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## **The German Reference Level for FM**

Background Paper

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## Derivation of a Reference Level for Forest Management in Germany

The following explanations are to illustrate the derivation of the German reference level (RL) on forest management (FM) under KP Art. 3.3 and Art. 3.4 as already represented in the Submission of the European Union in January 2011.

The document is structured in:

- 1) WEHAM – description of the model that is used for the calculation of the RL
- 2) Derivation of the submitted RL
- 3) Differences between WEHAM and JRC model approach
- 4) Incorporation of HWP data in the RL
- 5) Evaluation of the RL according to the requirements of “footnote 1 of paragraph 4 of the decision [-/CMP.6] on LULUCF”, “Draft LULUCF as of COP 15, footnote 11” and “table proposed by G77”

### **1) WEHAM – description of the model used for the calculation of the RL regarding living biomass**

The German projected RL of living biomass is based on a model called WEHAM (“Waldentwicklungs- und Holzaufkommensmodellierung“: Forest development and timber resource modelling). This model was developed at the vTI (Johann Heinrich von Thünen-Institute) and the Forest Research Institute Baden-Wuerttemberg. It is used as the core instrument for nation-wide future forest resource assessments since 1987 and has been improved according to scientific findings since its development.

WEHAM has been specifically designed to meet the requirements of and work with the data provided by the German “Bundeswaldinventur<sup>1</sup>” (BWI, national forest inventory).

The model consists of three parts:

- a growth simulator,
- a management simulator and
- a grading model.

The results are grouped according to parameters of interest, e. g. growing stock volume by age-class, species and region, by use of a database tool specifically designed for this purpose.

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<sup>1</sup> The BWI is a permanent, grid-oriented (4 km x 4 km) systematic inventory. Data measured include tree species, age, diameter at breast height of every tree at the sample plot (4 plots per grid point) as also height and upper diameter (in 7 m height) of 2 – 3 trees per plot. In addition, cause of death, dead wood volume, and various ecological parameters are noted in this inventory (for details please see BMVEL (2001): Survey instructions for Federal Forest Inventory II (2001 - 2002). Bonn, Bundesministerium für Verbraucherschutz, Ernährung und Landwirtschaft.)

The **growth simulator** extrapolates tree dimensions (DBH, height). Repeated measurements from trees included in at least two inventories (1987 and 2002, only pre-1990 FRG Federal States) are used to generate growth curves describing the development of DBH over age. Each tree sampled in a plot is referenced to a growth curve representative of / correlated with his DBH and age. The diameter increment over the period of interest is then derived from this growth curve. Heights are not modelled but calculated from tariff functions. Otherwise, especially in higher ages, height growth was overestimated. Both height and diameter growth functions are of a type used in forest growth research and validated with data from permanent research plots re-measured over up to more than 100 years, as also re-evaluated with every new turn of the BWI. WEHAM projects single tree data into the future. Stand-related or area-related data are compiled within the framework of "WEHAM in a broader sense" from these data by using the regional representativeness of a plot. A tree from a given plot is representative for a number of X trees per hectare (which are considered to form an imaginary even-aged pure-species stand) with the same attributes and dimensions. Management activities are modelled in a way that e.g., cutting of a number of Y trees per hectare (declared within the management simulator and handed over to the grading module) assort Y trees per hectare to the "cut" cohort, and  $(X - Y)$  trees per hectare remain.

Only trees that belong to the main stand are considered. The understorey or secondary trees are only minor parts of the stand total and are neglected, also because there is no method to attribute the area of the secondary stand to imaginary single-species even-aged stands as is done with the trees forming the main stand.

The **management simulator** runs according to the silvicultural guidelines of the federal states, amended by information about private and community forest management (if this deviates from state forests' management).

The simulator describes, for every plot, the timing and intensity of thinning and cutting activities by using tree species, federal state, thinning type, thinning intensity (recurrence interval and target stand basal area), rotation period length, and target DBH as parameters. This information is needed to emulate the BAU management concepts. In addition, type of ownership is also taken into account in some federal states where differences in management between ownership types are known. As default the stand basal area is compared with target basal area values derived from management tables and research plots.

Caps were identified to avoid unrealistic high harvesting at a single plot. As management rules are applied to all plots equally, and preferences of owners can only be modelled to a limited extent, the amount of timber extracted from the forest fluctuates in the first five year periods of the entire simulation period.

Thinning and harvesting are projected on a plot-based level, thus the resulting overall amount of timber is the aggregation of stand-oriented management decisions. Thinning is oriented towards stand basal area (also stand density is possible) and if a certain threshold is reached the stand will be cut back to the basal area recommended in the respective management guidelines. By default, all projections are done in five years steps and the state of the forest (plot, single tree) at the beginning and at the end of this period as also growth, tree species distribution, forest area of a given species, growing stock volume, the mean annual increment during this period, mean annual raw timber availability, and harvest during this period are given. Because the development of single trees is projected, results can be aggregated at various levels, from plot to stand, region and state level, by species or species groups, and by age classes (normally five, 10 or 20 years), and at any combination of these classifications.

The **grading module** assorts every stem cut by thinning or harvesting into size classes customary in the trade. It can distinguish up to 1600 variants and uses federal state, tree species, and top diameter of the stem as controls. In a first step, the timber volume of a given tree or stand is calculated as cubic metre solid volume over bark, then bark, normal losses due to harvest and cut-to-length division are subtracted. Stem parts not suitable as timber due to size restrictions are allocated to the dead wood pool.

The calculation of carbon stocks from standing stock volume is done by using the same equations and tools as used for Kyoto and UNFCCC reporting e.g. in the NIR 2010.

A detailed description of WEHAM and the associated other software solutions can be found in Anonymous 2005, Bösch 2005, Hennig 2003, Hennig 2009, Kublin 2002, and Kublin and Scharnagl 1988. Information on the reference scenario are given in Dunger *et al.* 2005, Dunger and Rock 2009, Polley and Kroihner 2006. The "Inventory Study 2008" has been presented in Dunger and Rock 2009, Dunger *et al.* 2009, Heuer 2009, Polley *et al.* 2009a, Polley *et al.* 2009b, and Schwitzgebel *et al.* 2009.

## **2) Derivation of the submitted RL**

### **Living (above- and below-ground) biomass**

The submitted RL is based on field data from the "Inventory Study 2008". This study was conducted on a sub-sample of the BWI inventory plots, using slightly modified BWI methodology, to provide information about the state of the German forest in 2008. In total, more than 48.000 sample trees with DBH larger than 7cm were measured at approximately 6.700 sample plots. These data were used as input for the growth projections and the BAU scenario was applied to model management impacts. The parameterisation of the management simulator and the grading model has been acquired in cooperation with the federal states. They describe the course of management the forest ser-

vices planned in 2003 for their own forests, amended by information about management of privately owned and community forests. Therefore, they represent conditions, aims and scopes as evident in the years around 2003. The parameterisation (“base scenario A” or “business as usual”) was used to calculate the RL used for the Copenhagen submission. With the state of the carbon pools measured in 2008, added growth of trees and subtracted losses due to planned harvests the living biomass pool was calculated and given in 5 years’ steps. The reference line was then calculated as the annual change (linearly interpolated) between the state 2008 and the projected state 2013 (one year - 2013), the states 2013 and 2018 (all years), and 2018 and 2023 (two years – 2019, 2020), respectively.

Annex 1 provides the main variables (with range of input) to be considered in the management simulator. As mentioned, the data have been compiled from management guidelines actually in place in the different federal states, supplemented by information gathered on the behaviour and management goals of private forest owners. The respective main variables used in the grading module are given in Annex 2.

### **Other Pools and sources of emissions than living biomass**

Projections with the described model (WEHAM) contain the change of carbon stocks in living biomass only and therefore additional estimations for emissions from other pools and emissions subject to forest management accounting have to be added. Those contain:

- CO<sub>2</sub>-emissions from mineral soils
- Emissions of other relevant gases from mineral soils (expressed in CO<sub>2</sub>-equivalent)
- CO<sub>2</sub>-emissions from organic soils
- Emissions of other relevant gases from organic soils (expressed in CO<sub>2</sub>-equivalent)
- CO<sub>2</sub>-emissions from litter
- CO<sub>2</sub>-emissions from deadwood
- CO<sub>2</sub>-emissions from forest fires
- Emissions of other relevant gases from forest fires (expressed in CO<sub>2</sub>-equivalent)
- Direct CO<sub>2</sub>-emissions from application of dolomite (CaCO<sub>3</sub>)
- Emissions of other relevant gases from fertilization (expressed in CO<sub>2</sub>-equivalent)

For these emissions sophisticated projection models are actually not available, so projected estimations have to be derived by extrapolation of historical data and trends. To capture mid-range trends as far as possible, data from the greenhouse gas inventory of the last 10 years is used as basis for extrapolation.

For a most possible conservative approach, the method considers a linear extrapolation in case of increasing historical emissions and the mean of historical emissions in case of declining emissions.

Pools/activity notes:

- No land-use change is included in the reference level calculation because the effect of the emissions cannot be estimated with satisfying accuracy and reliability.
- Emissions from mineral soils and litter are actually reported as zero under the use of IPCC methodology and are therefore considered as zero as well for the RL.
- CO<sub>2</sub>-emissions from forest fires are reported actually as included in the stock-change of living biomass and are not explicitly calculated. Therefore a separate estimation within the RL is not possible.
- Emissions of non-CO<sub>2</sub>-gases due to fertilization are not relevant, because application of fertilizers (except CaCO<sub>3</sub>) does not take place in German forests.
- Estimations for the emissions from other pools/categories are shown in the following table 1 and table 2:

Table 1: Estimation of annual emissions from pools/categories other than living biomass.

gas	category/pool	unit	2013-2020
CO <sub>2</sub>	organic soils	Gg * a <sup>-1</sup>	597,9
CO <sub>2</sub>	deadwood	Gg * a <sup>-1</sup>	-3668,4
CO <sub>2</sub>	liming (CaCO <sub>3</sub> )	Gg * a <sup>-1</sup>	108,2
non-CO <sub>2</sub>	forest fires	Gg CO <sub>2</sub> -eq. *	3,1
non-CO <sub>2</sub>	organic soils	Gg CO <sub>2</sub> -eq. *	44,6

Table 2: Historical trends of emissions from pools/categories other than living biomass (as reported in the national inventory submission).

gas	category/pool	unit	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO <sub>2</sub>	organic soils	Gg * a <sup>-1</sup>	599,0	598,7	598,4	598,1	597,9	597,6	597,3	597,0	596,8	598,1
CO <sub>2</sub>	deadwood	Gg * a <sup>-1</sup>	-3702,6	-3700,9	-3699,2	-3697,5	-3695,8	-3694,1	-3692,4	-3690,7	-3689,1	-3681,6
CO <sub>2</sub>	liming (CaCO <sub>3</sub> )	Gg * a <sup>-1</sup>	154,5	135,4	134,1	149,0	125,2	93,1	78,0	74,8	77,2	60,5
non-CO <sub>2</sub>	forest fires	Gg CO <sub>2</sub> -eq. *	3,0	4,2	0,9	0,9	9,6	2,0	1,4	3,6	1,9	4,0
non-CO <sub>2</sub>	organic soils	Gg CO <sub>2</sub> -eq. *	44,7	44,7	44,6	44,6	44,6	44,6	44,6	44,5	44,5	44,6

### **3) Differences between WEHAM and JRC model approach**

A number of member states use the model cluster GLOBIOM, G4M and EFISCEN to calculate their reference levels. These models project GDP and population on large scales to project land-use change and supply and demand quantities (GLOBIOM). In WEHAM, demand is considered by adjusting harvestable diameters and minimum stem top diameters used in the grading module to estimate the potential harvest. Bioenergy demand is incorporated in the scenario as well, as it can be saturated up to the level specified by the reference level by BAU management.

The forestry models of the cluster (G4M and EFISCEN) are less detailed than WEHAM and do not use the most current data for Germany as WEHAM does. WEHAM uses e. g. inventory data that must be aggregated and pooled if it was to be used by the other models, and incorporates growth and management in much greater detail. Thus, no post-processing to adjust model results to inventories is needed. In addition – and in contrast to the model cluster - WEHAM uses the same methodology to derive GHG stocks as is employed in the framework of Germany's reporting under KP and the Convention.

### **4) Incorporation of HWP data in the RL**

The contribution of harvested wood products (HWP) to the reference level of Germany amounts to -19,514 Mt CO<sub>2</sub>.

This estimation of HWP contribution to the RL constitutes an estimate of net-emissions from HWP due to changes in the HWP carbon pool. It has been calculated based on historic data and the WEHAM-projections on the future raw wood potential.

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. It incorporates activity data including the production of HWP that has been derived from TIMBER database of the United Nations Economic Commission for Europe (UNECE, 2011). It is furthermore based on the 2006 IPCC Guidelines (IPCC 2006, Vol. 4 Ch. 12) which suggests to estimate delayed net-emissions on the basis of the annual stock change of semi-finished HWP by means of Equation 12.1.

Following commodities, which are sub-categories of sawnwood (SW), wood based panels (WP) and paper and paperboard (P) were derived from UNECE 2011 TIMBER database:

- Coniferous sawnwood (SW)
- Non-coniferous sawnwood (SW)
- Veneer sheets (WP)
- Plywood (WP)
- Particle board (WP)

- Fibreboard (incl. hardboard, medium density fibreboard and insulating board) (WP)
- Paper and paperboard (P)

Data on the production and trade of industrial roundwood (coniferous and non-coniferous) have been used to calculate the share of HWP from domestic harvest.

The presented approach follows the initial assumption that all forests in Germany 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. 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 as compared to the last 5 years average of historic harvest was calculated and were applied equally to the historic HWP pool.

For more detailed information and explanation, please see working paper 'Proposal for setting a Reference level for Harvested Wood Products', which can be found under the following link: <http://www.holzundklima.de/lulucf>.

**5) Evaluation of the RL according to the requirements of “footnote 1 of paragraph 4 of the decision [-/CMP.6] on LULUCF”, “Draft LULUCF as of COP 15, footnote 11<sup>(2)</sup>” and “table proposed by G77<sup>(3)</sup>”**

**Table 3: Information on “footnote 1 of paragraph 4 of the decision [-/CMP.6] on LULUCF”.**

The elements contained in footnote 1 of paragraph 4 of the decision [-/CMP.6] on LULUCF are considered as follows:

<i>(a) Removals or emissions by forest management as shown in greenhouse gas inventories and relevant historical data:</i>	Using latest available country specific inventory data as described in NIR (2010), the RL is based on the NFI comprising increment and outflow of a significant sample as reported in the NIR.
<i>(b) Age-class structure:</i>	The age class structure is taken into account by using the latest available country specific inventory data (NFI 2002 and Inventory Study 2008) in WEHAM.
<i>(c) Forest management activities already undertaken:</i>	The RL is calculated inter alia on historical data of the NFI, thus comprising all management activities with meaningful impact of that period.
<i>(d) Projected forest management activities under a business-as-usual scenario:</i>	Projected FM activities considered are based on the silvicultural guidelines of the federal states in the last decade. The model was developed in 2003. No post 2009 domestic policies are included.
<i>(e) Continuity with the treatment of forest management in the first commitment period:</i>	Same treatment is applied as in the 1 <sup>st</sup> commitment period.
<i>(f) The need to exclude removals from accounting in accordance with decision 16/CMP.1, paragraph 1:</i>	There might be a need to exclude removals from accounting for instance discounting or capping or factoring out. However there is no need to exclude removals from establishing the RL as including all removals makes the RL more conservative and harder to top. Including all removals is thus a conservative approach.

<sup>2</sup> FCCC/KP/AWG/2009/17 28 January 2010. Report of the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol on its tenth session, held in Copenhagen from 7 to 15 December 2009 (LULUCF start from page 18).

<sup>3</sup> The table was proposed by G77 to the G EU LULUCF for increased transparency on submitted RLs in Bonn, 11.06.2010.

**Table 4: Information on “Draft LULUCF as of COP 15, footnote 11”.**

Requirements	Explanations
<i>The forest management reference levels described in the appendix were set transparently, taking into account:</i>	
<i>(a) Removals or emissions from forest management as shown in greenhouse gas inventories and relevant historical data;</i>	The RL (WEHAM) is based on the NFI comprising increment and outflow of a significant sample as reported in the NIR. WEHAM reflects the relevant in- and outflow as basis of its projections. Other pools/sources are considered.
<i>(b) Age-class structure;</i>	The RL (WEHAM) considers age-class structures for the respective calculation of increment and outflow (basis: NFI).
<i>(c) Forest management activities already undertaken;</i>	The RL is calculated inter alia on historic data of the NFI, thus comprising all management activities with meaningful impact of that period.
<i>(d) Projected forest management activities;</i>	The proposed RL is based on the BAU scenario, which is in line with the silvicultural guidelines and the overall goal of a close to nature and sustainable forestry.
<i>(e) Continuity with the treatment of forest management in the first commitment period;</i>	The proposed RL does not turn away from KP 3.4.
<i>(f) The need to exclude removals in accordance with decision 16/CMP.1, paragraph 1 (h).</i>	An accurate consideration of the factoring-out problematic is not practicable yet. Especially the CO <sub>2</sub> and N-fertilizing can not be factored-out easily.

**Table 5: Required information on historical data and reference level based on the “table proposed by G77” in July 2010.**

<b>“table proposed by G77”</b>	<b>NIR</b>	<b>WEHAM “+”</b>	<b>HWP</b>
<ul style="list-style-type: none"> <li>▪ <i>Pools</i></li> </ul>	above-ground and below-ground biomass, deadwood, litter <sup>4</sup> , soil-C	above-ground and below-ground biomass (“WEHAM”), plus extrapolation of historical data and trends for further pools (“+”)	Harvested Wood Products
<ul style="list-style-type: none"> <li>▪ <i>Non CO<sub>2</sub> gases</i></li> </ul>	included	included (“+”)	(-)
<ul style="list-style-type: none"> <li>▪ <i>Area under FM</i></li> </ul>	all FL	all FL	(-)
<ul style="list-style-type: none"> <li>▪ <i>Source of the data (forest management or proxy).</i></li> </ul>	forest management	forest management and proxy (management guidelines, growth model)	UNECE 2011
<ul style="list-style-type: none"> <li>▪ <i>Time series (from/to)</i></li> </ul>	1987-2002-2008	1987-2002-2008	1964-2009
<ul style="list-style-type: none"> <li>▪ <i>Model:</i> <ul style="list-style-type: none"> <li>▪ <i>Parameters: age class structure, harvesting rate, wood consumption, domestic wood (energy and HWP) imported wood (domestic and HWP)</i></li> <li>▪ <i>Assumptions; effect if the current policies on wood consumption and harvesting, other.</i></li> </ul> </li> </ul>	historical data only	historical data (NIR), age class structure and species, living biomass, planned harvesting rate (BAU, sustainability parameters), extrapolation of historical data and trends for further pools than living biomass (“+”)	<ul style="list-style-type: none"> <li>▪ 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. (IPCC 2006 GL, Equ. 12.1, half-lives 35/25/2 yrs)</li> <li>▪ Application of the same growth rates as harvest projections for HWP (<a href="http://www.holzundklima.de/lulucf">www.holzundklima.de/lulucf</a>).</li> </ul>
<ul style="list-style-type: none"> <li>▪ <i>Natural disturbances treatment</i></li> </ul>	force majeure		(-)
<ul style="list-style-type: none"> <li>▪ <i>Factoring out according to paragraph 1(f) dec16/CMP1</i></li> </ul>	no, not practicable yet		(-)

<sup>4</sup> Reported under ARD only.

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**Annex 1:** Important variables used in the BAU scenario and their range.

<b>Beech (<i>Fagus sylvatica</i> L.)</b>	<b>Range</b>
Rotation age	140 – 160
Tolerance for final harvest	10 – 30
Target DBH	55 – 70
Reduction factor	1,0 – 1,7
<b>Oak (<i>Quercus spec.</i>)</b>	
Rotation age	150 – 200
Tolerance for final harvest	20 – 40
Target DBH	60 – 80
Reduction factor	0,9 – 1,7
<b>Norway spruce (<i>Picea abies</i> (L.) Karst.)</b>	
Rotation age	80 – 160
Tolerance for final harvest	10 – 30
Target DBH	40 – 60
Reduction factor	0,85 – 1,4
<b>Scots pine (<i>Pinus sylvestris</i> (L.))</b>	
Rotation age	130 – 160
Tolerance for final harvest	10 – 50
Target DBH	45 – 60
Reduction factor	0,9 – 1,4

*(Tolerance for final harvest: Final harvest takes place within this frame of the rotation period, depends also on age target DBH is reached. The Reduction factor is used to adjust nation-wide derived growth values to regional conditions and situations.)*

**Annex 2:** Control parameters of the grading module [values are: median (minimum – maximum)].

<b>Parameter</b>	<b>Oak (Quercus spec.)</b>	<b>Beech, other broadleaves (except oaks)</b>	<b>Norway spruce, all conifers except pines and larch</b>	<b>Pine (Pinus spec.), larch (Larix spec.)</b>
top end diameter of stem bole (cm)	20 (14 – 35)	20 (14 – 40)	11 (8 – 25)	13 (10 – 25)
top end diameter for processing (cm)	12 (7 – 20)	15 (7 – 25)	8 (7 – 13)	10 (7 – 13)
minimum DBH for processing (cm)	20 (15 – 20)	20 (15 – 20)	12 (12 – 20)	12 (12 – 12)