EC4MACS

Uncertainty Treatment

The EU-FASOM Land Use Model

European Consortium for Modelling of Air Pollution and Climate Strategies - EC4MACS

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IIASA

LULUCF

1 Baseline and scenario development

To produce consistent projections on LULUCF at country level by 2020 and 2030, a number of different forest, agricultural and economic land use models communicate as shown in Box 1 below.

Box 1: The LULUCF model structure

The economic land use models EUFASOM and GLOBIOM use as macro-economic drivers recent baseline projections by DGTREN for future bioenergy demand (from PRIMES model) and related assumptions on population growth, economic development (GDP), and technical progress rates. Data on potential yields and GHG emissions and removals for diverse agricultural and forest management alternatives are derived from the more detailed forestry model (G4M) and the agricultural model (EPIC). For baseline and policy scenarios, the economic land use models will project domestic production and consumption, net exports and prices of wood and agricultural products and changes in land use for EU member states and other world regions. The sector specific information from the economic models is used by the forest and agricultural models to project GHG emissions and removals for detailed land management options (see Figure 1 below). These detailed models cover activities in forestry (afforestation/reforestation, deforestation and forest management), cropland and grazing land management. Two forestry models are applied in parallel to estimate emissions and removals from forest management and afforestation/reforestation activities to explore uncertainties of a potentially large contributor to carbon removals.

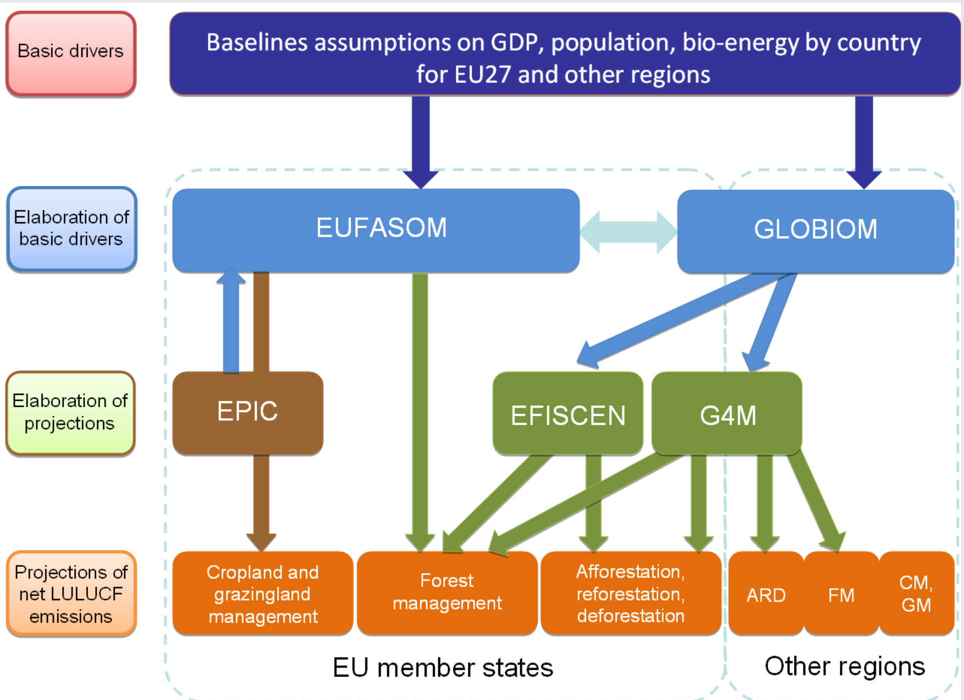

Figure 1: Overview of general modelling approach.

1.1 Baseline description

The Baseline scenario1 determines the development of the EU LULUCF emissions under current trends and policies; it includes current trends on population and economic development including the recent economic downturn and takes into account bioenergy markets. Economic decisions are driven by market forces and technology progress in the framework of concrete national and EU policies and measures implemented until April 2009.

The Baseline scenario benefited from the comments of Member States and many were accommodated in revising the draft Baseline scenario, while preserving a harmonised approach to LULUCF modelling.

1.1.1 Data bases used

Data for the baseline development (covering about 1990-2005) for all models is based on relevant international statistics (e.g. EUROSTAT, FAO) and publicly available databases (e.g. EFISCEN Forest Inventory Database (Schelhaas et al. 2006 a,b)). For the forest sector the current forest age structure in the different MS is crucial information, because it represents a major driver for predicting the future net emissions/removals. These data are already used as input for the detailed forestry models. The project dedicates time to harmonization of the most important input datasets and assumptions used in the models. The datasets will be presented to the Commission and the Member States, which will be given the opportunity to provide their most recent forest inventory datasets. The consortium expects more robust results and estimates of uncertainties of projections.

The sensitivity of the baseline is addressed explicitly by varying some key model and scenario parameters (e.g. GDP or bio-energy demand) that may affect the projections of the GHG emissions and removals from the LULUCF sector.

Table 1: Selection of common datasets used in modelling.

Dataset name	Dataset description	Sources
EFISCEN database	EFISCEN Forest Inventory Database	Schelhaas et al. 2006
FAOstat	Production of round wood for 1990 - 2007	FAO 2009
Harvest losses	Factor to be used to convert wood removals into fellings	UNECE/FAO 2000
Increment	Mean annual increment data per country	MCPFE 2007
Population and GDP	Population and GDP	E3MLab/GEM-E3
PRIMES bioenergy production	Projection of bioenergy production by different feedstocks until 2030	PRIMES biomass model, Dec 2009
Wood removals	Production of round wood for 1990 - 2007	FAO 2009; EU submission

[1] For details of the energy baseline scenario see: http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2030_update_2009.pdf

1.1.2 Population and Gross Domestic Product

The 2009 Baseline scenario builds on macro projections of GDP and population which are exogenous to the models used. They reflect the recent economic downturn, followed by sustained economic growth resuming after 2010. This data is entering both GLOBIOM and EU-FASOM that use these projections to translate them into demand for timber, bioenergy and agricultural commodities. The latest version of December 2009 was used. This dataset was also consistently used in the PRIMES biomass model that provided bioenergy projections to GLOBIOM and EU-FASOM (see below). The data for population and GDP development in EU countries for both, the base year 2007 (prior to the financial and economic crisis for comparison) and 2009 (used for this study) are displayed in Table 2.

Table 2: Rate of growth of population and GDP per year in percent.

	Baseline year	1995-2000	2000-2005	2005-2010	2010-2015	2015-2020	2020-2025	2025-2030
Population	2007	0.17	0.35	0.16	0.10	0.04	-0.01	-0.06
	2009	0.17	0.34	0.41	0.33	0.24	0.15	0.08
GDP	2007	2.89	1.74	2.57	2.49	2.22	1.94	1.59
	2009	2.93	1.82	0.56	2.29	2.13	1.82	1.65

Source: http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2030_update_2009.pdf

1.1.3 Projection of bioenergy production

Bioenergy demand was projected by the PRIMES biomass model (http://www.e3mlab.ntua.gr/manuals/The_Biomass_model.pdf). The biomass system model is incorporated in the PRIMES large scale energy model for Europe. It is an economic supply model that computes the optimal use of resources and investment in secondary and final transformation, so as to meet a given demand of final biomass energy products, driven by the rest of sectors as in PRIMES model.

The primary supply of biomass and waste has been linked with resource origin, availability and concurrent use (land, forestry, municipal or industrial waste etc). The total primary production levels for each primary commodity are restricted by the technical potential of the appropriate primary resource. The projection of total bioenergy demand as suggested by the PRIMES biomass model (version December 2009) is displayed in Figure 2.

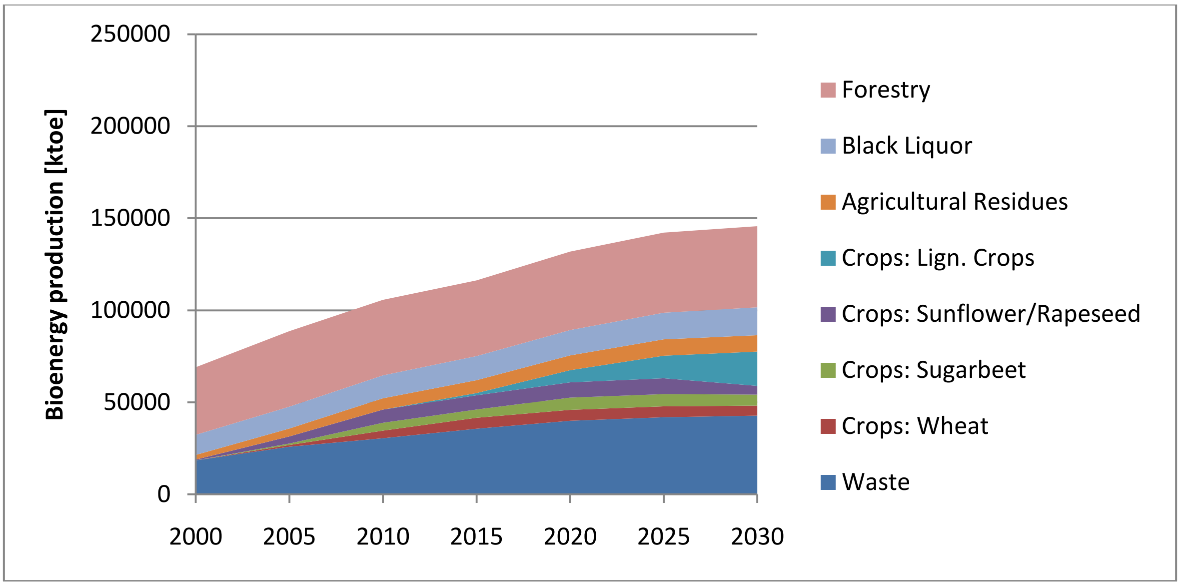

Figure 2: Baseline projection of total bioenergy demand as suggested by the PRIMES biomass model (version December 2009).

1.1.4 Projection of domestic wood demand

Wood demand that results in wood extraction is driving the forestry sector and has direct impact on the GHG balance of forests. When referring to wood demand in this report we mean “domestic wood demand”, i.e. “domestic wood production”. This is the demand for wood from domestic resources. Both terms “wood demand” and “wood production” are used.

The PRIMES projection on bioenergy production provides only one part of total wood demand projection in Europe. The model GLOBIOM was used to integrate energy wood demand from PRIMES and demand for other wood products. This was done in the following way.

Historic roundwood removals were collected by JRC through Member State consultations and served as a basis for the projection of future harvest. In general data between 1985 and 2008 where collected, where available. Trends of wood production (including sawnwood, pulp wood, fuel wood and other industrial roundwood according to FAO categories) were estimated by GLOBIOM by extrapolating the historic data into the future. To do so the historic data were averaged over the five year period 1998 to 2002 to estimate wood harvest in the base year 2000. Future wood for energy taken from PRIMES was fed into GLOBIOM to assess the impact on overall wood demand for EU (including trade and competition with other uses of wood). The energy wood production from PRIMES was set to match the amount projected by the PRIMES biomass model, i.e. the PRIMES bioenergy production is delivered. Other wood products however, were left to competing for the wood resource. Future demand for sawnwood and pulp wood for EU regions was taken from Rametsteiner et al (2009). The amount of fuel wood and other industrial roundwood was set to be constant until 2030. The resulting total wood demand for all EU27 countries is displayed in Figure 2.

As GLOBIOM used the base year 2000, projected roundwood production can be compared with observed harvest rates for the time 2000-2009. In general wood demand in EU27 was higher in 2005 than expected by the model. These differences can relate to short term responses that the model cannot include and also constraints that are not included. For example the model does not include the Russian tax barrier on round wood and also cannot account for constraints on forest accessibility of forest existing in some EU countries in the south.

To include the observed increase in wood demand that was not expected by the model in 2005, the European projected roundwood demand was adjusted by post processing the GLOBIOM data. Data for the year 2000 and 2005 were taken from historic data, estimates for the year 2020 and 2030 from the GLOBIOM projection. The year 2010 was interpolated.

The lack of realistic detailed projections of future wood demand per country was overcome by the preliminary assumption that timber demand in all EU countries will increase by the same factor estimated by GLOBIOM for the whole of Europe. Wood demand for energy was added to get total wood demand.

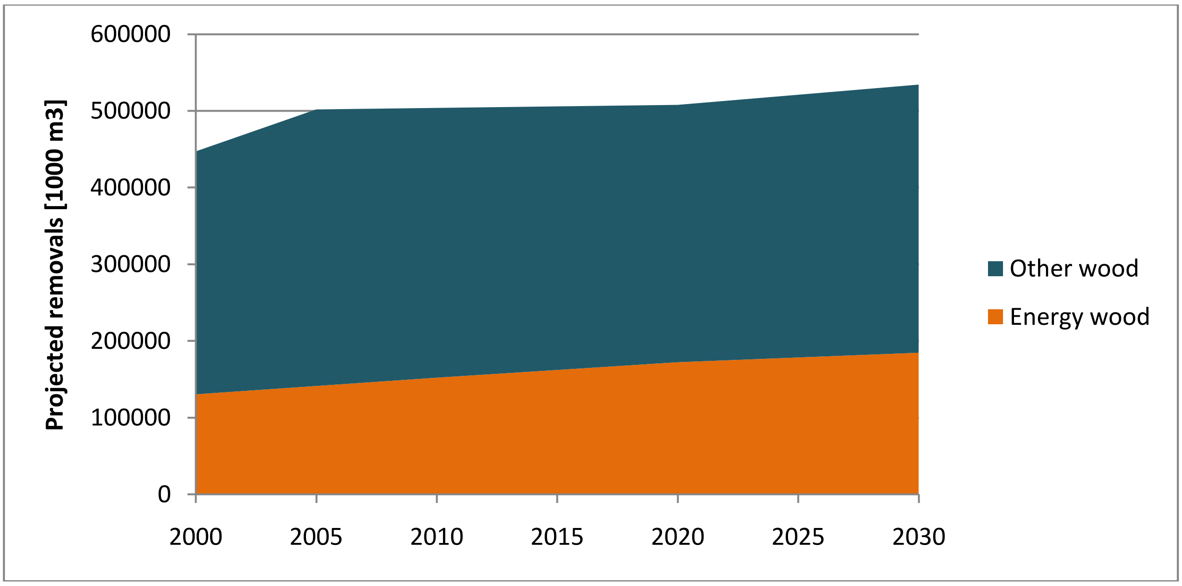

Figure 3: Baseline projection of domestic wood production for EU27 for energy wood (based on PRIMES bionergy from fellings and traditional fuel wood) and other wood (including sawnwood, pulp wood and other industrial roundwood). The original GLOBIOM data were scaled by historic wood demand and adjusted in the year 2005 to correct for observed wood removals.

1.1.5 Calibration to agricultural model Capri

The agricultural baseline of EUFASOM is consistent with the baseline of the CAPRI model. Links between CAPRI, EUFASOM, PRIMES and RAINS/GAINS have been developed within the EC4MACS project. Overlapping information between CAPRI and EUFASOM includes national area, production, feed processing, and consumption for major crops and animal herd sizes and livestock production. Sub-national accounts differ because the models use different resolutions on the sub national level. While EUFASOM depicts geographically implicit altitude, slope, and soil differences, CAPRI uses geographically explicit NUTS II regions. Management system categories are also different. For baseline emission predictions, EUFASOM national agricultural production accounts are simply forced to the level of CAPRI accounts. For scenario analysis, the restrictions are removed and replaced by dynamic cost calibrations.

1.2 Reference scenario description

The Reference scenario[2] is based on the same macroeconomic, price, technology and policy assumptions as the baseline. In addition to the measures reflected in the baseline, it includes policies adopted between April 2009 and December 2009 and assumes that national targets under the Renewables directive 2009/28/EC and the GHG Effort sharing decision 2009/406/EC are achieved in 2020.

The most relevant changes to the baseline for LULUCF are related to bioenergy production. Figure 4 shows the original PRIMES biomass model reference scenario, Figure 5 the translation into total wood demand by GLOBIOM.

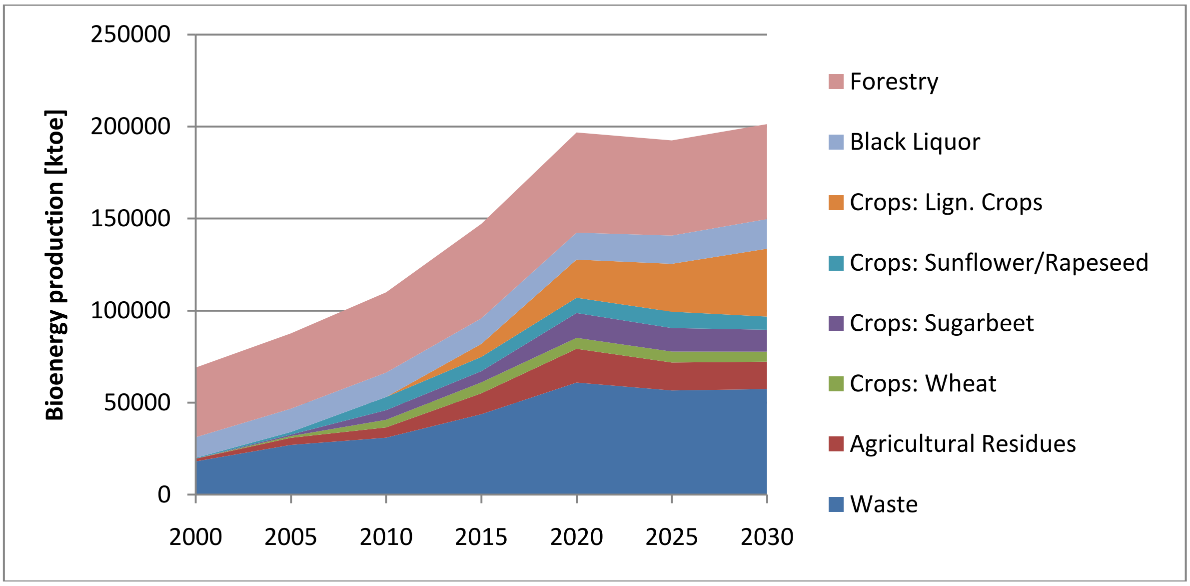

Figure 4: Reference scenario projection of total bioenergy demand as suggested by the PRIMES biomass model (version December 2009).

[2] For details of the energy reference scenario see: http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2030_update_2009.pdf

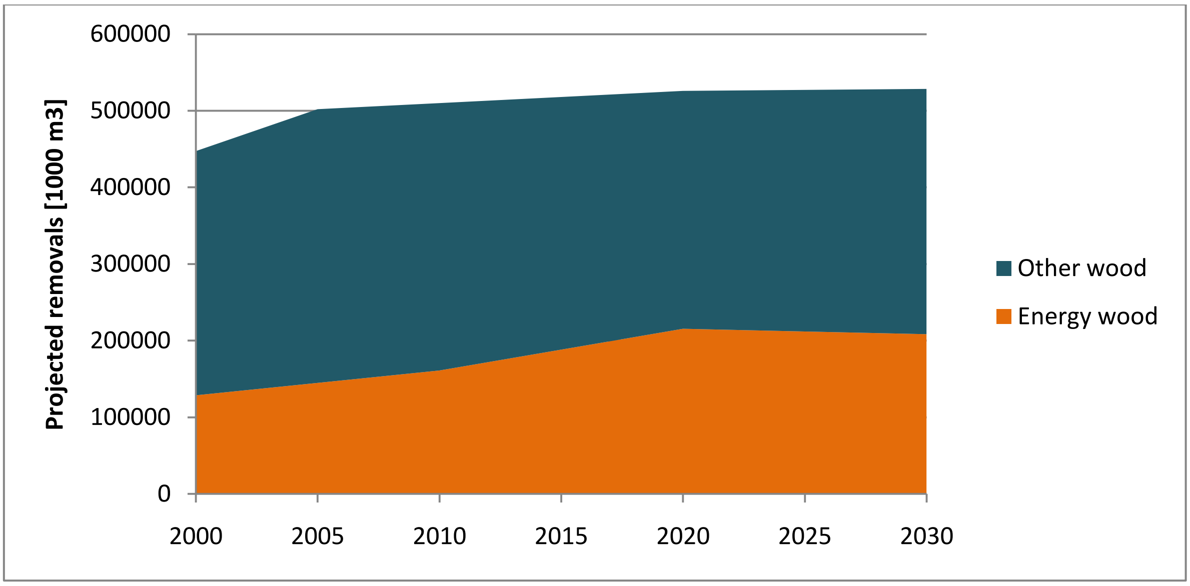

Figure 5: reference scenario projection of domestic wood production for EU27 for energy wood (based on PRIMES bionergy from fellings and traditional fuel wood) and other wood (including sawnwood, pulp wood and other industrial roundwood). The original GLOBIOM data were scaled by historic wood demand and adjusted in the year 2005 to correct for observed wood removals.

2 Results

2.1 Baseline

Figure 6 and Table 3 summarise the results of the baseline projection for LULUCF for EU-27. Deforestation emissions will slowly decrease until 2030. While emissions and removals from cropland and grassland will stay relatively stable, the forest sink is going to decline quickly (to less than 50% of the 2010 sink). The decline in removals from forest management is partly compensated by an increasing sink of new forests. However, in 2030 forest management will still be the dominating term in Europe's LULUCF carbon budget. In total the models expect a decrease of the land carbon sink by about 20%.

Table 3: Results of the baseline projection for LULUCF for EU27 for the different activities considered.

ACTIVITY DATA (kha)						
	2005	**2010**	**2015**	**2020**	**2025**	**2030**
Aff/Reforestation	6 944	8 945	10 695	12 012	13 142	14 172
Deforestation	133	102	88	75	60	49
Forest management	145 772	145 211	144 738	144 344	144 016	143 750
Cropland management	72 973	70 615	70 058	68 576	69 063	67 117

Grazing land management	79 204	80 428	79 413	78 348	75 441	74 155
EMISSIONS (Gg CO2)						
	2005	**2010**	**2015**	**2020**	**2025**	**2030**
Aff/Reforestation	-4 446	-11 149	-20 806	-32 707	-45 880	-59 363
Deforestation	30 265	25 799	25 056	22 622	18 803	15 684
Forest management	-321 513	-285 993	-254 500	-223 666	-186 770	-146 029
Cropland management	75 171	67 961	67 206	63 533	76 634	66 513
Grazing land management	-25 943	-26 502	-26 502	-26 502	-26 502	-26 502
SUM	-246 467	-229 883	-209 547	-196 719	-163 714	-149 696

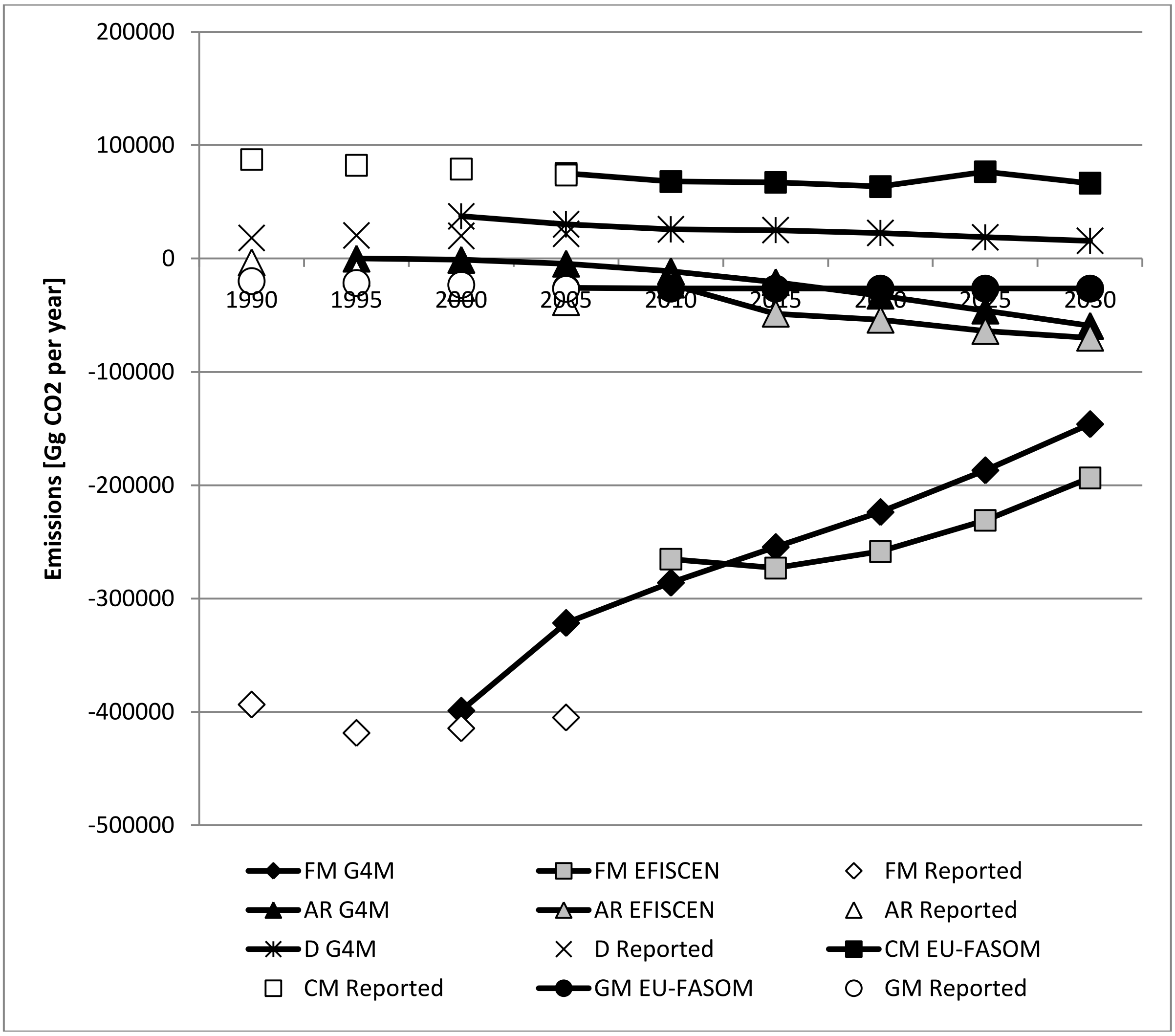

Figure 6: Projected development of emissions and removals by the different models in EU-27 for different LULUCF activities in the baseline scenario. Annual values are available in the database. For simplicity only five year steps are shown here.

2.2 Reference scenario

The most relevant changes in the reference run compared to the baseline for LULUCF are related to bioenergy production. The PRIMES reference scenario projects a higher production of bioenergy from waste and woody energy crops. Also forestry biomass is increasing through increased fellings and use of residues. The effect on the LULUCF CO2 emissions and removals can be observed in Figure 7. The reference scenario leads to a smaller sink of LULUCF in EU27 compared to the baseline. However, the effect is rather small and by the year 2030 only observable by comparing the accumulated emissions and removals as the annual emissions and removals in 2030 are the same for baseline and reference. Differences between baseline and reference are most pronounces for forest management activities.

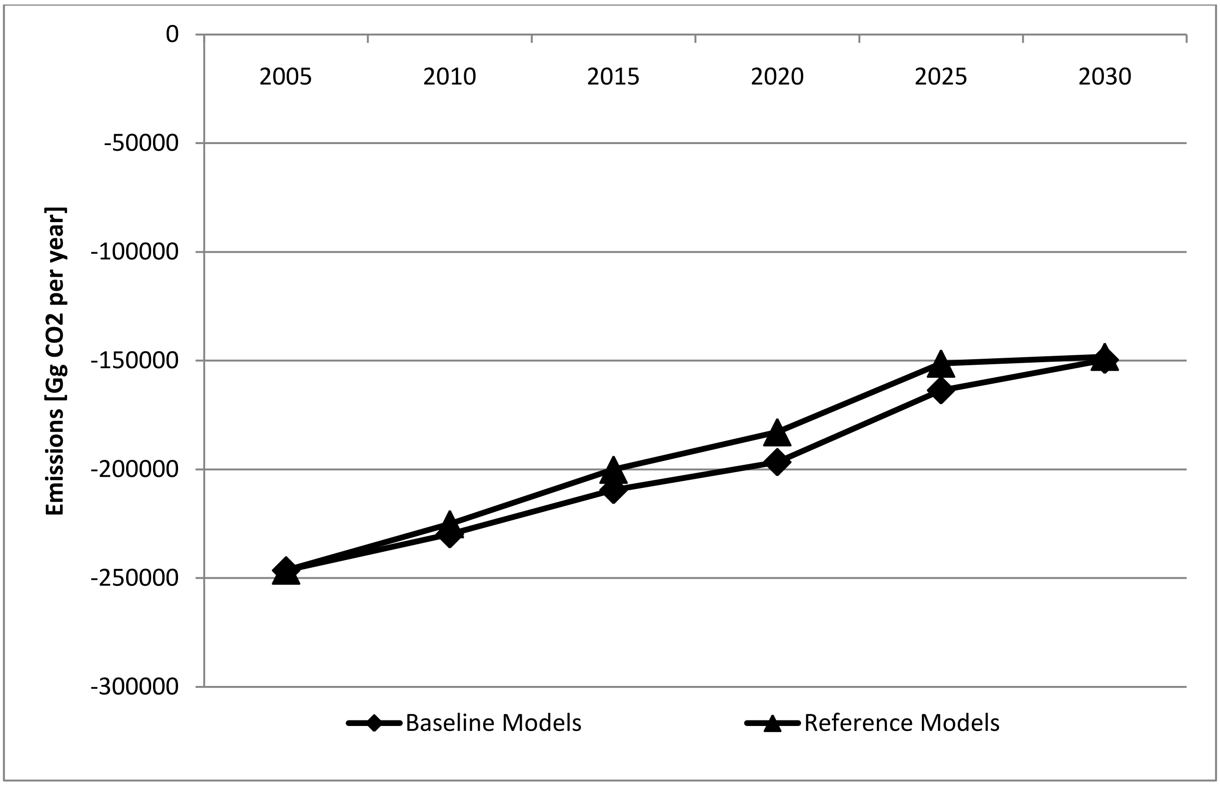

Figure 7: Projected development of emissions and removals in EU-27 for total LULUCF in the baseline and reference scenario.

2.3 Sensitivity analysis

To explore sensitivities of the forestry model further, a systematic sensitivity analysis was carried out by feeding G4M with two additional scenarios of wood demand, being 1) 20% higher and 2) 20% lower compared to the baseline. The effects on the projected forest sink are displayed in Figure 8. A 20% reduction of harvest levels increases the sink by about 20%. The same applies for an increase in harvest levels.

The sensitivity of the projected sink in both models is not symmetrical over the entire period. Especially in the years 2020 to 2030 the reduction effect of increased harvest is less than the increase effect of decreased harvest.

The scenario case of constant harvest rates from 2000 to 2030 reveals the different drivers of the decreasing sink. Despite constant harvest rates the sink further diminishes indicating the role of forest aging.

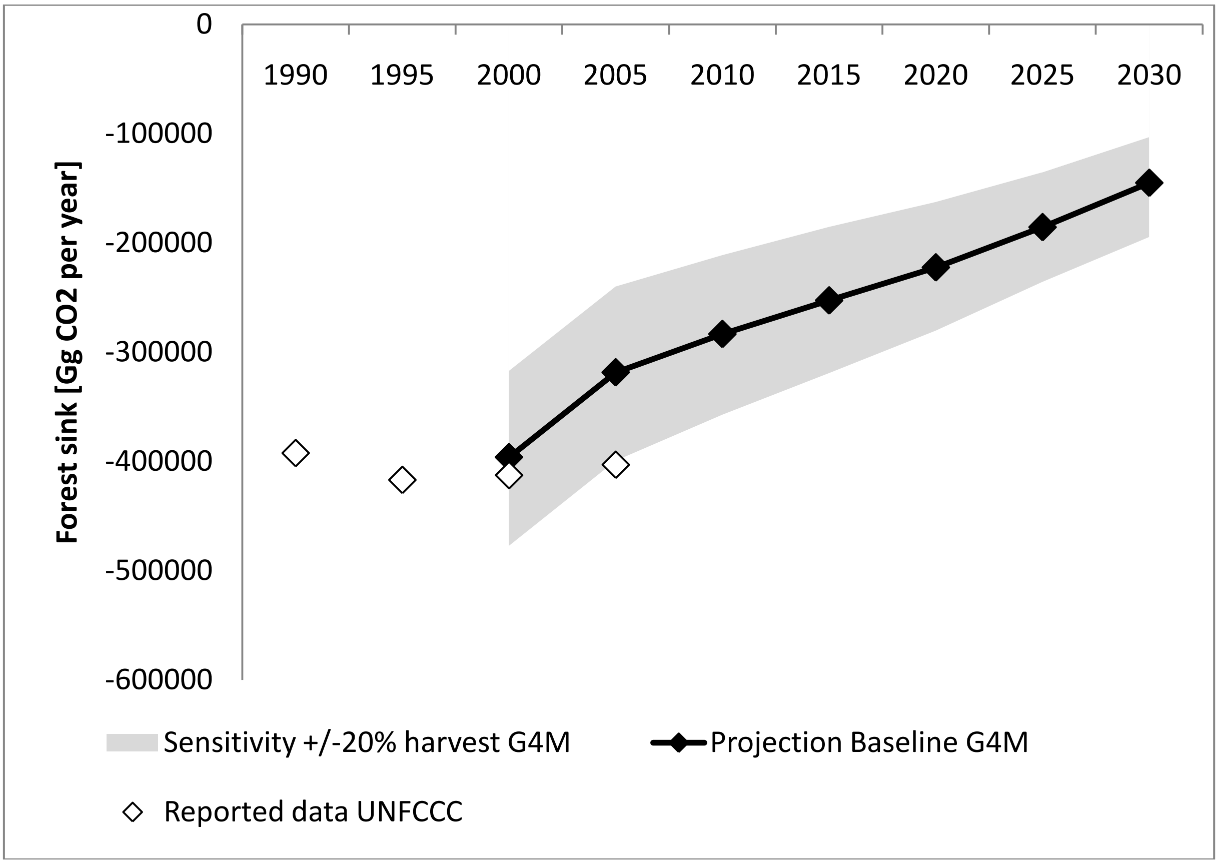

Figure 8: Projection of baseline emissions and removals of forest management activities for EU27 and estimates of 20% higher and lower total wood demand compared to the baseline. Sums do not include values of Cyprus, Malta and Greece in order to make numbers comparable among models

The sensitivity analysis gives also an indication of the effect of underlying uncertainties. The projection of future harvest is highly uncertain and depends on many parameters that cannot be modelled explicitly. However, the sensitivity analysis shows the likely effects of changes in the driver wood demand. It also shows that both models produce robust results.

2.4 Uncertainties

2.4.1 Uncertainty of input data and economic drivers

The approach applied in this study is to a large degree data-driven. Hence, the quality of the results presented depends heavily on the quality of the datasets that were used. The sensitivity analysis showed that the projections were rather sensitive to the assumed harvest rates. Historical roundwood removals (excl. harvest losses) were used to initialize the forest models and to estimate the future roundwood removals. Comparison of FAOSTAT data on historical wood removals with national statistics included in the EU submission to UNFCCC showed significant differences. For example, for France annual roundwood removals deviated up to 22 million m^3 per year (after converting FAOSTAT data from underbark to overbark volume). Such differences can have substantial impacts on the projected CO_2 emissions or removals.

The future roundwood production is based on projections by GLOBIOM and PRIMES. The projection by these two models depends on the same macro-economical developments. Furthermore, it was ensured that GLOBIOM reproduced the same numbers on bioenergy production. However, the development of the forest sector was not harmonized between the models. This could lead to discrepancies in the availability of e.g. black liquor and/or wood waste between GLOBIOM and PRIMES. Further harmonization between PRIMES and GLOBIOM could improve the projections of CO_2 emission or removals by forests.

2.4.2 Model limitations

The GLOBIOM model projected future wood production for the entire EU and it was assumed that production of wood for material use in all EU countries will increase by the same factor. However, the rate is likely to vary between countries (see e.g. Mantau et al. 2010). For some countries "ceilings" on maximum wood removals should be built in to constrain the GLOBIOM model. Current ceilings are based on forest growth, but do not take into account environmental, technical, social and economical constraints that further limit the potential wood supply.

Finally, the impact of growth changes and large-scale disturbances due to environmental and/or climate change on the estimated CO_2 emissions and removals were not included. It is expected that growth may decrease in Southern Europe due to reduced water availability, whereas growth in Northern regions may increase much more (Lindner et al. 2010). Changes in growth will reflect in changes in future CO_2 removals and emissions. In addition, disturbances were also not included in the analysis, but could have an important impact. The impact of growth changes and large-scale disturbances on the development of the LULUCF sector is difficult to model and would require further investigation.

3 Literature

FAO 2009 Production of round wood for 1990 – 2007

Havlík, P., U. A. Schneider, E. Schmid, H. Boettcher, S. Fritz, R. Skalský, K. Aoki, S. de Cara, G. Kindermann, F. Kraxner, S. Leduc, I. McCallum, A. Mosnier, T. Sauer, and M. Obersteiner 2009, Global land-use implications of first and second generation biofuel targets, Energy Policy, accepted.

Lindner, M., Maroschek, M., Netherer, S., Kremer, A., Barbati, A., Garcia-Gonzalo, J., Seidl, R., Delzon, S., Corona, P., Kolström, M., Lexer, M.J., Marchetti, M., 2010. Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. Forest Ecology and Management 259, 698-709.

Link, P.M., C.I. Ramos, U.A. Schneider, E. Schmid, J. Balkovič and R. Skalský 2008, The interdependencies between food and biofuel production in European agriculture - an application of EUFASOM, submitted to Biomass and Bioenergy.

Mantau, U., Saal, U., Prins, K., Steierer, F., Lindner, M., Verkerk, H., Eggers, J., Leek, N., Oldenburger, J., Asikainen, A., Anttila, P., 2010. EUwood - Real potential for changes in growth and use of EU forests. Final report to the European Commission DG TREN. University of Hamburg, Hamburg. http://ec.europa.eu/energy/renewables/studies/bioenergy_en.htm

MCPFE, 2007. State of Europe's Forests 2007: The MCPFE Report on Sustainable Forest Management in Europe, Ministerial Conference on the Protection of Forests in Europe, Liaison Unit Warsaw, Warsaw, Poland

National Technical University of Athens (NTUA, 2005), The PRIMES Energy System Model: Summary Description, Athens, Greece.

PRIMES biomass model (http://www.e3mlab.ntua.gr/manuals/The_Biomass_model.pdf) Dec 2009

Rametsteiner E, Nilsson S, Boettcher H, Havlik P, Kraxner F, Leduc S, Obersteiner M, Rydzak F, Schneider U, Schwab D, Willmore L (2007). "Study of the Effects of Globalization on the Economic Viability of EU Forestry. Final Report of the AGRI Tender Project: AGRI-G4-2006-06

Russ, P., T. Wiesenthal, D. van Regenmorter, and J. C. Císcar (2007), Global Climate Policy Scenarios for 2030 and beyond - Analysis of Greenhouse Gas Emission Reduction Pathway Scenarios with the POLES and GEM-E3 models, JRC Reference Reports, Joint Research Centre - Institute for Prospective Technological Studies, Seville, Spain.

Schneider U.A., J. Balkovic, S. De Cara, O. Franklin, S. Fritz, P. Havlik, I. Huck, K. Jantke, A.M.I. Kallio, F. Kraxner, A. Moiseyev, M. Obersteiner, C.I. Ramos, C. Schleupner, E. Schmid, D. Schwab, R. Skalsky (2008), The European Forest and Agricultural Sector Optimization Model – EUFASOM, FNU-156, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg. http://www.mi.uni-hamburg.de/fileadmin/fnu-files/publication/working-papers/wp156_eufasom.pdf

Schneider,U.A., B.A.McCarl, and E.Schmid (2007). "Agricultural sector analysis on greenhouse gas mitigation in US agriculture and forestry." Agricultural Systems. 94:128-140.

UN-ECE/ FAO, 2000. Forest Resources of Europe, CIS, North America, Australia, Japan and New Zealand, Contribution to the Global Forest Resources Assessment 2000. New York and Geneva, UN.

Williams, J.R. (1995). "The EPIC Model. In Computer Models of Watershed Hydrology" (Ed.: V.P. Singh). Water Resources Publications, Highlands Ranch, Colorado, 1995, pp 909-1000..