BIOMASS FUTURES

Biomass role in achieving the Climate Change & Renewables EU policy targets. Demand and Supply dynamics under the perspective of stakeholders . **IEE 08 653 SI2. 529 241**

Deliverable 3.4:

Biomass availability & supply analysis

Model assumptions and linkages, first results

IIASA

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Content

Preface

This publication is part of the BIOMASS FUTURES project (Biomass role in achieving the Climate Change & Renewables EU policy targets. Demand and Supply dynamics under the perspective of stakeholders - IEE 08 653 SI2. 529 241, www.biomassfutures.eu) funded by the European Union's Intelligent Energy Programme.

[Text about this publication]

1 Introduction

The aim of the work package WP3 is to provide a comprehensive strategic analysis of biomass supply options and their availability in response to different demands in a timeframe from 2010- 2030.

This report introduces models and assumptions that are used to assess spatially explicit biomass supply and associated impacts of increased biomass supply on biophysical and economic indicators (Task 3.5). In particular the integrated analysis focuses on:

- Measures of competitive economic potentials of biomass for important land based climate mitigation strategies under different policies
- Synergies and tradeoffs between different land based climate mitigation options
- Interregional effects of biomass use (trade, leakage)

To achieve this, the work described in this report builds on the findings from previous work packages. The detailed information flow is presented in the **Methodology** section. The section further describes in detail the involved models and basic data sets used for the analysis. Further, **Definitions** are introduced that are essential for the production of consistent results across the different work packages and for the interpretation of results. The linkages to Work Package 4, analysis of sustainability criteria, are discussed in the section **Sustainability criteria**.

The **Results** section presents the general output structure and what kind of results can be expected. The quantitative results presented in this version of the report are preliminary and do not yet fully integrate the results of the involved work packages in Biomass Futures. They are therefore not discussed in their detail. Finally, an extensive **Appendix** presents an overview of parameters and definitions of feedstocks and technologies used by models of Work Package 3 and 5.

2 Methodology

2.1 General approach

This report introduces models and assumptions that are used to assess spatially explicit biomass supply and associated impacts of increased biomass supply on biophysical and economic indicators (Task 3.5). To achieve this, the work described in this report builds on the findings from previous work packages. Essentially it makes use of the following information:

1) Biomass supply curves, sustainability constraints and cost information from **Work Package 3, Deliverable 3.3**
2) Results from the analysis of advanced sustainability constraints analysed in **Work Package 4**
3) Demand scenarios and information on characteristics of technologies from **Work Package 5**

Deliverable 3.3 of the Biomass Futures project delivers a spatially detailed and quantified overview of EU biomass potentials taking into account the main criteria determining biomass availability from different sources. It maps the technical potentials of the different feedstock at Nuts 2 level and synthesizes the results in terms of economic supply estimates (cost-supply). The availability maps, cost information and basic sustainability constraints that were found and presented in Deliverable 3.3 are fed into an integrated economic land use model (GLOBIOM). By doing this, the static supply curves of individual feedstocks are brought into competition and contrasted with the demand scenariuos. Further, the land use model is assisted by a detailed economic model of biomass transformation to assess economies of scale and scope under polyproduction (BEHWERE).

Only by integrating the static supply curves of Deliverable 3.3 into a dynamic model of land use, issues of future land use change, trade, leakage, indirect land use effects and economic viability related to biomass supply can really be assessed. Adding to the fundamental (supply related) sustainability criteria that were already applied for the production of the static supply maps, more complex sustainability constraints can be assessed in the integrated land use model. These include economic indicators and sustainability issues related to land use change. Therefore, this Deliverable 3.4 closes an important bridge between the static supply maps that and the demand oriented energy models of Work Package 5.

The following list summarises the information flow between work packages and WP3 tasks:

Task 3.3 (CRES) to Task 3.4 (Alterra)

- Matrix with key sustainability characteristics of 4F crops
    - Overview of 4F cropping possibilities including species, rotation cycles, yields, raw material characteristics
    - List of best crops per climatic zone (including assumptions)

Task 3.3 (CRES) to WP 4 (Oeko)

- Matrix with key sustainability characteristics of 4F crops

Task 3.3 (CRES) to WP 6 (IEEP)

- Strategy for 4F crops accounting for existing policy

Task 3.4 (Alterra) to Task 3.5 (IIASA)

- Prediction and spatial distribution of cropped biomass supply for EU Member States

Task 3.4 (Alterra) to WP 5 (ECN)

- Biomass supply patterns for waste, by-products and cropped biomass

Task 3.5 (IIASA) to Task 3.4 (Alterra)

- Information on land use models and input data set example

Task 3.5 (IIASA) to WP 5 (ECN)

- Biomass supply patterns for energy crops and forest biomass

WP 5 (ECN, PRIMES) to Task 3.4 (alterra) and 3.5 (IIASA)

- Scenarios of bioenergy demand
- Information on land use models and input data set example
- Specification of energy models
- Feedstocks considered
- Technologies considered
- Conversion factors and assumptions

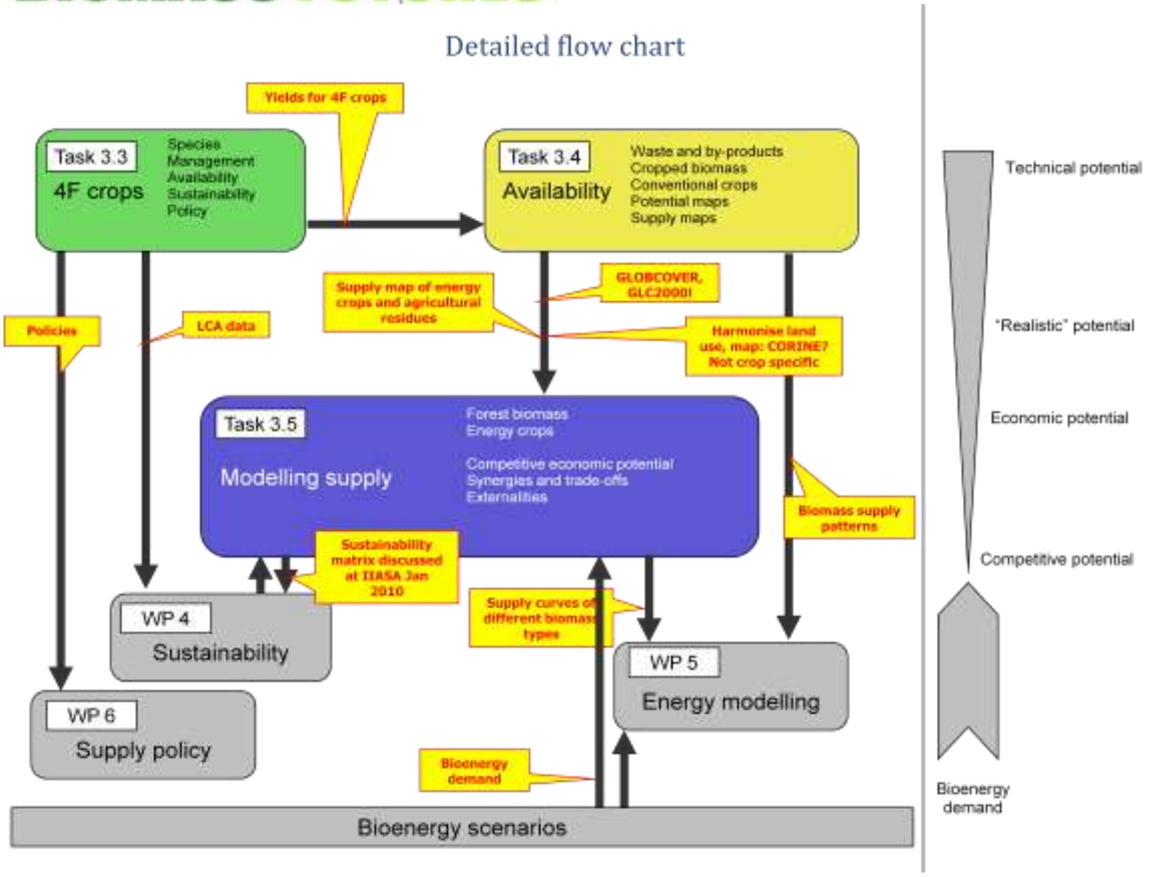

Figure 1: Detailed flow chart of WP3.

Figure 1 visualises the information flow and shows also the linkages of WP3 tass with other work packages. **Over the course of the project both, work flow list and work flow chart, will be constantly updated and adjusted**.

2.2 Model descriptions

2.2.1 Integrated economic land use model - GLOBIOM

The Global Biomass Optimization Model (GLOBIOM) is a global recursive dynamic partial equilibrium model integrating the agricultural, bioenergy and forestry sectors with the aim to provide policy analysis on global issues concerning land use competition between the major land-based production sectors (Figure 2). 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 policy constraints. Prices and international trade flows are endogenously determined for respective aggregated world regions. The flexible model structure enables one to easily change the model resolution. It covers 28 regions, representing a disaggregation of the eleven regions adapted to enable linkage with the POLES and/or PRIMES model.

The market is represented by implicit product supply functions based on detailed, geographically explicit, Leontief production functions, referring to the supply of agriculture and forestry production and explicit, constant elasticity, product demand functions Explicit resource supply functions, i.e. supply function for other inputs then land in the production process of agricultural and forestry products, are used only for water supply.

GLOBIOM can be used to estimate the role of cropland, grassland, and short rotation tree plantations expansion in global land use change projections. Data sources of parameters and driver variables used can be found in Table 12.GLOBIOM data sources

Table 12

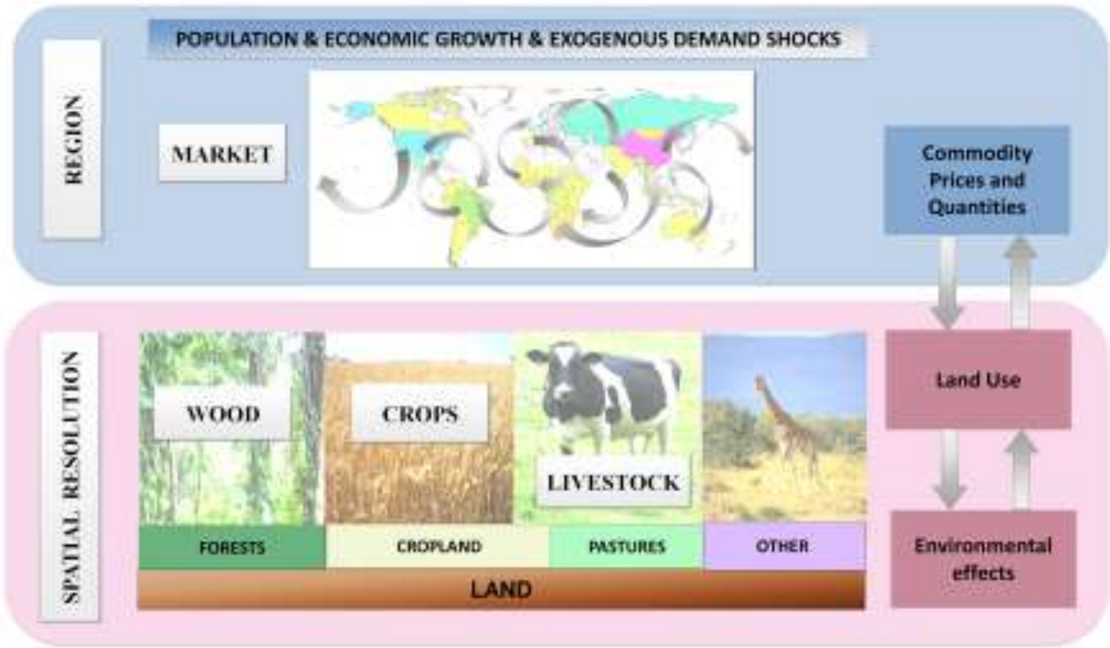

Figure 2: General structure of GLOBIOM model. More information on the model structure and modules can be found at www.globiom.org.

2.2.2 Spatial economic modelling – BEWHERE

The BEWHERE model calculates the optimal spatial distribution and size of bioenergy plants, pulp and paper mills and sawmills given the spatial biomass supply distribution from biophysical models to assess economies of scale and scope under polyproduction. Together with a demand estimated from a geographically explicit driver maps and aggregate production from GLOBIOM, BEWHERE calculates the optimal positions of plants and mills, such that economies of scale and scope under polyproduction of spatial explicit bioenergy systems can be assessed.

2.3 Definitions and data sources

2.3.1 Biomass types covered by models

The biomass categories covered by Biomass Futures were introduced in Deliverable 3.3 (based on harmonised BEE method handbook). The supply models build on these categories. However, the models applied in Work Package 3 and 5 represent the biomass categories and technology chains with varying degree of detail. The Annex lists parameters and level of detail for the involved land use and energy models. Table 1 summarises the feedstocks that can be addressed by all tools applied in Work Package 3.

Table 1: WP3 feedstocks.

Biomass type (BEE/NREAP Biomass types)	Biomass type detail	Feedstocks
Agricultural residues (Biomass from agriculture)	Primary agricultural residues	Hay, straw
		Sugar beet heads
		Oil crop residues
		Rapeseed residues
		Maize residues
		Other primary residues
	Secondary agricultural residues	Sugar beet pulp
		Potato peels
		Residuals from beer making
		Other secondary residues
	Manure	Wet manure
		Dry manure
Forestry biomass (Biomass from forestry)	Stemwood	Stemwood from fina fellings and thinnings
	Primary forestry residues	Tree tops, branches, thinning wood
	Secondary forestry residues	Saw dust
		Black liquor
	Other forestry biomass	
Biomass from waste	Biodegradable municipal waste	Domestic waste with sometimes the addition of commercial wastes collected by a municipality within a given area
		Demolition wood
	Industrial waste	Industrial waste
	Sewage sludge	Sewage sludge
	Used vegetable oil/fats	Used vegetable oil
	Animal waste	Waste from intensive livestock operations, from poultry farms, pig farms, cattle farms and slaughterhouses. In a few words, animal losses (cadavers)
	Landfill gas	Waste gas derived from landfills
Energy crops	Non-woody energy crops	Corn
	Sugar crops	Sugar cane
		Sugar beet
	Starch crops	Wheat and barley
		Sorgum
	Oil crops	Oil palm
		Soya
		Rapeseed
		Rapeseed+sunflower
	Woody energy crops	Canary reed, miscantus, switchgrass
		Poplar,willow,eucalyptus

2.3.2 Bioenergy technologies

The integration of biomass supply from different feedstocks and dmeand for bioenergy requires also an appropriate representation of bioenergy technologies that transform biomass into energy. The description of technologies is also taks of Work Packages 2 (market analysis) and 5 (energy modeling). To assess the energy potential of biomass feedstocks, account for competition between them and to model land use change, trade and leakage associated with bioenergy scenarios, however, technologies play a role also in the supply analysis.

The Annex lists the technologies that are represented in the models applied in Work Package 3 and 5 and also provides the parameters used to characterise them. It is important to harmonise these to the degree possible to ensure consistency and comparability of model results. **During the course of the project these tables will be further enhanced and updated**.

2.3.3 Other consistency issues

The base year of different datasets used for the analysis of availability and supply of biomass varies. The base year of the analysis is therefore an average of the base years used. Where available the most recent data are used. Currently the integarted land use model GLOBIOM uses the year 2000 as base year, which minimises the variability of base years in the data sets used because many data sets with base year 2000 exist. Also this is consistent with the energy model PRIMES and its biomass model (applied in Work Package 5).

2.4 Overview of sustainability criteria

At this moment the Commission has put forward recommended sustainability criteria for solid and gaseous biomass sources which can be adopted by Member States, but are not binding. The following criteria for inclusion into national schemes are recommended by the Commission:

- A general prohibition on the use of biomass from land converted from primary forest, other high carbon stock areas and highly biodiverse areas.
- A common greenhouse gas calculation methodology which could be used to ensure that minimum greenhouse gas savings from biomass are at least 35 per cent (rising to 50 per cent in 2017 and 60 per cent in 2018 for new installations) compared to the EU's fossil energy mix.
- A differentiation of national support schemes in favour of installations that achieve high-energy conversion efficiencies.
- Monitoring of the origin of biomass.

In the framework of the Biomass Futures project a detailed analysis is provided on how sustainability criteria may constrain the biomass feedstock availability (see results of Work Package 4 and Deliverable 3.3). In this report the focus is on the integration of sustainability criteria into the dynamic integrated land use model (GLOBIOM).

The consideration of sustainability constraints in Work Package 3 is implemented at two levels. Deliverable 3.3 assesses the effect of sustainability constraints on the portential supply of biomass for energy purposes at the level of basic environmental indicators. They address, depending on the type of biomass feedstock and targeted area criteria focusing on, e.g.:

Risk for increased input use with adverse effects on environmental quality (e.g. nitrogen pollution, soil degredation, depletion of water resources, etc..)

- Risk for disturbance of soil structure (compaction)
- Nutrient depletion in case of too much removal

The use of an integrated land use model allows the inclusion of additional criteria that can only be assessed in an integrated framework. These include economic criteria and criteria related to land use change effects and indirect effects (e.g. leakage). Table 2 presents the linkage betweeen model parameters and and sustainability criteria in a matrix format that will be explicitly addressed by the integrated land use model. It describes linkages between WP3 (supply modeling) and WP4 (sustainability criteria) and serves as a translating interface between models and relevant sustainability criteria, addressing in detail all principles, criteria, indicators and respective model interpretation resulting in concrete data needs.

The sustainability matrix table will be revised and enhanced in the course of the project and be updated according to the progress made in Work Package 4 and the further development of the models.

Table 2: Sustainability matrix. The matrix describes linkages between WP3 (supply modeling) and WP4 (sustainability criteria). It serves as a translating interface between models and relevant sustainability criteria, addressing in detail all principles, criteria, indicators and respective model interpretation resulting in concrete data needs.

Principles (what do we want)	Criteria (where)	Specification	Indicator (how to reach it, identify areas)	Model interpretation	Data needs, discussion
Protection of highly biodiverse land	Protection of primary forests and other woodlands	Biomass extraction not allowed	Native species, no human activity, undisturbed ecological processes	Harvest and thinning rate = 0, exclude areas from potential	Greenpeace map of intact forest landscapes 2000; problem that this is rather outdated (reference year 2008); need to revisit indicators used by Greenpeace? Updata may be reasonable.
	Protection of Protected Areas (designated by law)	Biomass extraction allowed as long as no interference with nature protection purposes	IUCN categories of protected areas? 1-4 untouched, high level, 5-6 used?	Allow sustainable use in cats 5-6, not allow in 1-4?	WCMC database on protected areas, protection categories - some data lacking, but it is the best global database
	Protection of areas designated for the protection of rare, threatened or endangered ecosystems or species	Biomass extraction allowed as long as no interference with nature protection purposes	Areas outlined by EU COM? As starting point, data from the WCMC Biodiversity and Carbon Atlas and from IBAT-tool	Proof of "interference" difficult, because no categories are available. Exclude areas from potential?	WCMC Biodiversity and Carbon Atlas, important bird areas, key biodiversity areas from IBAT-tool (CI/WCMC), checking data regarding international agreements
	Identification of grassland	Identification of grassland as a basis for the next two criteria	Grassland is dominated by herbaceous and shrub vegetation (including savannas, steppes, scrubland and prairie). Savannas of agro-forestry systems can show a tree cover up to 60%!	Used for classification…	Available data on grassland, savannas, scrubland, etc. (e.g. White et al. 2000)
	Protection of highly biodiverse natural grasslands	Biomass extraction is not allowed	Sites show natural species composition and ecological characteristics and processes are intact.	Exclude areas from potential - most natural grassland is likely to be highly biodiverse. As a first proxy, a share of 10% could bbe converted	White et al. 2000 (covers mainly natural grassland, but underrepresents non-natural grassland; use GLC2000 or other land cover products to identify grasslands in combination with livestock data; challenge of distinguishing natural and non-natural grasslands remains; comparison with Potential Natural Vegetation maps?

Principles (what do we want)	Criteria (where)	Specification	Indicator (how to reach it, identify areas)	Model interpretation	Data needs, discussion
					Degradation Maps from LADA might be used as proxy to identify areas where ecological prosesses are not intact. See existing mapping, list in OEKO et al. (2009)[1]
	Highly biodiverse non-natural grasslands	Biomass extraction allowed as long as status of highly biodiverse grassland is preserved.	Sites show species richness and are not degraded. Species richness is often associated with factors such as soil condition, water household, slope, etc. Identification of such indicators could be helpful	Reduced potential from and no conversion of highly biodiverse non-natural grasslands Because the yield from highly biodiverse grasslands may be very low it is reasonable to exclude these areas completely.	See above
Protection of land with high carbon stock	Conservation of carbon stock in wetlands	Biomass extraction allowed as long as status of wetland is preserved	Areas covered with or saturated by water, permanently or by significant part of the year	No conversion allowed	Global Lake and Wetland DB 2004, Uni Kassel, 1km resolution (enough?); RAMSAR site DB and other DB; Uwe Schneider's DB for Europe? Radar products?
	Conservation of carbon stock in forested areas (tree cover > 30%); including regenerating forests	Carbon stocks have to be preserved, regrowth must be guaranteed	Tree cover > 30%; 1 ha minimum size; min (potential) height of 5 m	Sustainable forest management allowed as long as the area will remain forested (tree cover >30%) in the long run.	Vegetation cover CF, Modis; Global land cover types yearly, 500 m resolution; GLOBCOVER
	Conservation of carbon stock in forested areas (tree cover 10-30%); including regenerating forests	Carbon stocks have to be preserved, regrowth must be guaranteed; Forest conversion allowed if GHG balance acceptable	Tree cover 10-30%; 1 ha minimum size; min (potential) height of 5 m	Sustainable forest management allowed as long as the area will remain forested (tree cover >10%) in the long run, but area can grow towards the category >30%! An area can be converted towards other vegetation types if GHG balance is acceptable.	Vegetation cover CF, MODIS; Global land cover types yearly, 500 m resolution; GLOBCOVER
Protection of peatlands	Conservation of Peatlands	Biomass extraction not	Use FAO soil maps (HWSD)	Simplest assumption: assume	Needed: map of drained and

[1] OEKO / ILN / HFR / WCMW (Öko-Institut / Institute for Landscape Ecology and Nature Conservation / University of Applied Forest Sciences / UNEP World Conservation Monitoring Centre) 2009: Specifications and recommendations for "grassland" area type (http://www.oeko.de/service/bio/en/index.htm)

Principles (what do we want)	Criteria (where)	Specification	Indicator (how to reach it, identify areas)	Model interpretation	Data needs, discussion
		allowed unless the peatland is already drained (2008) or no drainage is needed for cultivation	and apply threshold of carbon content. Other datasets?	that for any cultivation on peatlands drainage is needed. Peatland being used before 2008 has already been drained and can still be used, Peatland not in use before 2008 must be drained and cannot be used	undrained peatlands (mind reference year 2008). Which maps to use? Harmonized World Soil database (HWSD) does not consider land use (LU). EPIC currently initializes runs to to identify soil carbon for different LU types; check definition of peat in IIASA HRU Database. Have a look at background paper from Billen and Star (2009)[2] for definitions and field methods/thresholds.
Sustainable cultivation in the EU	Cross-compliance is fulfilled	Cultivation must be in line with EU legislation (only for EU MS)		Link to IIASA's CC-TAME Project	Are there any land use options that do NOT yet comply? E.g. conversion of grassland restricted to certain share etc. Databases on "payments"?
Reduction of GHG-emissions	Acceptable GHG balance	2008: saving of 35% (old plants from 1 April 2013) 2017: saving of 50% 2018: saving of 60% (for new plants starting production after 1.January 2017)	Include whole life-cycle and direct LUC	Use default data (do not include emissions from LUC); use detailed data for bioenergy chains; sensitivity analysis: how much complexity is needed?	Comparison/combination with GEMIS DB? Whole chain represented in the model, problem more that pathways cannot be traced in model solution

[2] Billen N (bodengut), Stahr K (Universität Hohnheim) 2009: Bodenkundlich relevante Aspekte in der BioSt-NachV. § 6: Schutz von Torfmoor, § 9 Abs. 1 Zif. 2 der Anlage 1: Degradierte Flächen. Auswahl von international anerkannten Feld- und Labormethoden zum Nachweis von Torfmoor und Degradierung (http://www.oeko.de/service/bio/en/index.htm)

2.5 Scenarios of background drivers and bioenergy demand

According to the workflow described above GLOBIOM and BEWHERE use bioenergy demand prescribed by the PRIMES biomass model. **The scenarios described here are preliminary and will be revised during the course of the project.**

2.5.1 EU Baseline description

The Baseline scenario[3] determines the development of the bioenergy demand under current trends and policies; it includes current trends on population and economic development including the recent economic downturn and takes into account bioenergy markets. Economic decisions are driven by market forces and technology progress in the framework of concrete national and EU policies and measures implemented until April 2009.

2.5.1.1 Population and Gross Domestic Product

The 2009 Baseline scenario builds on macro projections of GDP and population which are exogenous to the models used. They reflect the recent economic downturn, followed by sustained economic growth resuming after 2010. This data is entering GLOBIOM that uses these projections to translate them into demand for timber and agricultural commodities. The version of December 2009 was used. This dataset was also consistently used in the PRIMES biomass model that provided bioenergy projections to GLOBIOM. The data for population and GDP development in EU countries for both, the base year 2007 (prior to the financial and economic crisis for comparison) and 2009 (used for this study) are displayed in Table 3.

Table 3: Rate of growth of population and GDP per year in percent.

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

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

2.5.1.2 Projection of bioenergy production

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

The primary supply of biomass and waste has been linked with resource origin, availability and concurrent use (land, forestry, municipal or industrial waste etc). The total primary production levels for each primary commodity are restricted by the technical potential of the appropriate primary resource.

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

The projection of total bioenergy demand as suggested by the PRIMES biomass model (version December 2009) is displayed in Figure 3.

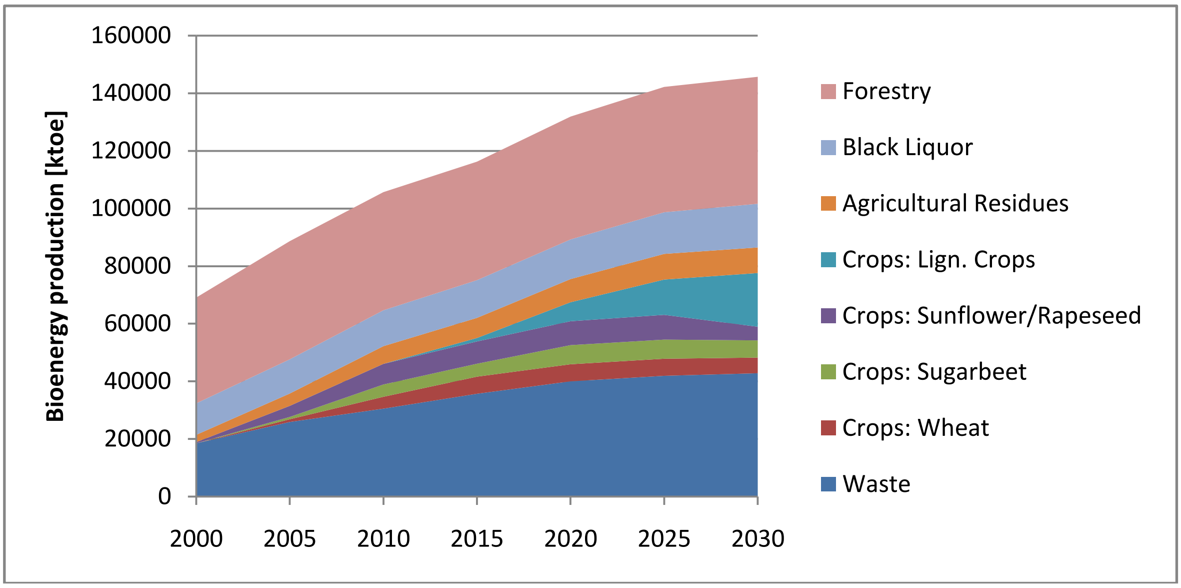

Figure 3: Baseline projection of total bioenergy demand as suggested by the PRIMES biomass model (version December 2009).

2.5.2 Rest of the world Baseline description

The rest of the world is currently described in GLOBIOM using data from the POLES model. As GLOBIOM operates in partial equilibrium, several parameters enter the projections as exogenous drivers. Wood and food demand is driven by gross domestic product (GDP) and population changes. In addition, food demand must meet minimum per capita calorie intake criteria, which are differentiated with respect to the source between crop and livestock calories. Demand is calculated for the different world regions on the basis of projections of regional per capita calorie consumption by source (vegetal, meat, milk and eggs). The regional population and GDP development is taken from POLES.

Bioenergy demand is directly taken from the 2010 POLES baseline scenario (see Figure 4). Population change is driving food and wood demand. Wood demand is further adjusted according to GDP change. Bioenergy demand from POLES is in GLOBIOM imposed as an exogenous constraint. Bioenergy demand is at the regional resolution delivered by POLES, and four types of bioenergy are differentiated – BFP1 (firest generation biofuels), BFP2 (second generation biofuels), BIOINEL (eat and power generation), and BIOINBIOD (direct biomass use for electricity production).

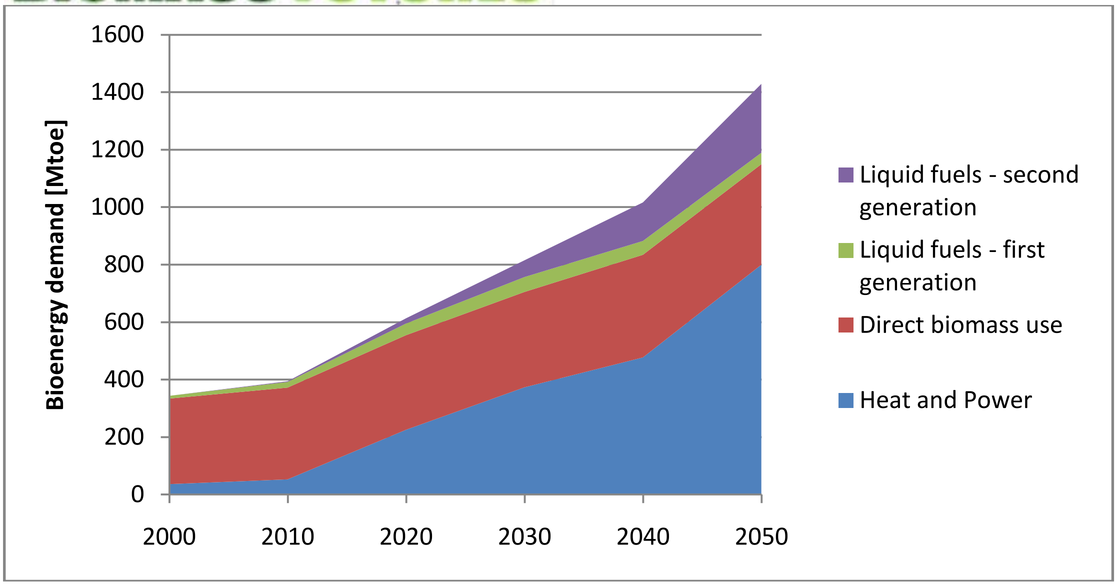

Figure 4: Global bioenergy demand prescribed by POLES and used by GLOBIOM for world regions except EU27.

3 Preliminary results

The results presented in this section of the draft report are preliminary. As laid out in the Methodology section, this task builds on products and decisions fro other Work Package 3 tasks and other Work Packages. The data flow has been described above. However, for the preliminary results presented here we used a simpler structure to run model tests and start to harmonise assumptions in the the models involved. This is an iterative process.

The preliminary results in this report are used to explore the following aspects related to bioenergy potentials and impacts on environmaental and economic systems:

- Land use projections for EU27
- Crop area
- Emissions

3.1 Introduction to the GLOBIOM GUI

Results of the integrated land use model GLOBIOM are written into a GUI that can be used to display the output in user defined setups. The GUI facilitates a direct access of model users to results of different scenarios and settings of the model. Individual tables can be generated and graphs can be drawn and exported. The GUI will allow partners advisory committee members and stakeholders of the Biomass Futures project to assess results in a common framework. Data contained in the GUI include:

- Input data, e.g.
    - base year supply and demand quantities, prices, tariffs
    - input use, crop, forest and livestock productivities,
    - related environmental parameters (GHG, nitrogen leaching)
- Exogenous baseline parameters e.g.
    - GDP and POP projections
    - human diet structure,
    - Projected bioenergy demand
- Forward looking scenario and sensitivity analysis results, e.g.
    - land use, land use change, land use management,
    - livestock management,
    - GHG emissions,

- projected prices,
- demand and supply quantities of inputs and outputs,
- trade flows

In the following some examples of GUI functionalities.

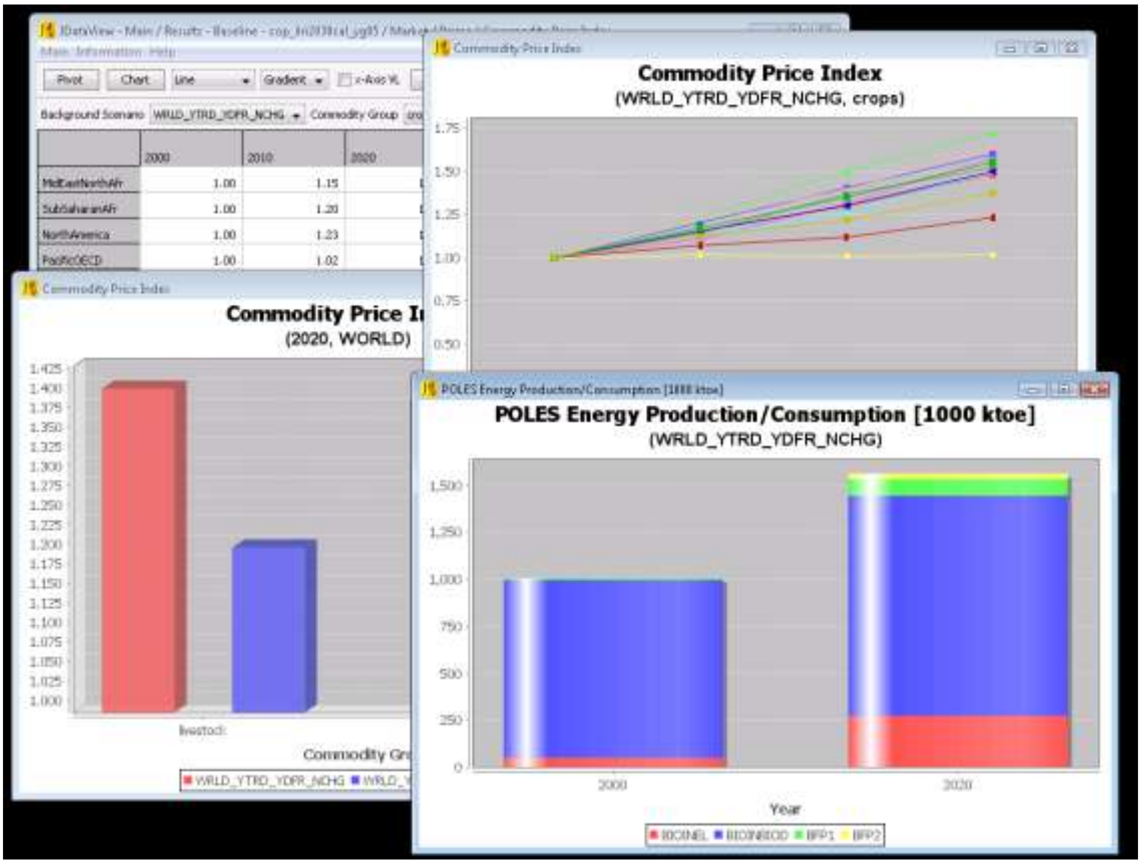

Figure 5: Screen shot of GUI application example.

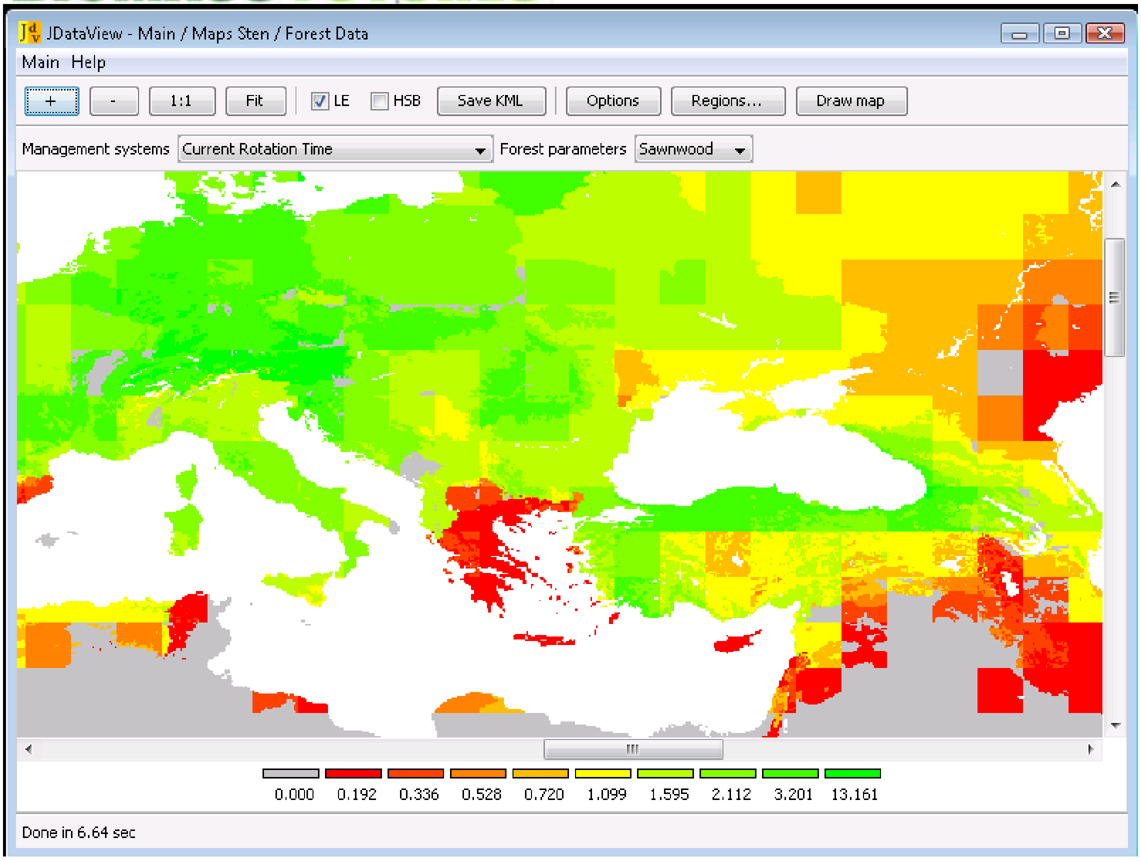

Figure 6: Screenshot of GUI application example.

3.2 Land use

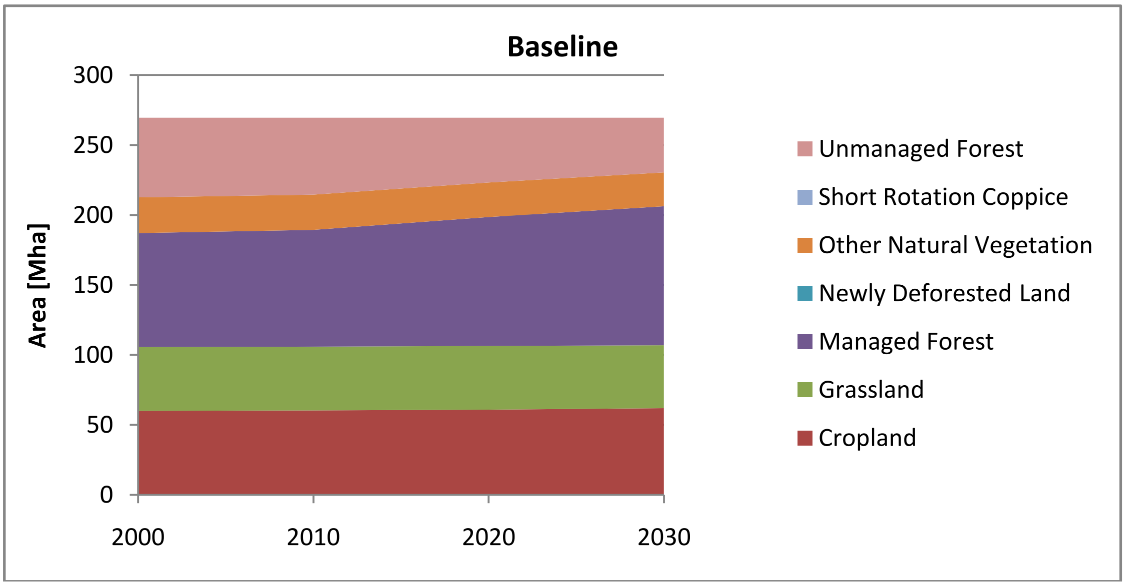

Figure 7: Land use projection for the baseline scenario of EU27 by GLOBIOM.

3.3 Crop areas

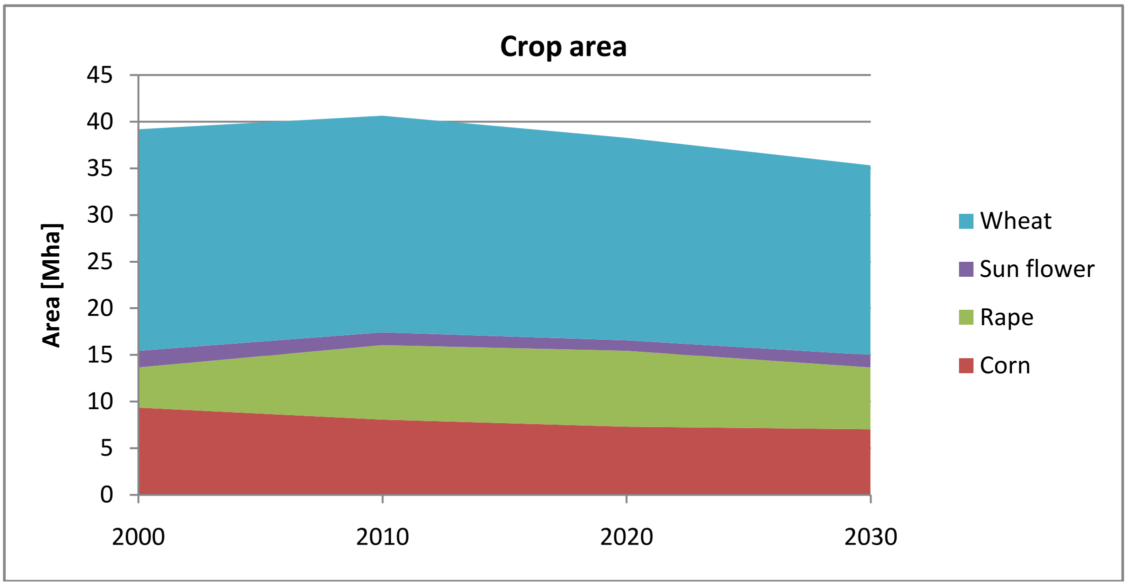

Figure 8: Crop area projection of selected crops for the baseline scenario of EU27 by GLOBIOM.

3.4 Emissions

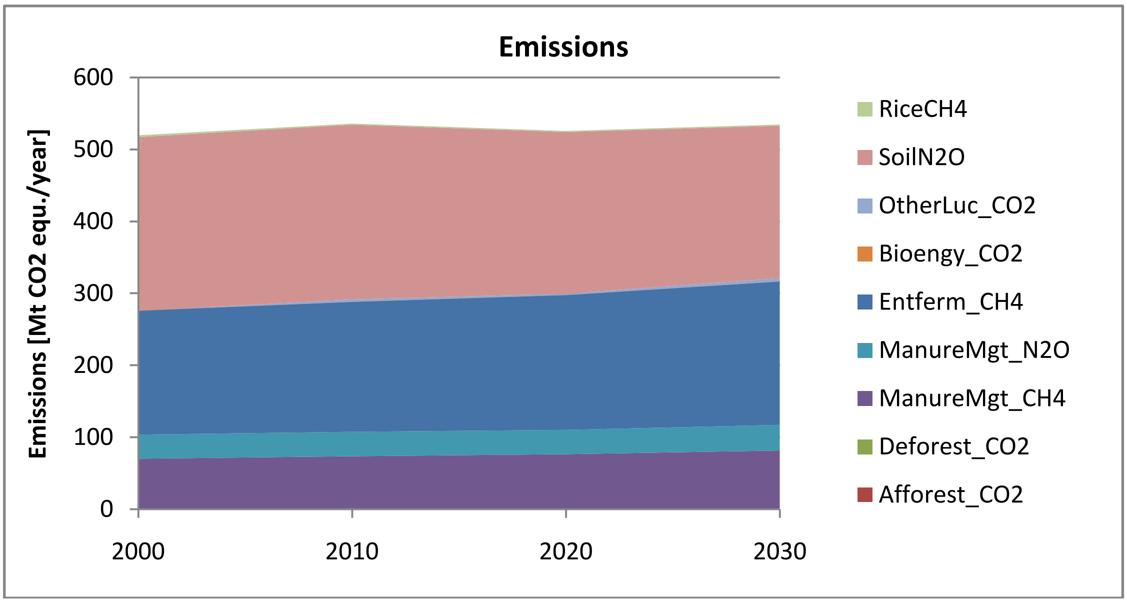

Figure 9: Emission projection forthe baseline scenario of EU27 by GLOBIOM.

Appendix

Biomass types covered by models

Table 4: WP3 feedstocks.

BEE/NREAP Biomass types	Biomass type	Biomass type detail	Feedstocks	Models/ tools
Biomass from agriculture	Agricultural residues	Primary agricultural residues	Hay, straw, , stalks, branches, leaves, wastes from pruning, residues from bulb sector and biomass from the processing of agricultural products (cotton ginning, olive pits, fruit pits potato peels etc)	GLOBIOM planned, RESolve, PRIMES Biomass
			Sugar beet heads	RESolve
			Oil crop residues	RESolve
			Rapeseed residues	RESolve
			Maize residues	RESolve
		Secondary agricultural residues	RESolve has only the aggregated category ‘agri foodprocessing residues’	RESolve
			Sugar beet pulp	
			Potato peels	
			Residuals from beer making	
		Manure	Wet manure	RESolve
			Dry manure	RESolve
Biomass from forestry	Forestry biomass	Fellings	Stemwood	GLOBIOM, RESolve, PRIMES Biomass
		Forestry residues	RESolve has only the aggregated category ‘forestry residues’	RESolve
		Primary forestry residues	Tree tops, branches, thinning wood	GLOBIOM planned, PRIMES Biomass
		Secondary forestry residues	Saw dust	GLOBIOM planned, PRIMES biomass but not in forestry
			Black liquor	GLOBIOM planned, RESolve, PRIMES biomass but not in forestry
		Other forestry biomass		

BEE/NREAP Biomass types	Biomass type	Biomass type detail	Feedstocks	Models/ tools
Biomass from waste	Waste, municipal	Biodegradable waste	Domestic waste with sometimes the addition of commercial wastes collected by a municipality within a given area	PRIMES Biomass, RESolve
		Wood waste	Demolition wood, Saw dust	PRIMES Biomass,
			Demolition wood	RESolve
	Waste Industrial solid	Industrial waste biomass	Waste biomass for example from sugar, pulp & paper industries and breweries (sugar beet pulp and brewers spent grain are included here and not in secondary agricultural residues	PRIMES Biomass
	Waste Industrial pulp	Black liquor	Black liquor	PRIMES Biomass
	Waste sewage sludge	Sewage sludge	Sewage sludge	PRIMES Biomass
	Waste vegetable oil	Used vegetable oil/fats	Used vegetable oil	PRIMES Biomass
	Waste animal	Waste from animal platform	Waste from intensive livestock operations, from poultry farms, pig farms, cattle farms and slaughterhouses. In a few words, animal losses (cadavers)	PRIMES Biomass
	Waste Landfill gas	Landfill gas	Waste gas derived from landfills	PRIMES Biomass
	Waste manure	Manure	Dry manure	PRIMES Biomass
		Demolition wood		RESolve
		Industrial waste		RESolve
		Sewage sludge		RESolve
		Land fill gas		RESolve
		Used fats/oils		RESolve
Energy crops	Energy crops	Non-woody energy crops	Corn	GLOBIOM, RESolve
			Sugar cane	GLOBIOM, RESolve
		Sugar crops	sugar beet, sugarcane, sweet sorghum, Jerusalem artichoke, sugar millet etc.	GLOBIOM, PRIMES Biomass
		Starch crops	maize, wheat, corn (cob), barley, potatoes, amaranth, etc.	GLOBIOM, PRIMES Biomass
		Oil crops	rapeseed, sunflower seeds, soybean, Olive-kernel, calotropis procera etc.	GLOBIOM, PRIMES Biomass

BEE/NREAP Biomass types	Biomass type	Biomass type detail	Feedstocks	Models/ tools
			Wheat	GLOBIOM,
			Wheat and barley	RESolve
			Soya	GLOBIOM
			Oil palm	GLOBIOM, RESolve
			Rapeseed	GLOBIOM,
			Rapeseed+sunflower	RESolve
			Sorgum	RESolve
		Herbaceous ligno.crosp	canary reed, miscantus, switchgrass	
		Woody energy crops	Generic (energy tree plantation)	GLOBIOM
			poplar,willow,eucalyptus, corn stover	PRIMES Biomass
		Herbaceous lignocellulosic crops	miscanthus, switchgrass, common reed, reed canarygrass, glant reed, cynara cardunculus, jatropha, alfalfa, etc.	PRIMES Biomass

Technologies covered in WP3

Table 5: ECN technologies.

Feedstock	Process	Product	Energy value GJ_input/t(m 3) feedstock	Bioeng y CO2	CO2 savings in kg per GJ[4]
Wood	Gasification	Electricity	15		
Wood	Gasification	SNG	18.4		
Wood	Co-firing	Electricity	15		
Wood	CHP	Electricity, Heat	15		
Wood	Combustion	Electricity	15		
Wood	Combustion	Heat	15		
Wood	Ethanol production from lignocellulosic crops	Ethanol	18.4		
Wood	FT-diesel production	FT-diesel	18.4		
Wood	DME-production	DME	18.4		
Sugar crops	Ethanol production from sugar crops	Ethanol	17.5		
Sugar crops	Co-firing	Electricity[5]	16.5		
Starch crops i.e. barley, maize, wheat, sorgum, etc.	Co-firing	Electricity	16.5		
Starch crops	CHP	Electricity, heat	16.5		
Starch crops	Ethanol production from starch crops	Ethanol	17.2		
Oil crops, i.e. sunflower, rapeseed	CHP	Electricity, heat	16.5		
Oil crops	Combustion	heat			
Oil crops	Transesterification	Biodiesel	26.5		
Herbaceous ligno.crosp	Co-firing	Electricity	16.5		
Herbaceous ligno.crosp	CHP	Electricity, heat	16.5		
Herbaceous ligno.crosp	Ethanol production from lignocellulosic crops	Ethanol	18.4		
Used fats/oils	Transesterification	Biodiesel	37.2		
Manure	Co-firing	Electricity	6.6		
Manure	Combustion	Electricity	6.6		
Manure	Gasification	Electricity	6.6		
Manure	Digestion	Electricity,heat	6.6[6]		
Manure	Digestion	SNG	0.26		
Manucipal Solid Waste	Combustion	Electricity	10		
Agricultural residues	Co-firing	Electricity	15		
Agricultural residues	Combustion	Electricity	15		
Agricultural residues	Gasification	Electricity	15		
Agricultural residues	CHP	Electricity, heat	15		
Agricultural residues	Gasification	SNG	18.4		

[4] For biofuels a combination feedstock used and biofuel was used, see the Excel file. Source: Concawe (2006): Well-to-wheels analysis of future automotive fuels and powertrains in the European context, Concawe, Eucar & JRC, May 2006

[5] At the moment energy crops for electricity are one category, so only one value of energy content is applied: 16.5 GJ/ton.

[6] Solid manure: 6.6 GJ/ton, liquid manure (incl. co-substrate): 2.9 GJ/ton

Agricultural residues	Ethanol production from lignocellulosic crops	Ethanol	18.4		
Agricultural residues	FT-diesel production	FT-diesel	18.4		
Agricultural residues	DME-production	DME	18.4		
Land fill gas & sewage sludge	Digestion	Electricity,heat	Energy content not directly used in model (Potentials is expressed in Gwhe)		
Palm oil	Transesterification	Biodiesel	36		

Table 6: PRIMES technologies

Feedstock	Process	Product	Energy value GJ input/t(m3) feedstock	Bioengy _CO2	CO2 savings in kg per GJ
Wood biomass	Gasification	Biogas-SNG	19		
Manure	Gasification	Biogas-SNG	19.77		
Agricultural residues	Gasification	Biogas-SNG	17		
Wood biomass	FT synthesis	Biodiesel	19		160
Agricultural residues	FT synthesis	Biodiesel	17		160
Waste oil	Transesterificat ion	Biodiesel	35		51
Pure vegetable oil from oil crops	Transesterificat ion	Biodiesel	39		51
Sugar crops	Fermentation sugar	Bioethanol	19		54
Starch crops	Fermentation starch	Bioethanol	16		54
Lignocellulosic crops	Fermentation lign.	Bioethanol	19		54
Wood biomass	Hydro thermal upgrade	Biocrude-Bioheavy	19		
Manure	Hydro thermal upgrade	Biocrude-Bioheavy	19.77		
Biocrude-Bioheavy	Hydro deoxygenation	Biodiesel	33.99		20
Wood biomass	Pyrolysis	Biodiesel	19		
Manure	Anaerobic Digestion	Biogas-Biomethane	19.77		
Waste animal	Anaerobic Digestion	Biogas-Biomethane	11		
Agricultural residues	Anaerobic Digestion	Biogas-Biomethane	13.88		
Sewage Sludge	Anaerobic Digestion	Waste gas	15		
Waste landfill gas	In-situ gas conditioning	Waste gas	12		
Waste Oil	Oil pretreatment	Bioheavy-input for transesterification	35		
Municipal waste	Mass burn waste conditioning	Waste solid	9.21		
Industrial waste	Mass burn waste conditioning	Waste solid	16.7		

Industrial waste	Refuse derived fuel preparation	Waste solid	16.7		
Wood biomass	Wood logging	Large and small scale solid	19		
Wood biomass	Pelletising	Large and small scale solid	19		

Table 7: GLOBIOM technologies.

Feedstock	Process	Product	Energy value GJ/t(m3) feedstock	Bioengy CO2	CO2 savings in kg per GJ
Wood	Gasification	Methanol	3.375		
Wood	Gasification	Heat	0.375		
Wood	Fermentation	Ethanol	2.175		
Wood	Fermentation	Heat	1.725		
Wood	Fermentation	Electricity	0.953		
Wood	Fermentation	Gas	1.373		
Wood	Combustion	Heat	5.4		
Wood	Combustion	Electricity	2.7		
Corn	CornToEthol	Ethanol	7.9	-0.28	35.6
Sugar Cane	SugcToEthol	Ethanol	1.75	-0.11	60.0
Wheat	WheaToEthol	Ethanol	9.9	-0.24	24.2
Soya	SoyaToFame	FAME	5.9	-0.23	38.8
Palm oil	OpalToFame	FAME	10.7	-0.42	39.6
Rape seed	RapeToFame	FAME	14.4	-0.59	41.2

More conversion factors

Table 8: General parameters.

	GJ	MWh	tce	toe	bbl
GJ	1	0.278	0.034	0.024	0.176
MWh	3.60	1	0.122	0.086	0.632
tce	29.31	8.148	1	0.703	5.155
toe	41.87	11.64	1.424	1	7.299
bbl	5.694	1.583	0.194	0.137	1
m3 wood				4.65	
t biomass				2.325	

Costs

Table 9: Feedstock costs.

Biomass type	Feedstock	Included costs	Model/tool
Forestry biomass	Fellings	Planting: land preparation, saplings transport, planting and fertilization	GLOBIOM
		Harvest: logging and extraction depending on slope and tree size	GLOBIOM

Wood	Fellings and logging	Cutting, collecting, transportation	PRIMES Biomass
Wood	Residues (Thinning wood, tops & small branches)	Cutting, collecting, transportation	PRIMES Biomass
		Transport	
Energy crops	Woody energy crops	Planting: land preparation, saplings transport, planting and fertilization	GLOBIOM
		Harvest: logging and extraction	GLOBIOM
	Lignocellulosic crops	Cultivation, land renting, labour, fertilizers, pretreatment	PRIMES Biomass
	Starch crops	Cultivation, land renting, labour, fertilizers, pretreatment	PRIMES Biomass
	Sugar crops	Cultivation, land renting, labour, fertilizers, pretreatment	PRIMES Biomass
	Oil crops	Cultivation, land renting, labour, fertilizers, pretreatment (including: extraction, pressing etc)	PRIMES Biomass
Agricultural residues to be used as feedstock for the final transformation technologies	Agricultural residues	Packaging, transportation and handling	PRIMES Biomass
Black Liquor	Industrial pulp	Separation from pulp waste	PRIMES Biomass
Waste	Wood waste	Collecting, transportation	PRIMES Biomass
	Industrial solid biomass	Pretreatment, transportation	PRIMES Biomass
	Municipal solid	Collecting, pretreatment	PRIMES Biomass
	Waste oil	Collecting, pretreatment	PRIMES Biomass
	Sewage sludge	Collecting, transportation	PRIMES Biomass
	Landfill gas	Collecting, transportation	PRIMES Biomass
	Manure	Collecting, transportation	PRIMES Biomass
	Animal waste	Collecting, transportation	PRIMES Biomass

Table 10: Processing costs.

Feedstock	Technology	Included costs	Model/tool
	Gasification	Processing	PRIMES Biomass
…	FT synthesis	Processing	PRIMES Biomass
	Transesterification	Processing	PRIMES Biomass
	Fermentation sugar	Processing	PRIMES Biomass
	Fermentation starch	Processing	PRIMES Biomass
	Fermentation lign.	Processing	PRIMES Biomass
	Hydro thermal upgrade	Processing	PRIMES Biomass
	Hydro deoxygenation	Processing	PRIMES Biomass
	Pyrolysis	Processing	PRIMES Biomass
	Anaerobic Digestion	Processing	PRIMES Biomass
	In-situ gas conditioning	Processing	PRIMES Biomass
	Oil pretreatment	Processing	PRIMES Biomass
	Mass burn waste conditioning	Processing	PRIMES Biomass
	Refuse derived fuel preparation	Processing	PRIMES Biomass
	Wood logging	Processing	PRIMES Biomass
	Pelletising	Processing	PRIMES Biomass

Country list

Table 11: country list.

Country	GLOBIOM Region	Group	Group2
Austria	EU Mid West	EU-15	EU-27
Belgium	EU Mid West	EU-15	EU-27
Bulgaria	EU Central East	EU-2	EU-27
Switzerland	ROWE (Rest of Western Europe)	non-EU	non-EU
Czech Republic	EU Central East	EU-10	EU-27
Croatia	RCEU (Rest of Central Europe)	non-EU	non-EU
Cyprus	EU South	EU-10	EU-27
Denmark	EU North	EU-15	EU-27
Estonia	EU Baltic	EU-10	EU-27
Finland	EU North	EU-15	EU-27
France	EU Mid West	EU-15	EU-27
Germany	EU Mid West	EU-15	EU-27
Greece	EU South	EU-15	EU-27
Hungary	EU Central East	EU-10	EU-27
Ireland	EU North	EU-15	EU-27
Italy	EU South	EU-15	EU-27
Latvia	EU Baltic	EU-10	EU-27
Lithuania	EU Baltic	EU-10	EU-27
Luxembourg	EU Mid West	EU-15	EU-27
Malta	EU South	EU-10	EU-27
Netherlands	EU Mid West	EU-15	EU-27
Norway	ROWE	non-EU	non-EU
Poland	EU Central East	EU-10	EU-27
Portugal	EU South	EU-15	EU-27
Romania	EU Central East	EU-2	EU-27
Slovakia	EU Central East	EU-10	EU-27
Slovenia	EU Central East	EU-10	EU-27
Spain	EU South	EU-10	EU-27
Sweden	EU North	EU-15	EU-27
Turkey	Turkey	non-EU	non-EU
United Kingdom	EU North	EU-15	EU-27
Ukraine	Former USSR	non-EU	non-EU

GLOBIOM data sources

Table 12: Sources of parameters used in GLOBIOM.

PARAMETER	SOURCE	YEAR
Land characteristics		
Soil Classes	ISRIC	
Slope Classes		
Altitude Classses	SRTM 90m Digital Elevation Data (http://srtm.csi.cgiar.org)	
Country Boundaries		
Aridity Index	ICRAF, Zomer at al. (2009)	
Temperature threshold	European Centre for Medium Range Weather Forecasting (ECMWF)	
Protected area	FORAF	
Land cover	Global Land Cover (GLC 2000)- Institute for Environment and Sustainability	2000
Agriculture		
Area		
Cropland area (1000 ha)	Global Land Cover (GLC 2000)- Institute for Environment and Sustainability	2000

PARAMETER	SOURCE	YEAR
EPIC crop area (1000 ha)	IFPRI- You and Wood (2006)	2000
Cash crop area (1000 ha)	IFPRI- You, Wood, Wood-Sichra (2007)	2000
Irrigated area (1000 ha)	FAO	average 1998-2002
Yield		
EPIC crop yield (T/ha)	BOKU, Erwin Schmid	
Cash crop yield (T/ha)	IFPRI- You, Wood, Wood-Sichra (2007)	2000
Average regional yield (T/ha)	FAO	average 1998-2002
Input use		
Quantity of nitrogen (FTN) (kg/ha)	BOKU, Erwin Schmid	
Quantity of phosphorous (FTP)(kg/ha)	BOKU, Erwin Schmid	
Quantity of water (1000 m3/ha)	BOKU, Erwin Schmid	
Fertilizer application rates	IFA (1992)	
Fertilizer application rates	FAOSTAT	
Costs for 4 irrigation systems	Sauer et al. (2008)	
Production		
Crop production (1000 T)	FAO	average 1998-2002
Livestock production	FAO	average 1998-2002
Prices		
Crops (USD/T)	FAO	average 1998-2002
Fertilizer price (USD/kg)	USDA (http://www.ers.usda.gov/Data/FertilizerUse/)	average 2001-2005
Forestry		
Maximum share of saw logs in the mean annual increment (m3/ha/year)	Kinderman et al. (2006)	
Harvestable wood for pulp production (m3/ha/year)	Kinderman et al. (2006)	
Mean annual increment (m3/ha/year)	Kinderman et al. (2008) based on the Global Forest Resources Assessment (FAO, 2006a)	
Biomass and Wood production (m3 or 1000 T)	FAO	2000
Harvesting costs	Kinderman et al. (2006)	
Short rotation plantation	Havlik et al. (2010)	
Suitable area (1000 ha)	Zomer at al. (2008)	2010
Maximum Annual Increment (m3 per ha)	Alig et al., 2000; Chiba and Nagata, 1987; FAO, 2006b; Mitchell, 2000; Stanturf et al., 2002; Uri et al., 2002; Wadsworth, 1997; Webb et al., 1984	
Potential NPP	Cramer et al. (1999	
Potentials for biomass plantations	Zomer at al. (2008	
Sapling cost for manual planting	(Carpentieri et al., 1993; Herzogbaum GmbH, 2008).	
Labour requirements for plantation establishment	Jurvélius (1997),	
Average wages	ILO (2007).	
Unit cost of harvesting equipment and	FPP, 1999; Jiroušek et al., 2007; Stokes et al., 1986; Wang et al., 2004	

PARAMETER	SOURCE	YEAR
labour		
Slope factor	Hartsough et al., 2001	
Ratio of mean PPP adjustment	Heston et al., 2006	
GHG emissions		
N2O emissions from application of synthetic fertilizers (kg CO2/ha)	IPCC Guidelines, 1996	
Fertilizer application rates	IFA, 1992	
CO_2 savings/emission coefficients	CONCAWE/JRC/EUCAR (2007) , Renewable Fuels Agency (2008)	
Above and below-ground living biomass in forests[tCO2eq per ha]	Kindermann et al. (2008)	
Above and below ground living biomass in grassland and other natural land [tCO2eq per ha]	Ruesch and Gibbs (2008) (http://cdiac.ornl.gov/epubs/ndp/global_carbon/carbon_documentation.html)	
Total Non-Carbon Emissions (Million Metric CO2-Equivalent)	EPA, 2006	
Crop Carbon Dioxide Emissions (Tons CO2 / hectare)	EPA, 2006	
GHG sequestration in SRP (tCO2/ha)	Chiba and Nagata, 1987;	
International Trade		
MacMap database	Bouet et al., 2005	
BACI (based on COMTRADE)	Gaulier and Zignago, 2009	
International freight costs	Hummels et al., 2001	
Process		
Conversion coefficients for sawn wood	4DSM model - Rametsteiner et al. (2007)	
Conversion coefficients for wood pulp	4DSM model - Rametsteiner et al. (2007)	
Conversion coefficients and costs for energy	Biomass Technology Group, 2005; Hamelinck and Faaij, 2001; Leduc et al., 2008; Sørensen, 2005	
Conversion coefficients and costs for Ethanol	Hermann and Patel (2008)	
Conversion coefficients and costs for Biodiesel	Haas et al. (2007)	
Production costs for sawn wood and wood pulp	internal IIASA database and RISI database (http://www.risiinfo.com)	
Population		
Population per country (1000 hab)	JRC Sevilla, POLES, Russ et al. (2007) *updated*	average 1999-2001
Estimated total population per region every ten years between 2000 and 2100 (1000 hab)	GGI Scenario Database (2007)- Grubler et al.	
0.5 degree grid	GGI Scenario Database (2007)- Grubler et al.	
Population density	CIESIN (2005).	
Demand		

PARAMETER	SOURCE	YEAR
Initial food demand for crops (1000 T)	FBS data - FAO	average 1998-2002
Initial feed demand for crops (1000 T)	FBS data - FAO	average 1998-2002
Crop requirement per animal calories (T/1 000 000 kcal)	Supply Utilisation Accounts, FAOSTAT	average 1998-2002
Crop energy equivalent (kcal/T)	FBS data - FAO	
Relative change in consumption for meat, anim, veg, milk (kcal/capita)	FAO(2006) World agriculture: towards 2030/2050 (Tables: 2.1, 2.7, 2.8)	
Own price elasticity	"International Evidence on Food Consumption Patterns", James Seale, Jr., Anita Regmi, and Jason A. Bernstein, Technical Bulletin No. (TB1904) 70 pp, October 2003	
GDP projections	GGI Scenario Database (2007)	
SUA data for crops (1000 tones)	FAO	
FBS data	FAO	
Bioenergy projections	JRC Sevilla, POLES, Russ et al. (2007) *updated*	
Biomass and Woodconsumption (m3/ha or 1000 T/ha)	FAO	