Submission of information on forest management reference levels by Hungary

This submission of Hungary addresses the requests by the Cancún decisions, i.e. Report of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol on its sixth session, held in Cancun from 29 November to 10 December 2010, Part One: Proceedings (FCCC/KP/CMP/2010/12), and specifically Decision 2/CMP.6, The Cancun Agreements: Land use, land-use change and forestry as found in the Addendum to the above Report (FCCC/KP/CMP/2010/12/Add.1).

1. *Forest management reference level value*

Based on modelling work as described later, Hungary suggests the forest management (FM) reference levels (RL) contained in **Table 1.** The numbers are somewhat different from the data contained in the last (voluntary) submission of the EU 30 July 2010, and now include emissions and removals from harvested wood products (HWP) using two types of approaches.

Table 1. Value of proposed reference levels (Gg CO2eq).

Proposed Reference Level (1), (4) (GgCO$_2$eq per year)	
applying first order decay function for HWP (2)	assuming instantaneous oxidation of HWP (3)
-452	-572

Note that:

(1) The reported values are averages of the projected FM data series for the period 2013-2020, taking account of policies implemented before mid-2009.

(2) HWP data includes emissions/removals from HWP estimated using the product categories, half lives and methodologies as suggested in para 27, page 31 of FCCC/KP/AWG/2010/CRP.4/Rev.4. Activity data is starting from 1964.

(3) The RL assuming instantaneous oxidation of HWP is provided for transparency reasons only.

(4) The RL includes emissions and removals from natural disturbances of the period 2000-2008.

2. *General description*

The RLs were derived using projections of emissions and removlas from FM. The projections from FM are provided by the Joint Research Centre of the European Commission (JRC), based on elaboration of the results of independent EU modeling groups, coordinated by the International Institute for Applied Systems Analysis (IIASA), assisted by the JRC and funded by the European Commission Directorate General of Climate Action (DG CLIM). This methodology was applied as it ensures an independent estimate by modelling groups. However, the projected values are verified using two other methods to increase the scientific validity of the estimates. The projections from HWP were provided by S. Rüter, Johann Heinrich von Thünen-Institut (vTI), Federal Research Institute for Rural Areas, Forestry and Fisheries, Institute for Wood Technology and Wood Biology , Hamburg, Germany.

When constructing the RL, all elements mentioned in footnote 1 of paragraph 4 of the decision -/CMP.6 on LULUCF were taken into account:

(a) Removals or emissions from FM as shown in greenhouse gas inventories and relevant historical data: they were taken into account by adjusting results of the modelling exercise through an “ex-post processing of models results” (see section 5 “Description of construction of reference levels”). This ex-post processing ensured that projections of the models for historical periods are fully consistent, also took into account the need for consistency with the inclusion of carbon pools.

(b) Age-class structure: models used the latest available country specific age-class structure data (see section 5 “Description of construction of reference levels”).

(c) Forest management activities already undertaken: indirectly taken into account through the use of the latest available forest time series data (from national forest inventory or other country statistics), and the estimation of the evolution of harvest demand by 2020 based on macroeconomic drivers and the application of policies and legislative provisions adopted implemented in Hungary by mid-2009 (see section 6, “Policies included”).

(d) Projected forest management activities under a business as usual scenario: they are taken into account through the estimation of the evolution of harvest demand by 2020 based on macroeconomic drivers and the application of the above policies (see section 6 “Policies included”).

(e) Continuity with the treatment of FM in the first commitment period: eventually, through the application of the “ex-post processing”, we ensured that the same area and same forests are considered. The consistency of the management of the forests is ensured by the forest management plans, which continue to represent the legal framework for forestry in Hungary.

(f) The need to exclude removals from accounting in accordance with decision 16/CMP.1, paragraph 1: No explicit factoring out was done, see section 5. I (g) below.

The reported RL was developed using the historical FM emissions and removals, which included emissions from natural disturbances that could be regarded as “disturbances in the context of force majeure”.

3. Pools and gases

The pools and gases included in the derivation of the RL are the same that are included in the estimates of GHG emissions and removals as reported in the last (in 2010) annual national inventory report. They are reported in **Table 2.**

Table 2. C pools and GHG sources included in the reference level. „Yes” indicates if the pool or gas is included, and „no” indicates that it is not included, in the projections used to set the RL.

Change in C pool included in the reference level						GHG sources included in the reference level					
Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil		Fertilization	Drainage of soils	Liming	Biomass burning		
				mineral	organic	N_2O	N_2O	CO_2	CO_2	CH_4	N_2O
yes	yes	no	no	no	no	no	no	no	yes	yes	yes

Under the Kyoto Protocol, Hungary demonstrated that soils, litter and deadwood are not a source, and it is probably going to stay so. Fertilization, drainage and liming have not been practiced any more for a long time in forests. Biomass burning includes both burning of slash on site and emissions from forest fires which, however, continued to be low level disturbances in Hungary.

4. Approaches, methods and models used

The models used to project annual emissions and removals from FM at the country level are G4M (from IIASA) and EFISCEN (from the European Forest Institute, EFI). These models can be used to develop information on potential yields and GHG emissions and removals for diverse forest management alternatives in Europe. The two models differ in the way they allocate harvest demand to thinnings and final fellings (including rotation length) with implications on emissions and removals from the forest. In general, both models follow the rules of sustainable forest management, securing sustainable yields. Further they follow different growth concepts (EFISCEN forest growth is based in inventory data, whereas G4M estimates growth from productivity maps, i.e. NPP maps) representing alternative approaches of forest growth estimation and projection. The two modes generate different results, and we believe that taking the mean of these two results produces the best estimates.

These emissions and removals estimates, which are the basis for the reference level calculations, must also be built on the estimation of the future timber demand. This demand in the first step is based on macro projections of GDP and population, which are exogenous to the models used. They reflect the recent economic downturn, followed by an assumed sustained economic growth resuming after 2010. The macro projections data enter a model called GLOBIOM that translates them into demand for timber.

To project future timber demand, the baseline scenario was used with GLOBIOM. For this baseline scenario, the economic land use models project domestic production and consumption, net exports and prices of wood products and changes in land use for EU member states and other world regions. For the main assumptions of the baseline scenario, see pp.13-16 of Capros et al., 2010[1] for more information).
More specifically, bioenergy demand was projected by the PRIMES biomass model[2]. The biomass system model is incorporated in the baseline scenario of the PRIMES large scale energy model for Europe[3]. 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.

In order that the projections are tested and that they are consistent with historical estimates, the historical projections were compared with historical data. Then, in the last step, the projectsions were corrected in a procedure called „ex-post correction”.

A more detailed description of modelling steps is provided in following sections.

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[1] P. Capros, L. Mantzos, N. Tasios, A. De Vita, N. Kouvaritakis (2010), EU energy trends to 2030 — UPDATE 2009, European Commission, Directorate-General for Energy in collaboration with Climate Action DG and Mobility and Transport DG. Luxembourg: Publications Office of the European Union, 2010. ISBN 978-92-79-16191-9. URL: http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2030_update_2009.pdf

[2] http://www.e3mlab.ntua.gr/e3mlab/PRIMES%20Manual/THE_NEW_PRIMES_BIOMASS_MODEL.pdf

[3] http://www.e3mlab.ntua.gr/e3mlab/PRIMES%20Manual/The_PRIMES_MODEL_2008.pdf

Table 3. Essential features of the main models involved in the projection of emissions and removals from forest management.

G4M	The Global Forest Model (G4M) provides spatially explicit estimates of annual above- and belowground wood increment, development of above- and belowground forest biomass and costs of forestry options such as forest management, afforestation and deforestation by comparing the income of alternative land uses.
EFISCEN	The European Forest Information Scenario Model (EFISCEN) is a large-scale model that assesses the supply of wood and biomass from forests and projects forest resource development on regional to European scale, based on forest inventory data. EFISCEN provides projections on basic forest inventory data (stemwood volume, increment, age-structure), as well as carbon in forest biomass and soil.
GLOBIOM	GLOBIOM is a global static partial equilibrium model integrating the agricultural, livestock, bioenergy and forestry sectors with the aim to give policy advice on global issues concerning land use competition between the major land-based production sectors.

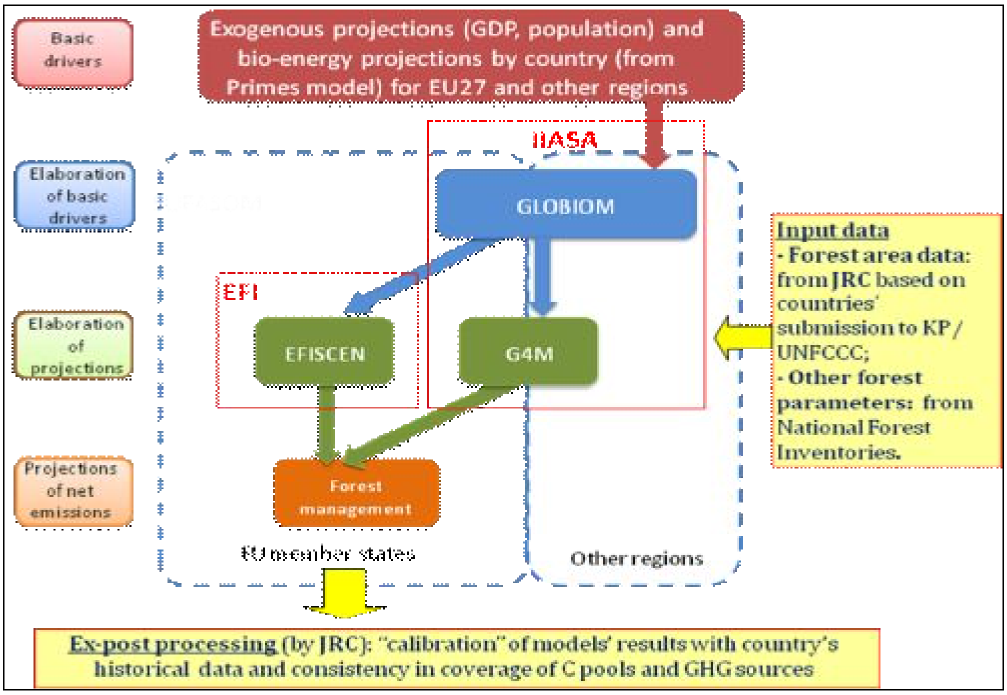

Figure 1. Synthetic flowchart of information exchange between models.

The modelling approach included the following main steps:

1) *Collection of relevant input data*

1. Forest area used by the models was taken from national forest inventories and scaled to match the area reported in GHG inventories by the MS (EFISCEN) or from recent literature (G4M), see **Table 4**.
2. Main forest and forest management parameters (age structure, increment, historical harvest) were taken from national forest inventories and other country statistics (see **Figure 2** and **4**, and **Tables 9** and **11**). Other forest parameters and management characteristics such as management characteristics, rotation length were taken from relevant sources (see **Table 10**).
3. Future harvest demand under a business as usual (BAU) scenario (see **Table 11**) was derived from key macroeconomic drivers (GDP, population), based only on policies and measures

enacted by Hungary by mid-2009 (the EU 2020 renewable target and the 20% GHG reduction targets are not included in this baseline). In particular, the bio-energy demand was estimated by the Primes model and the timber demand was estimated by the GLOBIOM model. See section 6 “Policies included” and the Annex for more information.

2) *Elaboration of input data*

The above input data, as well as the outputs from the GLOBIOM and PRIMES models, were elaborated by the two forest models (G4M and EFISCEN) to produce annual estimates of emissions and removals from FM untill 2020 (for the above and below ground biomass carbon pools). The two models with the unavoidable uncertainties produced different time series, and we took the average of two different sets of outputs (**Table 7**) to make the future trend estimate more robust.

Elaborations also included a simulation of the impact of +/-10% harvest as compared to BAU harvest levels (see sensitivity analysis in **Table 7**).

3) *Ex-post processing of models’ results:* In order to ensure consistency between models’ results and historical data reported by the country, the emissions and removals estimated by the models for the entire time series (up to 2020) were “calibrated” (i.e. adjusted) using historical data from the country for the period 2000-2008 (for which we had both data from the GHG inventories and data projected by the models). To this aim, an “offset” was calculated for two components:

- biomass: offest calculated as difference between [average of country’s emissions and removals from biomass for the period 2000-2008 (**Table 5**)] and [average of models’ estimated emissions and removals from biomass for the period 2000-2008 (**Table 7**)]

- non-biomass pools and GHG sources: offset calculated as the sum of non-biomass pools and GHG sources as reported by the country for the period 2000-2008 (**Table 5**), and not estimated by models.

The calibrated average of models, which is used for the setting of reference level, is obtained by adding the total offest (biomass offset + non-biomass pools and GHG sources offset) to the models’ average. In other words, models’ results were adjusted to match the average historical data provided by each country for the period 2000-2008. This ensures consistency between country data and models’ data in terms of:

(i) absolute level of emissions and removals from biomass, i.e. the calibration „reconciles” differences in estimates which may be due to a large variety of factors, including different input data, different parameters, different estimation methods (e.g., Hungary uses a „stock-change approach”, while the models use a „gain-loss approach”);

(ii) coverage of non-biomass pools and GHG sources.

The calibration procedure automatically incorporates into the projections the average rate (for the period 2000-2008) of the GHG impact of past natural disturbances, which are not explicitly estimated by the models (e.g. emissions from fires etc.).

The future *trend* of emissions and removals up to 2020 as predicted by the models is not affected by this calibration procedure, but only by the current (and projected) forest characteristics (e.g., age structure etc.) and the future harvest demand (for which no ex-post processing is applied).

It is important to note that, to maintain consistency in the future, technical corrections (as referred in para 15 quarter and 15 quinquies of the document FCCC/KP/AWG/2010/CRP.4/Rev.4) will be needed in theory in the following cases:

(i) if recalculations of emissions and removals from FM (or forest land remaining forest land) for the period 2000-2008 will be carried out in any future submission of annual GHG inventories of Hungary;

(ii) if any future threshold selected for "force majeure" indicates that events or emissions in the 2000-2008 period can be considered "force majeure", in which case the impact (in terms of GHG) should be removed from historical FM emissions/removals (according to provisions of any future decisions on force majeure), which might affect the calibration procedure described above. For transparency reasons, the section "Disturbances in the context of force majeure" reports the emissions from forest fires from 1990-2008 (expressed in Gg CO2-eq. and as % of 1990 total GHG emissions excluding LULUCF).

5. *Description of construction of reference levels*

I. Description of how each of the following elements were considered or treated in the construction of the forest management reference level, taking into account the principles in decision 16/CMP.1

(a) Area under forest management

Table 4. Area for FM as used by models (kha).

Model	Calendar year						Source of	
	2000	2005	2008	2010	2015	2020	historical data (up to 2008)	projected data (2010-2020)
G4M	1,649	1,646	1,644	1,642	1,627	1,610	(1)	(3)
EFISCEN	1,662	1,659	1,657	1,657	1,655	1,651	(2)	

Notes:

(1) G4M model: Gallaun, H., G. Zanchi, G. J. Nabuurs, G. Hengeveld, M. Schardt and P. J. Verkerk (2010). "EU-wide maps of growing stock and above-ground biomass in forests based on remote sensing and field measurements." Forest Ecology and Management 260(3): 252-261 (Based on CORINE and TBFRA). G4M is a spatially explicit forestry model and relies on the information from forest maps for its initialisation. This map served as a basis that was adjusted to the degree possible to data reported by countries.

(2) Estimated from time series of area data by using the formula: (area of "Forest land" in 1990, assuming that "managed forest" under UNFCCC equals to land under FM) – (area deforestations since 1990 as included in KP reporting).

(3) Data of 2008 minus the area of D projected as a linear extrapolation. Deforestation rate considered the same as in 1990-2008.

(b) Emissions and removals from forest management

1) Historical emissions and removals from forest management

The historical emissions and removals from FM are reported in **Table 5.**

Table 5. Hungary’s historical emissions and removals from FM (all pools and GHGs, Gg CO2eq)

Pool/source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	av. 2000-2008
Biomass (1)	-2589	-2868	-3531	-5087	-5531	-5547	-1577	-1774	-2720	-979	95	-1309	-672	-2676	-1555	-3576	-1536	-1769	-2808	-1756
Non-biomass pools	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GHG sources (2)	24	23	21	19	19	20	21	22	21	23	30	27	28	27	24	37	24	34	24	28
TOTAL	-2566	-2845	-3510	-5069	-5512	-5528	-1556	-1752	-2699	-957	125	-1281	-644	-2649	-1532	-3539	-1512	-1735	-2784	-1728

Notes:

(1) Includes above- and below-ground biomass.

(2) Pools included and excluded as presented in **Table 2** above**.**

Table 6. Hungary’s historical emissions and removals from FL remaining FL (Gg CO2eq), based on latest GHG inventory submitted to UNFCCC.

Pool/source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	av. 2000-2008
Biomass (1)	-2604	-2867	-3604	-5291	-5826	-5846	-1936	-2186	-3157	-1522	-518	-1935	-1408	-3533	-2559	-4649	-2684	-2930	-4039	-2695
Non-biomass pools	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GHG sources (2)	24	23	21	19	19	20	21	22	21	23	30	27	28	27	24	37	24	34	24	28
TOTAL	-2581	-2844	-3583	-5272	-5807	-5827	-1915	-2164	-3136	-1499	-488	-1907	-1381	-3506	-2536	-4612	-2660	-2897	-4016	-2667

Notes: as for **Table 5** above.

2) The relationship between forest management and forest land remaining forest land as shown in GHG inventories and relevant historical data, including information provided under Article 3.3., and, if applicable, Article 3.4 forest management of the Kyoto Protocol and under forest land remaining forest land under the Convention

Full consistency is ensured as demonstrated by a detailed calculation in Chapter 11 of the NIR of Hungary, as re-submitted 5 November 2010. Historical data for FM are reported in **Table 5**, whereas historical data for Forest Land remaining Forest land, as reported under the UNFCCC in our submission of 5 November 2010, are found in **Table 6.**

3) Modelled emissions and removals from forest management

Modelled emissions and removals from FM are presented in **Table 7**. Note that this table transparently shows the results of the two models mentioned above for historical data in the first step; how, in the second step, the average of the historical data was calibrated to obtain the level of net removals that is equal to the historical data estimated using the IPCC methodology, and how, in the third step, this offset was applied to the average values of the projected removals to obtain the reference level value. Finally, the table shows, for transparency reasons, a band around the calibrated model averages if we assume an uncertainty of ±10% in the harvest values.

Table 7. Emissions and removals from FM as estimated by models (above and below-ground biomass, Gg CO2eq), calibration of models' results, and sensitivity analysis.

Derivation of data			average 2000-2008	2000	2005	2010	2015	2020	average 2013-2020
Step 1: models' results (only biomass)	EFISCEN (1)		-4631	-4885	-4551	-4313	-3239	-2875	-3183
	G4M		-5274	-5438	-5269	-4886	-4614	-4016	-4410
	Average of models		-4952	-5161	-4910	-4600	-3927	-3445	-3797
Step 2: ex-post processing	Offset (2)	biomass	3196						
		non-biomass pools and GHG sources	28						
		total offset	**3224**						
	Calibrated average of models (3)		-1728	-1937	-1685	-1375	-702	-221	**-572**
Sensitivity analysis (4)		*+10% harvest*				*-383*	*320*	*794*	*447*
		-10% harvest				*-2140*	*-1451*	*-900*	*-1296*

Notes:

(1) EFISCEN does not estimate data for Hungary for 2000 and 2005, and backward extrapolation was applied as follow: sink in 2005 = sink in 2010 x ratio of harvest 2010/2005. This approach assumes that in the short term harvest is the main factor determining the sink.

(2) The "offset" is distinguished between:

- biomass: calculated as difference between [average of country's emissions and removals from biomass for the period 2000-2008 (**Table 5**)] and [average of models' estimated emissions and removals from biomass for the period 2000-2008 (**Table 7**)]

- non-biomass pools and GHG sources: calculated as the sum of non-biomass pools and GHG sources as reported by the country for the period 2000-2008 (**Table 5**).

(3) The calibrated average of models, used for the setting of reference level (i.e. the grey cell), is obtained by adding the offset to the average of models. See Section 4 3), ”Ex-post processing of model’s results” above for details.

(4) Simulation of the impact of +/-10% harvest as compared as BAU harvest on the emissions and removals from FM. Data are calibrated averages of models’ results.

(c) Forest characteristics and related management

1) Age class structure

The age-class structure is indeed very important in determining the future increment and harvest levels, even under the BAU scenario. In general, the age class distribution of the Hungarian forests (**Figure 2**) shows a somewhat decreasing area of the young (and thus fast growing) ages and an increasing area of the older forests. In Hungary, young forests under 20 years include a lot of Black locust (Robinia pseudoacacia) and poplar (Populus sp. and hybrids) stands whose increment falls beyond the age of 20 years, and old forests include oaks (Quercus sp.) and Beech (Fagus silvestris) of 60 years and older.

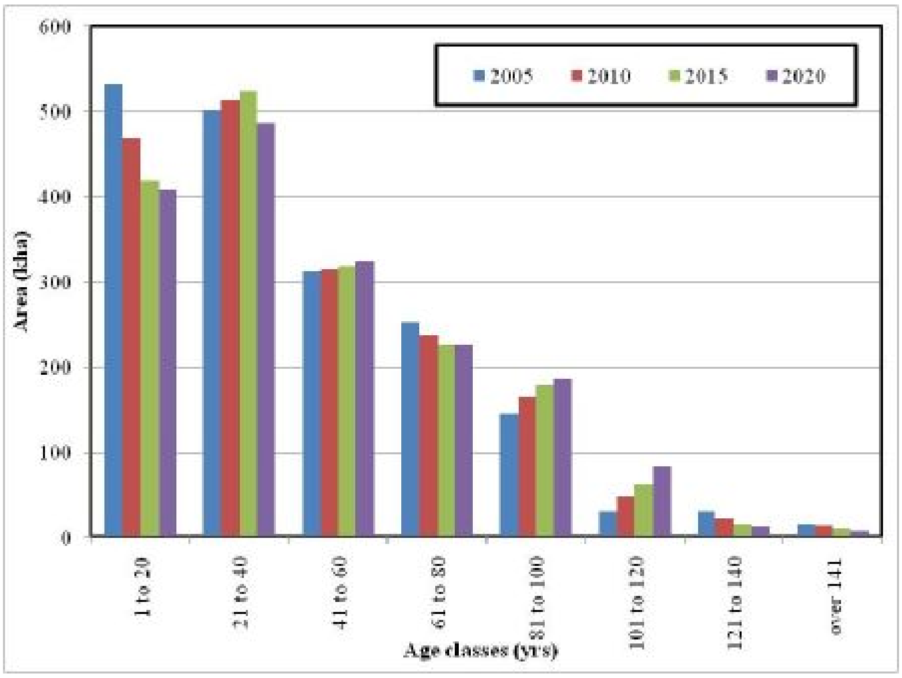

Figure 2. Evolution of the forest age class structure (in yrs) as modelled by EFISCEN.

Table 8. Age class structure in 1990-2008, for FM areas, from NFD

FM (area, kha), 1990	**1-20**	**21-40**	**41-60**	**61-80**	**81-100**	**101-**	**Sum**
Quercus robur	34.7	43.7	23.8	20.2	18.4	2.3	**143.1**
Quercus pertaea	26.1	27.6	53.1	47.1	24.8	7.3	**185.9**
Other quercus	8.2	4.1	3.6	5.5	3.4	2.2	**27.1**
Quercus cerris	24.7	26.2	55.3	48.3	17.3	4.4	**176.1**
Fagus silvatica	9.3	10.7	22.1	24.0	23.9	12.5	**102.5**
Carpinus betulus	8.1	15.3	35.8	25.4	8.8	2.0	**95.4**
Robinia pseudoacacia	135.7	137.3	17.2	0.7	0.1	0.0	**291.0**
Acer sp.	2.5	4.1	1.2	0.7	0.4	0.3	**9.2**
Ulmus sp.	0.3	1.1	0.4	0.1	0.0	0.0	**1.9**
Fraxinus sp.	4.5	9.5	10.6	6.5	2.4	1.0	**34.5**
Other hard broadleaves	3.7	3.0	1.6	0.6	0.2	0.1	**9.2**
Hybrid poplars	72.8	37.2	0.9	0.0	0.0	0.0	**110.9**
Indigenous poplars	19.4	14.1	4.6	0.6	0.1	0.0	**38.7**
Salix sp.	11.7	7.6	1.9	0.2	0.0	0.0	**21.4**
Alnus sp.	18.7	16.5	7.3	0.9	0.1	0.0	**43.4**
Tilia sp.	2.5	3.3	4.1	2.2	1.1	0.4	**13.6**
Other soft broadleaves	1.2	1.4	0.9	0.2	0.1	0.0	**3.8**
Pinus silvestris	69.6	55.9	13.3	7.0	2.7	0.4	**148.9**
Pinus nigra	30.9	27.0	4.1	2.5	1.4	0.1	**66.0**
Picea abies	13.8	6.2	1.6	1.3	0.5	0.1	**23.5**
Larix decidua	0.9	1.3	0.2	0.2	0.2	0.0	**2.8**
Other conifers	0.5	1.2	0.3	0.1	0.0	0.0	**2.1**
Sum	**499.9**	**454.3**	**263.8**	**194.3**	**106.0**	**33.1**	**1 551.4**

FM (area, kha),**2008**	1-20	21-40	41-60	61-80	81-100	101-	Sum
Quercus robur	21.6	30.2	38.9	20.0	12.9	7.8	131.4
Quercus pertaea	23.9	21.4	23.8	49.0	33.9	17.9	169.9
Other quercus	2.8	8.1	5.1	4.5	5.7	5.1	31.2
Quercus cerris	27.8	32.3	31.0	56.1	30.8	11.6	189.6
Fagus silvatica	15.4	9.1	11.1	22.5	23.1	22.3	103.5
Carpinus betulus	7.3	18.4	16.0	28.2	15.1	5.3	90.3
Robinia pseudoacacia	146.5	146.8	36.5	3.0	0.2	0.0	332.9
Acer sp.	3.4	6.1	4.9	1.4	0.8	0.6	17.2
Ulmus sp.	0.8	1.0	0.9	0.2	0.0	0.0	2.9
Fraxinus sp.	8.1	10.8	11.8	10.4	5.5	3.4	50.0
Other hard broadleaves	5.6	5.4	3.5	1.7	0.5	0.2	16.9
Hybrid poplars	34.4	26.8	4.1	0.2	0.0	0.0	65.5
Indigenous poplars	18.5	19.9	9.1	2.0	0.2	0.0	49.7
Salix sp.	2.0	11.7	5.0	1.0	0.1	0.0	19.8
Alnus sp.	6.3	19.6	16.2	2.7	0.3	0.0	45.1
Tilia sp.	1.5	5.8	5.3	4.5	2.0	1.2	20.3
Other soft broadleaves	1.8	3.0	1.0	0.2	0.1	0.0	6.1
Pinus silvestris	7.0	64.4	35.3	8.7	3.6	0.9	119.8
Pinus nigra	7.8	26.2	18.2	3.0	1.5	0.8	57.4
Picea abies	1.9	11.8	2.9	0.6	0.2	0.1	17.4
Larix decidua	0.7	1.2	1.2	0.2	0.2	0.1	3.6
Other conifers	0.1	0.8	1.4	0.1	0.0	0.0	2.4
Sum	345.1	480.8	283.1	220.0	136.6	77.3	1 543.0

We also checked if the specific increment of the various species and age classes remain the same, because modelling uses this kind of information. In fact, we developed **Figure 3** from the forest inventory data (which is described in the NIR in details) which shows rather robust specific increments.

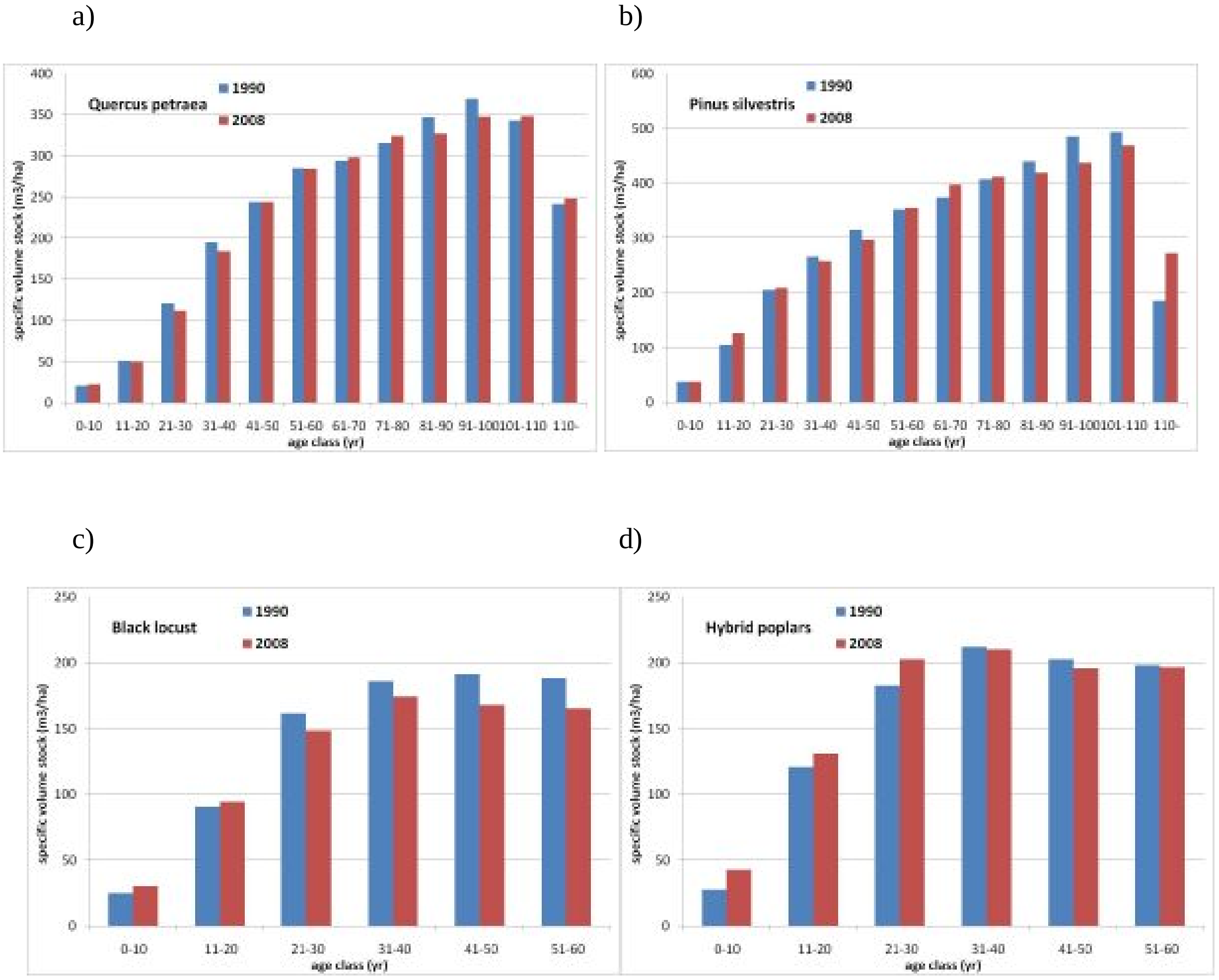

Figure 3. Specific volume stock over age class for frequently occurring, slow growing (a, b) and fast growing (c, d) species. It is only for Black locust where a general tendency occurs towards lower specific volume stocks. However, this is explained by the fact that most Black locust stands were privatized and the intensity of thinnings increased in these stands. To a lesser extent, this happened in the stands of fast growing species, however, the total amount of harvest did not increase, which means that the amount of final cuts decreased, which has lead to the relative increase of older forests.

2) Increment

The increment data as estimated and used by the IIASA and EFI models are reported in **Table 9.** In the latest estimation of increment based on the raw data of National Forest Database seems slightly different (7.1 m^3/ha/year), so it may requires some fine adjustment. The mean values are means across species, site fertility and age over which increment has a rather high variability.

Table 9. Increments as estimated by models (m^3 ha^{-1} yr^{-1}).

Specific increment (m3*ha-1*yr-1) by calendar year				
2000	2005	2010	2015	2020
7.5	7.6	7.6	7.4	7.3

3) Rotation length

In Hungary, about 15 species constitute by far the largest area of the forests. Among the extremes are oaks and beech that are harvested between ages 80 and 120+ years, and hybrid poplars that can be harvested at the age of 15 years on good sites.

Figure 4 summarizes the distribution of the forest area in various classes of rotation age.

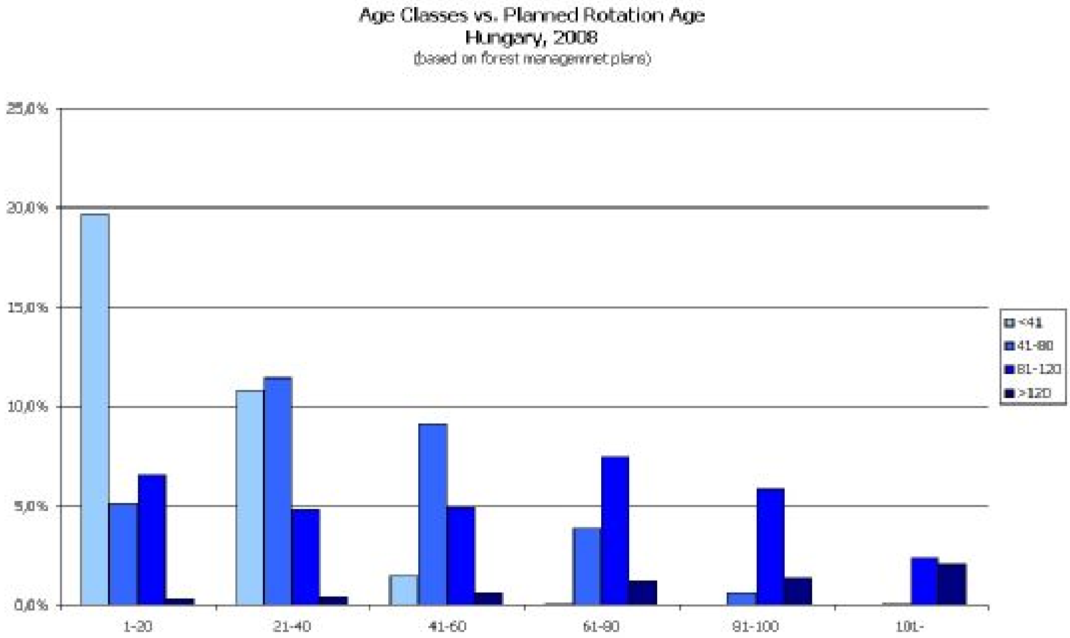

Figure 4. The distribution of forest area over age classes in various rotation age classes.

4) Information on forest management activities under “business as usual”

We already mentioned that privatization lead to changes in the intensity of thinnings and final cuts in the forests. This process has more or less ended. On the other hand, the management of forest has shifted towards more close-to-nature forestry. However, this means a shift in the way timber is harvested, and not necessarily the amount that is harvested, and it is the amount that matters with respect to reference levels.

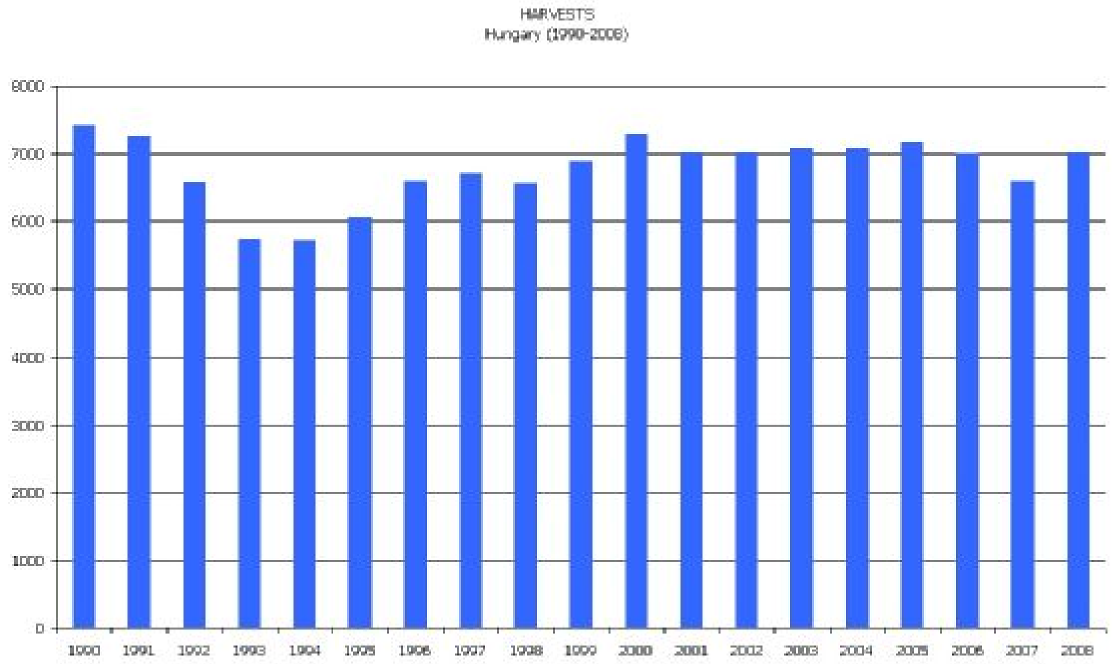

Figure 5. The harvest are constant since privatisaton (1993-94). Harvest rates are regulated by the forest management plans.

5) Other relevant information

The main forest parameters and characteristics as used by the models are summarized in **Table 10**.

Table 10. Source of the main forest parameters and characteristics as used by the models.

Model	Forest parameters and characteristics					
	Area (ha) by species group and age class	Growing stock (m^3) by species group and age class	Increment (m^3 ha^{-1} y^{-1}) by species group and age class	BEF, root/shoot ratio, wood density by species and age-class		Management regime (rotations, thinning…) by species (years, …)
				BEF and R/S ratio (dimensionless)	Wood density (t dry matter/ m^3 fresh volume)	
EFISCEN	Recent inventory data were provided by national correspondents and agencies		Increment functions are based on national forest inventory data. In case increment data was not available, yield tables have been used.	Species-specific and age-dependent BEFs have been developed for selected number of countries for EFISCEN by Vilén et al. 2005 (5) and national reports (22) and are applied to neighbouring countries	Basic wood densities are based on IPCC defaults (1)	Management regimes have been derived from a country-wise compilation of guidelines, handbooks and personal communication (6).
G4M	For area, GLC 2000 and for forest area (scaled to JRC data to the degree possible); for the increment NPP was scaled to MCPFE 2005; BEF and root/shoot ratio are assumed to be constant; carbon in biomass, soil, litter and dead trees are from Kindermann et al., based on FAO and GLC 2000; the age structure is taken from NFI.					

(d) Harvesting rates

1) Historical harvesting rates

Historical harvesting rates are reported in **Table 11.** The data are the same that are assumed in the estimation of historical GHG emissions in our latest (2010) NIR. (Note that this assumption is an indirect assumption as we apply the stock change method to estimate carbon stock changes for the biomass pools.)

Table 11. Historical and projected harvest rate and projected BAU harvest demand used by models (round wood overbark, (a)) and total harvest raw data from National Forest Database (NFD, (b)).

(a)

Harvest (thousand m^3 yr^{-1})					Source of historical data (till 2007)
2000	2005	2010	2015	2020	
6,179	6,632	6,998	7,363	7,728	FAO June 2010

(b)

Year	Harvest from NFD (1000 m3)
1990	7,415
1991	7,254
1992	6,589
1993	5,721
1994	5,717
1995	6,050
1996	6,603
1997	6,718
1998	6,578
1999	6,897
2000	7,289
2001	7,011
2002	7,011
2003	7,086
2004	7,095
2005	7,167
2006	7,005
2007	6,609
2008	7,024

Notes: values in the table of projected harvest rates express 5-yrs average (e.g. 2000 is the average 1998-2002, and 2005 is the average 2003-2007). Untill 2007, data are from national statistics (National Forest Database, NFD). Data for 2020 were estimated by the models PRIMES (wood for bioenergy) and GLOBIOM (timber). Data between 2008 and 2020 are interpolated. The harvest rate used by each model may slightly deviate from harvest demand (e.g. if the model did not “find” all the wood in the forests).

See also **Figure 5**.

2) Assumed future harvesting rates

Projected harvesting data is reported in **Table 11** above.

Note that the general assumption was made for the prediction that all the harvest predicted till 2020 is allocated to FM, i.e. it was assumed that the harvest till 2020 on areas afforested/reforested or deforested after 1990 is negligible as compared to the harvest of forest areas which qualify as FM. While this assumption may not be fully true for the total amount, it seems hold true for timber. As deforestation has been very small in Hungary, even the total amount of harvest from deforestation is very small (on average, 0,6% a year of all harvests, 0.03% a year of area of FM in 1990, altogether representing under 1% of all removals each year). On the other hand, AR forests are rather young and most harvest is pre-commercial or commercial thinning, most of which only produces firewood, which is accounted applying the instantaneous oxidation anyway. Thus, the above assumption can be regarded an „as far as practicable” assumption.

(e) Harvested wood products

The contribution of HWP to the reference level of Hungary amounts to 0,120 Mt CO_2.
It was calculated using the C-HWP-Model, which estimates delayed emissions on the basis of the annual stock change of semi-finished wood products as outlined in the 2006 GL (Rüter, 2011). The estimation uses the product categories, half lives and methodologies as suggested in para 27, page 31 of FCCC/KP/AWG/2010/CRP.4/Rev.4.

The activity data (production and trade of sawnwood, wood based panels and paper and paperboard) is derived from the TIMBER database (UNECE 2011) (time series 1964-2009).

In order to achieve accurate results, the HWP numbers have been calculated applying the sub-categories of sawnwood, wood based panels and paper and paperboard as specified in Table 1. Sawnwood includes the Items 1632 and 1633, wood based panels comprising of Items 1634, 1640, 1646, 1647, 1648, 1649 and 1650, and paper and paperboard corresponds to Item 1876.

The conversion factors used are summarized in **Table 12.**

Table 12. Conversion factors of considered commodities*

Classification		Description of commodity	Air dry density	C conv. factor	Source
FAO	UNECE		(g/cm³)	(Gg C/1000m³)	
1866	1.2.C	Industrial round wood, coniferous	0,450	2,250E-01	Kollmann (1982), (oak, beech)
1867	1.2.NC	Industrial round wood, non-coniferous	0,670	3,350E-01	Kollmann (1982), (oak, beech)
1632	5.C	Sawnwood, coniferous	0,450	2,250E-01	Kollmann (1982), (oak, beech)
1633	5.NC	Sawnwood, non-coniferous	0,670	3,350E-01	Kollmann (1982), (oak, beech)
1634	6.1	Veneer sheets	0,590	2,950E-01	IPCC (2003)
1640	6.2	Plywood	0,480	2,402E-01	IPCC (2003)

1646	6.3	Particle board	0,630	2,898E-01	Hasch (2002), Barbu (2011)
1647	6.4.1	Hardboard	0,850	4,165E-01	Kollmann (1982), Barbu (2011)
1648	6.4.2	Medium density fibreboard	0,725	3,190E-01	Hasch (2002), Barbu (2011)
1649	6.4.x	Fibreboard, compressed	0,788	3,504E-01	(50 % hardboard / 50 % medium density fibreboard)
1650	6.4.3	Other board (Insulating board)	0,270	1,148E-01	Kollmann (1982), Barbu (2011)
1876	10	Paper and paperboard	0,900**	4,500E-01**	IPCC (2006)

* Items 1866 and 1867 are needed for methodological reasons only (see following section)
** in (g/g) and (Gg C/1000t)

In order to only estimate emissions from HWP removed from forests which are accounted for by Hungary under Article 3, in a first step, the annual share of carbon in HWP coming from domestic forests has been calculated.

Equations (1) and (2) below were used as industrial round wood is assumed to serve as raw material for the production of HWP.

(1) $$ratio_{INDRW\ consumption\ from\ dom\ harvest} = \frac{(Production_{INDRW} - Export_{INDRW})}{(Production_{INDRW} + Import_{INDRW} - Export_{INDRW})}$$

(2) $$Production_{HWP\ from\ dom\ harvest} = Production_{HWP} \bullet ratio_{INDRW\ consumption\ from\ domestic\ harvest}$$

The ratio (Equation 1) was calculated both for coniferous and non-coniferous industrial round wood (*INDRW*, Items 1866 and 1867). For coniferous sawnwood and paper and paperboard, the ratio for coniferous industrial round wood was applied. For non-coniferous sawnwood the ratio for non-coniferous industrial round wood was applied. For the other HWP, the ratio of the annual mass weighted average of coniferous and non-coniferous industrial round wood was applied.

As a result, this share of HWP produced from domestically harvested timber is presented as a percentage in **Table 13.**

The presented approach follows the initial assumption that all forests in Hungary are managed, and in order to simplify matters, it is presumed that all harvest is allocated to forest management. This assumption is to be verified and corrected where necessary. The final allocation of carbon in HWP to forests which are accounted for under Article 3 shall be part of a technical correction as suggested in para 15 quater, page 27 of FCCC/KP/AWG/2010/CRP.4/Rev.4.

Table 13. Historic time series of amounts (first row, in 1000t C) and share of accountable carbon Inflow to the HWP pool (second row, %).

1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
233	225	242	241	220	225	248	287	289	278	291	324	324	301	370	402
72,2	69,6	69,1	58,2	53,9	49,1	48,1	55,6	51,9	46,0	46,2	50,4	51,6	45,6	51,6	55,9

1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
418	410	381	417	410	377	344	319	327	350	376	315	244	249	340	234
55,7	55,2	55,4	57,6	54,2	50,7	45,7	42,8	44,0	45,6	56,3	54,3	49,5	60,8	79,2	64,6

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
225	273	209	244	273	277	292	249	264	364	335	352	369	226
57,6	62,6	44,0	52,5	56,0	58,3	58,0	48,0	51,6	69,9	65,4	64,1	75,2	63,2

The annual carbon Inflow (= carbon in produced HWP) to the HWP pool prior to the year 1964 (first year for which activity data from TIMBER database (UNECE 2011) is available for Hungary) has been calculated from the 5 years average from 1964 to 1968 and was assumed to be the constant carbon pool Inflow for the time period 1900-1963.

In order to provide a projection for the development of the HWP pool consistent with the assumptions on the future harvest, the rates of change of the Projected harvest (Model GLOBIOM) as compared to the last 5 years average of historic harvest, for which up-to-date data is available, was calculated (cf. **Table 14**).

These projected growth rates as cp. to the average of the years 2003-2007 for Hungary were applied to the same 5 years average of historic carbon Inflow to the HWP pool in order to receive the future Inflow to the HWP pool.

Table 14. Projection of carbon Inflow to the HWP pool.

Average of historic harvest (2003-2007) [in $1000m^3$]	6.632										
Average HWP pool Inflow* (2003-2007) [in 1000t C]	313										
years	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Projected harvest rate [in $1000m^3$]	6997	7071	7144	7217	7290	7363	7436	7509	7582	7655	7728
Change as cp to historic harvest (2003-2007) [in %]	5,51	6,61	7,71	8,81	9,92	11,02	12,12	13,22	14,32	15,42	16,53
Projected carbon Inflow to HWP pool [in 1000t C]	330,1	333,5	337,0	340,4	343,9	347,3	350,8	354,2	357,6	361,1	364,6

*a similar approach was chosen by Kangas and Baudin (2003): ECE/TIM/DP/30

For calculating the pool of HWP in use, three half-lives for application in the first order decay function have been used as suggested by paragraph 7, page 31 of FCCC/KP/AWG/2010/CRP.4/Rev.4.

- Sawnwood: 35 years
- Wood based panels: 25 years
- Paper and paperboard: 2 years

The projected net-emissions are calculated from the annual stock change estimates following the calculation method provided in IPCC 2006, Vol.4, Ch. 12 (Equation 12.1).

Table 15. Historic (up to 2009) and projected net-emissions from HWP pool (in 1000t CO_2)

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
-409	-158	96	62	-239	191	230	74	329	213	129	136	99	262	202	-123	46

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
15	-37	938	92	112	123	129	130	129	125	121	115	109	102

(f) Disturbances in the context of force majeure

The calibration procedure described above automatically incorporates the average rate of past disturbances (for the period 2000-2008) into the projections. See further comments in section „Ex-post processing of models' results" on the need of future consistency. For transparency reasons, the tables below report the emissions from forest fires from 2000-2008 (expressed in Gg CO2-eq. and as % of 1990 total GHG emissions excluding LULUCF), i.e. for the years for which there have been appropriate data to estimate emissions from rather rare forest fires.

Table 16. Emissions from forest fires (Gg CO2eq and % of 1990 total GHG without LULUCF)

Amount	2000	2001	2002	2003	2004	2005	2006	2007	2008	average 2000-2008
GgCO2eq	49	35	35	30	1	104	2	90	2	39
% 1990 GHG	0.05	0.04	0.04	0.03	0.00	0.11	0.00	0.09	0.00	0.04

(g) Factoring out in accordance with paragraph 1(h) (i) and 1(h) (ii) of decision 16/CMP.1

The indirect effect of elevated carbon dioxide concentrations above the pre-industrial level and indirect nitrogen deposition was not directly factored out when developing the reference levels. On one hand, this is not possible at this stage, and the so called „managed land proxy", as stated by a recent IPCC report[4], „is currently the only widely applicable method to estimate the separation between anthropogenic and natural fluxes." Factoring out was done in this sense as both emissions and removals are only estimated for managed land. On the other hand, these effects cancel out when substracting the reference level from net emissions/removals that occur during a commitment period.

II. Description of any other relevant elements considered or treated in the construction of the forest management reference level, including any additional information related to footnote 1 in paragraph 4 of decision [-/CMP.6]

Two other approaches are presented below to demonstrate the robustness of the RL estimate. One is the

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[4] IPCC, 2009. Expert Meeting on Revisiting the Use of Managed Land as a Proxy for Estimating National Anthropogenic Emissions and Removals. 5-7 May 2009, Sao Paulo, Brazil. http://www.ipcc-nggip.iges.or.jp/meeting/pdffiles/0905_MLP_Report.pdf

linear extrapolation of reported FM removal estimates, and the other is the estimation of the trend of the FM removals using the carbon accounting model CASMOFOR.

The linear extrapolation is one approach that can only be used for the dynamic forestry systems for a short period of time. However, in this specific case, historical emissions from forest management are available between 1990-2008, they rather well fit on a straight line, and that line is only extrapolated until 2020. The average of the projected emissions between 2012-2020 is -481 Gg CO2 eq, which is rather close to the one estimated using the JRC projection (**Figure 5**).

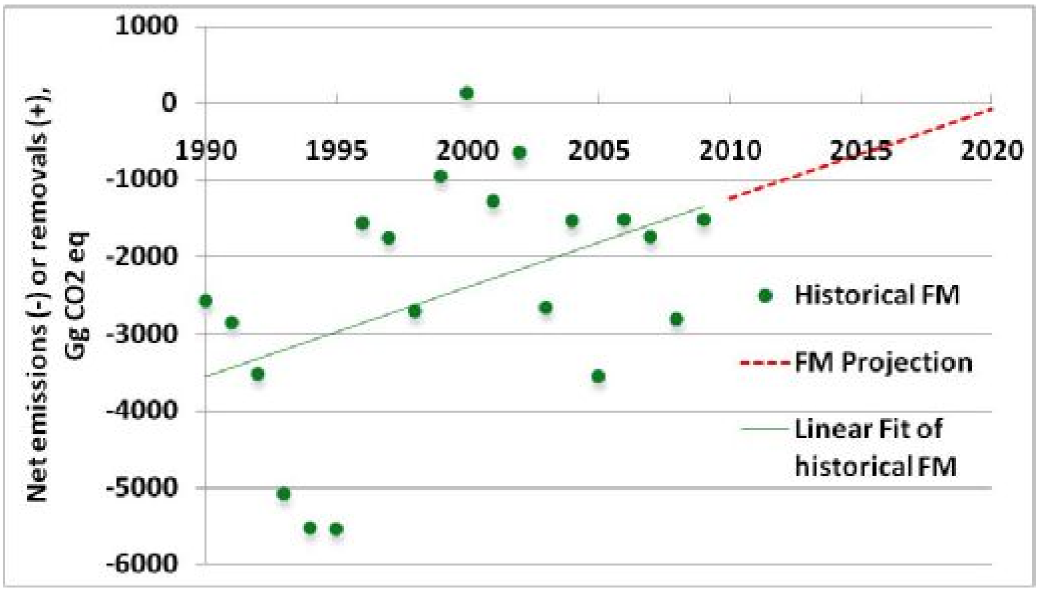

Figure 6. Historical, fitted and linearly extrapolated net emissions and removals from forest management.

Both the reported RL value and the extrapolation means that the net removals of the Hungarian forests are projected to decrease until 2020. In order to check this trend, another modelling was also undertaken. This excercise was based on a country-specific carbon accounting model CASMOFOR[5], which was already used several times in various GHG inventories and our fifth National Communication. This model is able to estimate future carbon stock changes of all major forest carbon pools. Its input data include forest area by species (or species group) and age, and the model runs country-specific growth and silvicultural models, as well as other models and conversion factors to calculate stocks in carbon. In this respect, it works similar to EFISCEN, however, it has partly better and more updated, more country-specific database.

The silvicultural model is a normative model that is only concerned with the optimal management of stands, which is often not the case for individual stands, and disregards the variability of the timber market. This model is thus able to analyse the effect of the age class legacy, but not able to model annual variations in climate and timber market conditions. In all, however, the model together with data, by species, of age-class distribution is able to predict carbon stock change trends in the forest biomass pool.

For this analysis, total forest area by species and age class was used, and both the negligible deforestation and the quite substantial afforestations were excluded. **Figure 6** shows the data for the individual years, as well as the linear fit to the data. Both the annual data and the linear trend is a bit different from the one

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[5] The detailed description of the model, and the model itself, is found at http://www.scientia.hu/casmofor

obtained by either the JRC projection or the above linear extrapolation, however, very well validates the trend itself.

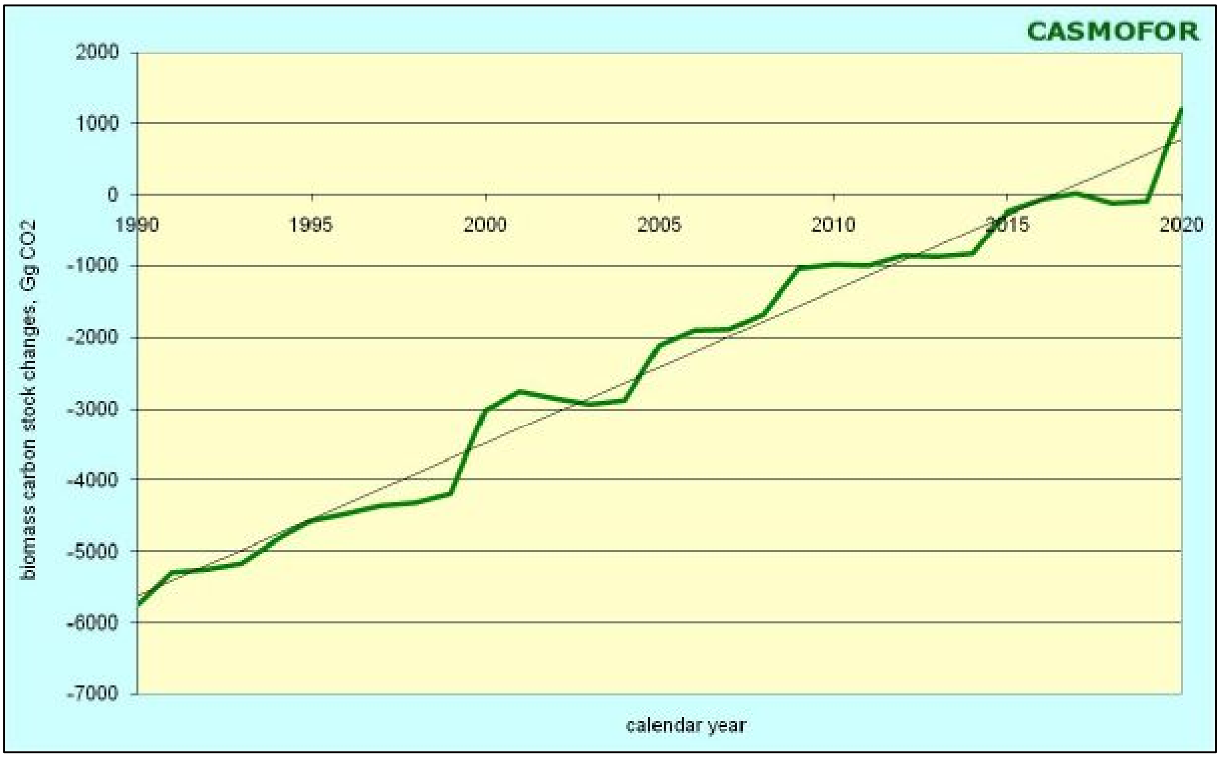

Figure 7. Historical and projected net removals and emissions from forest management using the CASMOFOR model and the total forest area of 1990 for the entire period (thick green line), and a linear fit to the annual data (thin black line).

6. *Policies included*

I. *Pre-2010 domestic policies included*

Policy assumptions for the projection of the JRC/IIASA methodology are made in the baseline scenario of the PRIMES model which underpins the projections for the construction of the RL. For the purpose of this submission, policies and measures included are those implemented by mid-2009 and legislative provisions adopted by mid-2009 that are defined in such a way that there is almost no uncertainty how they should be implemented in the future. An inventory of legal measures and EU financial support included in the PRIMES model is reproduced from Capros et al. (2010) in Annex II to this submission.

However, more details are provided on pp.17-21 ("BASELINE") of the publication *EU energy trends to 2030 - UPDATE 2009*.[6]

All hungarian forests are considered managed, as all have anthropogenic activities. Forest management is guided by the forest management plans. Forest management plans at local level are mandatory (and approved by the Forest Authority). Practically 100% of forest reported under KP and UNFCCC are under forest management plans. The management plans provide stand-based site description, digital maps and silvicultural models for each forest subcompartments (average area appr. 5ha), including silvicultural prescriptions and target figures of fellings, which are, in the most cases, are limitations of the possible harvest.

The average planned rotation ages of forest stand are slightly higher and higher year by year, because of the spread of the close-to-nature forest management methods enforced by forest management plans.

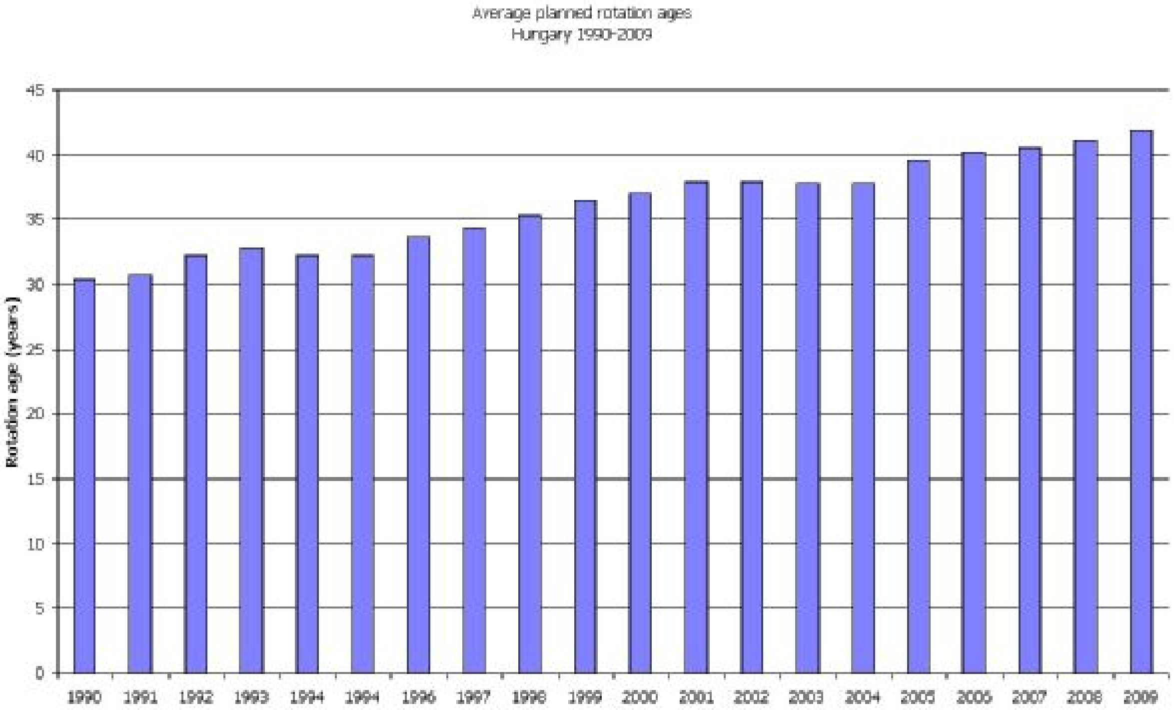

Figure 8. Average planned rotation ages enforced by forest management plans, 1990-2009

Confirmation of factoring out policies after 2009

Neither the most recently (May 2009) passed Forest Act of Hungary, nor other policies currently prescribe directly the amount of harvests that must be done. Markets are not inderictly regulated, either, in the BAU scenario. Discussions are under way within the country as to which harvesting level is required to meet the EU requirements on the use of renewable energy, however, no specific policy has been developed and implemented so far to specifically meet these requirements.

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[6] P. Capros, L. Mantzos, N. Tasios, A. De Vita, N. Kouvaritakis (2010), EU energy trends to 2030 — UPDATE 2009, European Commission, Directorate-General for Energy in collaboration with Climate Action DG and Mobility and Transport DG. Luxembourg: Publications Office of the European Union, 2010. ISBN 978-92-79-16191-9. Available online: http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2030_update_2009.pdf

ANNEX I: Description of models used in developing the JRC projections

GLOBIOM

GLOBIOM is a global static partial equilibrium model integrating the agricultural, bioenergy and forestry sectors with the aim to give policy advice on global issues concerning land use competition between the major land-based production sectors. The concept and structure of GLOBIOM are similar to the US Agricultural Sector and Mitigation of Greenhouse Gas (ASMGHG) model (Schneider, McCarl and Schmid 2007). The global agricultural and forest market equilibrium is computed by choosing land use and processing activities to maximize the sum of producer and consumer surplus subject to resource, technological, and political restrictions, as described by McCarl and Spreen (1980). Prices and international trade flows are endogenously computed for 28 world regions.
The market is represented through implicit product supply functions based on detailed, geographically explicit, Leontief production functions, explicit resource supply functions (land and water), and product demand functions.

Land and its characteristics are the key elements of our modelling approach. In order to enable global bio-physical process modelling of agricultural and forest production, a comprehensive database has been built (Skalsky et al., 2008), which contains geo-spatial data on soil, climate/weather, topography, land cover/use, and crop management (e.g. fertilization, irrigation).

The data are available from various research institutes (NASA, JRC, FAO, USDA, IFRPI, etc.) and significantly vary with respect to spatial, temporal, and attribute resolutions, thematic relevance, accuracy, and reliability. Therefore, data were harmonized into several common spatial resolution layers including 5 and 30 arcmin as well as country layers. Consequently, Homogeneous Response Units (HRU) have been delineated by including only those parameters of landscape, which are almost constant over time. At the global scale, we have included five altitude classes, seven slope classes, and six soil classes. In a second step, the HRU layer is merged with other relevant information such as global climate map, land category/use map, irrigation map, etc. to delineate Simulation Units, which are actually input into the Environmental Policy Integrated Climate model (EPIC, Williams 1995, Izaurralde et al. 2006). This HRU concept assures consistent aggregation of geo-spatially explicit bio-physical impacts that are simulated with EPIC (e.g. crop yields, nitrogen leaching, soil carbon sequestration).

Currently, two major land cover types are represented in the model: cropland and forest. Crop production accounts for about 20 globally most important crops. The data are taken from FAOSTAT, where national averages over the years 2001-2005 are used to define base levels for yields, harvested areas, prices, production, consumption, trade, and supply utilization. Irrigated crop yields, crop specific irrigation water requirements, and costs for five irrigation systems are derived from a variety of sources as described in Sauer et al. (2008). For selected crops (corn, sugarcane and wheat), management and land quality specific yields have been estimated with EPIC. Four management systems are currently represented which correspond to the IFRPI crop distribution data classification (irrigated, high input - rainfed, low input - rainfed and subsistence management systems). The number of crops, systems, and parameters (especially environmental parameters like soil carbon, erosion, and nutrient leakage) estimated with EPIC is being expanded.

Crop supply can enter one of three processing/demand channels: consumption, livestock production or biofuel production. Consumption is modeled by constant elasticity demand functions parameterized using

FAOSTAT data. Only a preliminary regional livestock production representation is applied in the present version of the model where a bundle of livestock products is assimilated to a generic commodity - “animal calories”. Feed requirements have been calculated from the Supply Utilisation Accounts, FAOSTAT. Demand for livestock products is represented through upward sloping demand curves. Biofuel options from crops include first generation technologies for a) ethanol from sugarcane or corn, and b) biodiesel from soya or rapeseed. The processing data are based on Hermann and Patel (2007) for ethanol and Haas et al. (2006) for biodiesel. Market demand for ethanol and biodiesel is represented through vertical demand functions.

Primary forest production is characterized also on the basis of HRUs and the resulting Simulation Units. The most important parameters for the model are mean annual increment, maximum share of sawlogs in the mean annual increment, and harvesting cost. These parameters are shared with the G4M Model – a successor of the model described by Kindermann et al (2006). More specifically, mean annual increment for the management is obtained by downscaling the biomass stock data from the Global Forest Resources Assessment (FAO, 2005) from the country level to the grid using the method described in Kindermann et al. (2008). This downscaled biomass stock data is subsequently used to parameterize the increment curves Kindermann (2008). Finally, sawnlwood share is estimated by the tree size which in turn depends on yield and rotation time. Harvesting costs is adjusted for slope and tree size as well.

Five primary forest products are defined: sawlogs, pulplogs, other industrial logs, firewood, and energy biomass. Sawlogs, pulplogs and energy biomass are further processed. Sawnwood and woodpulp production, and demand parameters rely on the 4DSM model described in Rametsteiner et al. (2007). FAO data and other secondary sources have been used for quantities and prices of sawnwood and woodpulp. For production cost estimates of these products, for example, mill costs, an internal IIASA database and purchased data were used. The energy biomass can be converted into methanol and heat or electricity and heat, where processing costs and conversion coefficients are obtained from Leduc et al. (2008), Hamelinck and Faaij (2001), Sørensen (2005), and Biomass Technology Group (2005). Demand for woody bioenergy production is implemented through minimum quantity restrictions, similarly as demand for other industrial logs and for firewood.

The final model calibration, supposed to correct data imperfections and get the baseline solution close to the observed values, is done by adjusting the cost parameters of selected activities so that for the baseline activity levels, their marginal cost equals to their marginal revenue, as assumed by the microeconomic theory. The controlled activities are crop areas, primary forest products supply and animal calories supply.

The main input data for the model is the following:

- Baseline prices and quantities of considered products
- Supply and demand elasticities
- Resource requirements (land, water etc.)
- Production costs
- Transformation costs
- Transport costs
- Conversion coefficients from primary to final products
- Initial land use

The main outputs from the model are the following:

- supply and demand quantities

- equilibrium prices
- volumes traded between the regions
- land use change
- water consumption

References

Biomass Technology Group (2005). Handbook Biomass Gasification. H.A.M. Knoef. ISBN: 90-810068-1-9.
FAO. 2005. “Global Forest Resources Assessment 2005, Progress towards sustainable forest management.” Vol. 147 of FAO Forestry Paper. FAO, Rome.
FAO. 2007. FAOSTAT. Available online at faostat.fao.org.
Haas, M.J., McAloon, A.J., Yee, W.C. and T.A. Foglia. 2006. “A process model to estimate biodiesel production costs.” Bioresource Technology 97: 671-678.
Hamelinck, C.N. and A.P.C. Faaij (2001). “Future Prospects for Production of Methanol and Hydrogen from Biomass.” Utrecht University, Copernicus Institute, Science Technology and Society, Utrecht, Netherlands 2001.
Hermann, B.G. and M. Patel. 2007. “Today's and tomorrow's bio-based bulk chemicals from white biotechnology - A techno-economic analysis.” Applied Biochemistry and Biotechnology 136: 361-388.
Izaurralde, R.C., J.R. Williams, W.B. McGill, N.J. Rosenberg, and M.C. Quiroga Jakas. 2006. Simulating soil C dynamics with EPIC: model description and testing against long-term data. Ecological Modelling, 192:362-384.
Kindermann, G.E. 2008. “Getting forest growth functions out of yield tables.”
Kindermann, G.E., McCallum, I. and S. Fritz. 2008. “A global forest growing stock, biomass and carbon map based on FAO statistics.” Forthcoming.
Kindermann, G.E., Obersteiner, M., Rametsteiner, E. and I. McCallum. 2006. “Predicting the deforestation-trend under different carbon-prices.” Carbon Balance and Management 1: 15.
Leduc, S., D. Schwab, E. Dotzauer, E. Schmid, M. Obersteiner (2008). “Optimal Location of Wood Gasification Plants for Methanol Production with Heat Recovery.” International Journal of Energy Research, IGEC-III special issue.
McCarl, B.A. and T.H. Spreen. 1980. “Price Endogenous Mathematical Programming as a Tool for Sector Analysis.” American Journal of Agricultural Economics 62: 87-102.
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 [2007].
Sauer, T., Havlík, P., Kindermann, G., and Schneider, U.A. 2008. Agriculture, Population, Land and Water Scarcity in a changing World - the Role of Irrigation. Paper prepared for the 2008 Congress of the European Association of Agricultural Economists in Gent, Belgium.
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.
Skalsky, R., Z. Tarasovic(ová, J. Balkovic(, E. Schmid, M. Fuchs, E. Moltchanova, G. Kindermann, and P. Scholtz. 2008. GEO-BENE global database for bio-physical modeling v. 1.0 – concepts, methodologies and data. The GEO-BENE database report. International Institute for Applied Systems Analysis (IIASA), Austria, pp. 58.
Sørensen, Å.L (2005) “Economies of Scale in Biomass Gasification Systems.” IIASA, Interim Report 2005, IR-05-030.
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.

EFISCEN

The European Forest Information Scenario (EFISCEN) model (Sallnäs 1990; Schelhaas et al. 2007) is a large-scale model that assesses the supply of wood and biomass from forests and projects forest resource development on regional to European scale (Eggers et al. 2008; Ťupek et al. 2010). The core of the model was developed in the late 1980s, as a forest resource projection model for Sweden.

EFISCEN uses forest inventory data as an input, including:

- area (ha);
- average standing volume of growing stock (m3/ha);
- net annual increment (m3/ha/y).

Based on this data, the state of the forest is described as an area distribution over age- and volume-classes in matrices. During simulations, forest area moves between matrix cells, describing different natural processes (e.g. growth and mortality) and human actions (e.g. forest management). Growth dynamics are simulated by shifting area proportions between matrix cells. In each 5-year time step, the area in each matrix cell moves up one age-class to simulate ageing. Part of the area of a cell also moves to a higher volume-class, thereby simulating volume increment. Growth dynamics are estimated by the model's growth functions whose coefficients are based on inventory data.

Management scenarios are specified at two levels in the model. First, a basic management regime defines the period during which thinnings can take place and a minimum age for final fellings. These regimes can be regarded as constraints on the total harvest level. Thinnings are implemented by moving area to a lower volume class and final fellings by moving area outside the matrix to a bare-forest-land class, from where it can re-enter the matrix. The applied management regimes are based on a country level compilation of management guidelines (Nabuurs et al. 2007). Second, the demand for wood is specified for thinnings and for final felling separately and EFISCEN may simulate to "fell" the demanded wood volume if available. If wood demand is high, management is intensive and rotation lengths are close to the lower limit defined in the management regimes. If wood demand is low, rotation lengths are longer, because less fellings are needed to fulfil the demand.

EFISCEN projects (i) stemwood volume, (ii) increment, (iii) age-classes and (iv) wood removals for five year time-steps. To assess biomass carbon stocks, stemwood volume is converted into carbon in stems, branches, foliage, coarse and fine roots, using basic wood densities, a generic carbon content, and age-dependent biomass distribution factors. Felling residues and litter production of trees, due to turnover and natural mortality, are used as input data for the dynamic soil model YASSO (Liski et al., 2005) and incorporated as independent module.

The soil model **YASSO** in turn is used to estimate changes in the soil C pool by EFISCEN model. YASSO consists of three litter compartments and five decomposition compartments. For the soil carbon module, the litter is grouped as non-woody litter (foliage and fine roots), fine woody litter (branches and coarse roots) and coarse woody litter (stems and stumps). Each of the litter compartments has a fractionation rate determining the proportion of its contents released to the decomposition compartments in a time step. For the compartment of non-woody litter, this rate is equal to 1, which means that all of its contents is released in one time step, whereas for the woody litter compartments, this rate is smaller than 1. Litter is distributed over the decomposition compartments of extractives, celluloses and lignin-like compounds according to its chemical composition. Each decomposition compartment has a specific decomposition rate, determining the proportional loss of its contents in a time step. Fractions of the losses from the decomposition compartments are transferred into the subsequent decomposition compartments having slower decomposition rates while the rest is removed from the system. The fractionation rates of woody litter and the decomposition rates are controlled by temperature and water availability and are based on litterbag data across Europe (Liski et al., 2003).

The model is especially suited for simulating managed, even-aged forests at large scales. The model has been validated for Finland (Nabuurs et al. 2000) and Switzerland (Thürig and Schelhaas 2006) by running EFISCEN on historic data. Other validations have been performed by comparing its growth functions against growth functions of other models and by comparing projections against projections of other models (e.g. Ťupek et al. 2010).

References

EFISCEN: URL: http://www.efi.int/portal/virtual_library/databases/efiscen/
EFISCEN: URL: http://www.environment.fi/default.asp?contentid=250208&lan=EN
Eggers J, Lindner M., Zudin S, Zaehle S, Liski J. (2008). Impact of changing wood demand, climate and land use on European forest resources and carbon stocks during the 21st century. Global Change Biology, 14: 2288-2303.
Liski, J., Nissinen, A., Erhard, M., Taskinen, O., 2003. Climatic effects on litter decomposition from arctic tundra to tropical rainforest. Global Change Biology 9, 575-584.
Liski J., Palosuo T., Peltoniemi M., Sievänen R. (2005). Carbon and decomposition model Yasso for forest soils. Ecological Modelling, 189 (1-2): 168-182
Nabuurs, G.J., Schelhaas, M.J., Pussinen, A., 2000. Validation of the European Forest Information Scenario Model (EFISCEN) and a projection of Finnish forests. Silva Fennica 34, 167-179.
Nabuurs G.J., Pussinen A., van Brusselen J., Schelhaas M. J. (2007). Future harvesting pressure on European forests. Eur. J Forest Res, 126: 391-400.
Sallnäs, O., 1990. A matrix model of the Swedish forest. Studia Forestalia Suecica 183, 23.
Schelhaas, M.J., Eggers, J., Lindner, M., Nabuurs, G.J., Päivinen, R., Schuck, A., Verkerk, P.J., Werf, D.C.v.d., Zudin, S., 2007. Model documentation for the European Forest Information Scenario model (EFISCEN 3.1.3). Alterra-rapport 1559/EFI Technical Report 26, Alterra, Wageningen, 118 pp.
Thürig E., Schelhaas M. J. (2006). Evaluation of a large scale forest scenario model in heterogeneous forests: a case study for Switzerland. Canadian Journal of Forest Research, 36 (3): 671-683.
Ťupek, B., Zanchi, G., Verkerk, P.J., Churkina, G., Viovy, N., Hughes, J.K., Lindner, M., 2010. A comparison of alternative modelling approaches to evaluate the European forest carbon fluxes. Forest Ecology and Management 260, 241-251.

GLOBAL FORESTRY MODEL: G4M

The Global Forest Model (G4M) is applied and developed by IIASA and estimates the annual above ground wood increment and harvesting costs. By comparing the income of managed forest (difference of wood price and harvesting costs, income by storing carbon in forests) with income by alternative land use on the same place, the decision of afforestation or deforestation is made. As G4M is spatially explicit (currently on a 30"x30" resolution) the different deforestation pressure at the forest frontier can also be handled. The model can use external information (like wood prices, prescribed land-use change) from other models or data bases, which guarantee food security and land for urban development or account for disturbances. As outputs, G4M produces estimates of land-use change, carbon sequestration/emissions in forests, impacts of carbon incentives (e.g., avoided deforestation), and supply of biomass for bio-energy and timber.

The model handles age classes of one year width. Afforestation and disturbances cause an uneven age-class distribution over a forest landscape. The model performs final cuts in a manner that all age classes have the same area after one rotation period. During this age class harmonization time the standing biomass, increment and amount of harvest is fluctuating due to changes in age-class distribution and afterwards stabilizing.

The main forest management options considered by G4M are variation of thinning and choice of rotation length. G4M does not model species explicitly but a change of species can be emulated by adapting NPP, wood price and harvesting costs. The rotation length can be individually chosen but the model can estimate optimal rotation lengths to maximize increment, maximize stocking biomass or maximize harvestable biomass.

For adjustment and harmonization, an EU-wide forest/ non-forest map was generated, consistent with the Temperate and Boreal Forest Resource Assessment –TBFRA 2000 (UNECE-FAO, 2000) at the national level. For areas where CORINE land cover data are available, the CORINE dataset was aggregated from the original 100 meters to 500 meters spatial resolution. Firstly, the number of forest pixels within each 5 by 5 pixel aggregation unit was calculated. Secondly, a threshold with the minimum number of forested pixels within the aggregation units was determined for each country. This threshold was selected accordingly, to generate a forest map in agreement with the total forest area given by TBFRA 2000 at the national level.

For areas not covered by CORINE data, a similar approach was applied with Vegetation Continuous Fields (VCF) data (Hansen et al. 2003). The area covered with woody vegetation in the VCF data is given in percent. A percentage threshold of the minimum area covered by woody vegetation was defined for each country to match total forest area from TBFRA 2000. Based on FAO data the map distinguishes between managed and unmanaged forest. Criteria of wilderness and remoteness were used to locate the unmanaged forest areas on the map. The initial growing stock per grid cell was taken from the European forest biomass map from Gallaun et al. (in press). For countries outside Europe the forest biomass map compiled by Kindermann et al. (2008) was used.

Increment is determined by a potential NPP map (Cramer et al. 1999) and translated into mean annual increment (MAI). At present this increment map is static but can be changed to a dynamic growth model which reacts to changes of temperature, precipitation or CO_2 concentration. For the purpose of this study the increment map was scaled at country level to match either MCPFE or reported country data. Age structure and stocking degree are used as additional information for adjusting MAI. If stocking degree of forest modelled with a given age structure (country average) in a cell is greater than 1.05 age structure of the modelled forest is shifted iteratively by a few age classes towards older forest. If stocking degree of forest modelled in a cell is smaller than 0.5 age structure of the modelled forest is shifted iteratively by a few age classes towards younger forest. It is required that the shifts are symmetrical to keep country average age structure close to statistical value. If the age structure shift distribution within a country is skewed towards older forest, the country's average MAI is increased iteratively. If the age structure shift distribution within a country is skewed towards younger forest country MAI is decreased iteratively.

The model uses external projections of wood demand per country to calculate total harvest iteratively. The potential harvest amount per country under a scenario of rotation lengths that maintain current biomass stocks is estimated. If total harvest is smaller than wood demand the model changes grid per grid (starting from the most productive forest) management to a rotation length that optimizes forest increment and thus allows for more harvest. This mimics the typical observation that managed forests in Europe are currently not managed optimally with respect to yield. The rotation length is changed at maximum by 5 years per time step. If harvest still too small and unmanaged forest is available the status of the unmanaged forest will change to managed. If total harvest greater than demand the model changes management to maximum biomass rotation length, i.e. manages forests for carbon sequestration. If wood demand is still lower than potential harvest managed forest can be transferred into unmanaged forest.

Thinning is applied to all managed forests. The stands are thinned to maintain a stocking degree specified between 0.5 and 1.05, i.e. thinning mimics natural mortality along the self-thinning line. The model can consider the use of harvest residues e.g. for bioenergy purposes.

Despite the harmonization efforts to reproduce observed data on increment, area and harvest, the forest carbon balance as described in the model might still deviate from the observed forest carbon sink or source. This might be due to differences in forest management or forest disturbances. The model cannot account for such effects. To compensate for processes affecting the carbon balance that cannot be modelled, an adjustment algorithm has been introduced. Rotation length of unmanaged forest is set to the value that yields constant biomass (equal to observed biomass in 2000). If modelled carbon sink/source from forest management (averaged over 1990-1995) is smaller/larger than reported by a country, the rotation length of unmanaged forest is changed to maximizing biomass. The procedure is applied cell by cell within the country’s unmanaged forest until the reported stock change is matched.

References

Böttcher H., Aoki K., De Cara S., Gusti M., Havlik P., Kindermann G., Schneider U., Obersteiner M. (2008). GAINS GHG mitigation potentials costs from land-use, land-use change and forestry (LULUCF) in Annex 1 countries. Methodology. International Institute for Applied Systems Analysis, Laxenburg, Austria, 39 pp.
Gusti M., Havlik P., Obersteiner M. (2008). Technical description of the IIASA model cluster. IIASA. 12 p.
Kindermann G., McCallum I., Fritz S., Obersteiner M. (2008). A global forest growing stock, biomass and carbon map based on FAO statistics. Silva Fennica. Vol.42(3), pp.387-396.
Kindermann G., Obersteiner M., Rametsteiner E. and McCallcum I. (2006). Predicting the Deforestation–Trend under Different Carbon–Prices. Carbon Balance and Management, 1:15; doi:10.1186/1750-0680-1-15.

The PRIMES Energy Systems Model

A summary description of the energy systems model for is provided on http://www.e3mlab.ntua.gr/e3mlab/PRIMES%20Manual/The_PRIMES_MODEL_2008.pdf and of the biomass system model, which is incorporated in the large scale model, on http://www.e3mlab.ntua.gr/e3mlab/PRIMES%20Manual/The_PRIMES_MODEL_2008.pdf.

ANNEX II – Description policies and measures included in the Reference Level at the EU level

Table Annex II-1 below has been extracted from pp.17-19 in P. Capros, L. Mantzos, N. Tasios, A. De Vita, N. Kouvaritakis (2010), EU energy trends to 2030 — UPDATE 2009, European Commission, Directorate-General for Energy in collaboration with Climate Action DG and Mobility and Transport DG. Luxembourg: Publications Office of the European Union, 2010. ISBN 978-92-79-16191-9. Available online: http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2030_update_2009.pdf.

Table Annex II-1. Inventory of legal measures and Community financial support included in Primes

Measure	How the measure is reflected in PRIMES
I. Regulatory measures	
Energy efficiency	
Eco-design implementing measures	
Eco-design Framework Directive 2005/32/EC	Adaptation of modelling parameters for different product groups. As requirements concern only new products, the effect will be gradual (marginal in 2010; rather small in 2015 and up to full effect by 2030). The potential envisaged in the Eco-design supporting studies and the relationship between cost and efficiency improvements in the model's database were cross-checked.
Stand-by regulation 2008/1275/EC	
Simple Set-to boxes regulation 2009/107/EC	
Office/street lighting regulation 2009/245/EC	
Household lighting regulation 2009/244/EC	
External power supplies regulation 2009/278/EC	
Other energy efficiency	
Labelling Directive 2003/66/EC	Enhancing the price mechanism mirrored in the model
Cogeneration Directive 2004/8/EC	National measures supporting cogeneration are reflected
Directive 2006/32/EC on end-use energy efficiency and energy services	National implementation measures are reflected
Buildings Directive 2002/91/EC	National measures e.g. on strengthening of building codes and integration of RES are reflected
Energy Star Program (voluntary labelling program)	Enhancing the price mechanism mirrored in the model
Energy markets and power generation	

Measure	How the measure is reflected in PRIMES
Completion of the internal energy market (including provisions of the 3rd package)	The model reflects the full implementation of the Second Internal market Package by 2010 and Third Internal Market Package by 2015. It simulates liberalised market regime for electricity and gas (decrease of mark-ups of power generation operators; third party access; regulated tariffs for infrastructure use; producers and suppliers are considered as separate companies) with optimal use of interconnectors
EU ETS directive 2003/87/EC as amended by Directive 2008/101/EC and Directive 2009/29/EC	The ETS carbon price is modelled so that the cumulative cap set for GHGs covered by the ETS is respected[7]. The permissible total CDM amount over 2008-2020 is conservatively estimated at 1600 Mt. Banking of allowances is reflected. The model endogenously calculates carbon prices clearing the ETS market that allow to match cumulative emissions over the period 2008-2030 with cumulative allowances assuming the maximum permissible use of CDMs. Resulting carbon prices in the baseline 2009 are: 25 €'08/t CO2eq in 2020 and 39 €'08/t CO2eqin 2030.
Energy Taxation Directive 2003/96/EC	Tax rates (EU minimal rates or higher national ones) are kept constant in real term. The modelling reflects the practice of MS to increase tax rates above the minimum rate due to i.e. inflation.
Large Combustion Plant directive 2001/80/EC	Emission limit values laid down in part A of Annexes III to VII in respect of sulphur dioxide, nitrogen oxides and dust are respected. Some existing power plants had a derogation which provided them with 2 options to comply with the Directive: either to operate only a limited number of hours or to be upgraded. The model selected between the two options on a case by case basis. The upgrading is reflected through higher capital costs.
IPPC Directive 2008/1/EC	Costs of filters and other devices necessary for compliance are reflected in the parameters of the model
Directive on the geological storage of CO2 2009/31/EC	Enabling measure allowing economic modelling to determine CCS penetration
Directive on national emissions' ceilings for certain pollutants 2001/81/EC	PRIMES model takes into account results of RAINS/GAINS modelling regarding classical pollutants (SO2, NOx). Emission limitations are taken into account bearing in mind that full compliance can also be achieved via additional technical measures in individual MS.
Water Framework Directive 2000/60/EC	Hydro power plants in PRIMES respect the European framework for the protection of all water bodies as defined by the Directive
Landfill Directive 99/31/EC	Provisions on waste treatment and energy recovery are reflected
Transport	
Regulation on CO2 from cars 2009/443/EC	Limits on emissions from new cars: 135 gCO2/km in 2015, 115 in 2020, 95 in 2025 – in test cycle. The 2015 target should be achieved gradually with a compliance of 65% of the fleet in 2012, 75% in 2013, 80% in 2014 and finally 100% in 2015. Penalties for non-compliance are dependent on the number of grams until 2018; starting in 2019 the maximum penalty is charged from the first gram.

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[7] For the allocation regime for allowances in 2010, the current system based on National Allocation Plans and essentially cost-free allowances is assumed, with price effects stemming from different investment and dispatch patterns triggered by need to submit allowances. For the further time periods, in the power sector there will be a gradual introduction of full auctioning, which will be fully applicable from 2020 onwards, in line with the specifications of the amended ETS directive. For the other sectors (aviation and industry), the baseline follows a conservative approach which reflects the specifications in the directive on the evolution of auctioning shares and the provisions for free allocation for energy intensive sectors based on benchmarking.

Measure	**How the measure is reflected in PRIMES**
Regulation EURO 5 and 6 2007/715/EC	Emission limits introduced for new cars and light commercial vehicles
Fuel Quality Directive 2009/30/EC	Modelling parameters reflect the Directive, taking into account the uncertainty related to the scope of the Directive addressing also parts of the energy chain outside the area of PRIMES modelling (e.g. oil production outside EU).
Biofuels directive 2003/30/EC	Support to biofuels such as tax exemptions and obligation to blend fuels is reflected in the model The requirement of 5.75% of all transportation fuels to be replaced with biofuels by 2010 has not been imposed as the target is indicative. Support to biofuels is assumed to continue. The biofuel blend is assumed to be available on the supply side.
Implementation of MARPOL Convention ANNEX VI - 2008 amendments - revised Annex VI	Amendment of Annex VI of the MARPOL Convention reduce sulphur content in marine fuels which is reflected in the model by a change in refineries output
II. Financial support	
TEN-E guidelines (Decision 1364/2006)	The model takes into account all TEN-E realised infrastructure projects
European Energy programme for Recovery (Regulation 2009/663/EC)	Financial support to CCS demonstration plants; off-shore wind and gas and electricity interconnections is reflected in the model. For modelling purposes the following amounts for CCS power plants were assumed, following as-sumptions of summer 2009: Germany: 950 MW (450MW coal post-combustion, 200MW lignite post-combustion and 300MW lignite oxy-fuel), Italy 660 MW (coal post-combustion), Netherlands 1460 MW (800MW coal post-combustion, 660MW coal integrated gasification pre-combustion), Spain 500 MW (coal oxy-fuel), UK 3400 MW (1600MW coal post-combustion, 1800MW coal integrated gasification pre-combustion), Poland 896 MW (306MW coal post-combustion, 590MW lignite post-combustion).
RTD support (7th framework pro-gramme-theme 6)	Financial support to R&D for innovative technologies such as CCS, RES, nuclear and energy efficiency is reflected by technology learning and economies of scale leading to cost reductions of these technologies
State aid Guidelines for Environmental Protection and 2008 Block Exemption Regulation	Financial support to R&D for innovative technologies such as CCS, RES, nuclear and energy efficiency is reflected by technology learning and economies of scale leading to cost reductions of these technologies
Cohesion Policy – ERDF, ESF and Cohesion Fund	Financial support to national policies on energy efficiency and renewables is reflected by facilitating and speeding up the uptake of energy efficiency and renewables technologies.

Measure	How the measure is reflected in PRIMES
III. National measures	
Strong national RES policies	National policies on e.g. feed-in tariffs, quota systems, green certificates, subsidies and other cost incentives are reflected
Nuclear	Nuclear, including the replacement of plants due for retirement, is modelled on its economic merit and in competition with other energy sources for power generation except for MS with legislative provisions on nuclear phase out. Several constraints are put on the model such as decisions of Member States not to use nuclear at all (Austria, Cyprus, Denmark, Estonia, Greece, Ireland, Latvia, Luxembourg, Malta and Portugal) and closure of existing plants in some new Member States according to agreed schedules (Bulgaria 1760 MW, Lithuania 2600 MW and Slovakia 940 MW). The nuclear phase-out in Belgium and Germany is respected while lifetime of nuclear power plants was extended to 60 years in Sweden. Nuclear investments are possible in Bulgaria, the Czech Republic, France, Finland, Hungary, Lithuania, Romania, Slovakia, Slovenia and Spain. For modelling the following plans on new nuclear plants were taken into account: Bulgaria (1000 MW by 2020 and 1000 MW by 2025), Finland (1600 MW by 2015), France (1600 MW by 2015 and 1600 MW by 2020), Lithuania (800 MW by 2020 and 800 MW by 2025), Romania (706 MW by 2010, 776 MW by 2020 and 776 MW by 2025), Slovakia (880 MW by 2015). Member States experts were invited to provide information on new nuclear investments/programmes in spring 2009 and commented on the PRIMES baselines results in summer 2009, which had a significant impact on the modelling results for nuclear capacity.