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Resource efficiency impacts of future EU bioenergy demand (ReceBio) – An analysis commissioned by DG Environment of the European Commission

Background Paper for 30 November 2015 - Workshop Presenting Outcomes from the Analysis, Key Messages and Conclusions

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1 Introduction

1.1 Aim of the Workshop

The workshop on the 30 November 2015 offers stakeholders the opportunity to see the draft final results of the ReceBio analysis. The day will focus on presenting, explaining and discussing with stakeholders:

- the key outcomes of the model scenarios ie the outcomes in terms of biomass production and harvest rates, feedstock use and land use;
- the potential environmental impacts including Greenhouse Gas (GHG) emissions and biodiversity consequences from land use change; and
- key messages from the project.

Comments and interventions made will help the team to frame and present the findings in the final project report, to be completed early 2016.

This background paper gives an overview of the scenario modelling results and topics that will be discussed in the workshop. The numbers presented in this report should be viewed as preliminary and not as the final view of the consortium.

The information and views set out in this report are solely those of the author(s).

1.2 Introduction to the ReceBio Project

In the European Union, biomass use for electricity and heat production is expanding. This is happening within a context of increased use of renewable energy intended to contribute to reduced greenhouse gas emissions and increased energy security. In general, the impact of increased bioenergy use on resources and on other biomass-using sectors is not sufficiently well understood. The ReceBio study, therefore, seeks to develop understanding of the various interactions and impacts that can arise as a result of different levels of EU demand in bioenergy, and their implications for resource efficiency.

The specific objective of the work under ReceBio is to understand the resource efficiency implications of different future trajectories for EU use of bioenergy for electricity and heat[1], including indirect impacts. To this end, analysis has been undertaken to understand the consequences of fulfilling different levels of bioenergy demand up to 2050 and the impacts on: the utilisation of different biomass feedstocks; land use; land management; GHG emission and biodiversity consequences. The starting point for the study is the EU 2020 climate and energy targets and the proposed EU 2030 package. In this context the scenarios, and the basis for determining the level of bioenergy demand to be assessed up to 2050, are specified building on the 'EU Reference Scenario' as described in the 2014 EU Impact Assessment[2] (hereafter, "2014 IA report").

[1] The consideration of changes in biofuel demand is outside the scope of ReceBio and as such has not been specifically analysed within the study. However, feedstock used for the production of biofuels for the transport sector is included in the model in accordance to the levels stemming from the relevant scenarios of the 2014 IA Report

[2] http://ec.europa.eu/smart-regulation/impact/ia_carried_out/docs/ia_2014/swd_2014_0015_en.pdf - see p. 24 for details of reference scenario and p. 62 for details of biomass for energy purposes

The study has used The Global Biosphere Management Model, GLOBIOM[3], to assess the potential impacts of policy scenarios that each addresses issues of key importance as to the future bioenergy demand. The project has built up the analysis in a number of steps including:

- an assessment of the state of play and availability of biomass for energy in the EU to understand trends and use patterns (task 1);
- a review of literature relating to the impact of bioenergy on the environment to understand critical issues and potential indicators (task 2);
- modeling of policy scenarios and supporting analysis of model assumptions to assess the consequences in terms of feedstocks use and competition between their uses, land use and land management of different bioenergy use patterns (task 3);
- assessment of the impacts of these patterns against key environmental parameters (task 4);
- analysis of three country case examples to understand the emerging trends in policy and use of biomass and how these compare with model outputs (task 5).

Elements highlighted form the basis for the workshop discussions.

1.3 Introduction to the Modelling Approach and Framing of the Study

GLOBIOM is a global model of the forest and agricultural sectors, where the supply side of the model is built-up from the bottom (land cover, land use, management systems) to the top (production/markets). The GLOBIOM model has a long history of publication[4] and has previously been used in several European assessments[5]. The model computes market equilibrium for agricultural and forest products by allocating land use among production activities to maximise the sum of producer and consumer surplus, subject to resource, technological and policy constraints. The level of production in a given area is determined by the agricultural or forestry productivity in that area (dependent on suitability and management), by market prices (reflecting the level of supply and demand), and by the conditions and cost associated to conversion of the land, to expansion of the production and, when relevant, to international market access. Trade flows are computed endogenously in GLOBIOM, following a spatial equilibrium approach so that bilateral trade flows between individual regions can be traced for the whole range of the traded commodities.

The following modelling features are reflected in the GLOBIOM integrated framework used for this particular project:

- As the focus of the project is to assess the potential impact of increasing bioenergy demand, the project makes no attempt to estimate future bioenergy demand levels and all bioenergy demand projections are exogenously defined. They stem from PRIMES and POLES modeling results developed for previous Commission work[5]. GLOBIOM uses these bioenergy demand projections as exogenous inputs, they always have to be fulfilled, even if it reduces the availability of biomass resources for other purposes.
- The PRIMES estimates of bioenergy demand related to the use of wood from forests, SRC and industrial by-products is, within the ReceBio modelling, expressed as a single total demand (and not as feedstock specific demands). Where technically feasible, full substitution between the use of wood, SRC, and forest based industrial by-products is therefore considered. While this demand must be fulfilled, the model decides, based on the

[3] http://www.globiom.org

[4] See Havlík, P., Valin, H., Herrero, M., Obersteiner, M., Schmid, E., Rufino, M.C., Mosnier, A., Thornton, P.K., Böttcher, H., Conant, R.T., Frank, S., Fritz, S., Fuss, S., Kraxner, F., Notenbaert, A., 2014. Climate change mitigation through livestock system transitions. Proc. Natl. Acad. Sci. 111, 3709–3714.

[5] See EC, (2013). EU Energy, Transport and GHG Emissions Trends to 2050: Reference Scenario 2013. European Commission Directorate-General for Energy, DG Climate Action and DG Mobility and Transport., Brussels, p. 168. and EC, (2014). A policy framework for climate and energy in the period from 2020 to 2030. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. European Commission, Brussels, p. 18.

assumptions applied concerning costs and potentials, which feedstocks are the most appropriate to be used to fulfill the overall bioenergy. As a result, further disaggregation regarding the sources, feedstocks and land use impacts is possible as compared to previous work.

- There is no feedback from price signals of feedstocks upon total bioenergy demand ie increases in bioenergy use may well push up prices for feedstocks, however, this will not feedback to reduce demand for bioenergy (over other energy technologies). Indeed, in this exercise, we are interested in the consequences of delivering a given bioenergy level and this is, therefore, fixed at a certain level for each scenario. In other words, the composition of feedstocks being used for bioenergy production is influenced by the price signal of individual feedstocks, but not by the total bioenergy demand.
- During the modelling, change in GHG emissions and removals due to increased or reduced biomass demand linked to land use and land use change (LULUCF) is not accounted for in the efforts needed for reaching an overall EU GHG emission reduction target for each scenario. Therefore, increasing or decreasing forest carbon stocks in relation to the forest management levels are not reflected back to the bioenergy demand, however, GHG consequences are analysed as outputs of the study.
- The starting year of the assessment is that of the year 2000, and the potential impact of bioenergy demand is being assessed until 2050. Bioenergy demand and model outcome are presented on a ten-year basis.

The results of the scenarios are analysed in terms of feedstocks use and competition between their uses, focusing on the observed results for the time period from 2010 to 2030 and further to 2050. The main interest is on the wood biomass used for heat and electricity production, and the competition between the material and energy use of wood within the EU. More specifically, the results assess changes and impacts on:

- EU land use development
- Forest harvest levels within the EU
- Development of short rotation coppices for energy production in the EU
- Use of wood biomass for material and energy production, and production of semi-finished forest products (sawnwood, plywood, fiber- and particleboards, wood pulp)

Box 1 – Introduction to the Feedstock and End Use Categories Used within ReceBio

This box gives a short description of the central feedstocks and end use categories considered in the project. This is not an exhaustive list of the biomass types considered within the project, but instead gives an overview of the main categories where central project results are reflected.

- ***Forest based industries*** – the project covers production of chemical and mechanical pulp, sawnwood, plywood, fibre- and particleboard (both referred to as particleboard), and woodpellets. The initial production of commodities within GLOBIOM is based on the production quantities as of FAOSTAT.
- ***Firewood*** – wood used as fuel for cooking, heating and power production in a non-industrial scale (as household fuelwood). This type of wood use for energy is a large driver for forest harvests within the EU as well as globally. However, the statistics are highly uncertain. In this project, FAOSTAT estimates of firewood within the EU were refined using data from national statistics and Joint Wood Energy Enquiry (JWEE). For rest of the world, FAOSTAT statistics were used.
- ***Roundwood for energy*** – in this project, we differentiate direct combustion of industrial-quality roundwood from firewood. Roundwood for energy is defined in this project as roundwood of sufficient quality and dimension to be used for material production, but is instead used directly for energy production in small or large conversion facilities. In GLOBIOM, direct competition is modeled between roundwood used for energy and material production (mostly for pulp and particleboard production). Initially (as of 2010), it is assumed that no roundwood is being used directly for energy in EU28.

- ***Wood pellets*** - Wood pellets are refined wood fuels that are mostly made of industrial by-products, such as wood chips, sawdust and/or shavings. In the ReceBio project, wood pellets produced within the EU are included within industrial residues. EU imports of wood pellets, however, are differentiated as a separate feedstock, to facilitate trade analysis. EU trade of wood pellets as of 2010 is based on EUROSTAT and Indufor data.
- ***Industrial by-products*** – By-products and residues of the mechanical wood-processing industry, including chips, sawdust, shavings, trimmings and bark. They are an important raw materials for pulp, panel and pellet production, and used also as such for bioenergy.
- ***Recycled wood*** – all kinds of wood material which, at the end of its life cycle, is made available for re-use or recycling. Re-use can be either for material purposes or energy production. This group mainly includes used packaging materials, wood from demolition projects, and unused or scrap building wood. The availability and consumption estimates for 2010 are based on collected data from JWEE, EPF, COST 31, Wood Recyclers' Association UK, BAV Germany, and Indufor data.
- ***Short rotation coppice (SRC)*** – tree plantations (mostly poplar and willow) established and managed under an intensive, short rotation regime on agricultural land. In ReceBio, the land availability for SRC and other ligno-cellulosic biomass (miscanthus, reed canary grass) is based on CORINE/PELCOM (2000) land cover estimates, and the same as in the 2014 IA report.
- ***Harvests*** – in the ReceBio project, harvests refer to removal of biomass from forests or SRC.
- ***Forest residues*** – leftover branches, stumps and stem tops from logging operations that can be used for bioenergy. In this project, the estimated levels for forest residue harvests are based on a compilation of national statistics and JWEE reporting.

1.4 Assessing Environmental Impacts - Methodology

In earlier tasks of the project a list of potential indicators had been defined that can be used to assess environmental impacts of increased biomass use. Selected indicators related to GHG emissions and removals, potential environmental impacts on biodiversity, soil and water were translated into GLOBIOM model variables. The indicators are used to assess model output and to detect potential impacts of changes in biomass use between different scenarios in EU28 and Rest of the World (RoW). The changes in scenario assumptions are expected to affect indicators differently.

The main indicators for assessing environmental impacts of biomass use in EU28 in different policy scenarios are derived from the following model output variables:

- Land use (addressing the model variables Forest area, including the categories Afforestation, Used Forest, Unused Forest; Area of Deforestation; Area of Cropland, including the category Short Rotation Coppice; Area of Grazing land; Area of other natural land)
- Biodiversity (addressing the model variables Unused forest area; Unused forest converted to other land use; Land with high biodiversity value (HBV); Forest rotation period
- Greenhouse Gases (addressing the model variables Emissions from agriculture and livestock; Emissions from forest activities and Harvested Wood Products; Total net land use emissions)
- Water and soil (addressing the model variables Water used for agriculture; Irrigation area; Forest area with steep slopes)

Box 2 – Introduction to Land Use Categories Used in ReceBio

Within this box some land use categories and their features under the models GLOBIOM/G4M, are

defined. These serve as the basis for establishing environmental indicators,

- ***Forest*** - The FAO FRA 2010[6] definition is used when classifying land as forest. Forest that is not protected is considered as potential production forest. The model allocates harvests to this area so that the projected demand for wood for material and energy purposes will be satisfied.
- ***Used forest*** **-** Forests that are used in a certain period to meet the wood demand are modelled to be managed for woody biomass production. This implies a certain rotation time, thinning events and final harvest.
- **Unused forest** – Forests that currently do not contribute to wood supply (for economic reasons) as determined by the model.
- ***Area classified as afforestation*** **-** Land that has been converted to forest after the year 2000 (the start of the model run). All new forests established through afforestation are considered to be used for wood supply.
- ***Agricultural land*** – Includes cropland, grazing land, short rotation coppice and other natural land.
- ***Cropland*** **-** Land used for crop production. This also includes set-aside areas declared as cropland, but not currently used for crop harvesting (e.g. fallow land). This land category also includes annual and perennial lignocellulosic plants (e.g. miscanthus and switchgrass) that are increasingly used for biofuel production as well as Short Rotation Coppice.
- ***Grazing land*** – Pasture lands used for ruminant grazing. It does not include unused natural grasslands.
- ***Other natural vegetation or other natural land*** – A mixture of land that cannot be properly classified such as unused cropland (if not fallow) or unused grassland, including natural grasslands. Other land categories (e.g. settlements, wetlands etc.) are ignored by the model and kept fixed in the scenarios.
- **Protected forest areas** - Protected forest areas (as defined by WDPA Consortium 2004) are delineated outside from the analysis and no conversion or use is assumed. Other conservation initiatives (e.g. Natura 2000, which are often not reserves but where sustainable management is allowed) and local protection initiatives are not considered within the analysis.
- ***Areas of high biodiversity value*** (HBV) – Within the model we consider HBV areas based on the Carbon and Biodiversity Atlas by WCMC[17]. This atlas presents a set of maps of different biodiversity hot spots. In this study, we assume that where at least three maps of biodiversity hot spots of species groups (e.g. birds, mammals) overlap, land is considered to be of high biodiversity value. These areas are then overlaid with the land use information in GLOBIOM. HBV areas can be found on cropland, grazing land, used and unused forests and other natural land.

[6] FAO 2010: Global Forest Resources Assessment 2010. Main report. United Nations Food and Agriculture Organisation, Rome. p. 378 http://www.fao.org/docrep/013/i1757e/i1757e.pdf

[7] http://www.unep.org/pdf/carbon_biodiversity.pdf

2 The Baseline Scenario – A Starting Point for Assessment

The basis for the baseline scenario examined in ReceBio is 'EU Reference Scenario' of the 2014 IA Report. The goal of the baseline scenario is to depict a future with continued increasing global population, intermediate economic developments including consideration to EU's economic downturn, and ongoing development of international fuel prices. Moreover, it portrays a future in which consumption patterns of food, fibre, and fuels continue to evolve over time following current trends.

The baseline scenario also considers the same range of policy targets as assumed for the 'EU Reference Scenario'. It takes into account a broad range of policy commitments, currently implemented policies, legislations and targets that have been announced by countries and adopted by late spring 2012. Key policies for the EU that are considered include the EU ETS Directive (2009/29/EC), the Renewable Energy Directive (2009/28/EC), Energy Efficiency Directive (2001/27/EU), and GHG Effort Sharing decision (No 406/2009/EC). From 2012 onwards, no changes in policies are assumed and no new policies are considered.

Resulting from these policies, and as estimated for the 'EU Reference Scenario', renewable energy share (RES) in the EU28 would account for a 24.4% of gross final energy consumption by 2030, and 28.7% in 2050. Bioenergy plays an important role in this trend and total bioenergy production from biomass and waste increases from 85 Mtoe in 2005 to 124 Mtoe in 2010, 150 Mtoe in 2020, date after which bioenergy production increases at a slower pace until 2050 (to 153 Mtoe to 2030, and 164 Mtoe as in 2050)[8].

The ReceBio Baseline Scenario is based on the same underlying assumptions concerning socio-economic growth, statistical data, and policy targets as for the 'EU Reference Scenario'. It assumed the same total bioenergy demand as that for the 'EU Reference Scenario'. However, under the ReceBio Baseline Scenario certain assumptions made in the 'EU Reference Scenario' have been further developed to take account of additional information identified and assessed within the project and to enable more effective assessment of bioenergy demand. The key differences are set out below:

- Data concerning wood-based industries, as collected in the state of play assessment (Task 1), has been integrated within the modelling framework. This allows for more accurate representation of these industries as well as the biomass sources being used for the production of the various woody commodities.
- Collection and consumption of particular wood biomass resources has also been updated taking into account latest available data as collected with Task 1. In particular, firewood (household fuelwood) consumption, collecting of forest residues (e.g. leftover branches, stumps and stem tops from logging operations), and recycled wood (e.g. wood from used packaging material, scrap timber from building sites, wood from demolition projects) used for production of wood based panels and/or energy purposes.
- Agricultural residues and biogenic waste are an important source of bioenergy. The increasing use of these feedstocks for energy purposes is within this project fully in line with that of the 2014 IA report.
- International trade of primary woody products, namely chips for material use, pellets, and roundwood has also been updated within the project based on data as available and collected within the framework of the project.

2.1 Key Results and Trends in the Baseline Scenario

The baseline scenario shows a clear increase in the use of wood up to 2050, for both material and energy purposes in the EU. The increased demand for wood biomass is seen to lead to an intensification in the use of forests in the EU28. There is an expansion in the area of used forest in Europe. There is also a significant expansion in the use of SRC both in terms of volume consumed

[8] Commission E. EU Energy, Transport and GHG Emissions: Trends to 2050, Reference Scenario 2013. (2013).

and area of land devoted to production. These expansions in used forestry and land devoted to SRC lead to a decline in the area of unused forest (most notably leading up to 2050) and a more significant decline in the area of 'other natural land'. These trends of intensification of land use and land use change are also observed in the rest of the world (outside the EU).

Key results and trends identified in the baseline analysis are set out below.

2.1.1 Changes in Wood Flows and the Use of Bioenergy Feedstocks

The baseline scenario projects a clear increase in the use of wood for both material and energy from the 2010 levels. Material use of wood is increasing over time, driven by socio-economic development and export of semi-finished wood products. The overall consumption of wood for energy is estimated to expand from 306 million m^3 in 2010 to 419 million m^3 in 2050. This includes black liquor and other industrial by-products used for energy, as well as firewood, forest residues, recycled wood, imported wood pellets and SRC produced for energy. In terms of the comparative uses of wood, the proportion of total wood consumption going to energy use increases between 2010 (36%) and 2050 (38%). It should be noted, however, that the consumption level for material use of wood also grows over the same period (from 535 to 686 million m^3, some of which will become residues and by-products, and be used for energy) although not as sharply as the wood to energy consumption (as indicated by the shift in proportions).

Figure A illustrates the flow of wood biomass between the different wood using industries in the EU. The figure provides an overview of the flow of wood in the Baseline scenario for the years 2010, 2030, and 2050. Analysis of these figures shows clear growth in the forest-based industries producing materials, driven by increasing population and GDP development. This growth is seen in all material production (sawnwood, wood-based panels and pulp production). The increased material production also leads to an increased production of industrial residues and by-products used for energy purposes.

The flow charts highlight that a significant amount of wood will be required for meeting the bioenergy demand. A large part of this is sourced from SRC, which increases from a negligible amount in 2010 to 60 million m^3 in 2050. By-products of the material-producing industries are also a notable source of biomass for energy. In addition, the net-import of wood pellets is expected to increase from 10 Mm^3 in 2010 to 23 Mm^3 by 2050. USA and Canada are still foreseen as major trading partners for pellets, but Latin America, the former USSR, and South-East Asia are also expected to develop into major players on this front. Contrary to other sources of wood biomass for energy, the amount of firewood is estimated to decrease within EU28, driven by an expected shift from domestic to district heating (this development is modelled in line with estimates from PRIMES).

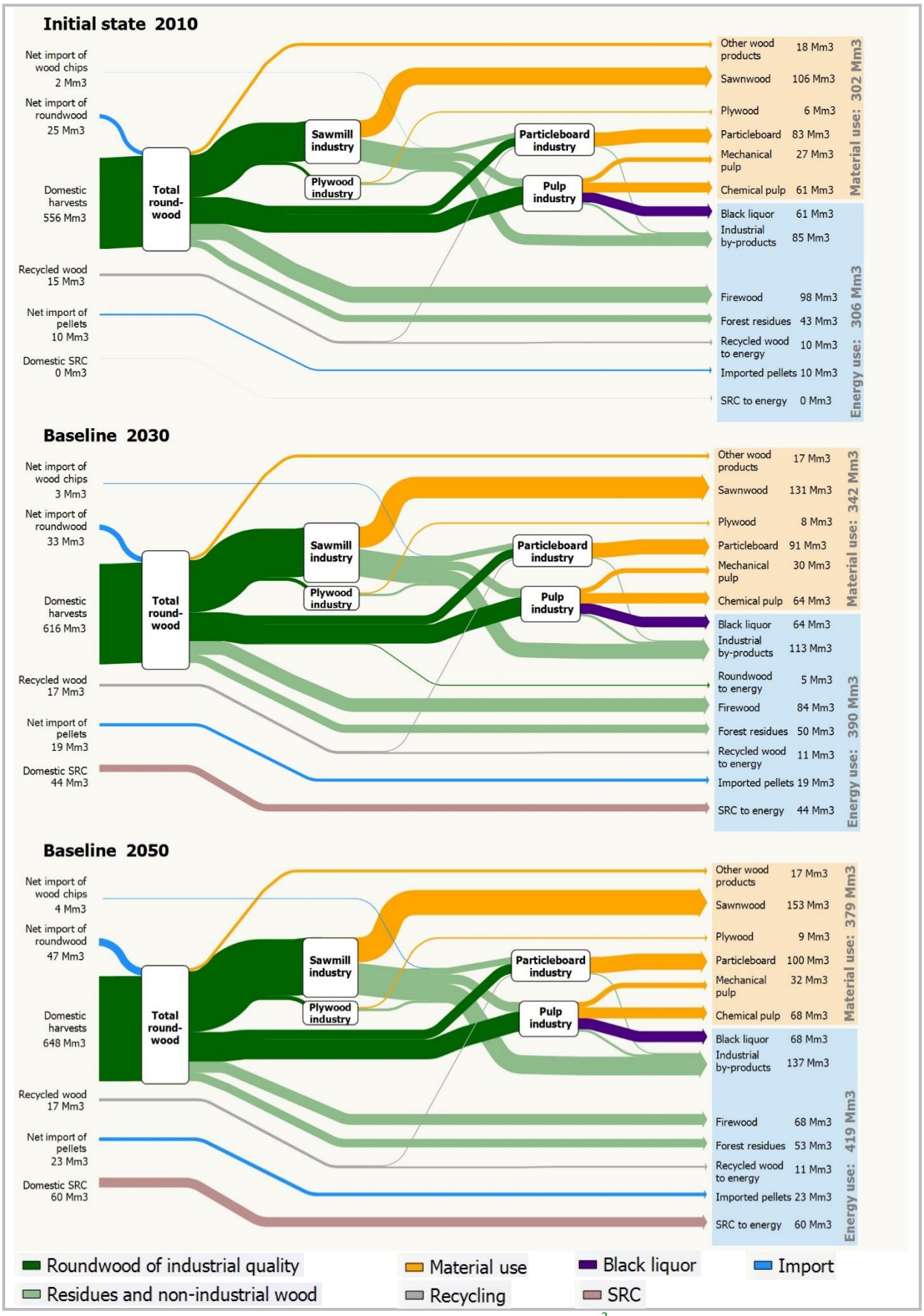

Figure A. Flow of wood in the EU in the Baseline scenario, in Mm^3 solid wood equivalent. Note that the volumes of particleboard, mechanical and chemical pulp, and black liquor reflect the amount of wood in the products, not the actual material yield.

2.1.2 Harvest Rate and Forestry Production

In the baseline scenario, the total forest harvest level in EU increases clearly, from 556 million m^3 in 2010 to 616 million m^3 in 2030 and 648 million m^3 in 2050. In particular harvests for material production, especially sawlogs, show a steadily increasing trend, and this expanding trend appears to drive overall harvest level. Harvests for energy stay on a more stable level until 2030. After 2030, harvest levels for energy actually decrease (from 158 to 143 million m^3). The key driver for this decrease is the decreasing use of firewood. In addition, increasing import of wood pellets and the expansion in SRC for energy purposes replace harvested wood from forests for energy. Overall, this draws also the total harvest level downwards, causing a slightly slower increase of the total harvest level after 2030 than in the prior two decades.

As shown in Table 1, the baseline results for 2010 are on the same overall level as the corresponding levels reported by the EUWood study[9] and by Indufor[10]. Discrepancies between the different studies can largely be attributed to uncertainty/lack of reliable EU statistics relating to household fuelwood use.

Table 1. Comparison of the project results and reference literature on wood consumption in the EU28, divided into material and energy uses.

Study	EUWood	Indufor	ReceBio Baseline		
Reference year	2010	2011	2010	2030	2050
					Million m³
Total Wood Consumption	825	942	841	1004	1106
Total Material Use*	*457*	*649*	*535*	*613*	*686*
Wood Products Industry**	314	308	367	436	498
Pulp and Paper		341			
Pulp	143		162	172	182
Total Energy Use, excl. SRC	*368*	*293*	*306*	*346*	*359*
Wood products industry side streams***		150	155	188	216
Wood used primarily for energy****		143	151	158	143
Energy Biomass from SRC			*0*	*44*	*60*
Energy use, %	**45%**	**31%**	**36%**	**39%**	**38%**
Material use, %	**55%**	**69%**	**64%**	**61%**	**62%**

Note that this table describes the input volumes for wood-using industries. This means that some of the wood biomass is counted both within "Total Material Use" and "Total Energy Use", because by-products of the material industries can be used in the production of other materials (pulp and/or particleboards), or for energy. This is a common way of accounting for wood use found in the literature, but partial double-counting makes it impossible to compare these numbers with actual harvest volumes. The flowcharts used in this report (e.g. Figure 4) bypass this problem by showing the actual wood biomass flows through the industries.
**In ReceBio: Sawmill and board industries, pulp production, and recycled wood used for material*
***In ReceBio: Sawmill and board industries*
****In ReceBio: Sawdust, wood chips, bark and black liquor used for energy, and recycled wood*
*****In Recebio: fuelwood, forest residues, industrial-quality roundwood used directly for energy, imported pellets.*

[9] See Mantau et al. 2010. Real potential for changes in growth and use of EU forests. EUWood final report. Project: Call for tenders No. TREN/D2/491-2008.
[10] See Indufor 2011. Study on the Wood Raw Material Supply and Demand for the EU Wood-processing Industries. Final report. European Commission, Enterprise and Industry Directorate General.

3 Consequences of Varying EU Bioenergy Demand

The baseline selected for this study forms a point of comparison in terms of understanding different evolutions in bioenergy use. Within ReceBio, in addition to the baseline, four scenarios modeling different potential evolutions in the bioenergy demand profiles were set out. These all use key elements of the GHG40/EE scenario from the 2014 IA Report. This scenario delivers 40% GHG emissions reduction in the EU by 2030 as compared to 1990, together with a 26.4% share of renewable sources in total energy consumption and total energy savings of 29.3% by 2030 (as compared to 2007 projection for 2030).

In the GHG40/EE scenario, energy consumption from renewable sources in 2030 is slightly lower than in the EU Reference Scenario, due to energy efficiency policies that contribute to reducing overall energy demand. Total bioenergy demand in the EU follows a similar pattern, reaching a level of 166 Mtoe in 2030 under the GHG40/EE as compared to 178 Mtoe in the EU Reference Scenario. After 2030, however, bioenergy demand increases in the GHG40/EE scenario at a much higher rate than in the EU Reference Scenario (2014 IA).

In the ReceBio project, the Emission Reduction scenario models the outcomes related to bioenergy demand in line with the GHG40/EE scenario up to 2050, with similar improvements in the modeling setup and underlying data as for the ReceBio Baseline scenario. While the Emission Reduction scenario and associated consequences is the primary focus of this section; the most important results from other scenarios under ReceBio are also presented here. These scenarios are:

- the Constant Bioenergy Scenario – that uses the GHG40/EE as a basis but fixes levels of bioenergy demand for the EU at 2020 between 2020 and 2050, ie demonstrating consequences of a stabilised bioenergy demand. Bioenergy demand as of 2020 for the Constant Bioenergy Scenarios is lower than that in the baseline scenario for 2020, as a result of the implementation of energy efficiency measures;
- the Increased Rest of the World Demand scenario that assumes the GHG40/EE pattern of bioenergy demand for the EU, plus increased demand for bioenergy in the rest of the world, based on the GECO Global Mitigation Scenario[11] recently published by the European Commission; and
- the Increased EU Biomass Import Scenario that assumes the GHG40/EE levels of bioenergy demand for the EU but an enhanced level of biomass imports modeled through decreased trade costs between the EU and Rest of the World for feedstocks for energy and material use.

3.1 Key Results and Trends – Understanding Different Patterns of Bioenergy Demand

The development seen in the Baseline scenario is found to be accentuated in the EU Emission Reduction scenario up to 2050. In this scenario, the development of biomass use follows a trend to a large extent similar to that of the baseline scenario until 2030. Thereafter, the results show a considerable increase in the use of imported pellets (52 Mm^3 in 2050, double to that in the Baseline), SRC (161 Mm^3 in 2050, almost triple compared to Baseline), and, additionally, we see also large quantities of roundwood (of pulpwood quality and dimensions) directly being used for bioenergy production (78 million m^3 in 2050). The increased use of biomass for energy has a direct impact on forest harvests, which are more than 700 million m^3 in the EU Emission Reduction scenario in 2050, almost a 9% increase when compared to the Baseline results for that year (Figure B).

[11] This scenario depicts a development wherein joint global efforts are taken to reduce GHG emissions beyond 2020 in line with ambitions to keep global warming below 2°C. Globally, the current use of biomass in the energy sector represents about 50 EJ/yr, which develops in 2050 to more than double in the Baseline Scenario and triples to 150 EJ/yr in the Global Mitigation Scenario.

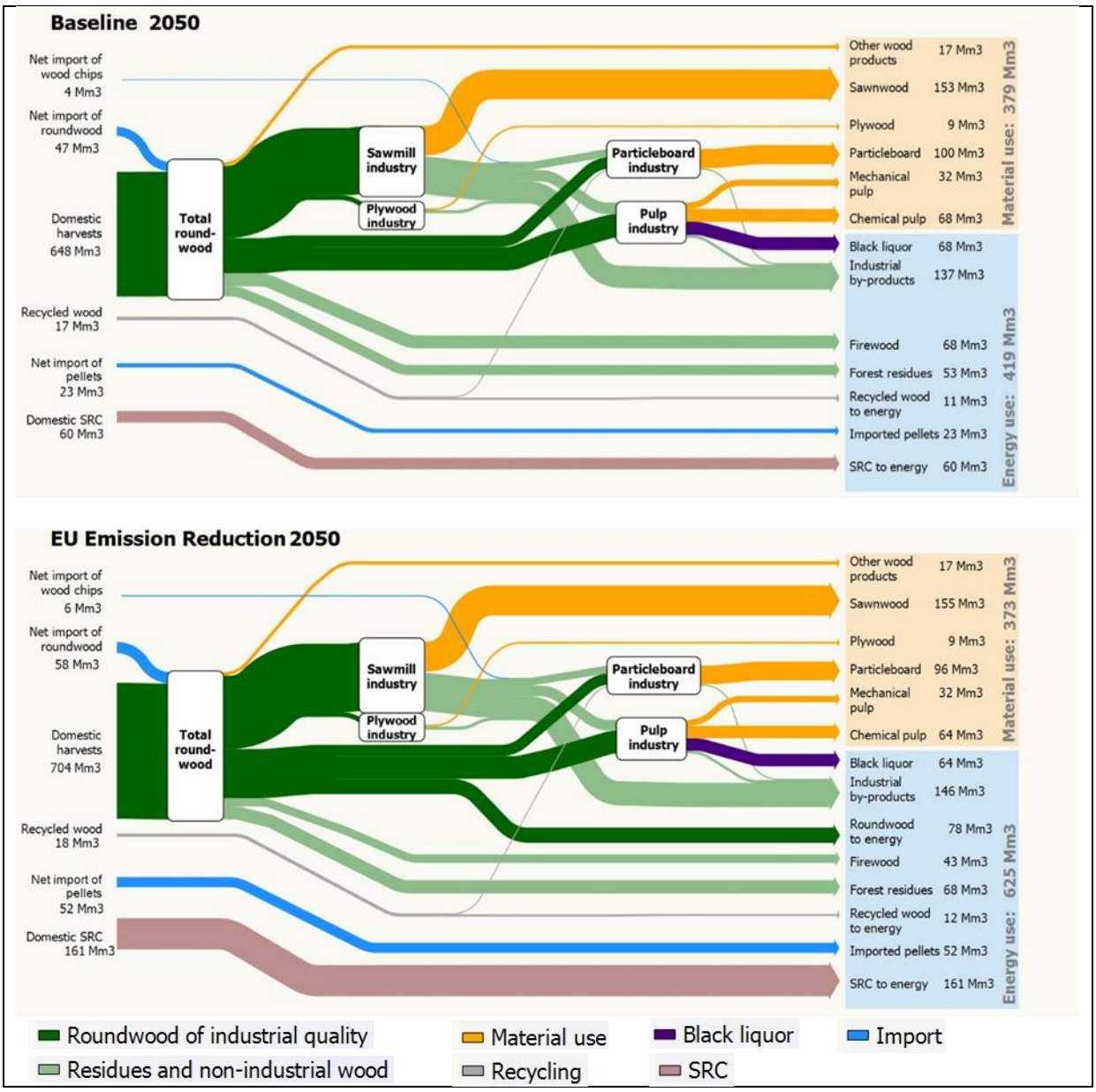

Figure B. The wood flows in the EU28 in 2050 in the baseline and EU Emission Reduction scenarios, in Mm3 solid wood equivalent. Note that the volumes of particleboard, mechanical and chemical pulp, and black liquor reflect the amount of wood in the products, not the actual material yield**.**

3.1.1 Harvest Rate and Forestry Production

The forest harvests in the EU Emission Reduction scenario increase over time. Until 2030 harvest levels are slightly lower than those seen in the baseline, associated with the reduced demand for energy resulting from higher effort in terms of energy efficiency; from 2030 onwards, harvest levels increase above and beyond the Baseline.

Up until 2030, use of wood for material purposes is expected to be the major driver for the increasing forest harvests in the EU (Figure C). This development has its roots partly in the strong interrelationship between material and energy uses of wood; increasing material use of wood also provides more biomass for energy through industrial by-products. The increase in material production, and associated by-products, is almost enough to satisfy the bioenergy demand until 2030 (together with increasing SRC and pellet imports).

Beyond 2030 high bioenergy demand under the Emission Reduction Scenario has a clear impact on the overall forest harvest level. After 2030, the increasing harvests of wood for direct energy production is expected to become the main driving force for the increasing forest harvests in the EU.

This development affects especially the harvest of wood that is of pulpwood-quality and a sufficient dimension to be used for material purposes, but that is used directly for energy production. Figure C highlights the changing patterns of harvest and the associated drivers, comparing the results from the Baseline and EU Emission Reduction Scenarios.

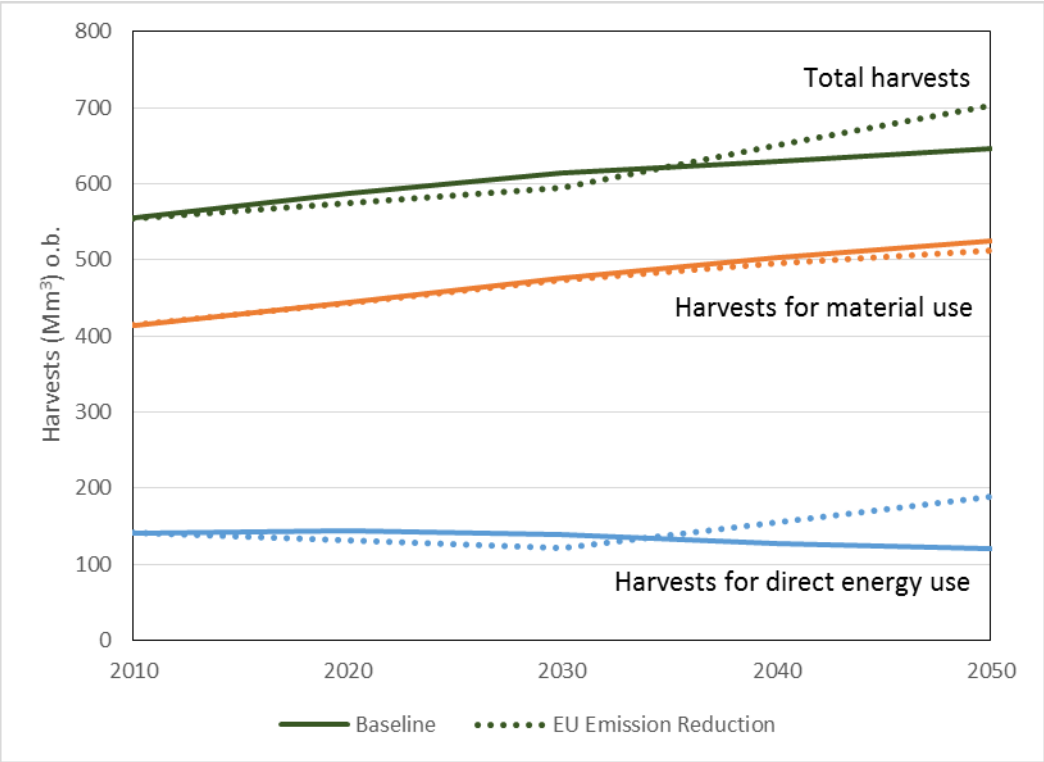

Figure C. Forest harvests in the baseline and the EU Emission Reduction scenario. The category "Harvests for direct energy use" combines harvests of forest residues, fuelwood, and pulpwood that are used for energy as such, or after chipping and/or pelletization. "Harvests for material use" shows the harvested amount of wood that is used for material production in the forest industries and production of other wood products (part of this volume will eventually become industrial residue and be used as energy as well). Total harvests is the aggregate of forest harvests for energy and material use.

Box 3 – Examining the Role of Recycled Wood and its Relationship with Forest Harvests

Using more recycled wood for material production represents a potential opportunity to increase the resource efficiency of biomass consumption in the EU. Potential future amounts of recycled wood are, however, difficult to model due to data availability. Information on current and historical amounts and prices are not fully available or based on rough estimates. The level of recycled wood assumed in ReceBio is therefore based on the statistics collected in the Task 1 of the project and assumed to stay constant throughout the projection period.

To investigate the impacts of the assumptions made for the level of recycled wood available for material use, the EU Emission Reduction scenario was run with varying levels of recycled wood. The amounts of recycled wood were increased by 20%, 40%, 100% and 200% by year 2050 from the amounts as assumed in the EU Emission Reduction scenario. The displacement impacts in material wood use and consequences for energy use of wood are elaborated in Figure D.

The results show that, when recycled wood was increased, it released industrial by-products from material left-hand side of figure D), which, consequently, are used for energy purposes and in turn decreased the use of pellets, roundwood and SRC for energy (right-hand side of figure D). In other words, the increasing use of recycled wood for material purposes leads to a decreasing use of pellets, roundwood and SRC for energy.

Increased wood recycling also increases the use of pulpwood in the material sectors: the majority of recycled wood is used for particleboard production, and a certain amount of virgin wood is needed in the production process alongside with recycled wood. Most of the industrial residues replaced by recycled wood in material production will instead be used for energy production. Nevertheless, even when increased by 200%, the amount of recycled wood for material production is only 3% of the total wood biomass used for material and energy. As a result, the changes modeled in the level of wood reccyclingy were found not to have a notable impact on the forest harvest levels in the EU.

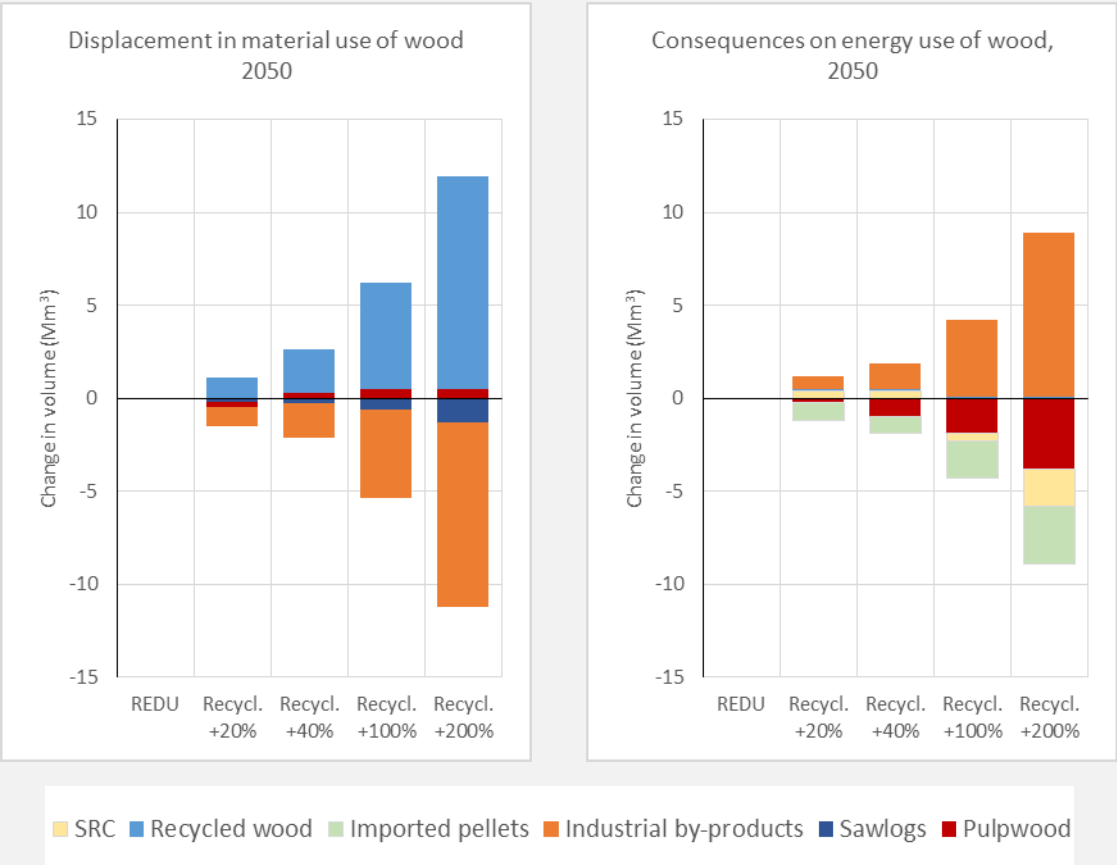

Figure D - Effect of increasing the amount of recycled wood used for material production on the types of woody biomass used for material and energy in 2050. Positive values represent an increase in the use of the biomass feedstock for material or energy use, while negative values represent a decreasing use of biomass feedstock for material or energy use.

3.1.2 The Changing Profile of Biomass Feedstocks Use

Analysis of the Emission Reduction scenario identifies several key trends in terms of the type and origins of biomass being used for energy production. This includes: the rising use of roundwood (specifically pulpwood) for energy production; increasing levels of pellet imports; and expanding use of SRC. These trends were all originally noted in the baseline, but are exacerbated by the increasing bioenergy demand seen to 2050 under the Emission Reduction Scenario. When considering the changes in feedstock use we found important to understand better both the nature of the feedstocks being used and what happens if a particular feedstock is not forthcoming as anticipated by the model.

The results from the model, for both the Baseline Scenario and to an even greater extent under the Emission Reduction Scenario, show a highly significant expansion in the EU in the use of SRC towards 2030 and 2050, rising both in volume and in surface area (from 0.4 in 2010 to 66 million m^3 by 2050 and from 10 000 ha in 2010 to 3.4 million ha in 2050 under the Baseline, and to 161 million m^3 and

8.9 million ha in 2050 in the EU Emission Reduction scenario). Rapid development of SRC in both scenarios indicates that satisfying a high demand of biomass for energy will rely increasingly on the development of SRC.

Evidence from other studies and from discussions with experts has suggested that SRC is often difficult to gain acceptance of in terms of promoting its expansion. There are barriers to farmers establishing SRC, which are perhaps not totally reflected in a purely economic model. This includes the loss of flexibility in terms of crop rotation/response to the market and the lack of income over the establishment period of the crop. As a consequence, the assumptions regarding feedstock availability were investigated further to better understand what would occur in the absence of the SRC expansion (Figure E). The results show that, if SRC would not develop as estimated in the model, a majority of the 'gap' would be taken up by increasing use of roundwood for direct combustion and by imported pellets. A similar analysis for other feedstocks also shows the importance of SRC expansion in providing for any 'gap' in supply were, for example, forest residues or pellet imports to be restricted.

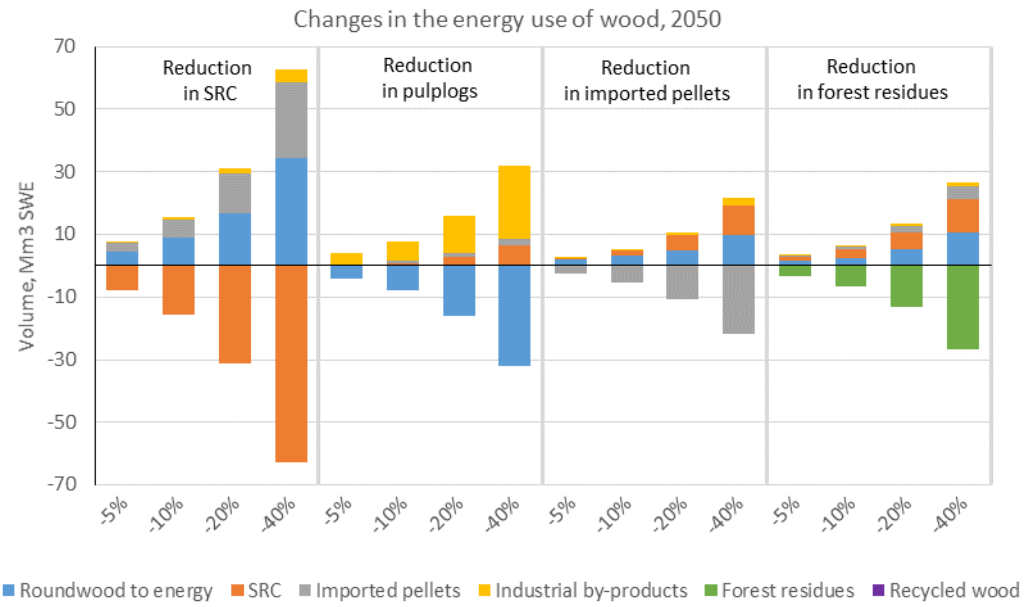

Figure E - The effects of a reduction in one type of feedstock on the use of other wood biomass for energy in 2050. In this analysis the levels of each feedstock category seen in 2050 under the Emission Reduction Scenario were progressively reduced by between 5 and 40 per cent to understand the consequences of reducing a specific feedstock stream and the feedstocks that might plug the 'gap' in supply generated.

Box 4 – What is the Impact on Feedstock Use of Increased Imports of Biomass?

The increased EU Biomass Import scenario investigated the impact of increasing the EU reliance on imported biomass feedstocks to EU from the Rest of the World. The scenario as such assesses how the pressure on domestic production would react to increasing EU reliance on imported biomass. Under the EU Biomass Import Scenario the EU net import of pellets grows to 218 Mm^3 in 2050 (more than four times the amount foreseen in the EU Emission Reduction scenario), and the net import of roundwood grows to 71 Mm^3 by 2050 (a 22% increase when compared to the EU Emission Reduction scenario).

Recently, EU imports of wood pellets from North America, especially the USA, have increased considerably. This development is seen to continue in the ReceBio scenarios, but further expansion in pellet demand seen under the EU Biomass Import scenario suggests increasing EU pellet imports also from other parts of the world, especially from Canada, Latin America and South-East Asia. Following the growth of pellets into a major biomass feedstock for energy, domestic harvests in the EU will only increase modestly over time in this scenario. As a direct effect of the increased pellet

imports, the EU forest harvest level decreases and is only 624 Mm^3 in 2050, an 11% decrease from the EU Emission Reduction scenario and a 3.7% decrease from the Baseline scenario. A further consequence is that the material production level in the EU also grows slightly (especially particleboard and chemical pulp production).

Box 5 – What if the bioenergy demand stabilises after 2020?

To investigate development where no further action for promoting the development of the bioenergy sector comes into play after 2020, a scenario referred to as the Constant Bioenergy Demand scenario was constructed.. In this scenario, the bioenergy demand in EU28 follows the same trend as the other scenarios until 2020 and stays constant thereafter. This implies that the total energy production from biomass and waste for EU28 stays constant after 2020 at the approximate level of 150 Mtoe.

As the population and GDP development is still projected to continue under the Constant Scenario as in Baseline, the main driver for the consumption of woody products is the same between the scenarios and there are only small differences between this scenario and the Baseline on the material production side. There is, however, a clear difference in the composition of feedstocks used for energy production. Most importantly, pressure to produce SRC for energy is significantly reduced. Meeting bioenergy demand up to 2020 requires an increase in the production of SRC, thereafter the bioenergy demand can be increasingly satisfied through other feedstocks. As for SRC, pellet imports also increase until 2020, but remain almost constant thereafter. In this scenario, no roundwood of sufficient quality and dimensions to be used for material production is projected to be used directly for bio-energy purposes.

The stagnation in the heat and power sector in terms of bioenergy use under Constant Bioenergy Demand scenario results in a higher level of fuelwood used for domestic heating than in the Baseline. Overall, the harvest level in the EU in 2050 is 15 million m^3 (2.3%) lower than in the Baseline. When compared to the Baseline scenario under the Constant Bioenergy Demand scenario there is more particleboard production and less sawnwood production. This can be explained as follows:

- the demand for industrial by-products from sawmills (chips and sawdust) for bioenergy production is lower reducing sawmill profitability and leading to lower levels of production;
- the drop in bioenergy demand for the chip and sawdust by-products causes prices to drop making particleboard production, utilising these feedstocks, more profitable.

3.1.3 The Impact of Expanding Global Demand for Bioenergy

In the EU Emission Reduction scenario, EU imports of both roundwood and wood pellets increase notably. From this follows that the availability of imported feedstocks is increasingly dependent also on the demand for biomass outside of the EU. The imports may not materialize if countries outside of EU are increasingly reliant on their own biomass sources to fulfil their own increasing bioenergy demand. This development was assessed in the "Increased Rest of the World (RoW) Bioenergy Demand" scenario, wherein joint global efforts to reduce GHG emissions beyond 2020 were assumed, thereby enhancing the development of the bioenergy sector for the RoW. In the EU, the bioenergy increase was modelled similarly the EU Emission Reduction scenario. Consequently, this scenario depicts a situation where EU may not be able to import as much of the biomass feedstocks as in the other scenarios.

The results show that, with an increased RoW bioenergy increase, net EU import of wood pellets is only 39 million m^3 in 2050, 25% less than in the EU Emission Reduction scenario. In addition, also EU

roundwood imports decrease by more than 20%. This puts more pressure to the development of the SRC sector in the EU: in this scenario, the production of SRC in the EU28 is the highest of all scenarios at 172 million m^3 in 2050 (a 7% increase to the EU Emission Reduction scenario). Material production levels stay at almost the same level as in the EU Emission Reduction scenario. However, as EU roundwood imports decrease, the domestic forest harvest level increases to 718 million m^3 in 2050 (14 Mm^3 higher than in the EU Emission reduction scenario, and 162 Mm^3, or 29%, higher than in 2010).

There are significant impacts on land use and environmental factors as a consequence of expanding rest of the world demand for bioenergy in combination with that of the EU28. These essentially represent an expansion upon trends observed in the following section.

3.2 Land Use Change and Environmental Consequences

3.2.1 Land use change

The key changes in land use already under the Baseline scenario are an increase in the area of cropland and used forest in the EU, driven to some degree by the increased demand for SRC and increased forest harvest level, respectively (Figure F). Following this development, we see a decline in the area of unused forest and, most significantly, other natural land. These trends are seen to be enhanced further under the Emission Reduction scenario with, by 2050, higher amount of land being used in the EU for SRC, and lower amounts of other cropland and other natural land (including abandoned cropland and grazing land) and grazing land (2030 and 2050). When comparing the Baseline and Emission Reduction Scenario, the total forest area (sum of used and unused forest) does not differ significantly; however, there are comparably large shifts within the forest, converting unused forest to used forest.

Land use change in the rest of the world, ie outside the EU 28, is seen to change under the Baseline Scenario with again other natural land and unused forest being converted into cropland, grassland and used forest. However, there is an additional impact in terms of land use change in the rest of the world associated with the EU Emission reduction scenario, if only EU increases its bioenergy demand, leading to relatively more cropland and SRC area in 2050and less other natural and unused forests. For 2030, similarly to the development in EU28 the reverse effect can be observed due to efficiency increases reducing biomass demand.

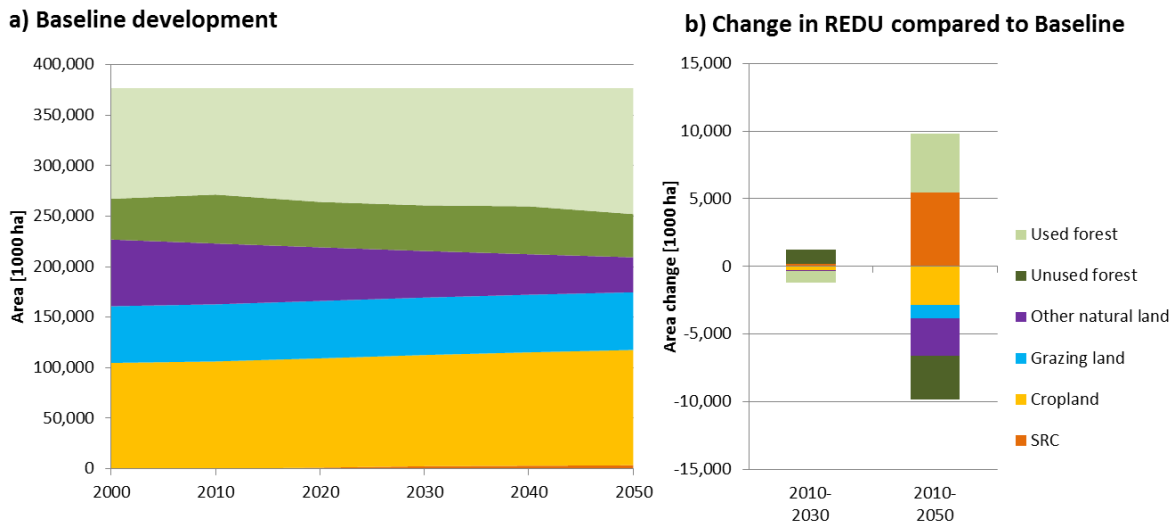

Figure F. Land use in EU28 in the Baseline a) and differences in the EU Emission reduction scenario (REDU) b).

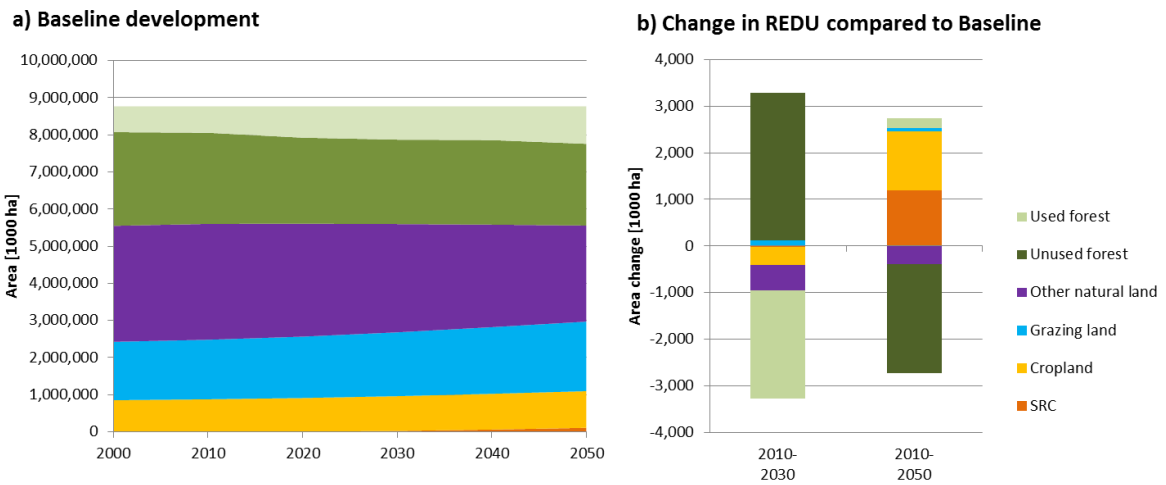

Figure G. Land use in RoW in the Baseline a) and differences in the EU Emission reduction scenario (REDU) b).

3.2.2 Biodiversity

Under both the baseline and the EU emission reduction scenario, the impacts in the EU28 on land classified as high biodiversity value are comparably low. This is due to the fact that less than 1% of the area considered in the model in the EU28 is categorized as area of high biodiversity value, according to the global biodiversity data set from IUCN-WCMC. Looking at the rest of the world, the conversion of land with high biodiversity value is more important because 20% of the global land area considered by the model is highly biodiverse. Unused forests form the largest share of the areas impacted, followed by other natural land and grazing land. It should be noted that, as for land use change, the Baseline results already show a significant impact on highly biodiverse areas in the rest of the world. Under the EU emission reduction scenario, these impacts are further increased but rather limited compared to the Baseline.

3.2.3 GHG emissions

Land use change has a number of important associated environmental impacts and consequences. Under ReceBio specifically, besides biodiversity impacts, GHG emission balance implications have been investigated. For GHG emissions effects primarily stem from changing patterns of forest use, patterns of afforestation and deforestation, the decline in other natural land and the changes in the use of agricultural land ie cropland and grassland.

When considering the GHG emissions, there are a number of aspects that were analysed. Compared to the Baseline, the forest management carbon sink is seen to decline more strongly by 2050 under the EU Emission reduction scenario (see Figure H), demonstrating a more intensive use of the forests. In 2050, the EU emission reduction scenario shows decreased deforestation emissions that are compensating for the loss of the forest sink to a large degree. Under the EU Emission reduction scenario, sequestration into harvested wood products in 2050 is 6 Mt CO2eq higher compared to the Baseline. More products are being produced causing the stock of carbon stored in wood products to increase. Under the Baseline, there is already a strong increase in afforestation GHG removals over time and, comparatively, there is only a small effect on afforestation GHG removals in the EU Emission reduction scenario. In total, compared to the Baseline, the EU emission reduction scenario is reducing net emissions from LULUCF and Agriculture for the EU28 in 2030 and 2050 (see Figure I).

Under the EU Emission reduction scenario, both CO_2 and non-CO_2 GHG emissions increased in the rest of the world in 2050 when compared to the baseline (see Figure J). This implies that the EU exports emissions to the rest of the world as a consequence of increasing land used for bioenergy in the EU but also reduction of livestock production and increased imports of such products.

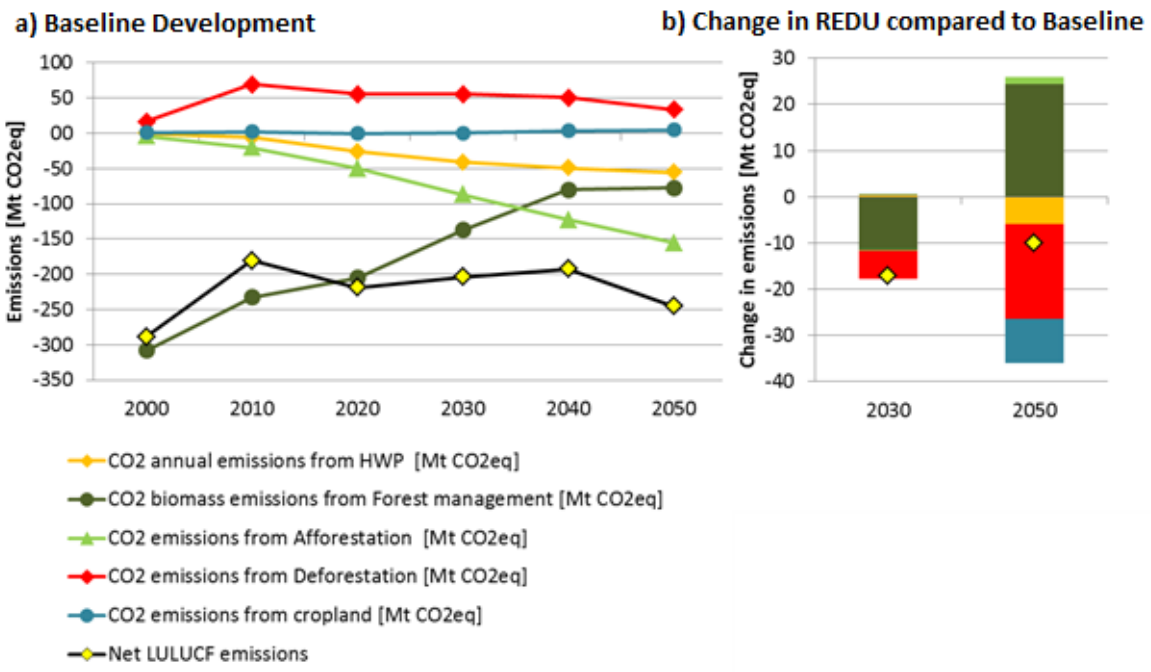

Figure H. LULUCF GHG emissions in EU28 in the Baseline a) and differences in the EU Emission reduction scenario (REDU) b).

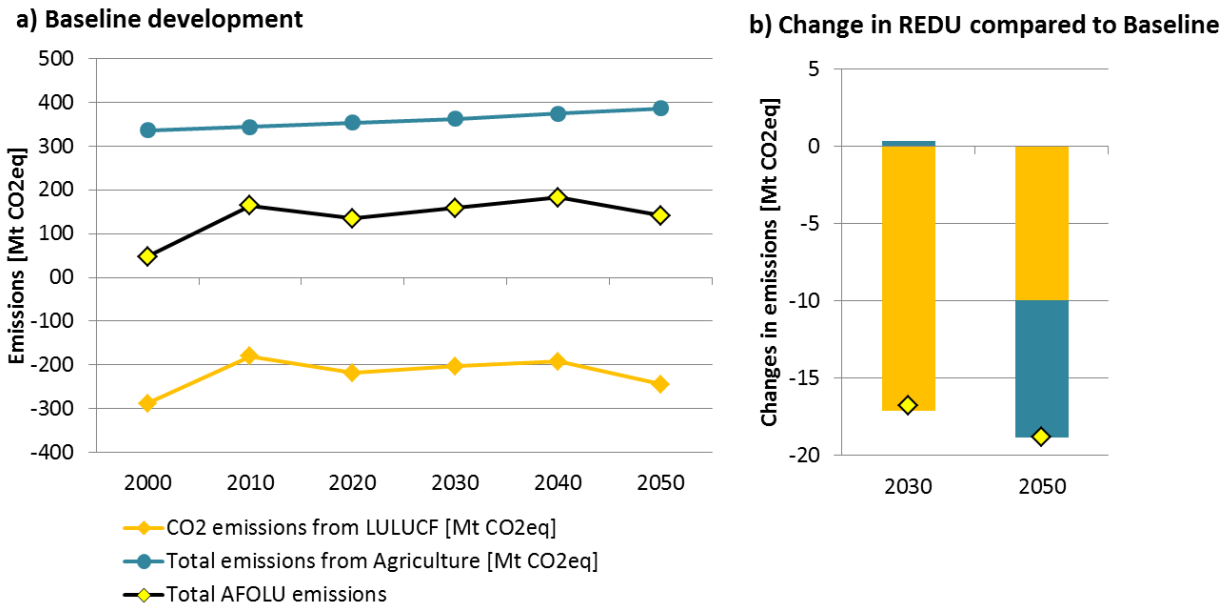

Figure I. Total land use GHG emissions in EU28 in the Baseline a) and differences in the EU Emission reduction scenario (REDU) b).

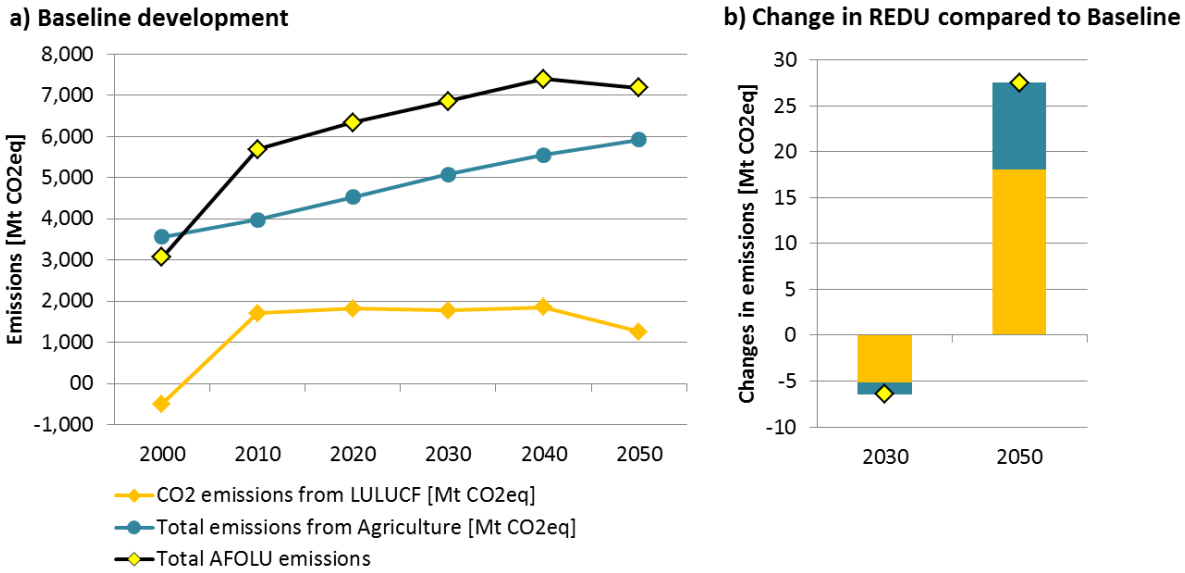

Figure J. Total land use GHG emissions in RoW in the Baseline a) and differences in the EU Emission reduction scenario (REDU) b).

Box 6 – Methodology on assessing the impact of environmental constraints of EU biomass resource efficiency.

After an assessment of environmental impacts ReceBio foresees that a set of **environmental constraints** are introduced into the model. These constraints are based on key environmental indicators, such as Area of unused forest converted to used forest, Area of HBV converted and Other natural land converted. These indicators showed significant impacts across the policy scenarios. In a second stage the respective model variables are constrained to not exceed a certain threshold (e.g. no conversion of highly biodiverse grazing land beyond Baseline levels). The result of **combination of individual constraints** and one model set up where **all constraints combined** are implemented will be assessed for the EU Emission reduction scenario. Indicators to be looked at in the constrained scenarios are:

- Production of biomass in the EU by biomass type (i.e. round wood, forest and agricultural harvest residues, energy crops, industrial-by products)
- Import and export of biomass to (and from) EU with breakdown by type and export/import region.
- Use of biomass in relevant sectors (i.e. energy, material)
- Land use of the various classes of land being accounted for (forest, energy plantations, cropland, grazing land, other natural land)
- Total GHG emissions from the land use sector

Annex 1 - Authors and contact information

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The team conducting the work consists of:

- International Institute for Applied Systems Analysis (IIASA) – Project lead, coordinating modeling efforts;
- Indufor – experts in woody biomass, coordinating input on the state of play;
- Öko-Institut (OEKO) – lead on natural resource and environmental impacts;
- European Forest Institute (EFI) – experts in biomass trade and analysis; and
- the Institute for European Environmental Policy (IEEP) – lead in stakeholder engagement and experts in biomass for energy