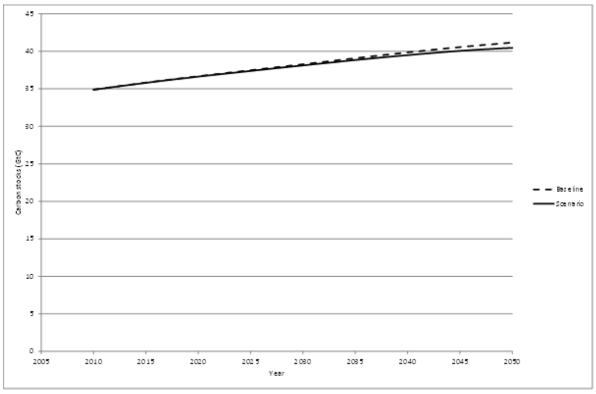


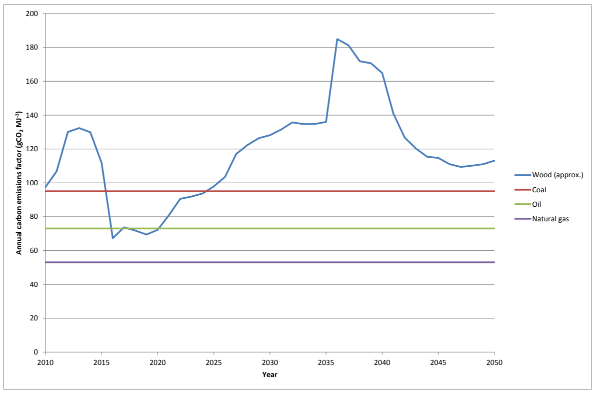
Scenario C3, 'Synergistic' approach, USA

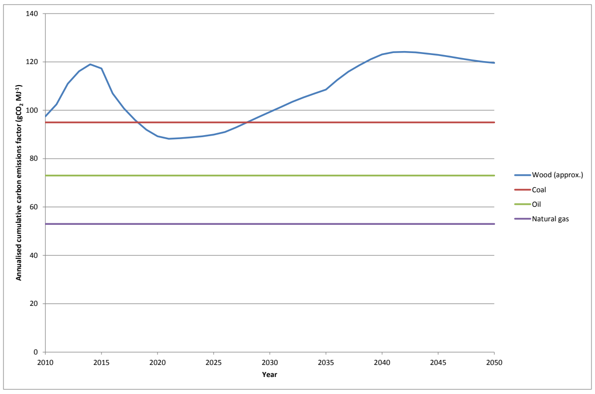




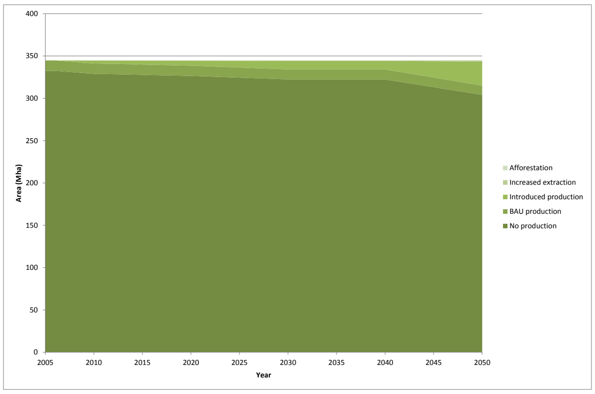


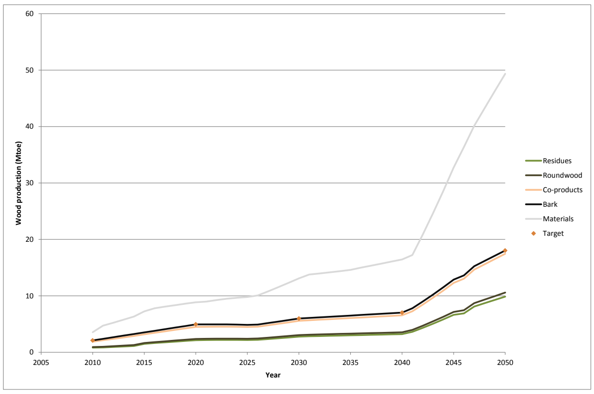


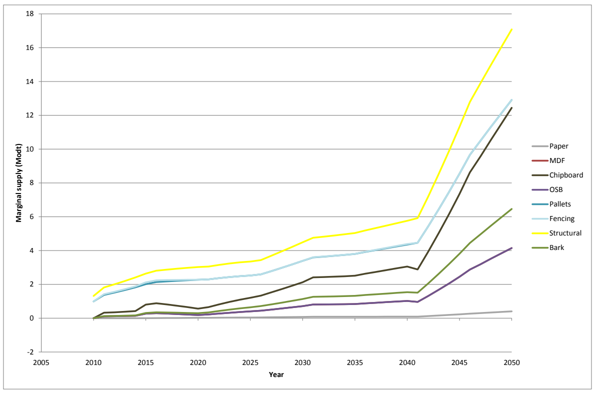


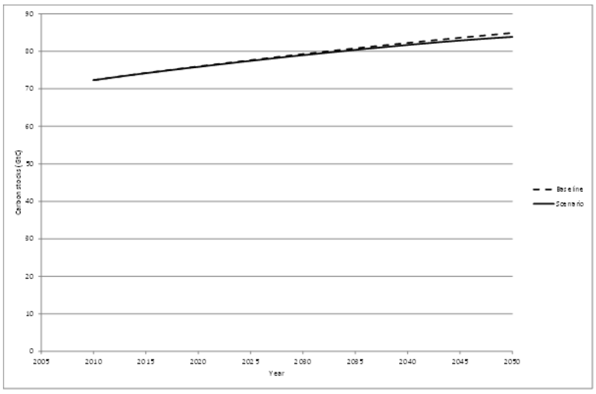


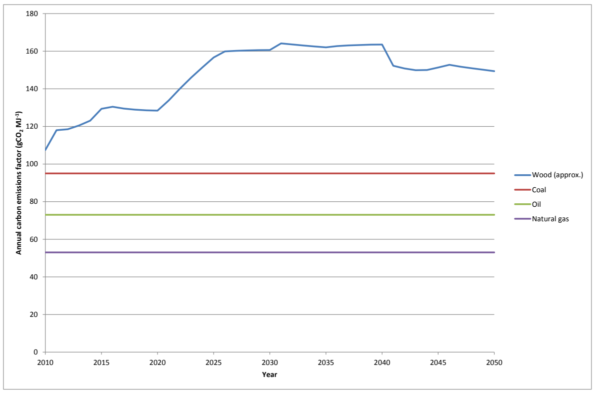
Scenario C3, ‘Synergistic’ approach, Canada

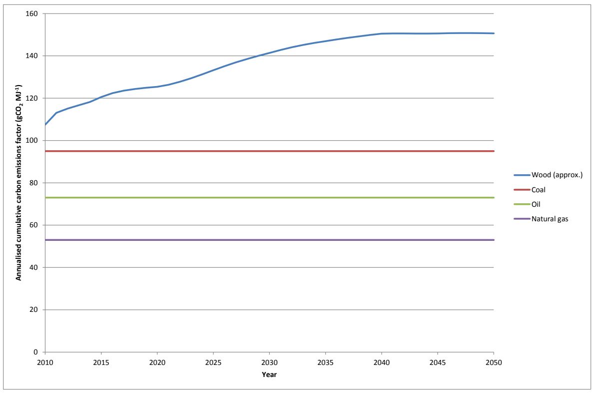




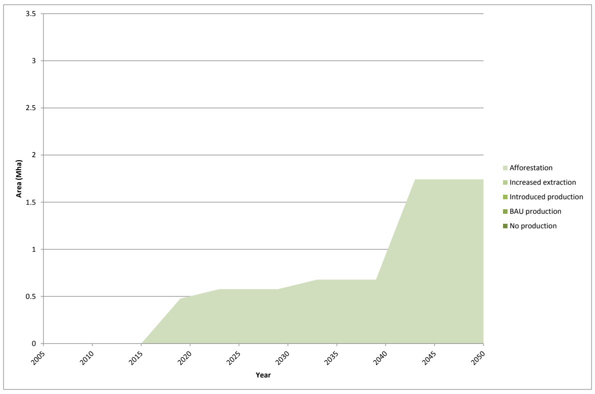


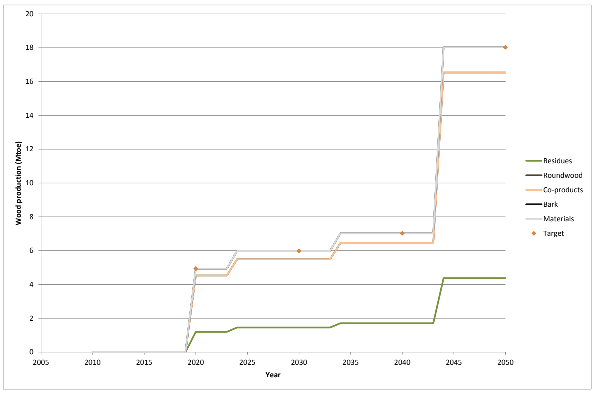


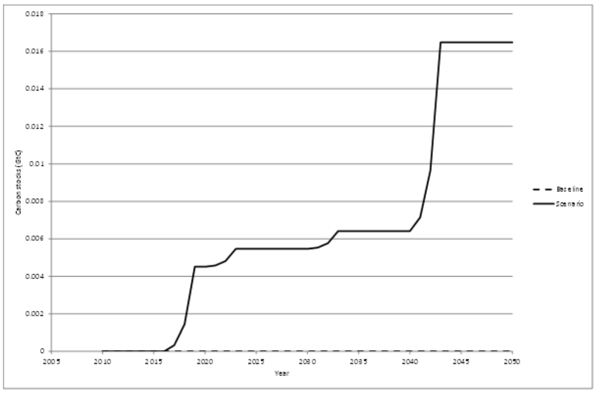


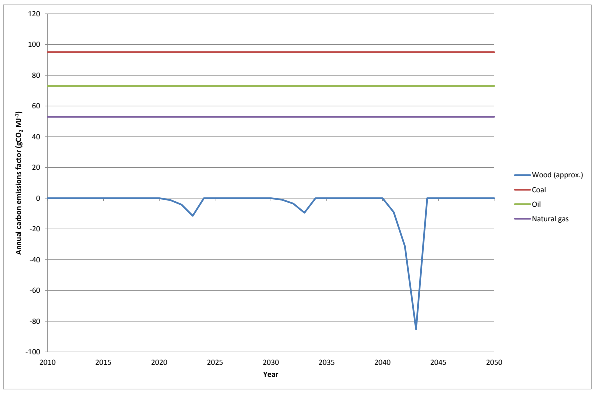


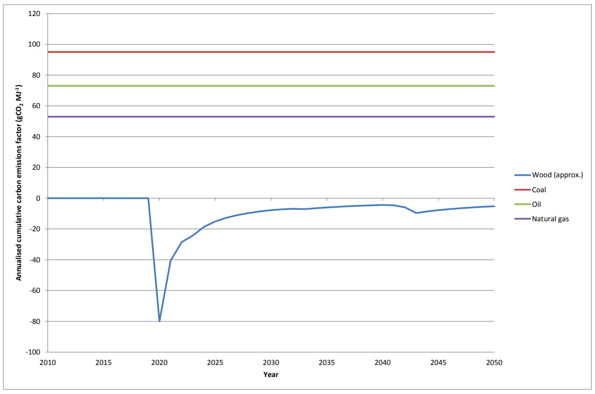
Scenario C3, 'Synergistic' approach, LAM











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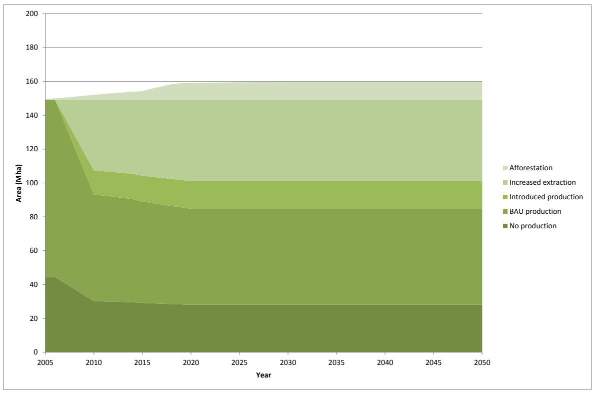
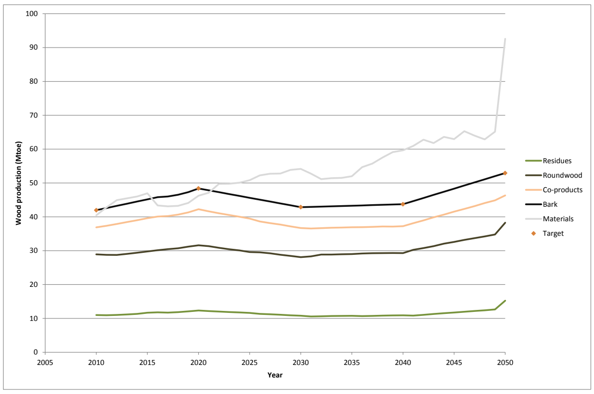
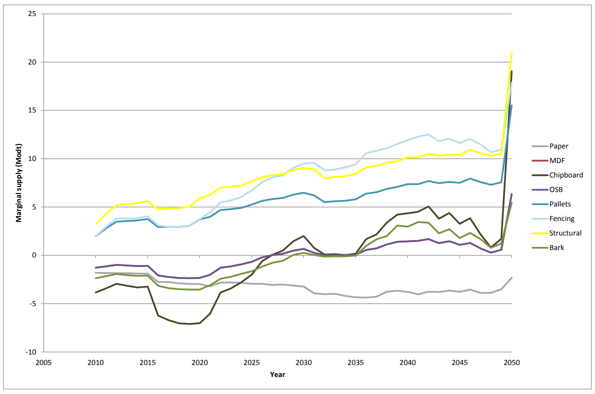
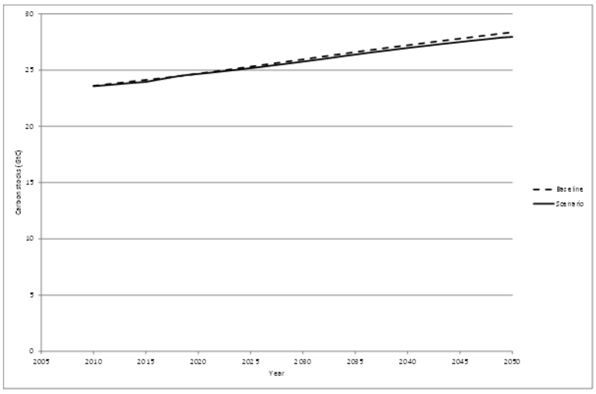
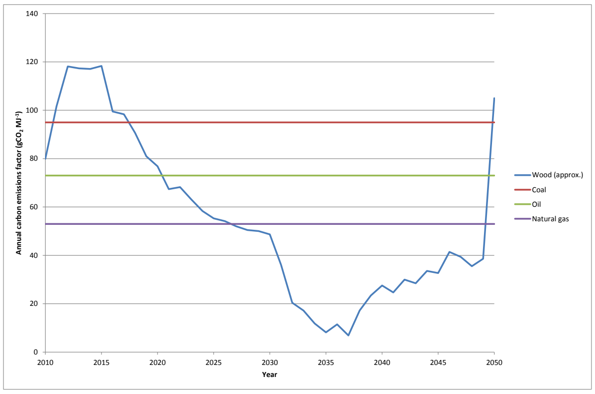
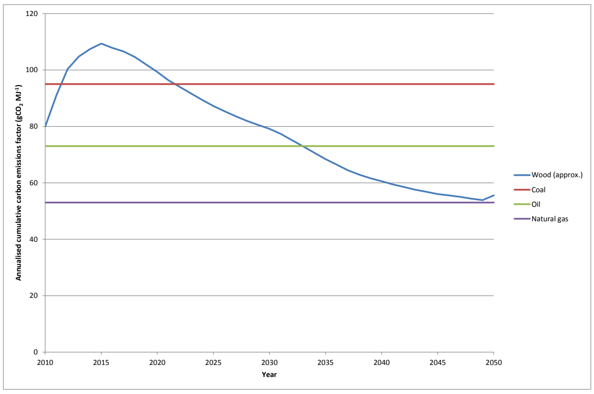




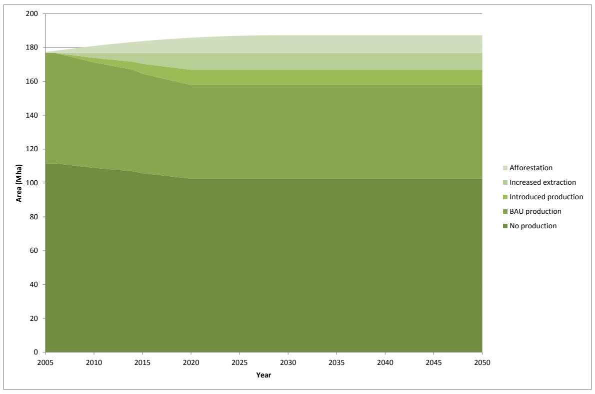


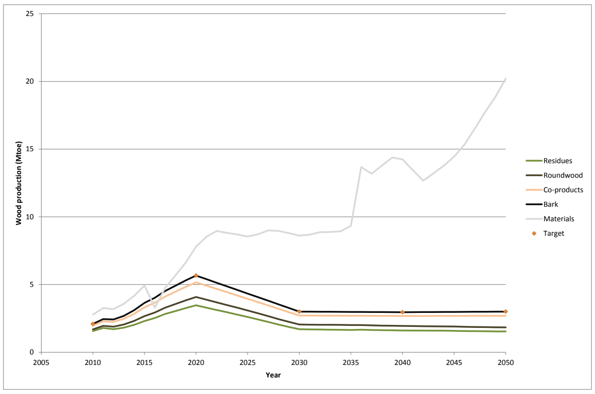


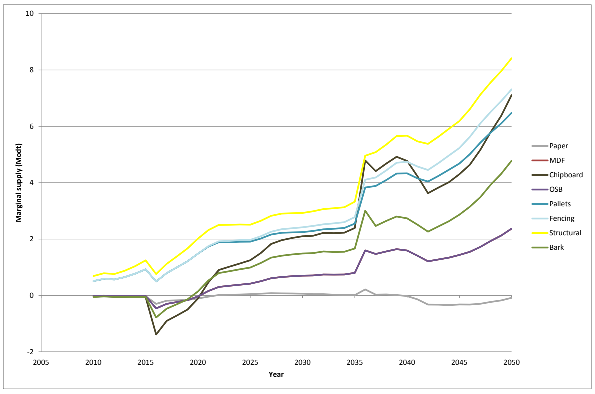


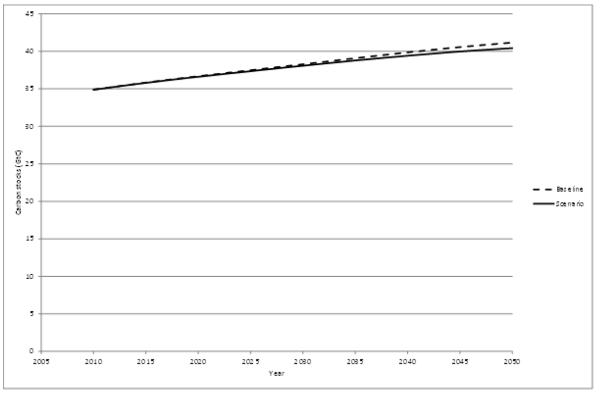


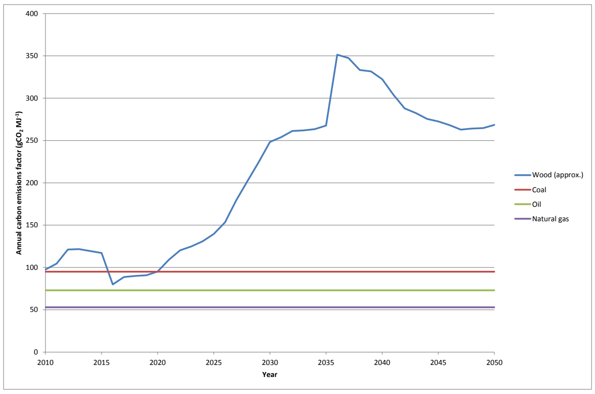
Scenario D, 'Synergistic' approach, USA

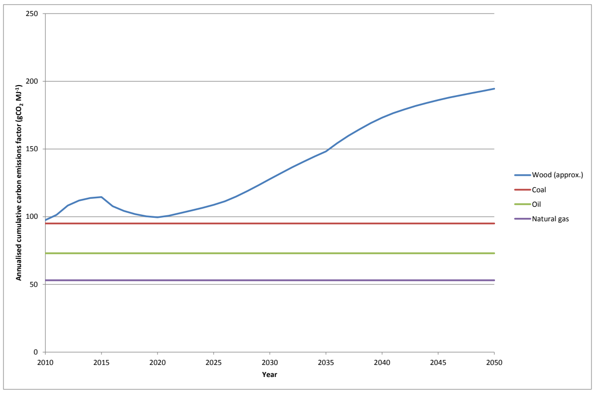




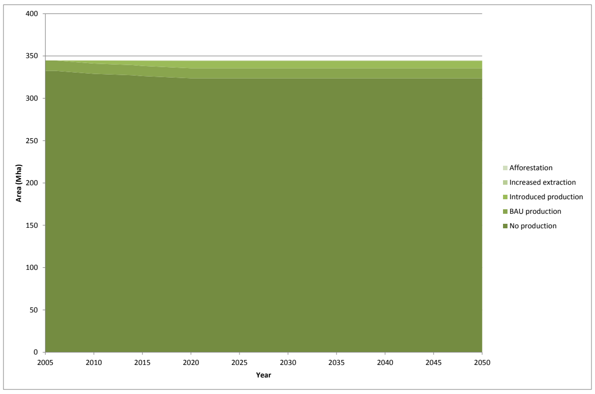


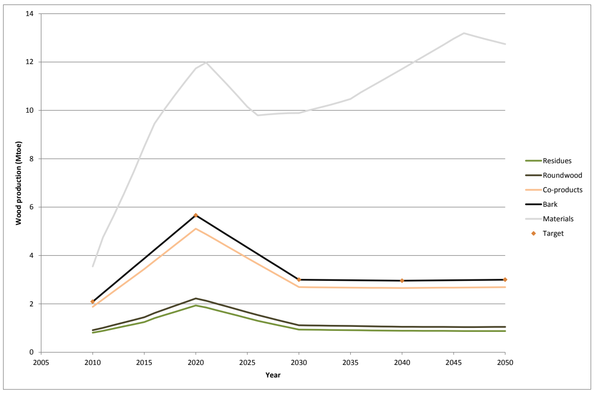


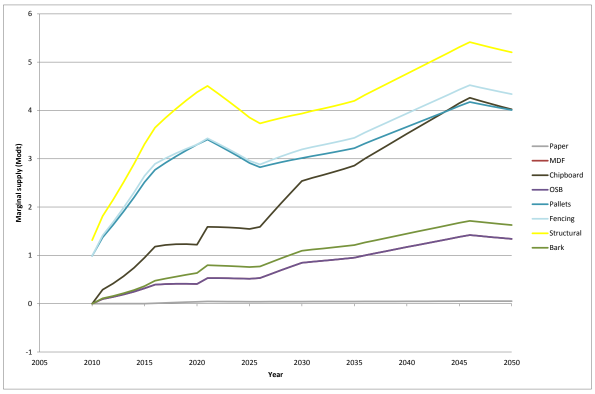


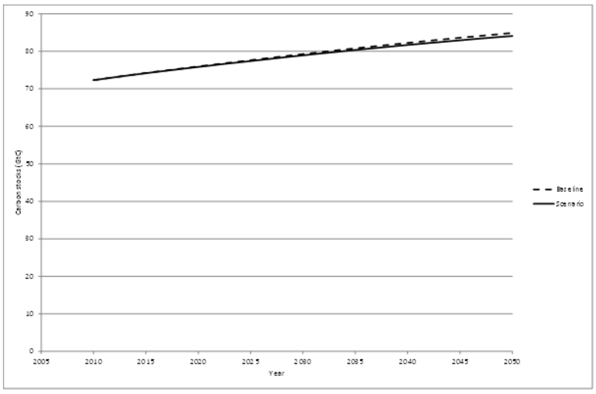


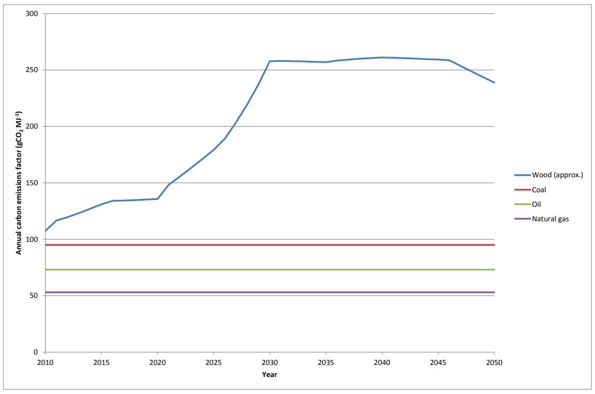
Scenario D, 'Synergistic' approach, Canada

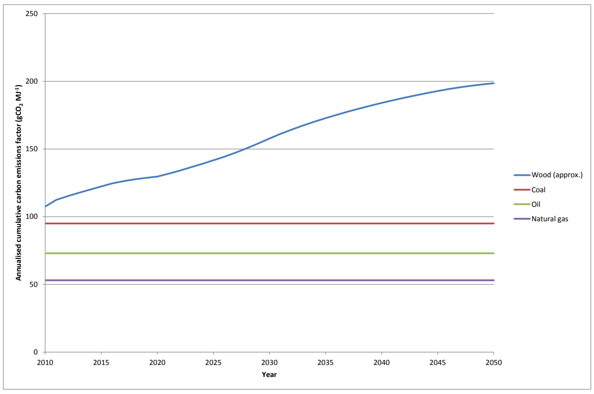




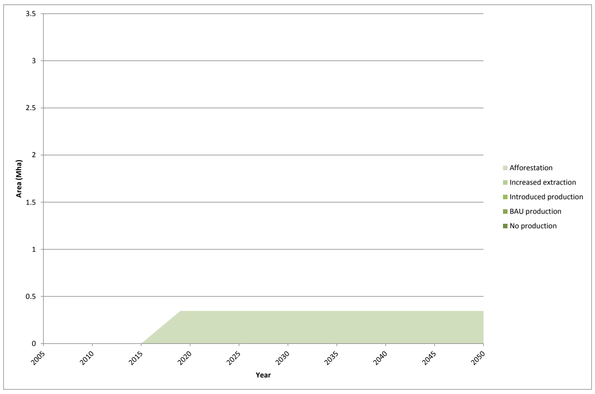


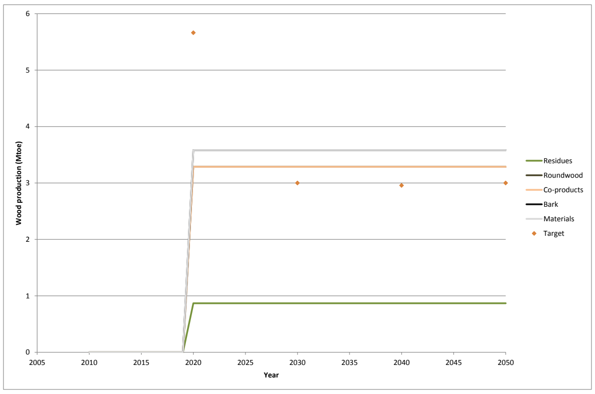


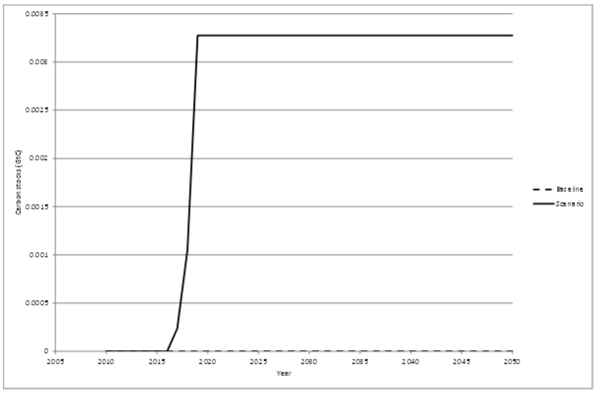


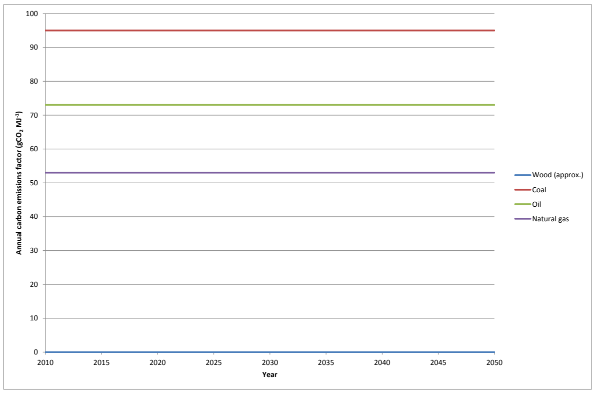


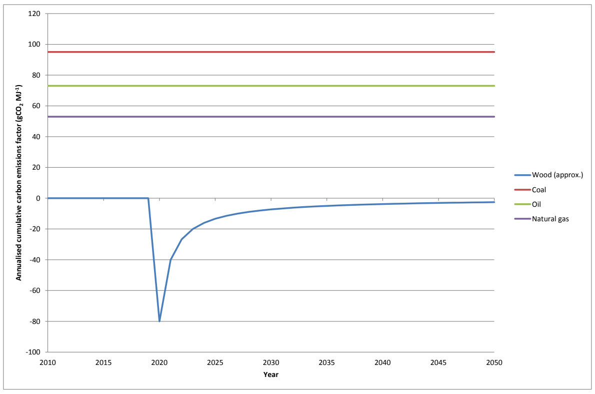
Scenario D, 'Synergistic' approach, LAM











Appendix 12 Graphs of final project results

This appendix contains a set of graphs showing the main final project results for all scenarios developed in this project, also illustrating sensitivity to assumptions about GHG emissions factors applied in calculations, and to assumptions about forest management practices and patterns of wood use involved in the supply of additional forest biomass to the EU for use as energy. Sets of four graphs are included in this appendix for each scenario, based on:

1. Application of average GHG emissions factors and assumptions representing the 'Precautionary' approach to forest management and wood use
2. Application of average GHG emissions factors and assumptions representing the 'Synergistic' approach to forest management and wood use
3. Application of high GHG emissions factors and assumptions representing the 'Precautionary' approach to forest management and wood use
4. Application of low GHG emissions factors and assumptions representing the 'Synergistic' approach to forest management and wood use

As explained in Section 6.2 of the main final project report, it is important to understand that a number of different sources of GHG emissions are taken into account in developing these estimates:

- GHG emissions from the combustion of fossil fuels within the EU27 region, prominent GHG emissions associated with the supply of fossil fuels within the EU27 region, and prominent GHG emissions from agricultural activities related to food production in the EU27 region; these sources are referred to, collectively and in shortened form, as "EU Emissions (non-biomass)"

- Indirect GHG emissions associated with the supply of imported fossil and nuclear fuels, and electricity into the EU27 region; these sources are referred to as "Imported Fossil and Nuclear Fuels, and Electricity"

- Direct and indirect GHG emissions, including CO_2 emissions associated with biogenic carbon and due to net forest carbon stock changes, associated with the supply of wood fuels from outside and within the EU27 region and co-produced harvested wood products (HWP), their counterfactuals and their end-of-life disposal; these sources are referred to as "LAM Wood Fuel to EU/HWP Co-products"[4] , "CIS Wood Fuel to EU/HWP Co-products", "USA Wood Fuel to EU/HWP Co-products", "CAN Wood Fuel to EU/HWP Co-products", and "EU Wood Fuel/HWP Co-products"

- Indirect GHG emissions associated with EU27-region agricultural biomass, consisting of the production of wood fuel from arboricultural arisings, and the production and use of straw fuel as well as net CO_2 emissions from soil organic carbon changes due to straw removal/avoided straw incorporation; these sources are referred to as "EU Agricultural Biomass"

[4] It should be noted that, in fact, no co-production of material wood products (HWP) is associated with forest bioenergy supply from the LAM region (i.e. Brazil), see Section 4.8.3.

- Indirect GHG emissions associated with EU27-region energy crops, including all energy crop cultivation and harvesting as well as GHG emissions from direct land-use change; biodiesel production from oilseed rape and sunflowers, and bioethanol production from barley, maize, sugar beet and wheat, accounting for animal feed co-product counterfactuals, and use; wood fuel production from poplar and willow; fuel production and use from miscanthus, reed canary grass and switchgrass; and fodder maize processing by anaerobic digestion; these sources are referred to as "EU Energy Crops"

- Indirect GHG emissions associated with EU27-region aggregated wood fuel use, including transportation within the EU27 region, combustion for heating, CHP and electricity generation: lignocellulosic processing for bioethanol production and use; fast pyrolysis and hydrotreatment for petrol and diesel blendstock production and use; gasification for bioSNG production and use; and Fischer-Tropsch processing for biokerosene production and use; these sources are referred to as "EU Aggregated Wood Use"

- Indirect GHG emissions associated with biodiesel imports to the EU27 region, consisting of soy bean cultivation and harvesting, and biodiesel production, accounting for animal feed co-product counterfactuals, transportation and use; these sources are referred to as "Imported Biodiesel"

- Indirect GHG emissions associated with bioethanol imports to the EU27 region, consisting of maize, sugar cane and wheat cultivation and harvesting, and bioethanol production, accounting for animal feed co-product counterfactuals, and use; these sources are referred to as "Imported Bioethanol"

- Indirect GHG emission associated with biokerosene imports to the EU27 region, consisting of petrol blendstock and biokerosene production from wood; these sources are referred to as "Imported Biokerosene"

- Indirect GHG emissions associated with EU27 region black liquor use, consisting of combustion in mainstream paper and card production[5]; these sources are referred to as "EU Black Liquor"

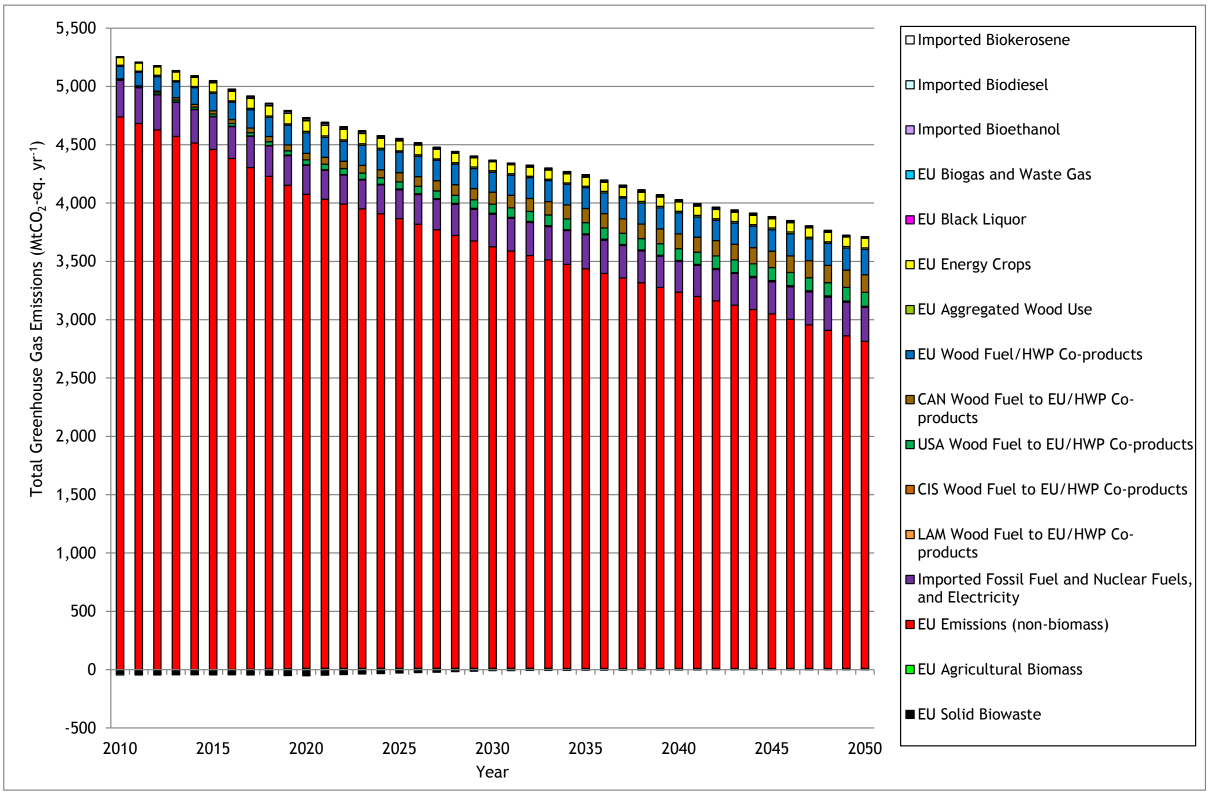
- Indirect GHG emissions associated with EU27 solid biowaste use, consisting of transportation, incineration for CHP generation, and bioethanol conversion and use, accounting for counterfactual solid biowaste disposal; these sources are referred to as "EU Solid Biowaste"

- Indirect GHG emissions associated with EU27 region biogas and waste gas use, including biogas-fired heat, CHP and electricity generation, and biogas grid injection and use by combustion; these sources are referred to as "EU Biogas and Waste Gas".

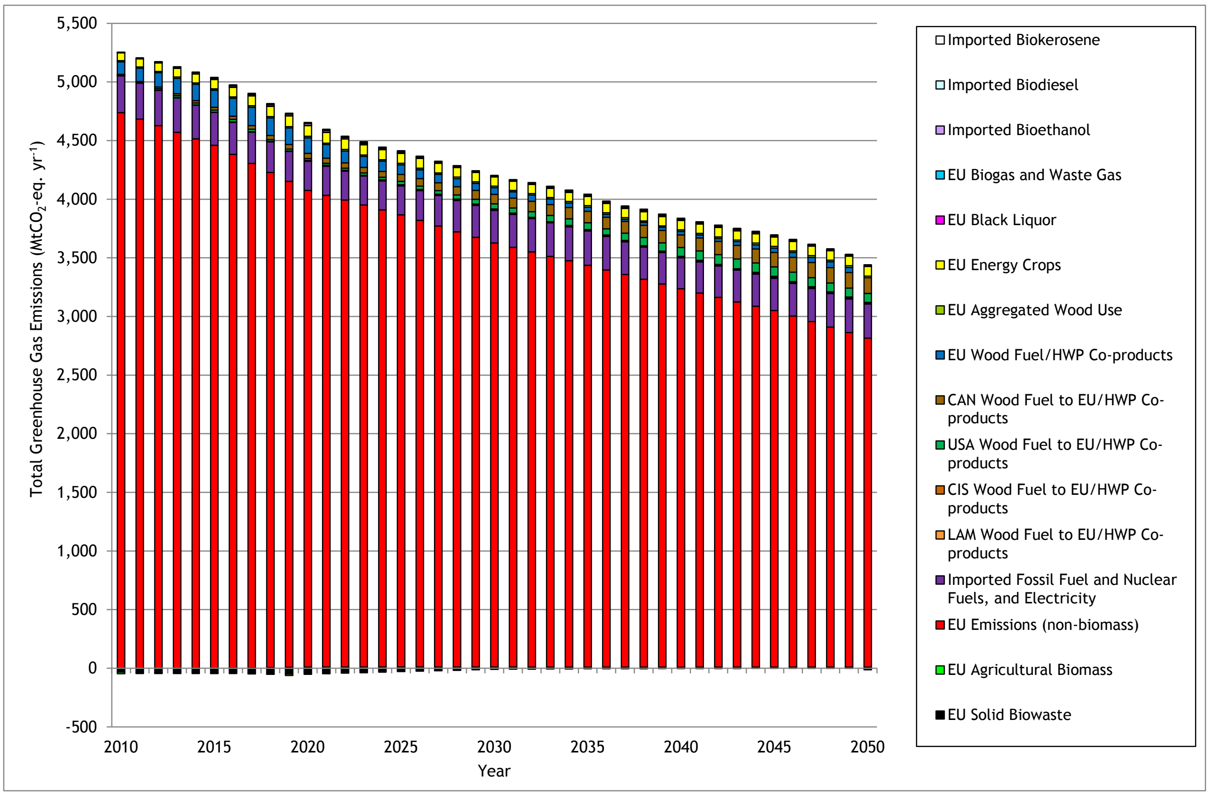
Further discussion of the basis for calculation of GHG emissions and the representation of various emissions sources in final project results can be found in Section 6.4 of the main final project report.

[5] This is separate from marginal paper and card production associated with wood fuel supply from forests in the EU27 region which is included elsewhere ("EU Wood Fuel/HWP Co-Products").

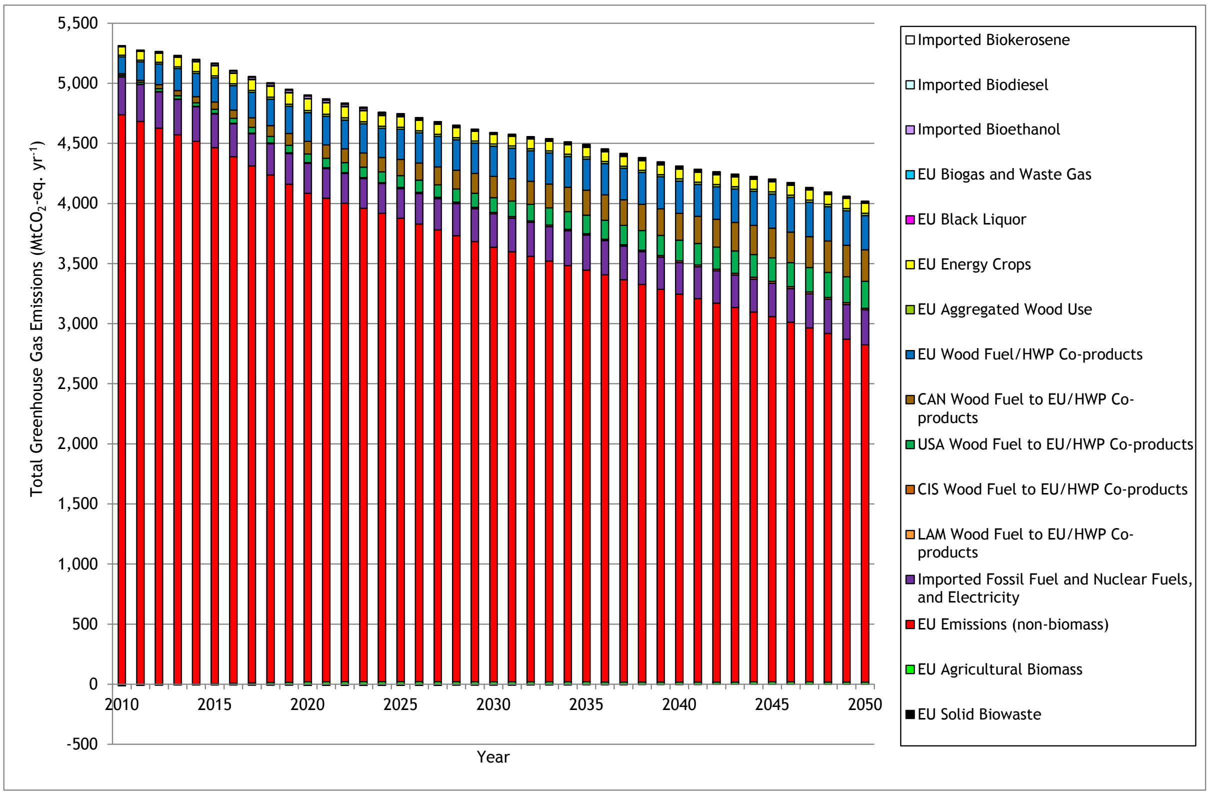
Scenario A, 'Precautionary' approach, average GHG emissions factors



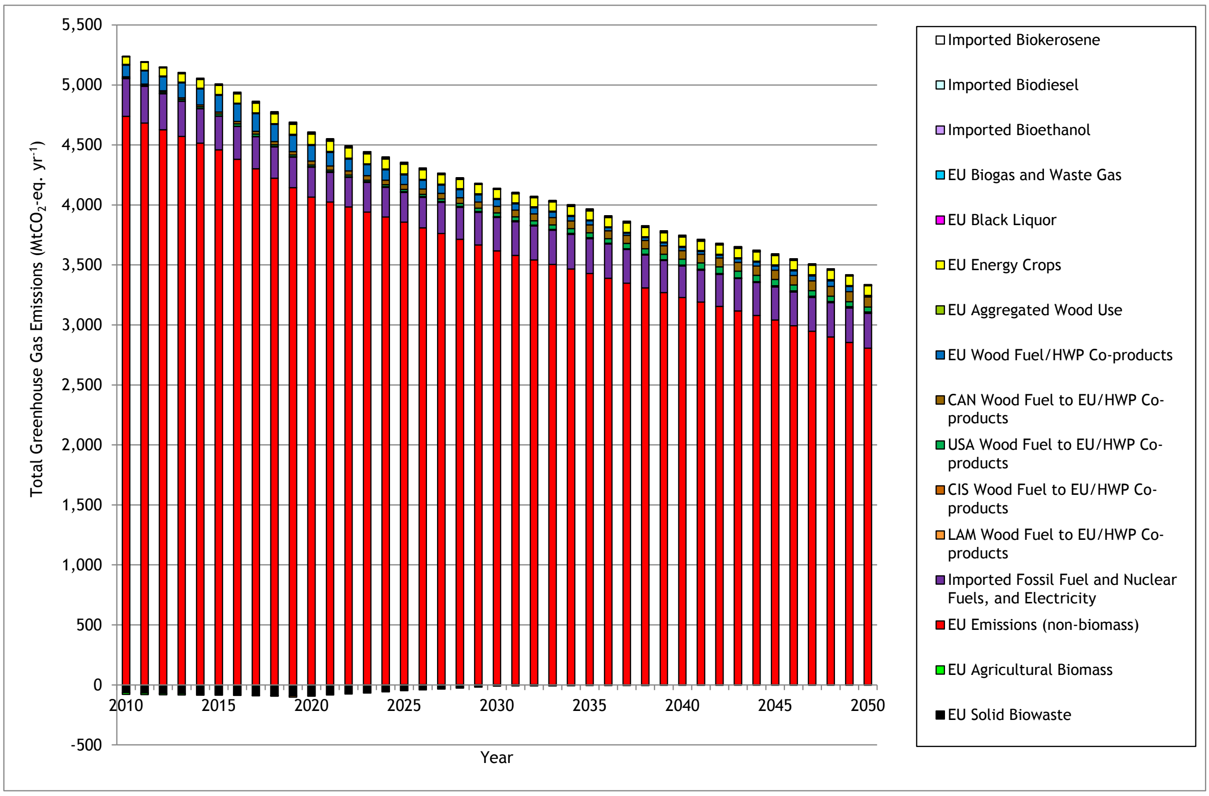
Scenario A, 'Synergistic' approach, average GHG emissions factors



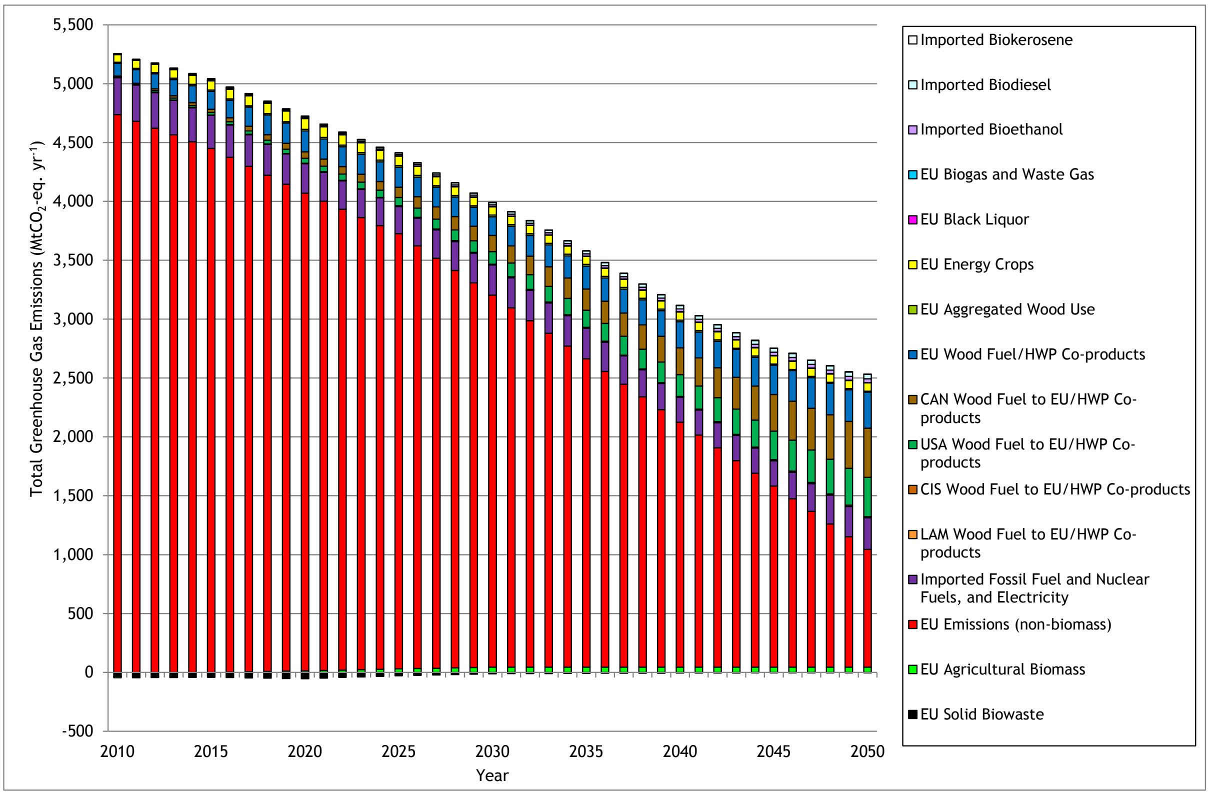
Scenario A, 'Precautionary' approach, high GHG emissions factors



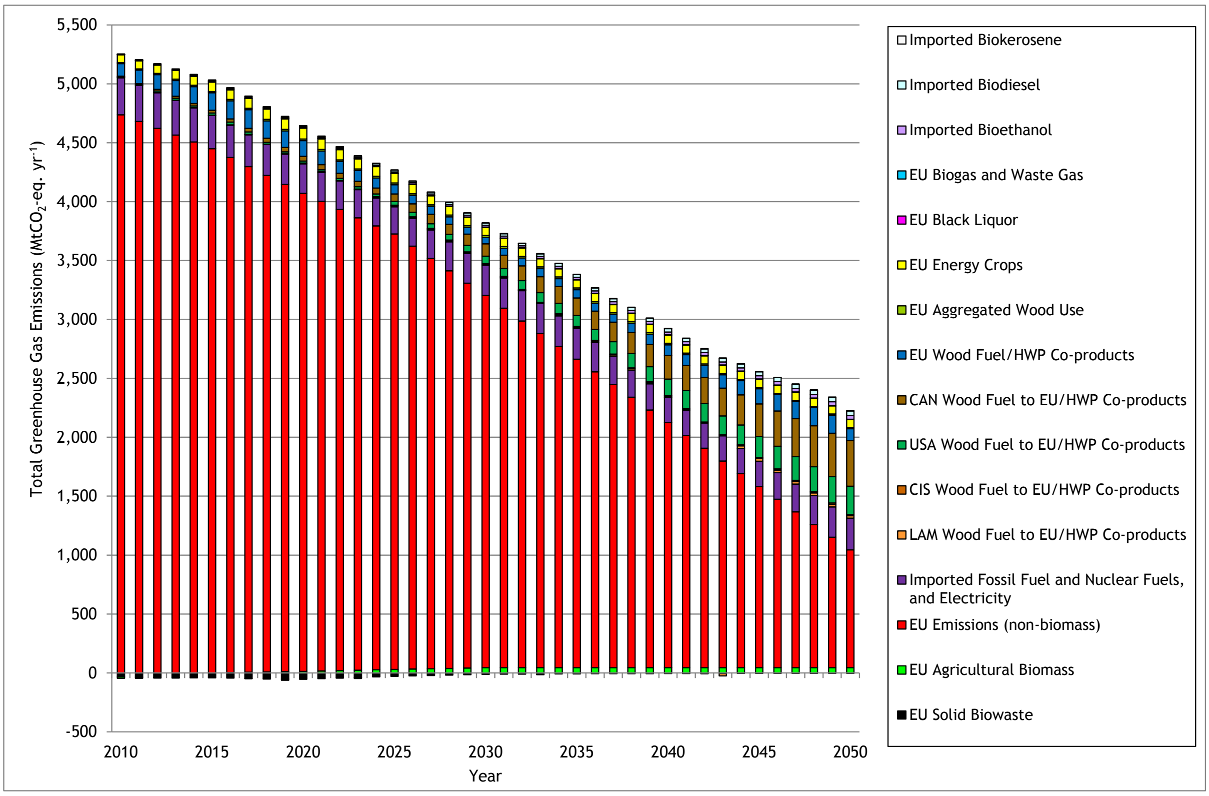
Scenario A, 'Synergistic' approach, low GHG emissions factors



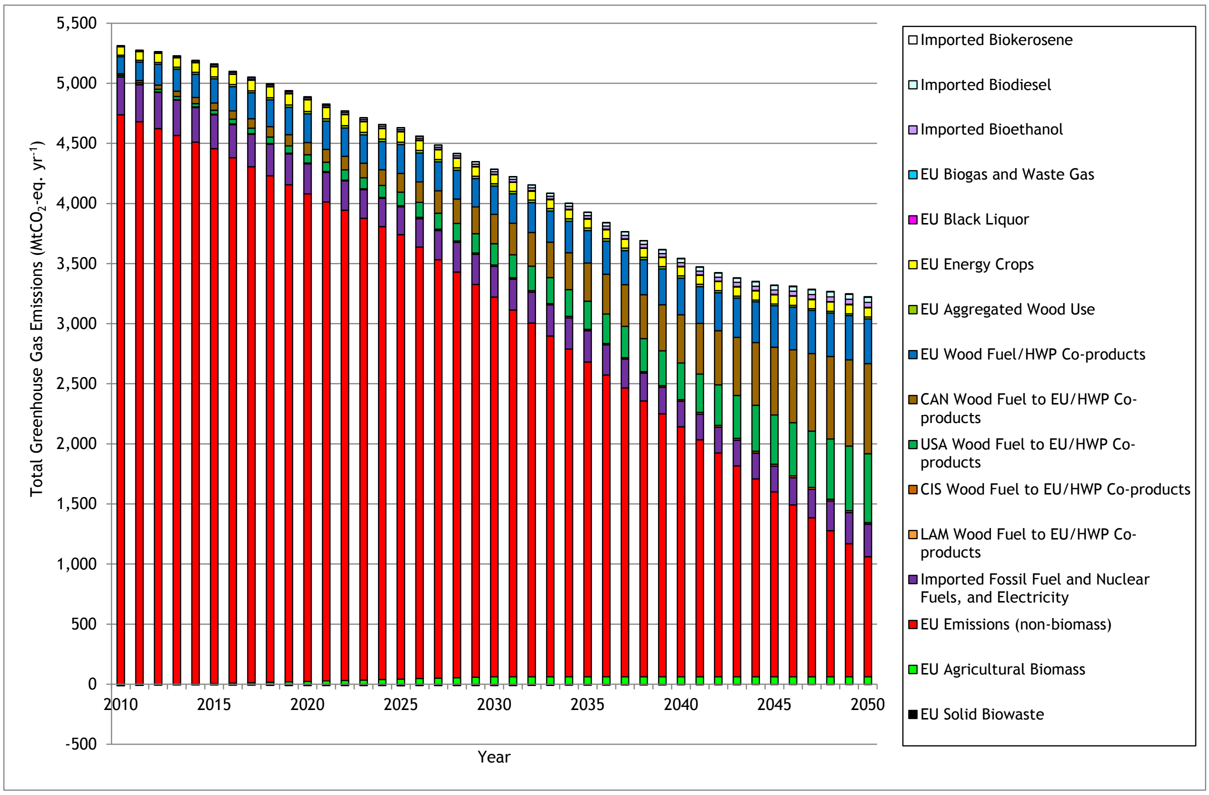
Scenario B, 'Precautionary' approach, average GHG emissions factors



Scenario B, 'Synergistic' approach, average GHG emissions factors



Scenario B, 'Precautionary' approach, high GHG emissions factors



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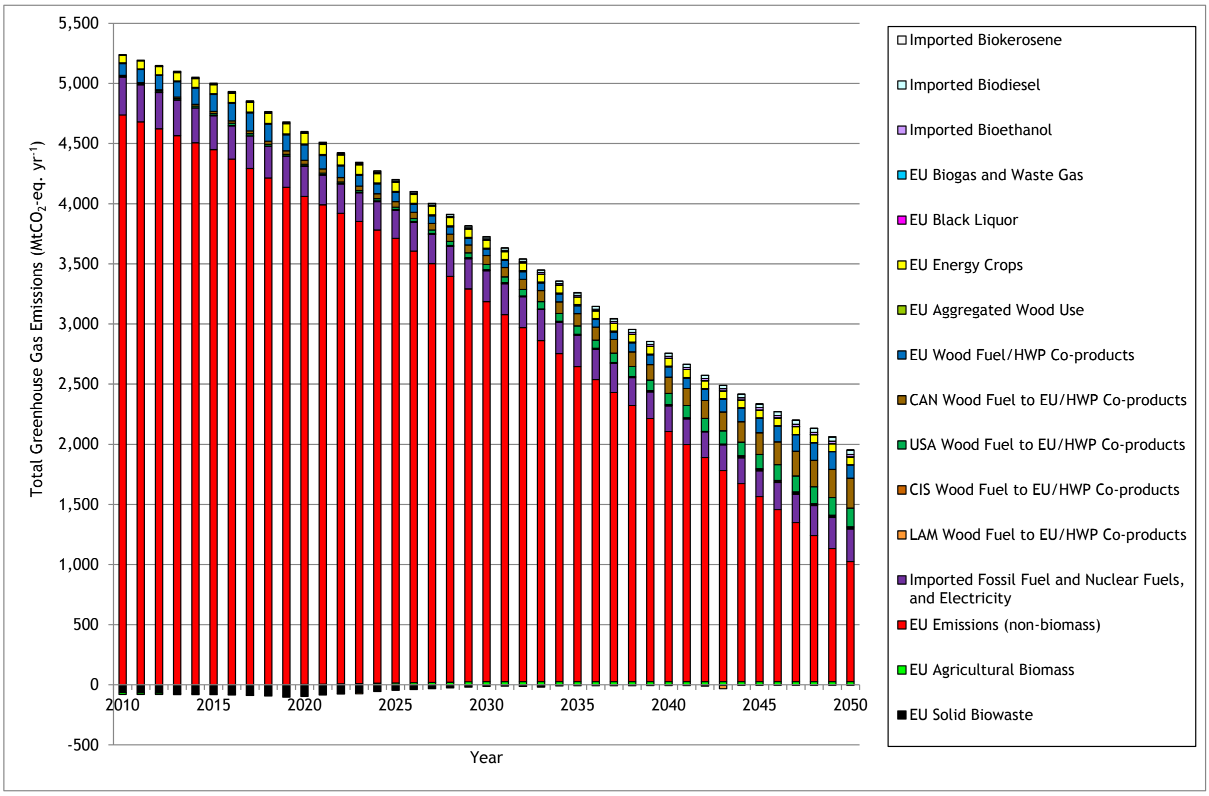
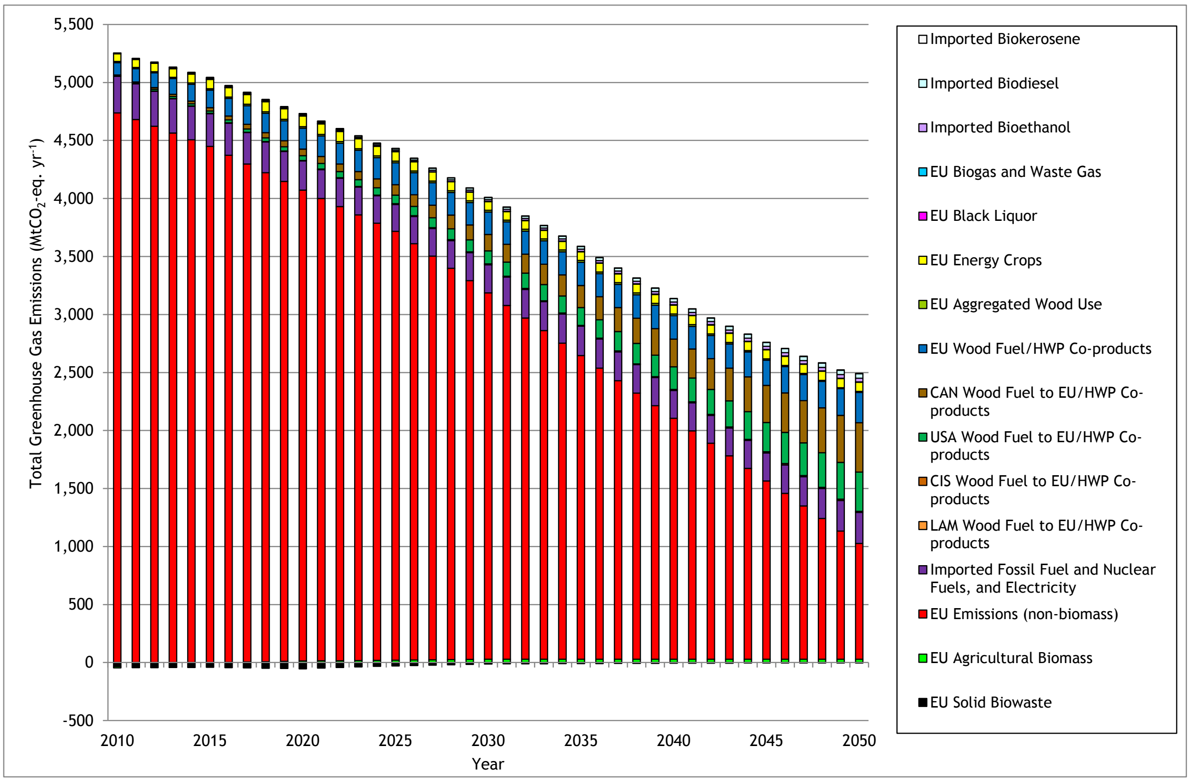
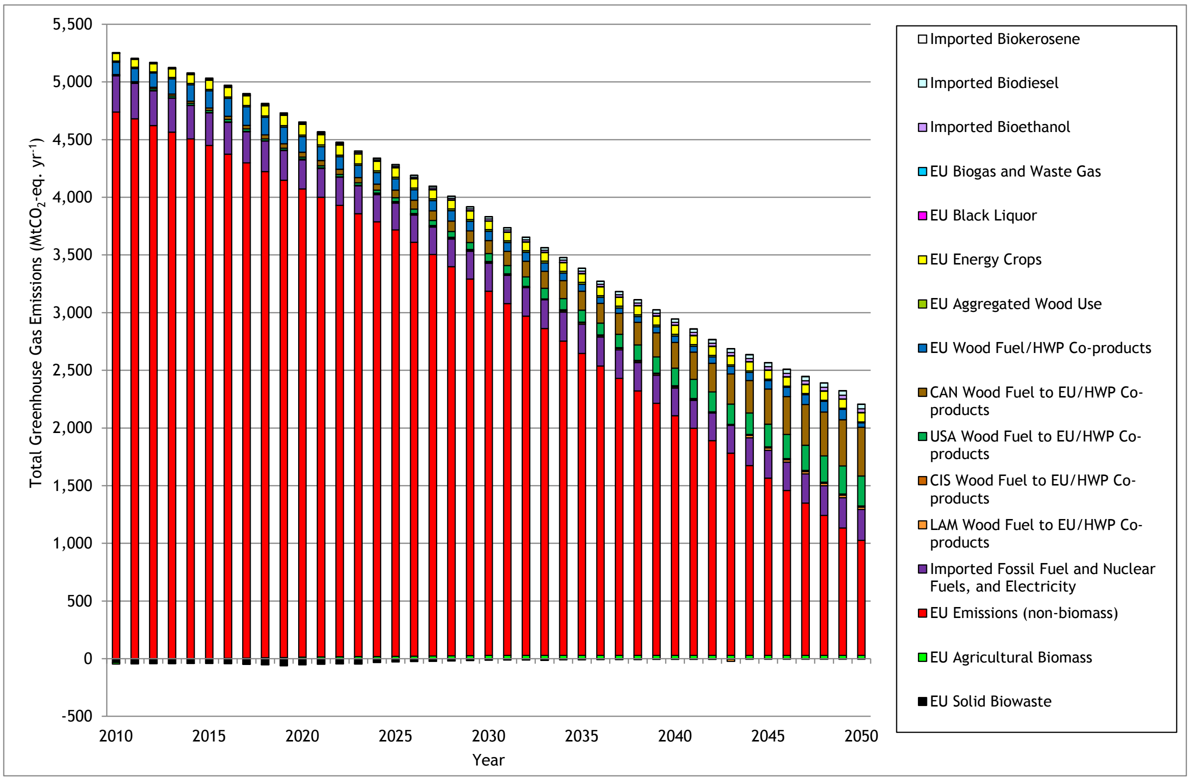


Scenario C1, 'Precautionary' approach, average GHG emissions factors



Scenario C1, 'Synergistic' approach, average GHG emissions factors



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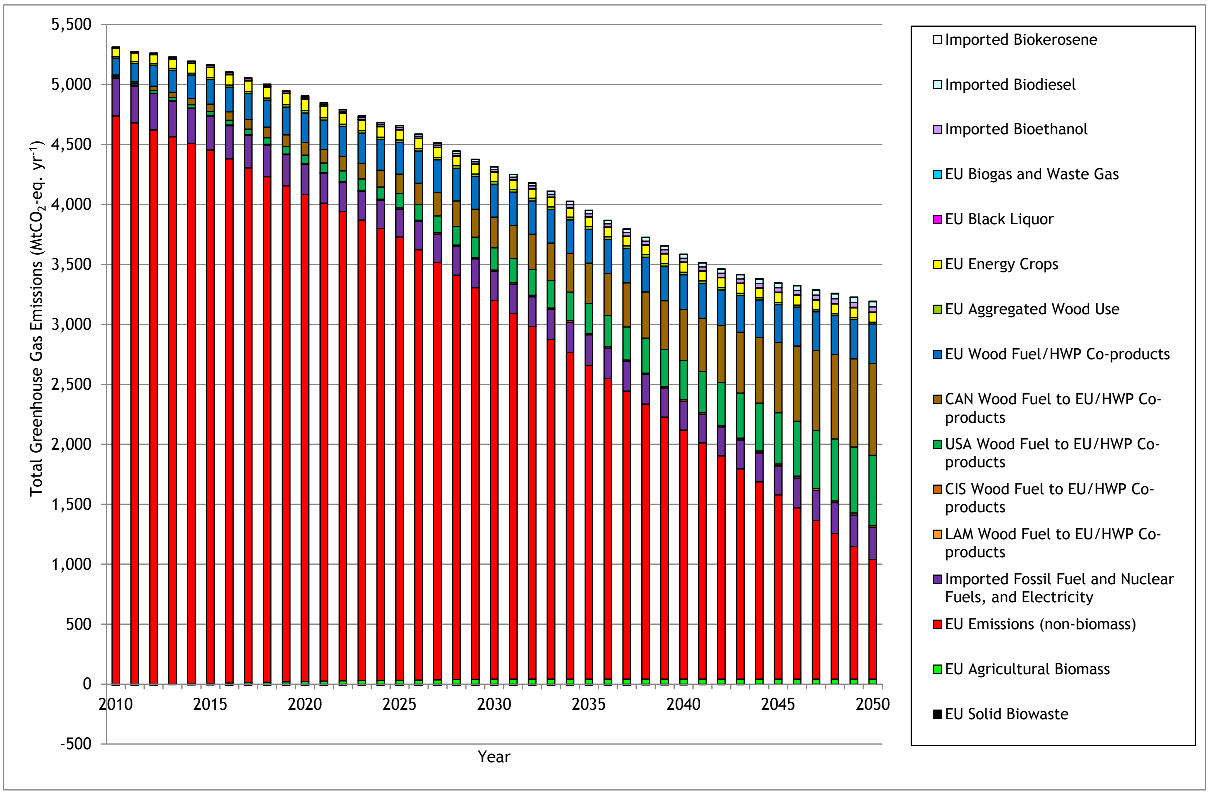
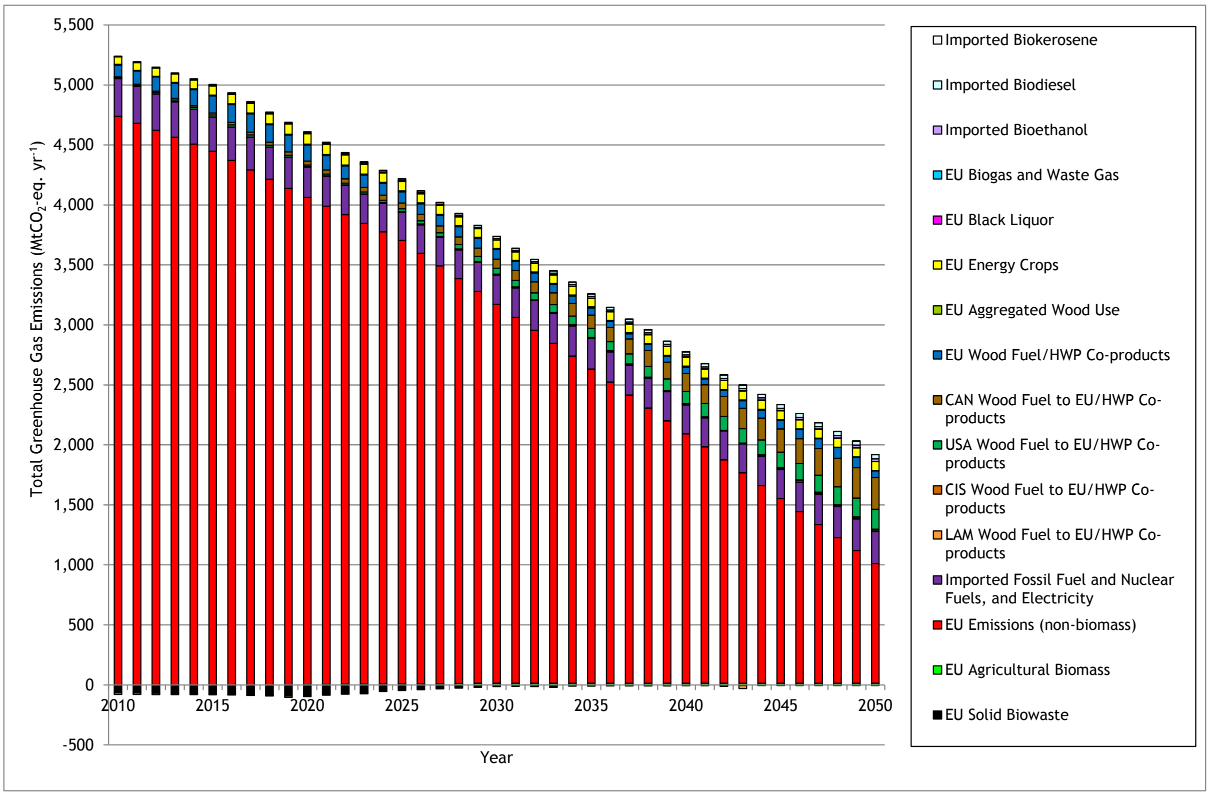
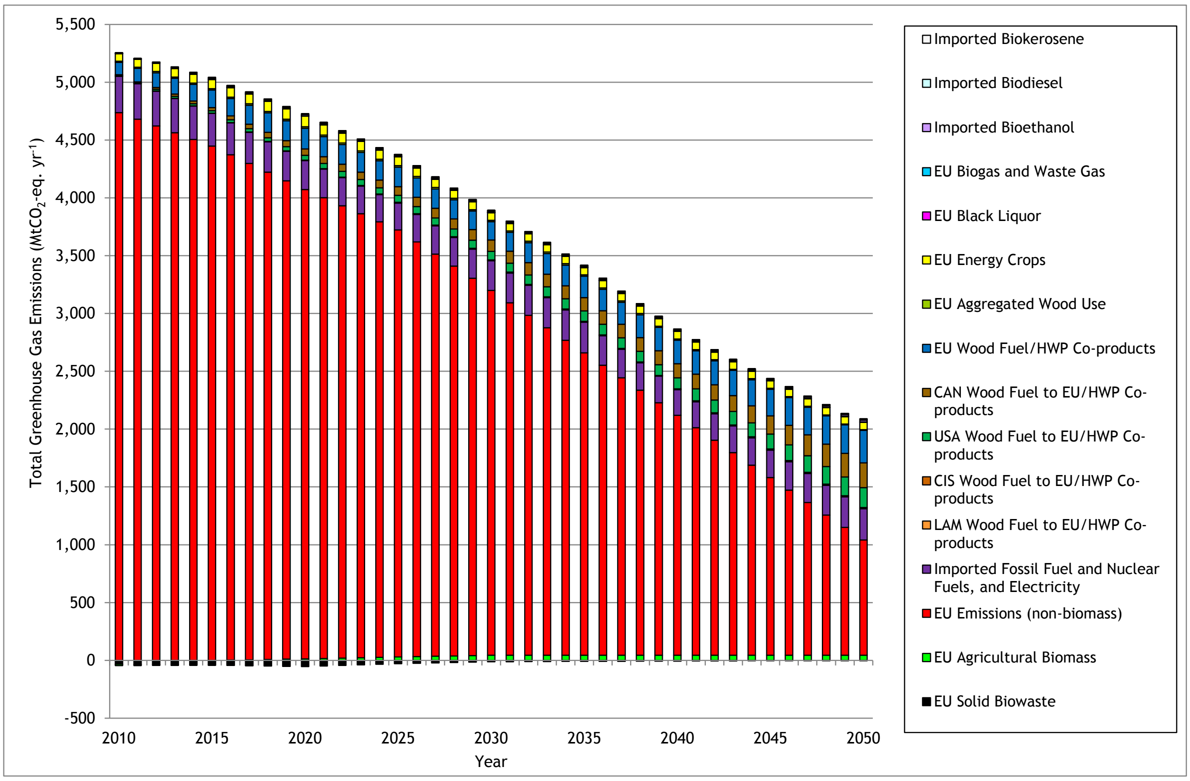


Scenario C1, 'Synergistic' approach, low GHG emissions factors



Scenario C2, 'Precautionary' approach, average GHG emissions factors



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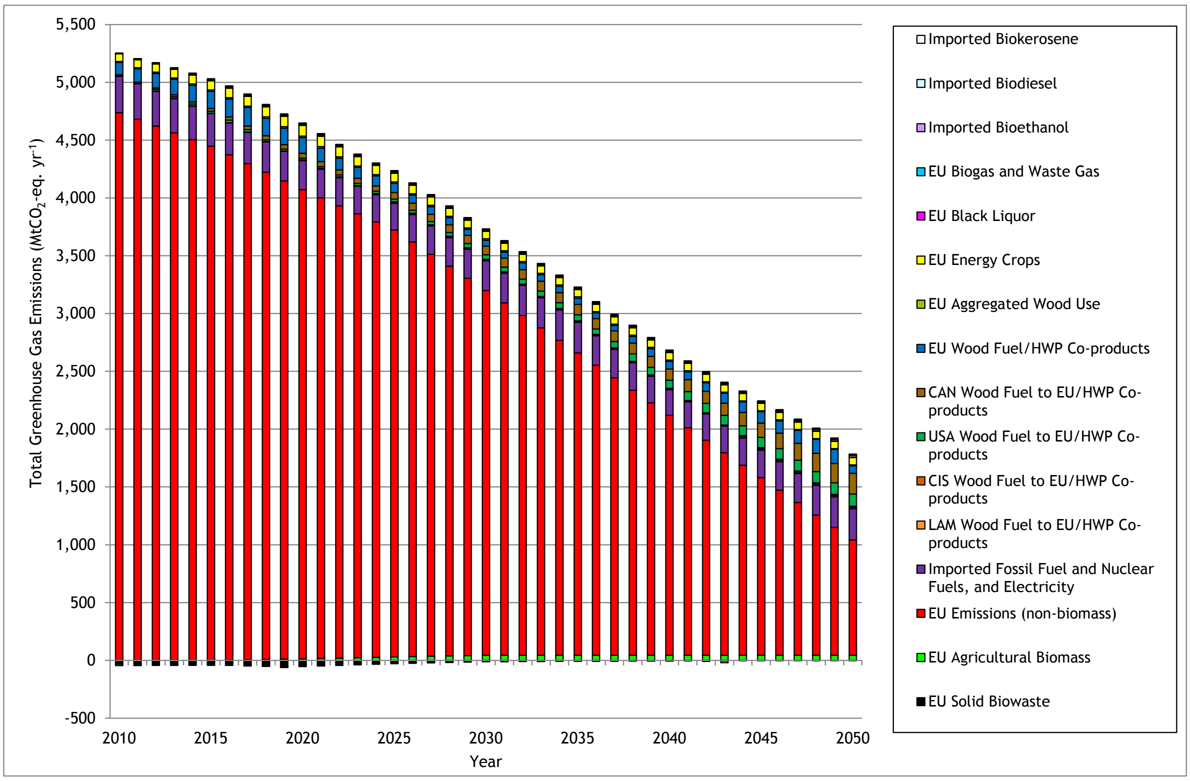

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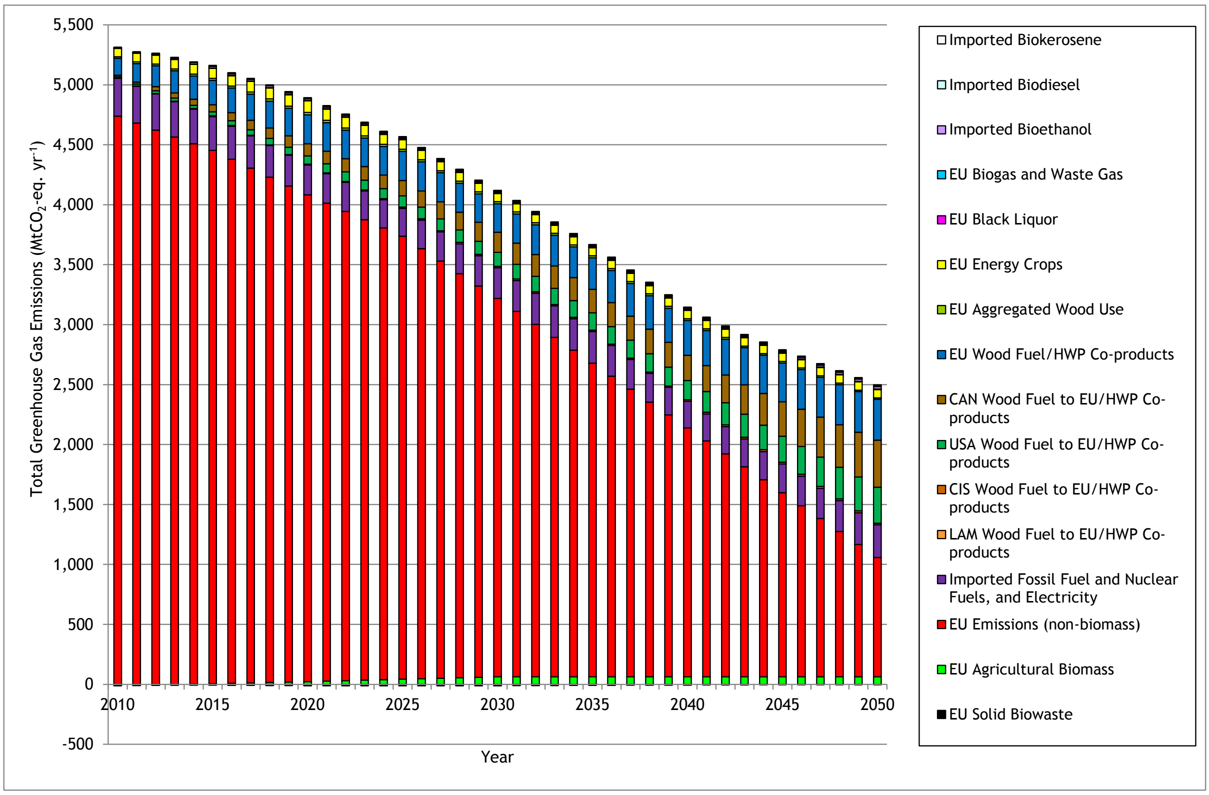
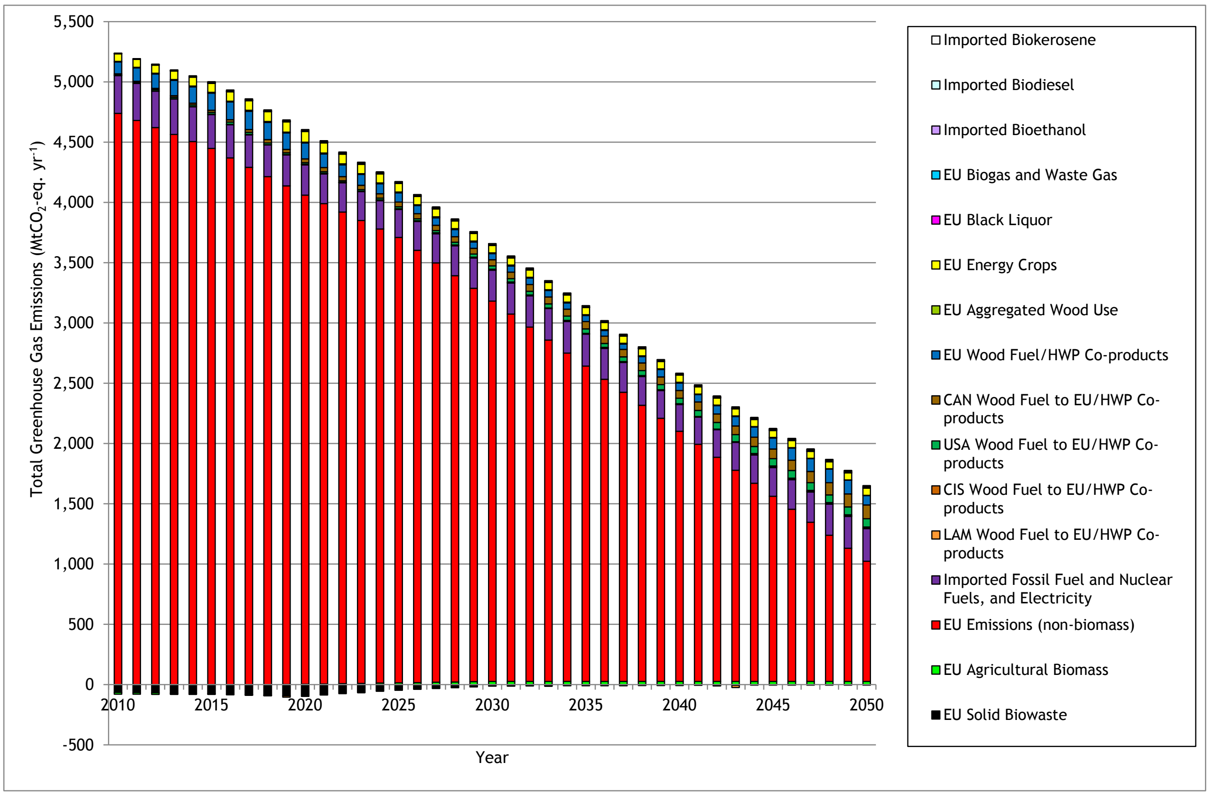
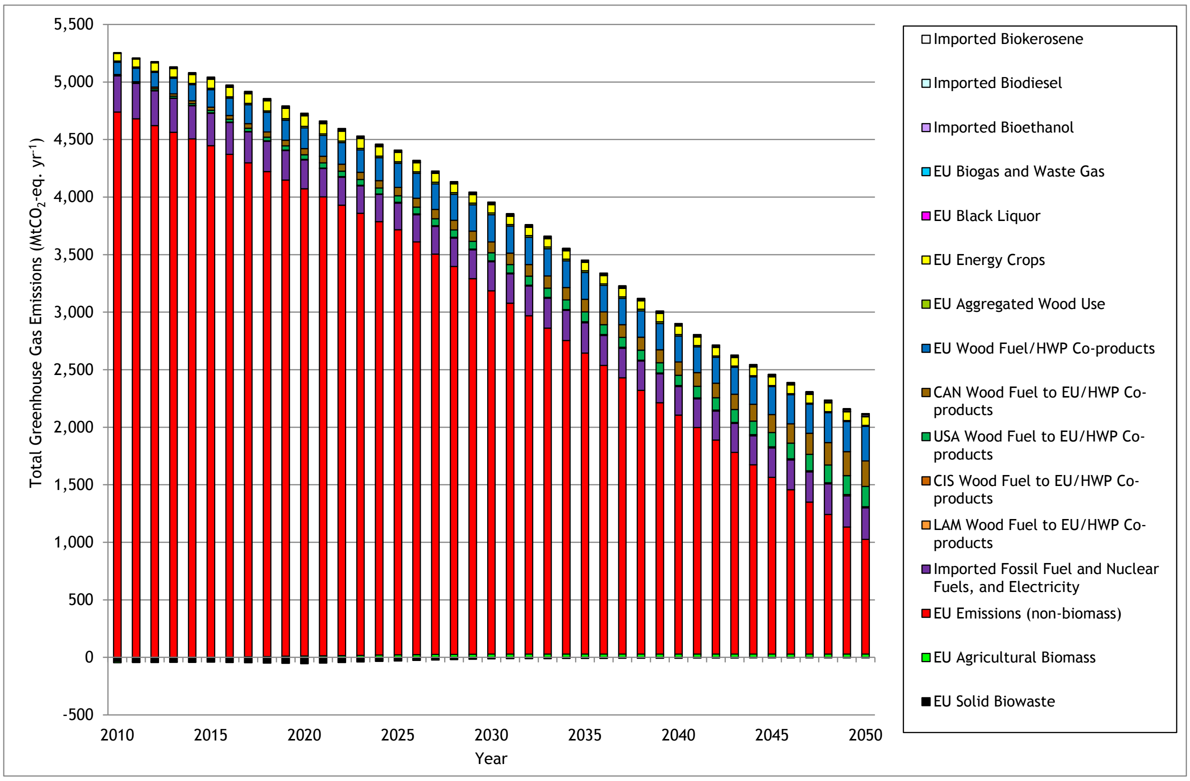


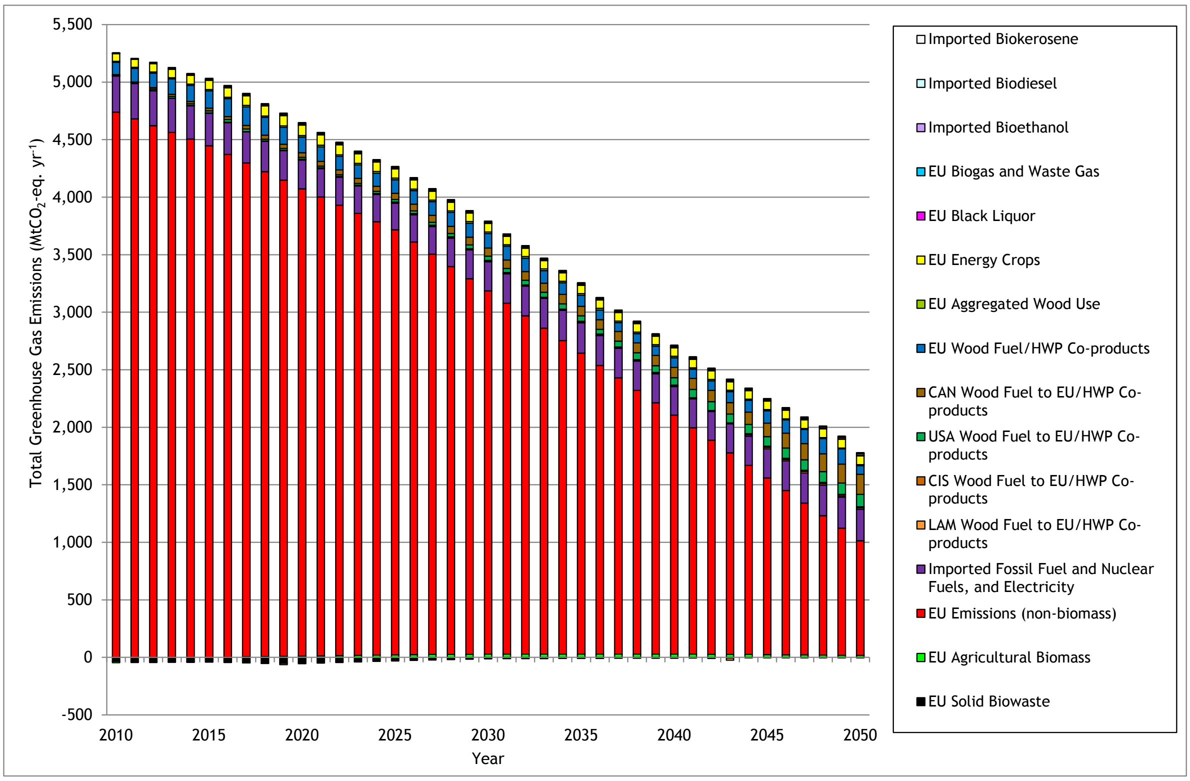
Scenario C2, 'Synergistic' approach, low GHG emissions factors



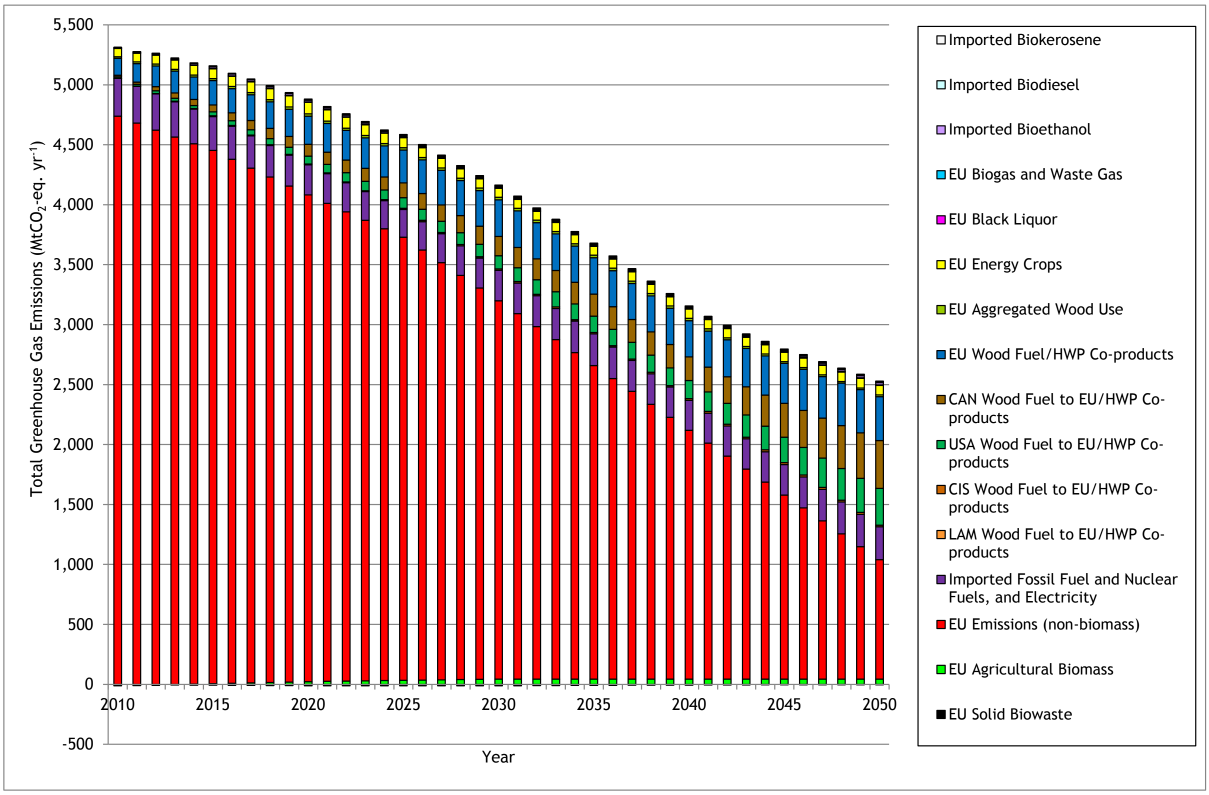
Scenario C3, 'Precautionary' approach, average GHG emissions factors



Scenario C3, 'Synergistic' approach, average GHG emissions factors



Scenario C3, 'Precautionary' approach, high GHG emissions factors



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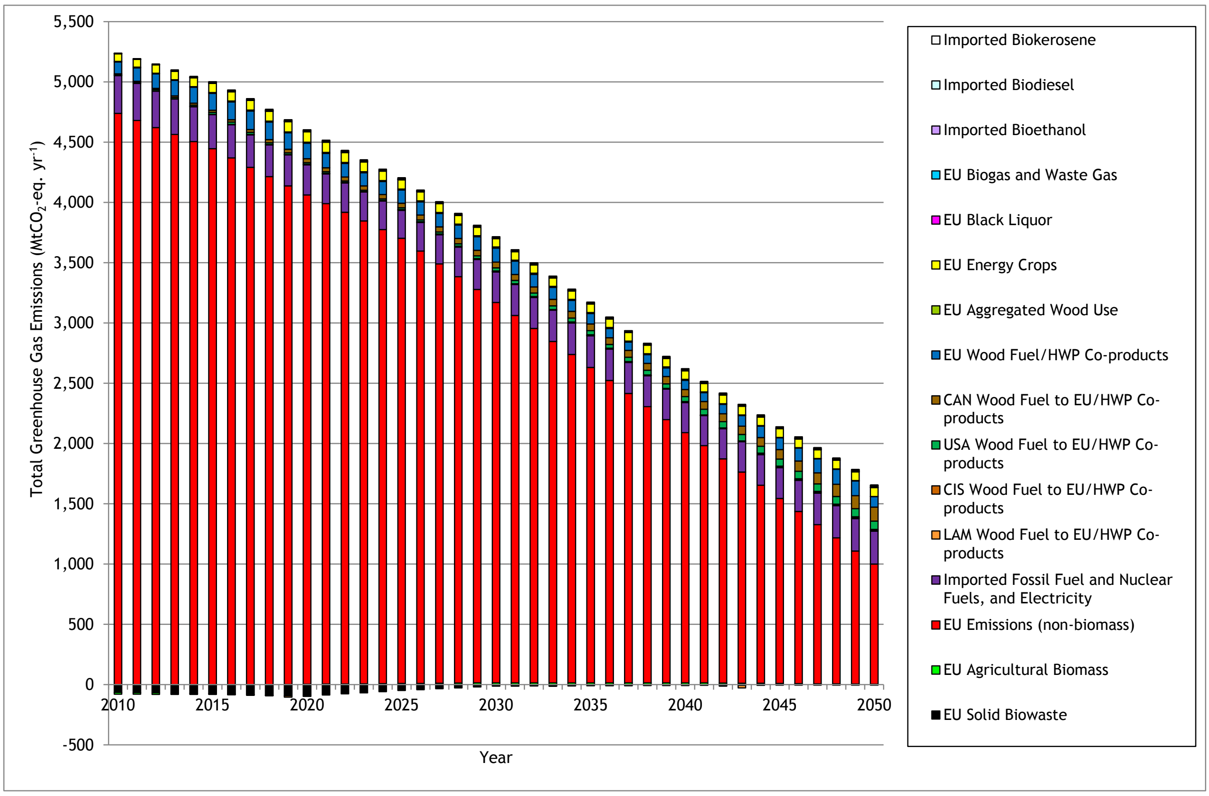
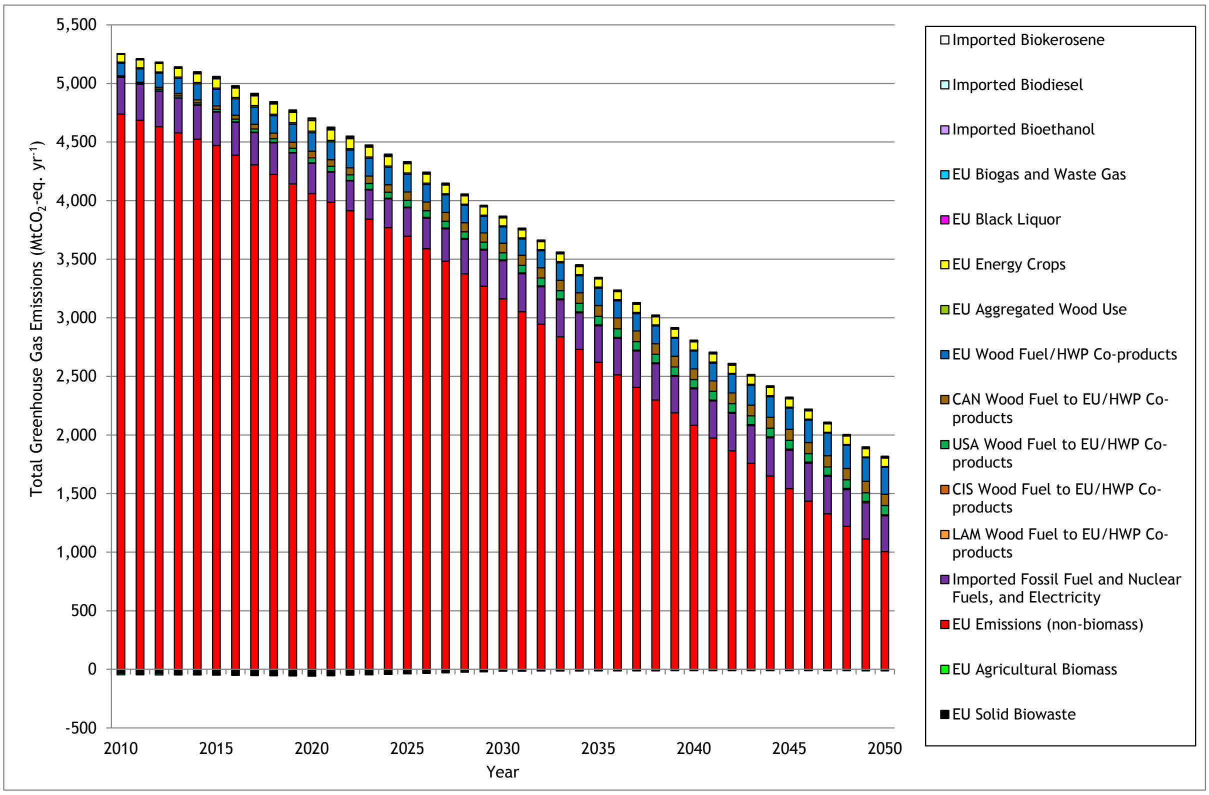


Scenario D, 'Precautionary' approach, average GHG emissions factors



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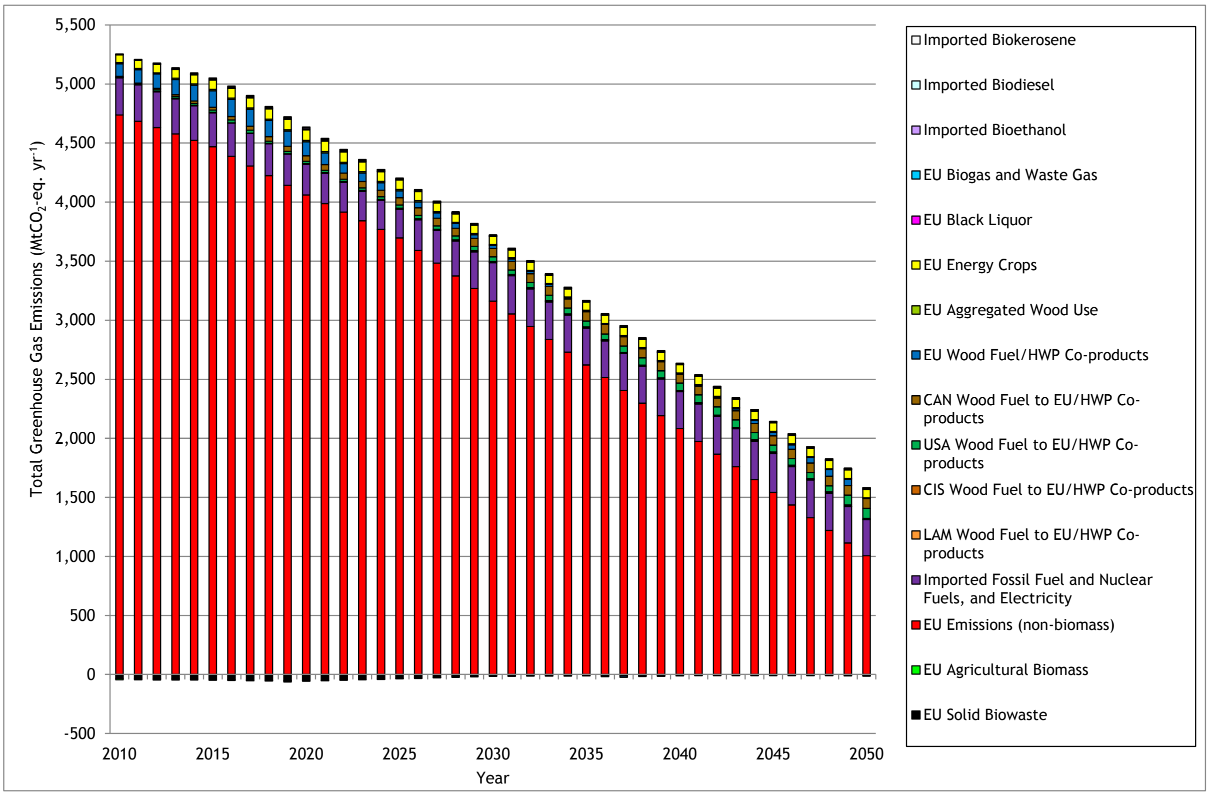

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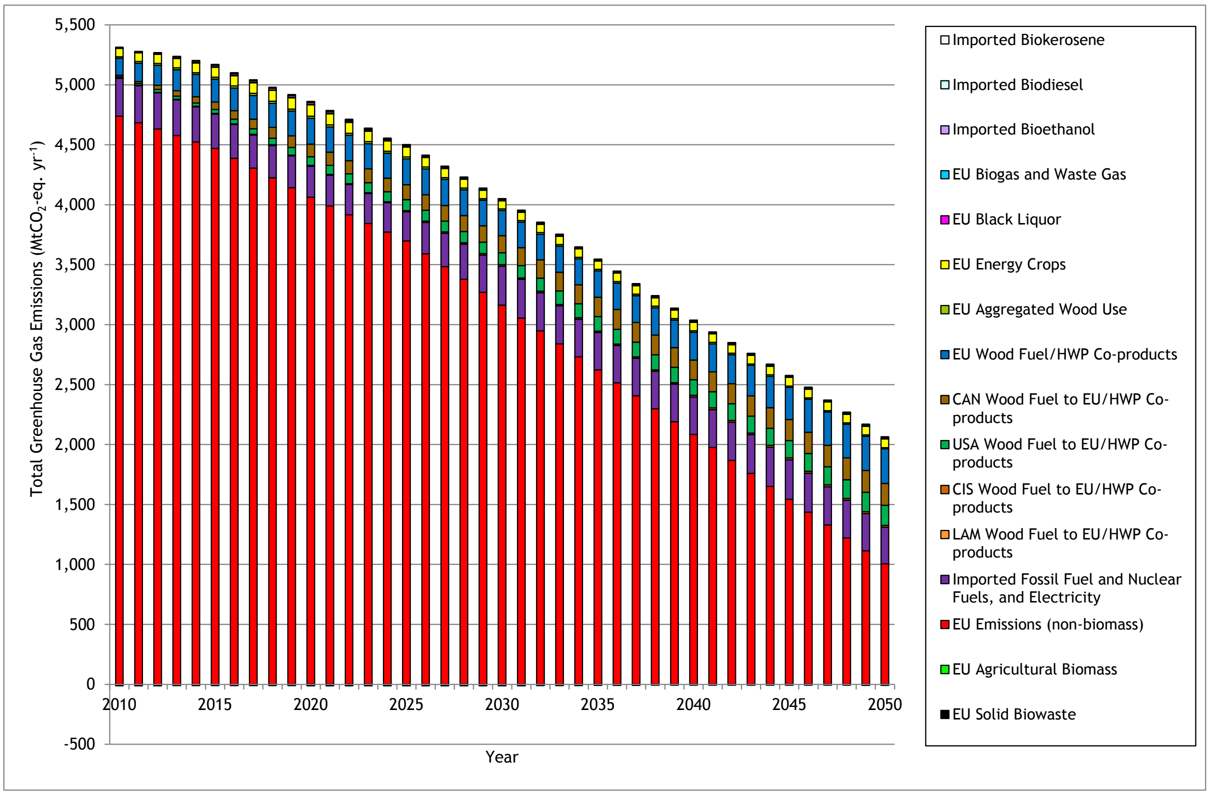

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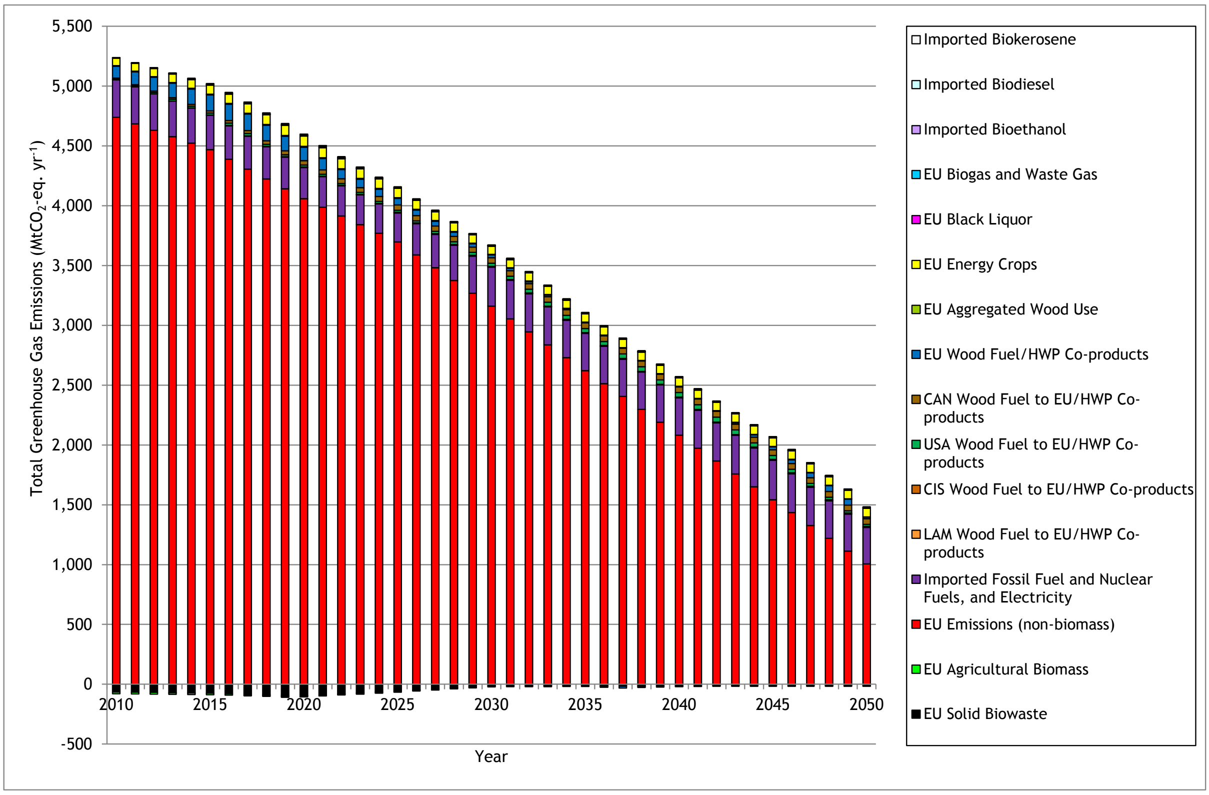

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