



Guidelines for data collection to estimate and monitor technical and sustainable biomass supply

Deliverable 2.2 of the Biomass Policies project

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List of Abbreviations

BEE Biomass Energy Europe project

BL Black Liquor

BMW Biodegradable Municipal Waste

CAP Common Agricultural Policy

CAPRI Common Agricultural Policy Regionalised Impact model

CEEC Central and Eastern European Countries

CLC CORINE Land Cover

CO₂ Carbon dioxide emission (a greenhouse gas)

CORINE Coordination of Information on the Environment

DEM Digital Elevation Model

DM Dry matter

EC European Commission

EEA European Environment Agency

EO Earth Observation

EU European Union

Eurostat Statistical institute of the EU

FADN Farm Accountancy Data Network

FAO Food and Agriculture Organisation of the United Nations

GAINS **G**reenhouse Gas and **A**ir Pollution **I**nteractions and **S**ynergies

GHG Greenhouse gas

GIS Geographic Information Systems

GJ GigaJoule

GLOBIOM Global Biomass Optimization Model

GMES Global Monitoring for Environment and Security

Ha Hectare

HNV High Nature Value

IPCC Intergovernmental Panel on Climate Change

Ktoe Kilo Tonnes Oil Equivalents

LHV Lower heating value

LU Livestock Unit

MSW Municipal Solid Waste

Mtoe Million tonnes of oil equivalent

NUTS Nomenclature of Territorial Units for Statistics

PRIMES Energy System Model

RESolve RESolve model kit consists of 3 models: RESolve-E (Electricity), RESolve-T (Transport model) and RESolve-H (heat)

RES Renewable Energy Sources

RS Remote Sensing

SOC Soil Organic Carbon

SRC Short rotation coppice

SRF Short Rotation Forestry

Toe Tonnes of oil equivalent

UNFCCC United Nations Framework Convention on Climate Change

Summary

This report is aimed at providing practical guidelines to policy makers and also commercial actors to make realistic estimates of technical and sustainable biomass potentials at national and regional levels. It presents the guidelines for identifying, quantifying and monitoring biomass resources in EU countries and regions for bioenergy and wider bioeconomy uses and the sustainability risks related to their production and non-food uses. The report will especially focus on providing information on how to assess technical and sustainable potentials in relation to type of information required, potential sources of data, calculation of biomass potentials, biomass conversion ratios, different approaches to assessing biomass potentials and main known competing uses and sustainability risks. It will also guide the reader to the key studies already done to assess biomass potentials and on sustainability risks of producing and harvesting biomass for non-food uses.

In the following table a summary overview is provided of the biomass types covered, the recommended approaches to quantify the potential, the main data sources needed and the relevant studies and publications to take into account and the key sustainability issues to take into account for the technical sustainable potential assessment.

Table 1 Summary of main approaches, data and model needs, relevant projects and sustainability risks per biomass type covered in this study

Group III	Type of biomass	General methodology for quantification of potential	Main data sources/models	Relevant studies/projects	Main sustainability aspects
Sugar & starch crops	Cereals	Statistical/modeling	Eurostat and national agricultural crop and land use statistics. Models like CAPRI, GLOBIOM, AGLINK-COSIMO, POLES, RAUMIS, CLUE etc.	4Fcrops, S2BIOM, FIBRA, OPTIMA, Crops2Industry, Crops2water	Competition with food & feed production, ILUC, negative effects on biodiversity if it leads to land use intensification, loss of (semi) natural areas, increased irrigation water use.
	Sugarbeet				
	Grain maize				
Oil crops	Rape				
	Sunflower				
	Soya				
Forrage crops	Fodder maize				
	Grass				
Woody/ ligno cellulosic crops	Miscanthus	Statistical/modeling	Eurostat and national agricultural crop and land use statistics. Models like GLOBIOM, CLUE, LUISA etc.	4Fcrops, S2BIOM, FIBRA, OPTIMA, Crops2Industry, Crops2water	Risk for loss of semi-natural farmland habitats, direct land use and landscape structural changes which can have negative but also positive impacts for biodiversity
	Switchgrass				
	Reed Canary Grass				
	Poplar				
	Willow				
Solid manure	Poultry	Statistical/modelling	Eurostat and national agricultural statistics, GAINS, FADN, SAPM	BEE, BIOBOOST	Limited risks
	Cattle				

Group III	Type of biomass	General methodology for quantification of potential	Main data sources/models	Relevant studies/projects	Main sustainability aspects
	Pig				
	Sheep & goats				
Liquid manure	Poultry	Statistical/modelling	Eurostat and national agricultural statistics, GAINS, FADN, SAPM	BEE, BIOBOOST	Limited risks
	Cattle				
	Pig				
	Sheep and goats				
Straw/ stubbles	Cereals	Statistical/modelling	Eurostat and national agricultural crop and yield statistics. CESAR, CENTURY, MITERRA	Scarlat et al., 2010, ECOFYS (Spöttle, 2013) , BEE, BIOBOOST (Pudelko,et al., 2014)	Loss of SOC and nutrients at too high straw removal rates.
	Rape-sunflower				
	Rice				
	Grain maize (stover)				
	Sugarbeet leaves & tops				
Pruning/ cutting	Apple, pear & apricot pruning	Statistical/modelling	Eurostat and national agricultural crop and yield statistics.	EUpruning	Loss of SOC and nutrients at too high residue removal rates
	Cherries and other soft fruits				
	Vineyards				

Group III	Type of biomass	General methodology for quantification of potential	Main data sources/models	Relevant studies/projects	Main sustainability aspects
	Olives				
	Citrus				
	Nut trees				
Olive pits	Olive pits	Statistical	Eurostat and national crop statistics, literature	-	-
Other agro-industrial residues	Other vegetal industrial residues	Statistical	Eurostat and national crop statistics, literature	BEE, BIOBOOST	Competition with animal feed
Other agro-industrial residues	Other organic industrial residues				
Stemwood	Stemwood	Statistical, GIS analysis and modelling	National forest inventory data, FAOSTAT, models like EFISCEN, GLOBIOM, EFI-GTM	EUwood, EFSOSII, BEE	Soil quality loss, biodiversity risks, Carbon debt
Primary residues	primary residues	Statistical, GIS analysis and modelling	National forest inventory data, FAOSTAT, models like EFISCEN, GLOBIOM, EFI-GTM	EUwood, EFSOSII, BEE	Soil quality loss, biodiversity risks, Carbon debt

Group III	Type of biomass	General methodology for quantification of potential	Main data sources/models	Relevant studies/projects	Main sustainability aspects
Secondary residues	Sawmill by-products (excl saw dust)	Statistical	FAOSTAT, EUwood	EUwood, EFSOSII, BEE	Competition
	Sawdust				
	Other industrial residues				
	Black liquor				
Landscape care wood	Landscape care wood	GIS analysis	Land use and land cover high resolution data	EUwood, EFSOSII, BEE	Biodiversity risk when too intensively managed
Road side verge grass	Road side verge grass	GIS analysis	Road network data	Biomass Futures	-
Household waste	Paper cardboard	Statistical/modelling	Eurostat and national waste statistics	BEE, ARCADIS (2009)	Competition
	Wood waste				
	Animal & mixed food waste				
	Vegetal waste				
	Municipal solid waste (MSW)				
	Common sludge				
Waste from other sectors than households	Paper cardboard				
	Wood waste				
	Animal & mixed food waste				
	Vegetal waste				
	Municipal solid waste (MSW)				
	Common sludge				
	Used fats and oils (UFO)				

1 Introduction

Biomass Policies is a project supported by the Intelligent Energy for Europe programme. The project aims to impact Member States' policies to improve the policy conditions/framework for the mobilisation of indigenous resource efficient bioenergy value chains in order to contribute towards bioenergy targets for 2020 and 2030. The focus is on the countries participating in the project, namely Austria, Belgium, Germany, Greece, Spain, Croatia, the Netherlands, Poland, Slovakia, the UK and Finland.

Aim of this report is to provide practical guidelines to policy makers and also commercial actors to make realistic estimates of technical and sustainable biomass potentials at national and regional levels. It presents the guidelines for identifying, quantifying and monitoring biomass resources in EU countries and regions for bioenergy and wider bioeconomy uses and the sustainability risks related to their production and non-food uses. It is particularly aimed at providing guidelines for data collection and analysis to estimate and monitor the technical biomass potential at regional and national level. The guidelines were developed in Tasks 2.1 (Key biomass availability) and 2.2 (Value chains and competing pathways) of the Biomass Policies project. The approach of the assessments and the information derived on data sources, availability and assessment approaches is formalised in guidelines that can be repeated by others in other regions. The report will especially focus on providing information on how to assess technical and sustainable potentials in relation to type of information required, potential sources of data, calculation of biomass potentials, biomass conversion ratios, different approaches to assessing biomass potentials and main known competing uses and sustainability risks. It will also guide the reader to the key studies already done to assess biomass potentials and on sustainability risks of producing and harvesting biomass for non-food uses.

Structure of the report:

- The second chapter describes the different types of biomass potentials, it provides an overview and definitions of the different types of biomass covered in this report and in the Biomass Policies project and a detailed description of the way to assess the base technical-sustainable potential for the analysis and monitoring of biomass potentials.
- The third chapter describes the approach to assessing the agricultural biomass types. It will systematically describe the identification of the technical potential, key data to use, the main sustainability considerations to take into account to assess the sustainable potential and it will provide an overview of the main known current uses. While doing so it will especially provide references to important publications where further details and guidelines can be obtained.
- The fourth chapter provides an overview of the assessment of biomass potentials from the forest sector structured in the same way as for the agricultural biomass in chapter 3.
- The last chapter describes the approach to assessing the biomass potentials from the waste sector again following the same structure as for chapters 3 and 4.

2 A typology of biomass potentials

2.1 Introduction

Several biomass potential studies have been done in the last decades. Their approaches have been very different and their results difficult to compare and interpret. The BEE study was developed in response to this¹. It provides a wide overview of state-of-the-art biomass resource assessments and it also proposes several generic approaches, definitions, conversions and a classification of biomass feedstock types in order to improve the accuracy and comparability of future biomass resource assessments (Retenmaier et al., 2008 and Vis et al., 2010). In the Biomass Futures project a biomass cost-supply atlas was already prepared incorporating the BEE principles. Like in the Biomass Futures project also in this Biomass Policies project we will build as much as possible on the state-of-the-art overview of biomass assessment studies provided by BEE and as much as possible on the same biomass classifications and definitions of potentials.

The guidelines for biomass potential assessment presented in this report will link to what is regarded as the technical-sustainable potential also applied to generate the potentials for the baseline scenario as presented in D2.3 of this study. In the following first an overview is given of the types of biomass this report covers, followed by an explanation of different scenario definitions. In the last section an explanation is given of the central approach to assessing base potentials for which the guidelines in this report are elaborated per biomass type.

2.2 Biomass types and definitions

Based on the Biomass Futures study an initial overview and quantification of biomass cost supply was made building on the typology and definitions elaborated in the BEE project. In the Biomass Policies an up-date is made of the biomass cost-supply assessment for the EU improving further the biomass definitions, data input and increasing the spatial resolution of the assessment. In this report the guidelines are presented to assess the biomass potential for the main biomass categories for both agriculture, forestry and waste sectors in order to propose a standardized approach to be repeated by practitioners working in the field of biomass valorisation for non-food purposes. In this report we will also refer as much as possible to other recent biomass potential assessment studies for the whole EU or certain member states.

An overview of the biomass types, their classification and their definitions under focus in this report is provided in Table 2.1. The classification is further refinement of the BEE and Biomass Futures classification in that it links more strongly to the main statistical data sources the technical potential needs to be based on.

The Biomass types are grouped in 3 hierarchical levels and an additional qualifier has been added linking the biomass type to a crop or land use type for the biomass from agriculture. For the forest biomass types an additional qualifier is introduced linking it to specific harvesting and production processes producing different residues.

¹ See BEE project website: <http://www.eu-bee.com/>

For the biomass from waste the main classifying principle is whether it is produced by households or by other economic actors. A further classification has been applied according to waste separation practices and the way these are registered in Eurostat statistics.

In addition to the classification information is added on the type of biomass in terms of where it is available, e.g. field, farm, plant and in relation to whether it is a bulk biomass or whether it is a good of some standardized quality for which a developed market is already there and thus can be called a commodity. This information is relevant as it provides understanding on the additional cost to be in relation to transport and pre-treatment. Biomass concentrated in larger units like at production plants/mills require lower collection cost and biomass that is already a commodity can be handled and stored according to existing logistical arrangements which has advantages. The disadvantage of a commodity is however that there is already a developed market demand for it which also implies competition and a higher price level. E.g. straw is a commodity with a well-developed demand and market in many countries of the EU, although not all, which leads to high prices particularly in countries where demand is higher than supply (e.g. Netherlands).

Table 2.1 Overview of biomass categories and their definitions

Group I	Group II	Group III	Type of biomass	Definition
Biomass from agriculture	Energy crops	Sugar & starch crops	Cereals	Grains from soft wheat, durum wheat, barley, oats, rye and other cereals grown on existing agricultural lands, usually in rotation with other crops and in competition with other food and feed crops. Cereal grains consist largely of carbohydrates (around 60% on dry basis)
			Sugarbeet	Sugar beet is the root from the sugarbeet plant. It contains water, sugar (between 12%-21%) and pulp. It's a crop with the highest amount of fermentable sugars per hectare. Sugarbeet is a cash crop grown in rotation with other crops (e.g. grains, potatoe). It only grows in temperate climates on good agricultural lands. It competes with other food and feed crops.
			Grain maize	Grains of the grain maize plant grown on existing agricultural lands, usually in rotation with other crops. Grain maize mostly grows in most parts of central and southern Europe. It's a C4 plant and therefore not suitable for production in Northern latitudes as seeds need to be well developed before the plant is killed by frost. Maize grains consist largely of carbohydrates (around 60% on dry basis) and worldwide it's currently the main source of bioethanol (1G), although not in Europe.
		Oil crops	Rape	Grains from rape, sunflower and soya grown on existing agricultural lands, usually in rotation with other crops and in competition with other food and feed crops. Oil seed grains consist largely of oil which are the main feedstock for biodiesel
			Sunflower	
			Soya	
		Forage crops	Fodder maize	Fodder crops generally grown to feed to animals, but also for the use in digestion installations to produce biogas.
			Grass	
		Woody/ ligno cellulosic crops	Miscanthus	Ligno-cellulosic perennial crops grown on existing agricultural lands, but also suitable to be grown on lower quality lands that can be defined as 'marginal' and abandoned lands. These perennials are produced plantations have a lifetime of 15 to 20 years and the biomass harvest takes place at a yearly basis starting from the 2nd year onwards. The yield consists of the whole plant which grows back every year when cut off just above the ground.
			Switchgrass	
			Reed Canary Grass	
			Poplar	Woody crops grown on existing agricultural lands, but also suitable to be grown on lower quality lands that can be defined as 'marginal' and abandoned lands. These crops are perennials grow in a short rotation coppice system which implies that their plantations have a lifetime of around 20 years and the biomass harvest takes place every 3 years usually from the 3rd year onwards. The yield consists of the whole plant which grows back every 3 years until harvested again.
			Willow	
	Manure	Solid manure	Poultry	Solid manure produced in stables and mixed with straw. The manure needs to be removed from the stable by hand or tractor and collected.
			Cattle	
			Pig	
			Sheep & goats	
		Liquid manure	Poultry	Liquid manure produced in stables in which the manure is converted to slurry and stored in liquid manure storage tanks.
			Cattle	
			Pig	
			Sheep and goats	
	Primary residues	Straw/ stubbles	Cereals	

Group I	Group II	Group III	Type of biomass	Definition
				Dried stalks of cereals (including rice), rape and sunflower which are separated from the grains during the harvest. Often these are (partly) left in the field.
			Rape-sunflower	
			Rice	
			Grain maize (stover)	Corn stover consists of the leaves, stalks and empty cobs of grain maize plants left in a field after harvest
			Sugarbeet leaves & tops	The sugareet leaves and tops are the harvest residues separated from the main product, the sugar beet, during the harvest and (often) left in the field.
		Pruning/ cutting	Apple, pear & apricot pruning	The prunnings and cuttings of fruit trees, vineyards, olives and nut trees are woody residues often left in the field (after cutting, mulching and chipping). They are the result of normal pruning management needed to maintain the orchards and enhance high production levels.
			Cherries and other soft fruits	
			Vineyards	
			Olives	
			Citrus	
			Nut trees	
	Secondary residues using agricultural products	Olive pits	Olive pits	Olive pits are separated from the rest of the olives when these are processed for making olive oil or when processed to tale olives
		Other agro-industrial residues	Other vegetal industrial residues	Agro-industries process primary agricultural products into final products through peeling, crushing, drying, etc. and in this results in many vegetal residues (e.g. soya and rape cake, seed husks, etc.).
		Other agro-industrial residues	Other organic industrial residues	The processing of animal products in slaughterhouses goes together with large amounts of organic residues such as bones and fats which are not always suitable for human or animal consumption and can be treated as residues for other nonfood/feed purposes.
Biomass from forestry	Stemwood	Stemwood	Stemwood	Stemwood from thinnings and final fellings 1. Current stem wood harvests 2. Currently unused stem wood production potential
	Primary residues	Primary residues	primary residues	1) Early thinning stems 2) Early thinnings crown incl fuelwood 3) Logging residues of final fellings 4) Logging residues thinnings 5) Stump extraction final felling (only where removal of these is common practice, e.g. mostly in Scandinavia) 6) Stump extraction thinnings (only where removal of these is common practice, e.g. mostly in Scandinavia)
		Secondary residues	Sawmill by-products (excl saw dust)	These consist of bark, slabwood and offcuts . Bark is removed from the stemwood after delivered to the sawmill. Slabwood consists of the long rounded sides of the logs that are sawn off the outside in order to produce the main wood products (planks). Slabwood can be available intact as paticles or as chips. Offcuts are generated during the sawmilling process, through cutting off edges and trimming of planks

Group I	Group II	Group III	Type of biomass	Definition
				and to correct length or to take out defects., usually these offcuts are chipped.
			Sawdust	Sawdust is produced in sawmills when stemwood is cut into planks and other sawmill products. The sawdust is collected to be used in other processes.
			Other industrial residues	Cover all residues produced in wood industries including wood-based panel industry, furniture, (wood)construction material and packaging industry. These residues consist of sawdust, shavings, trimmings, rejections, peeler cores or square-cuttings.
			Black liquor	Black liquor is a by-product from the production of wood pulp for paper making. The pulping process residues mainly consist of lignin and hemicelluloses, cooking chemicals (for pulping) and water. Black liquor results from chemical pulping processes when wood is cooked with appropriate chemicals to separate cellulose fibres from lignin and other wood components.
Biomass from waste	Landscape	Landscape care wood	Landscape care wood	Biomass from trees/hedges outside forests incl. landscape elements& excluding road side verges
		Road side verge grass	Road side verge grass	Herbaceous biomass from road sides.
		Household waste	Paper carboard	These are used paper and cardboard from separate sorting by households.
			Wood waste	These wastes are separately collected wood waste from household. They can be hazardous when containing hazardous substances like mercury or tar-based wood preservatives, which makes it only suitable for incineration and not recycling.
			Animal & mixed food waste	These are animal and mixed wastes from separately collected biodegradable kitchen and canteen waste, and edible oils and fats.
			Vegetal waste	These wastes are vegetal wastes from separate collection from households.
			Municipal solid waste (MSW)	Household and similar wastes are mixed municipal waste, bulky waste, street-cleaning waste like packaging, kitchen waste, and household equipment except separately collected fractions. They originate mainly from households but can also be generated by all sectors in canteens and offices as consumption residues.
			Common sludge	See underneath NACE 'common sludges'
		Waste from other sectors then households	Paper carboard	These wastes are paper and cardboard from sorting and separate sorting by businesses (and households). This category includes fibre, filler and coating rejects from pulp, paper and cardboard production. These wastes are largely generated by three activities: separate collection, mechanical treatment of waste and pulp, and paper and cardboard production and processing. All paper and cardboard wastes are non-hazardous.
			Wood waste	These wastes are wooden packaging, wood from the construction and demolition of buildings; and separately collected wood waste from household and industries. They mainly originate from households, the demolition of buildings but can occur in all sectors in lower quantities due to wooden packaging. Wood wastes are hazardous when containing hazardous substances like mercury or tar-based wood preservatives, which makes it only suitable for incineration and not recycling.
			Animal & mixed food waste	These are animal and mixed wastes from food preparation and products, including sludges from washing and cleaning; separately collected biodegradable kitchen and canteen waste, and edible oils and fats. They originate from food preparation and production (agriculture and manufacture of food and food products) and from separate collection. Animal and mixed waste of food preparation and products are non-hazardous.
			Vegetal waste	These wastes are vegetal wastes from food preparation and products, including sludges from washing and cleaning, materials unsuitable for consumption and green wastes. They originate from food and beverage production, and from agriculture, horticulture and forestry. Vegetal wastes are non-hazardous.

Group I	Group II	Group III	Type of biomass	Definition
			Municipal solid waste (MSW)	See MSW from HH above.
			Common sludge	These are waste water treatment sludges from municipal sewerage water and organic sludges from food preparation and processing. They mainly originate from households and industrial branches with organic waste water (mainly pulp and paper as well as food preparation and processing). They can also occur in waste water treatment plants or in the anaerobic treatment of waste. All common sludges are non-hazardous. Comparability can be problematic between countries using different statistical units as they will not assign the waste to the same economic sector.
			Used fats and oils (UFO)	Used animal fats and vegetal oils.

2.3 Types of potentials and approach for estimating potentials in Biomass Policies

Following the BEE assessment (Retenmaier et al., 2008 and Vis et al., 2010), four types of biomass potentials are commonly distinguished (see Table 2.2).

Table 2.2 Types of biomass potentials according to BEE (Torén, J. et al., 2011)

Type of potential	Definition
Theoretical potential	<i>Is the overall maximum amount of terrestrial biomass which can be considered theoretically available for bioenergy production within fundamental bio-physical limits. In the case of biomass from crops and forests, the theoretical potential represents the maximum productivity under theoretically optimal management taking into account limitations that result from soil, temperature, solar radiation and rainfall. In the case of residues and waste, the theoretical potentials equal the total amount that is produced.</i>
Technical potential	<i>Is the fraction of the theoretical potential which is available under the regarded technological framework conditions with the current technological possibilities (such as harvesting techniques, infrastructure and accessibility, processing techniques). It also takes into account spatial confinements due to other land uses (food, feed and fibre production) as well as ecological (e.g. nature reserves) and possibly other non-technical constraints.</i>
Economic potential	<i>Is the share of the technical potential which meets criteria of economic profitability within the given framework conditions.</i>
Implementation potential	<i>Is the fraction of the economic potential that can be implemented within a certain time frame and under concrete socio-political framework conditions, including economic, institutional and social constraints and policy incentives. Studies that focus on the feasibility or the economic, environmental or social impacts of bioenergy policies are also included in this type.</i>
Sustainable implementation potential	<i>It the result of integrating environmental, economic and social sustainability criteria in biomass resource assessments. This means that sustainability criteria act like a filter on the theoretical, technical, economic and implementation potentials leading in the end to a sustainable implementation potential. Depending on the type of potential, sustainability criteria can be applied to different extents.</i>

In this study and this report the focus will be on the **technical and sustainable potential**. The guidelines presented here will focus on identifying the amount of biomass that can technically be produced, harvested and collected given known technical limitations and linking as much as possible to what is current or near future practice given state-the-art technologies.

For the guidelines regarding sustainable biomass potential assessment the focus in this report will be on environmental and ecological sustainability criteria rather than social criteria. For consideration of the full suite of sustainability criteria, including for resource efficiency, we refer to another Biomass Policies deliverable which is D2.6: *Guidelines and a set of technical- economic & environmental related indicators for resource efficient biomass value chains*. The reason to address the wider sustainability criteria in a separate deliverable is because many of the criteria to define the full sustainable implementation potential need to be assessed through the full biomass delivery chain (from biomass source to end-use of the biomass product) and not only with respect to the biomass supply.

The guidelines presented in this report therefore apply to the technical-environmentally sustainable biomass potential for wider bioeconomy uses. So it will refer to any biomass available for non-food

uses which can be produced and harvested given state-of-the-art technologies and practices and with a low risk of putting any additional pressures on water, soil, air and biodiversity resources.

Guideline will therefore be provided on:

- 1) How to estimate the amount of biomass that can technically be produced, harvested and collected given current state of the art land management practices and machineries.
- 2) What main environmentally and ecological risks are involved when producing and harvesting the biomass and in what way do they constrain the biomass potential.
- 3) How to estimate and exclude the main uses of the biomass for food and feed applications and exclude these from the potential estimates.

The potentials resulting from the guidelines presented in this report should be the basis for practitioners, including policy makers and investors, to filter further according to their own specific economic and socio-political framework conditions. These conditions depend strongly on the specific end-uses these practitioners have for the biomass.

Figure 2.1 Overview of combinations of approaches and methodologies for biomass energy assessment to investigate different types of biomass potentials (copied from BEE report 'Executive summary, evaluation and recommendations' Torren, J. et al., 2011)

General approach	General methodology	Type of biomass potential	
		Theoretical-technical	Economic-implementation
Resource-focussed	Statistical analysis	Yes	No
	Spatially explicit analysis	Yes	No
Demand-driven	Cost-supply analysis	No ^a	Yes
	Energy-economics and energy-system model analysis	No	Yes ^b
Integrated assessment modelling	Integrated assessment model analysis	Yes ^c	Yes

^a Some demand-driven cost-supply analysis start with a statistical analysis or spatially explicit analysis of technical biomass energy potentials, although this is not the key focus of these studies.

^b Some demand-driven energy-economics and energy-system model analysis use the results of cost-supply analysis.

^c IAMs typically focus on the economic and/or implementation potential, although IAMs are also used for the theoretical and/or technical biomass energy potential

In addition to the type of potentials the BEE project also distinguished several methodologies of assessing potentials (see Figure 2.1). The approach presented here can be categorized under the 'Resource-focussed' approach aiming to identify the technical biomass potential using statistical and spatially explicit GIS analysis methods. Approaches to cost-supply assessments are not presented in this report but these are addressed in Deliverable 2.3 of Biomass Policies (Elbersen et al., 2015) in which the approach and results are presented of the cost-supply assessment performed in this project implementing the guidelines presented in this report and making cost and/or price estimates for the different biomass categories outlined in Table 2.1 in this report.

2.3.1 Overall approach for estimating the potentials in Biomass Policies

The guidelines presented in this report for the technical-sustainable potential will follow the following formula:

$$\text{Availability} = \text{Presence} - T1 \text{ (- } T2)$$

Where:

Availability = Biomass availability given what can be produced, harvested and collected with current or near future practices and known given state-the-art technologies and taking account of basic environmental sustainability requirements regarding soil and biodiversity conservation.

Presence = Presence of biomass now (and in future given land use change expectations)

T1 = has to be left behind for soil conservation/biodiversity/erosion control

T2 = conventional known competitive uses (feed and food)

As to the aspect of 'conventional competing uses' the guidelines will provide information on the main feed and food uses every type of biomass might have and how the extend of these can best be assessed in order to subtract these uses before the final non-food biomass potential can be assessed.

For the presentation of the guidelines to estimating the availability of biomass from the different biomass types (presented in Table 2.1) a similar structure will be followed in the next chapters:

- 1) Firstly, it will be described how to assess the total presence of the biomass
- 2) Secondly, it will be explained what the main conventional uses are (T2), and particularly to which extent these are uses for food and feed and how they can be quantified. As to the latter guideline of data availability and methods and models to be used are presented.
- 3) Thirdly, an overview is given of the main sustainability risks are particularly in relation of soil and biodiversity conservation and guidelines will be provided on how to estimate the sustainable biomass potential taking account of these aspects.

3 Estimating agricultural biomass potentials

3.1 Introduction

In this chapter the guidelines are presented for assessing the technical-sustainable biomass potential from the agricultural sector for the categories and definitions presented in Table 2.1 for this sector.

3.2 Dedicated biomass cropping potential

For assessing the potential for dedicated cropped biomass potential the starting point is always the land availability. Generally it can be assumed that land that is suitable for biomass production for non-food purposes may as well be used for the production of food and feed. Current agricultural land use patterns are strongly influenced by a market demand for agricultural products. This demand consists of demand for food, feed and in the last decades also increasingly it is coming from non-food uses, particularly bioenergy but also from the bio-chemical industries producing bio-products. So in order to identify the potential for biomass crops the land availability needs to be assessed first. The identification of land availability is crucial as that determines the amount of hectares that can be cropped and the type of land and infrastructure and thus yielding capacity.

Land demand is however a sensitive issue as it is a scarce resource and many ecosystem services are related to good management of it. Because of this, good estimates of land availability for biomass production for non-food uses cannot be done without taking the complex sustainability risks related into account.

Another important challenge for making a potential assessment for cropped biomass (now and in the future) is that the eventual availability of the biomass is determined by an agricultural market demand and production response. This production response does not distinguish between production for food, feed or energy. So identifying the part in the production produced for non-food uses is complex and requires a lot of information on tracing back where the final feedstock used in processing facilities came from. Also for future cropped biomass assessments complex market simulation models are a requirement. Results in these models are produced at the level of volumes of agricultural products for which it remains a challenge to make a distinction between use for food and feed and for non-food applications (bioenergy and bioproducts), at least at the level of regions and countries as import and export flows also need to be taken into account.

For identifying the land availability for cropped biomass a distinction needs to be made between the type of crop and the type of land demand. Sugar, starch and oil crops, currently mostly used for 1G biofuel production, are food crops and their use for biofuel generation increases the market demand and therefore increases the demand for good agricultural lands. The same applies for forage crops, like maize and grass, used for biogas generation, which leads to an increase in the demand and thus the production of crops on relatively good quality farmlands which are also suitable for food and feed production. The competition for land therefore increases because of increased non-food uses of agricultural products and this goes together with increased pressures on soil and water resources and loss of valuable (semi-)natural habitats. This effect is taken seriously by many groups because bioenergy demand for land comes on top of the already huge land demands that are expected to come

from food (see e.g. Harvey and Pilgrim, 2010; Royal Society, 2009). For further details on sustainability risks see next sections.

On the other hand biomass, lignocellulosic and woody biomass, can also be delivered by perennial crops, e.g. crops that have a lifetime of 15 to 20 years. Their land demand and effect on agricultural markets can be relatively different from that of an annual crop like e.g. rape, sugarbeet or barley. Firstly, because most lignocellulosic and woody crops have lower soil quality requirements than rotational arable crops (e.g. Zegada-Lizarazu, 2010; Varvel et al, 2008; Gelfant et al., 2013 ; Lewandowski, 2014.) If these are grown on lower productive lands, i.e. lands that are not or less suitable for rotational/annual arable crops, acceptable yields can still be reached. Secondly, because these perennials cannot compete (given current and also future price levels for lignocellulosic biomass) with food and feed crops unless low productive soils are involved where perennials may give higher yields and returns. Thirdly, farmers are usually not willing to lose their flexibility by turning their land into long term perennial plantations. After all they want to flexibly respond to market changes. Perennial plantations with a long lifetime of 15 to 20 years do not fit with this preference.

In spite of all complexity related to assessing the land availability and related potential for dedicated crops the key approach for quantification of crop potential is the following formula:

$$\text{Crop potential} = \text{land availability (total hectares)} * \text{yield per hectare (tons biomass/ha)}$$

In the following guidelines will be provided on possible approaches to identifying land availability and yield levels for different biomass crops on high and low productive lands in the different EU regions. This is done first for the arable rotational crops which have generally higher land quality requirements and then for the perennial biomass crops. This is then followed by an overview of main data sources and models to be used for their potential assessment, the main sustainability risks related to cropped biomass and the main (competing) uses.

3.2.1 Potential assessment for annual sugar, starch, oil and forage crops

The most common crops for starch, sugar, vegetal oil in Europe are annual arable crops which implies that these are grown in a rotation system with other arable crops and that they are established (planted or seeded) and harvested in the same year. Crops delivering starch are typically food crops like different types of cereals (e.g. wheat, barley, rye) etc.) and grain maize. The main sugar crop produced at large scale in the EU is sugarbeet, but other less common sugar producing crops produced in the EU territory are sorghum and sugar cane. Cereals, grain maize and sugar beet are the most commonly used feedstocks to produce bioethanol from in Europe. The starch and sugar from these crops also serves as feedstock for the production of other biochemical building blocks or intermediate products, such as butanol, acrylic and adipic acids, iso-butene etc. from which biomaterials and other biochemical products can be made.

Oil crops which are also currently produced and used in the EU for as feedstock for non-food purposes, especially the production of biodiesel, are oil seed rape and sunflower and (although to lesser extend) soya. Like for the conventional starch and sugar crops, oil crops are mostly used and produced for food and feed purposes and in the last 10 to 15 years their production has increased because of the additional demand for vegetal oils for the production of biodiesel. Their use for non-food applications

increases the competition with food and feed crops. Also the vegetable oils extracted from these plants are increasingly becoming used as feedstock for the production of bio-chemical products such as paints and bioplastics.

Perennial crops can also deliver sugar because more technological applications are available to extract sugar from lignocellulosic material. This is further addressed in the next Section (3.2.2) (see also Box 1). The focus in the rest of this Section will be on the conventional arable sugar and starch crops produced at large scale on European arable lands.

For the existing rotation arable crops that are used for food, feed and non-food applications their technical potential ('presence') is mainly dictated by the market demand and the availability of land suitable to produce these crops. Current arable land use patterns are basically the representation of these 2 factors. To estimate the total current presence of sugar, starch and oil crop potentials basic input data are required on land use (number of hectares) for all crop types producing starch, sugar and oil (see Tale 3.1), average yields per hectare and conversion factors to sugar, starch and oil. The results for can be expressed in tons of main products (e.g. grains for cereals, seeds for rape, beets for sugarbeet), starch, sugar or oil content and energy content through conversion into joules using higher (for dry mass) or lower heating factors (for wet biomass/as received).

Table 3.1 Main input factors to calculate the technical potential of starch, sugar and oil crops

Starch, sugar, oil crop	Main crop types	Yield of main crop/hectare	Ratio % starch, sugar and vegetal oil in main product (seeds)
Starch crops	Durum Wheat	All very common crops in Europe with yields varying strongly per EU region. See yield levels in Annex 1.	Starch content (%; on dry basis) is around 60%. For barley 59% and for wheat 65%.
	Soft wheat		
	Barley		
	Rey		
	Oats		
	Grain maize		
Sugar crops	Sugarbeet	Common crop, see yield levels in Annex 1.	Sugar content (%; on dry basis) is 16%. In the EU the average yield in ton sugar per hectare is around 10 ton/ha.
	Sweet sorghum	Not a common crop in the EU, but good prospects for Mediterranean regions. Expected yield levels are between 54-69 ton per hectare*	Sugar content results showed 5-6 ton of sugar per hectare in trial fields in Montpellier
Oil crops	Oil seed rape	Very common crops in Europe with yields varying strongly per EU region. See yield levels in Annex 1.	Oil content per ton seeds is 37% for rapeseeds, 32% for sunflower seeds and 14% for soya.
	Sunflower		
	Soya		
Forage crops suitable for biogas production	Forage maize	Common crops, see yield levels in Annex 1	The whole crop is harvested, so 100% of the biomass can be assumed to be available.
	Grass		

*source is Sweetfuel project: <http://www.sweetfuel-project.eu/project>

For assessing the technical potential there are several approaches possible:

- 1) Extreme approach: Identify the area currently cultivated with the starch, sugar and oil crops in every country and multiply with the yield levels as specified in Annex 1, or better specified in national and regional statistics (for the territory one is focusing on) and convert to the unit

desired (e.g. Kton product, Kton starch, sugar or vegetal oil and Joule). For conversion into joules use the conversion table in Annex 3.

- 2) Implemented potential: This identifies the currently used non-food potential. To assess this first the technical potential as in approach 1 needs to be identified. Secondly, information needs to be collected on which part of this total technical potential is currently and in the future used or needed for food and feed consumption and which part is available for other non-food uses (mostly bioenergy).

A challenge in this approach is how to deal with imports and exports and how to separate these from the domestically produced and consumed and processed products. Some studies applying this approach assume that exports can be diverted to domestic non-food uses (e.g. EEA, 2006).

In this approach one can also take account of future yield improvements leading to lower land requirements per ton product which declines the space needed for feed and food production and 'frees' space for the non-food potential.

- 3) Future technical-economic potential assessment approaches: This requires the identification of future land use change developments taking account of expected market and policies induced changes in food, feed and biomass demands and technological developments in relation to yields and crop management. Such land use changes can only be assessed through economic and integrated modelling approaches. The principal pathways of market response to higher feed-stock demand are higher prices and consequently reduced consumption, but also higher production through higher yields and ultimately an increase in the cultivated area and potentially a reduction in natural vegetation. There is a range of modelling studies already implemented which requires high expertise and specialised assessments. When not having access to such modelling capacities it is recommended to identify modelling studies already done for the region/country of interest and evaluate the outcomes of these in relation to the land availability and biomass crop potential results and key assumptions made. Best is to have access to different modelling study outcomes for the region/country of interest to be able to compare against each other and evaluate which study starts with most realistic assumptions and/or matches best with the existing expectations about future land use changes. For an overview of types of models used to make such assessments see Annex 4.

For the assessment of the potential from rotational arable crops for starch, sugar and vegetal oil in this project we have followed the last approach building on the results of the Capri model. The approach and results of this analysis are presented in D2.3 'Outlook of biomass value chains'. The choice for the CAPRI model assessment results was chosen because it is the key model which predicts the EU markets and production responses at the regional level for the whole EU-28, western Balkans, Turkey and Norway. It is the best source of information available that gives a plausible overview taking account of the specific diverse regional circumstances in the EU, of what land-use changes can be expected by 2020 and 2030 and the extent to which they can be related to dedicated bioenergy cropping for 1G and partly for 2G biofuels. For further details on the further elaboration of the CAPRI model results for assessing the final potentials for sugar, starch and oil crops in 2010, 2020 and 2030 see D2.3 'Outlook of biomass value chains' (Chapter 2).

3.2.2 Woody and lignocellulosic biomass crops

Most perennials have interesting prospects as they have the capacity to still deliver relatively high yields and considerable higher yields of biomass on lands of lower quality than most annual crops, which only give minor non-competitive yields on low quality lands or cannot be cultivated at all. The lower quality lands are usually on the soils that first go out of agricultural use. The reason is usually for abandonment that on these lands yields are too low and cost do not meet the market prices paid for the conventional agricultural products farmers produce. From the CAPRI baseline calculations it becomes apparent that this abandonment of land by agriculture is expected to be quite significant particularly in certain regions in central and southern Europe where land uses in 2010 are significantly larger than in certain regions in 2020 and 2030.

If a market indeed develops for lignocellulosic crops it is likely that the lands that are no longer used for conventional cropping with food and feed crops is partly used for the production of the less demanding crops like Miscanthus, Switchgrass, Arundo Donax (giant reed or reed canary grass) and Short Rotation Coppices (SRC) of willow and poplar. After all most lignocellulosic crops have lower soil quality requirements than rotational arable crops while their biomass yield could be many times higher even on lower quality soils. If they are grown on lower productive lands, at which they do not compete with rotational arable crops (mostly used for food and feed) and acceptable yields can still be reached, their displacement effects are also limited.

Since feedstocks used for biofuel generation and other biochemical processes are commonly used as food and feed crops there is now an increasing interest to develop technologies to extract sugars from lignocellulosic material. This material can come from residues (e.g. straw) and also from less demanding perennial crops grown on more marginal lands. The advantage is that competition with food crops is lower. Currently more technological applications are developed and brought to demonstration and also commercial phases to extract sugar from lignocellulosic material. Lignocellulose is the most abundant biomass type but it is also still a challenge to convert it into fermentable sugars at commercial scale (see Box 1).

Box 1: Extraction of sugars from lignocellulosic material from crops and residues (e.g. straw):

Lignocellulosic biomass feedstocks contain cellulose, hemicellulose- both polymers of monomeric (C6 and C5 sugars respectively), and lignin. An extensive pretreatment is required in order to derive fermentable (C₆ and C₅) sugars from cellulose and hemicellulose. The process usually consists of a physical or chemical pretreatment, that is followed by a hydrolysis process where enzymes are applied to degrade cellulose and hemicellulose into fermentable sugars. The byproduct is lignin, which is non-fermentable and that can be used for conversion to renewable electricity and heat. After this pretreatment, the sugars can be further converted through bio-chemical and thermo-chemical processes in so-called intermediate or sugar platform products such as iso-butanol, lactic acid, ethylene etc. (see E4tech, RE-CORD and WUR (2015) *"From the Sugar Platform to biofuels and biochemicals"*. Final report for the European Commission, contract No. ENER/C2/423-2012/SI2.673791).

The use of lignocellulosic biomass as a feedstock for bioethanol and other biochemical products is currently implemented pilot- demonstration and also commercial plant scale. Often, the product of these biofuel or biorefinery plants is referred to as 2nd generation ethanol, or cellulosic ethanol.

The large scale production of these dedicated perennial biomass crops is still very limited. Estimates of the area of existing plantations were made in ETC-SIA (2013) and Elbersen et al. (2012) and indicated

that in the EU-27 there were 5.5 million hectares used for dedicated biomass crops (for energy) and the dominant share (81%) was for oil crops (rape and sunflower) while only 1% was used for perennial biomass crops. This illustrates that perennials are not easily be fitted into existing arable cropping land. Also for the future the likeliness that increased demand for lignocellulosic biomass will lead to large production of perennials on existing good quality arable lands is rather low. Firstly because these perennials cannot compete with food and feed crops unless low productive soils are involved where perennials may give higher yields and returns. Secondly, farmers are usually not willing to lose their flexibility by turning their land into long term perennial plantations. After all they want to flexibly respond to market changes. Perennial plantations with a long lifetime of 15 to 20 years do not fit with this preference. Thirdly, on the other hand perennials are interesting as they have the capacity to still deliver relatively high yields and considerable higher yields of biomass on lands of lower quality, that only give minor non-competitive yields for rotational food and feed crops. The lower quality lands are usually on the soils that first go out of agricultural use.

If a market indeed develops for lignocellulosic crops it is likely that the lands that are no longer used for conventional cropping with food and feed crops is partly used for production with crops like *Miscanthus*, Switchgrass, *Arundo donax* and SRC crops. For the technical potential assessment of perennials it is logical to consider all types of lands but it is recommended especially put effort in identifying the lands that are no longer productively used for food and feed production, but also other unproductive marginal lands such as former mining areas, unused building sites etc. These could include the categories specified in Table 3.3. In this table guideline are given on how to identify these types of lands from existing statistical and spatial data sources.

Since the focus is first on assessing the technical potential no consideration is initially given to sustainability considerations. However these should not be ignored and therefore these are discussed in the following in a separate sub-section. The incorporation of sustainability considerations should however be done in an early stage and can be combined with assessing the technical potential. To structure the guidelines presented here it was however logical to discuss the sustainability criteria separately. Furthermore the focus of this report is on the technical biomass potential assessment while sustainability criteria are also separately in another report of the project

Overall the potential lands considered can be classified in 3 groups:

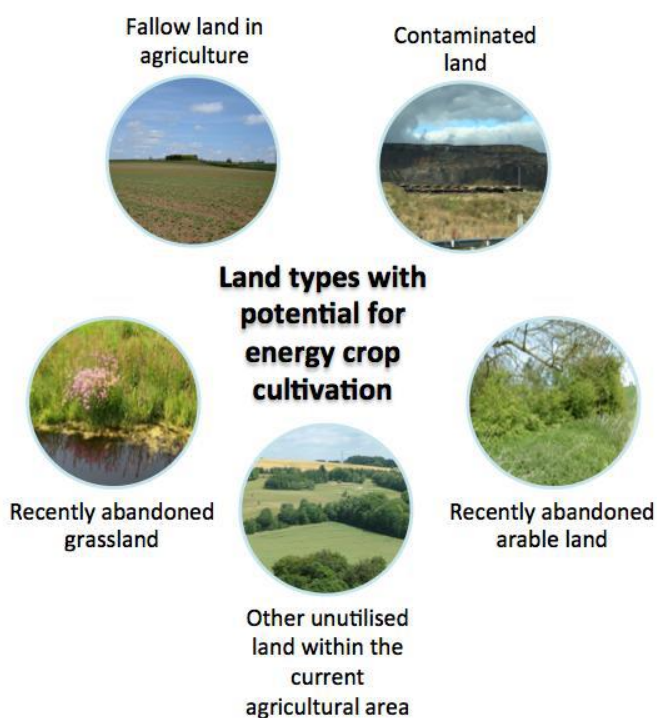
- a. Fallow lands
- b. Unused agricultural lands (abandoned lands)
- c. Derelict lands of all kinds of categories (e.g. unused building sites, former quarries, contaminated lands)

Table 3.3 Types of unused and marginal lands

Type of land	Description	How to identify from statistical sources or through modelling
Fallow land	In FSS Eurostat (Council Regulation 543/2009) the definition of Fallow land (short term) is all arable land included in the crop rotation system, whether worked or not, but with no intention to produce a harvest for the duration of the crop year. The essential characteristic of fallow land is that it is left to recover normally for the whole crop year. Fallow land can be either bare land bearing no crops at all; land with spontaneous natural growth which may be used as feed or ploughed in; land sown exclusively for the production of green manure (green fallow). Long term fallow land refers to the same land as above, but is taken out of production for more consecutive years	In FSS, FADN, LPIS and national agricultural statistical land use sources (see next section on main data sources) the land category 'fallow' is registered as a separate category.
Unused permanent grassland and meadows no longer used for production purposes	The specific definition of this category in EC statistical sources is: 'Permanent grassland and meadows no longer used for production purposes but eligible for CAP payments as long as they are kept in a good agricultural condition according to the GAEC-standards'	This category is specifically registered in FSS, FADN and LPIS as a separate category as this type of land is still eligible for payments even though no productive use is made of it.
Abandoned agricultural lands	This category of land does not have any productive agricultural use any more and is no longer managed in any way.	This category of land is not registered in statistics and there is no public obligation to register it in any database. Identifying this type of land is challenging as and no systematic registration of this land exists. However an identification of recently abandoned grassland areas was made using LUCAS point information (see next section) and main text.
Ecological focus areas	According to the 'Greening of the CAP farmers with an area larger than 15 hectares (excluding permanent grassland) need to withdraw from arable cropping so called "ecological focus area" and these should cover at least 5% (as from 2017 even 7%) of the arable area of the holding and can consist of field margins, hedges, trees, fallow land, landscape features, biotopes, buffer strips, afforested area. In some countries part of the ecological focus areas can be used for biomass production.	Identifying the Ecological focus areas at which dedicated biomass cropping may take place requires evaluation of the RDP programmes and access to the LPIS data on land use status.
Other unused and/or contaminated lands	This category may cover a wide range of land categories with one common characteristics and this is that these are unused. An interesting land category in this group is the contaminated land. Dedicated perennials may be grown here to produce non-food biomass while helping to clean the land via (phytoremediation).	Through existing land use statistics these categories of land are difficult to identify. For contaminated lands there is information collected by the JRC European Soil Data Centre (ESDAC, 2011) but this database is incomplete (see Alen et al, 2014).

The type of lands potentially available for energy crops were also identified in a recent study by Allen et al. (2014) in which a similar typology of land availability as copied underneath in Figure 3.1 was presented. In this study for these different categories of land EU wide data were also identified to quantify these, although on a brought European scale and only for the current situation. Details on the existing data sources for the identification of most categories are provided and the Alen et al. (2014) study should therefore be regarded as an important source for obtaining guidance on collection of data at an EU wide level. For many land use categories however, the study of Alen et al. (2014) also indicates that the available EU wide information is rather incomplete. It is likely therefore that many of the categories of land can be identified further using specific national data sources, which will also help to identify the unused land resources at higher spatial resolution.

Figure 3.1 Type of lands considered available for energy crop cultivation according to Allen et al. (2014)



The quantification by Alen et al. (2014) should be considered as conservative because for many categories of land data sources were incomplete and therefore provide an under estimation. Secondly, because in the study by Alen et al. (2014) a sustainable potential estimate was made excluding several land categories on the basis of 'environmental importance'. For a technical potential estimate all lands should be included initially on the basis of their technical potential to grow perennials on. The specific sustainability considerations related to dedicated cropping are very important but are separately addressed in the next su-section.

For the final technical potential assessment the identification of suitable land is only the first step. Next steps are then:

- 1) to classify the available land area in suitability types for dedicated cropping taking account of soil type and soil and weather limiting factors (e.g. fertility, stony, water holding capacity, shallowness, etc.) and other limiting factors (e.g. slope, infrastructure) apply that make it impossible to grow crops or that only very specific types of perennials can be used (e.g. contaminated lands with heavy metals).
- 2) Per type of land the average yielding capacity of the crop needs to be estimated, this requires specific crop suitability information preferably matching to the bioclimatic and soil circumstances of the region/country under focus
- 3) Finally the hectares of land per type can be multiplied with the crop yield level to come to a total biomass potential in tons dry mass and joules.

For an initial overview of yielding levels of the main perennials candidates for biomass production we refer to Annex 2. These initial yield levels calculated using a crop simulation model were elaborated in the Biomass Futures (Elbersen et al., 2014) and ETC-SIA projects (ETC-SIA, 2014). However much relevant work on biomass crop selection and performance has been done and is being done in larger EU projects. A lot of valuable material is generated in these projects on identifying the best suitable perennial crops for bioclimatic and soil diversity in Europe in experimental fields and wider meta assessments by best European crop experts. A selection of the relevant projects that are already providing and will provide valuable information on best suitable crops and their performance in the near future are:

- 1) S2BIOM project (<http://www.s2biom.eu/en/>) will deliver a database (for EU28, western Balkans, Turkey and Ukraine) data- and knowledge base on characteristics of perennial biomass crops, cropping system combinations and economic and environmental performance in every biogeographical and soil combination in Europe. With the database the most environmentally sustainable selection of crops per region and soil and land type can be made.
- 2) 4Fcrops project (www.4fcrops.eu) was finalised in 2011 and delivered already a lot of reports and publications on the most viable crops for non-food biomass production (either for energy production or biobased materials) in every environmental zone in the EU, cost structure and economic and environmental performance of the different crops. The project also made an estimate of the land availability for these crops in different futures and scenario situations which could also provide further information on land identification.
- 3) Crops2Industry (<http://www.crops2industry.eu/>). Provides data on biomass crops that are best suited for selected industrial applications, namely oils, fibers, resins, pharmaceuticals and other specialty products. Information is provided on yield and tolerance to abiotic and biotic conditions for different crops and at the end the project provides output of an integrated technical, environmental, and economic assessment in the form of best non-food crops for every location and end use in the EU.
- 4) OPTIMA (<http://www.optima7.eu/>) is an ongoing project (started in 2014) that aims at identifying high-yielding perennial grasses for the Mediterranean area, within optimized production chains (for both energy and new plant derived bio-products). The focus is particularly on identifying and evaluating best performing crops, genotypes and farm management systems on lands that are coping with water limitations which is a key issue in Mediterranean environments
- 5) FIBRA (<http://www.fibra7.net/>) provides relevant information on most suitable crops and genotypes for fibre production in the diverse environmental zones in Europe, on the ecological

adaptation and the agricultural practices and the best harvesting, processing and logistics practices to handle these crops.

- 6) Water4Crops (<http://www.water4crops.org/>) stands for can provide information on suitable crops and their performance bio-treatment of wastewater in Europe.

Assessing future technical potentials for perennial biomass crops

Since there is very limited dedicated cropping with perennials already taking place in the EU and the realisation of plantations needs time and will only happen if a clear market demand develops and stimulation measures are taken to start producing these crops it is more useful to assess the future potential for these dedicated crops. This thus requires information on future land use changes particularly in relation to the developments in the categories of land no longer needed for food and feed production and marginal lands as identified above. For identifying these future land use change situations there are generally two approaches to follow:

- 1) Modelling approaches with models covering all sectors that have a biomass demand and that supply the biomass (e.g. forest, agricultural and other land managing sectors). Ideally it would require a model assessment simulating the production response of the agricultural and forest sector to increased lignocellulosic biomass demand. This however does not exist, not in the least place because there are no models covering all land using and biomass demanding activities in an integrated manner and because there are simply too little reliable data available on types of lands available to cover the real land resources and related production responses in the model.
- 2) Trend extrapolation and expert judgement to estimate land use change (LUC) and indirect land use change (ILUC) effects

As to modelling we can see that more efforts are being made to incorporate the biomass supply and demand for food, feed, forest biomass and bioenergy in one integrated model. An example is the integrated assessment model GLOBIOM of IIASA which provides useful results at a wider global and European scale in terms of land availability and use. However the results are rather coarse and therefore need to be interpreted with care when focussing on one single European country or region. Further examples of the well-known models covering the demand and supply of biomass in one or more sectors are presented in Annex 4 of this report.

Another option which has been followed in the assessment of future dedicated cropping potentials in this project is presented in D2.3 'Outlook of biomass value chains' is a post model assessment. This approach can be seen as a combination of modelling and application of trend extrapolation and expert judgement. Because the identification of land and production response of dedicated crops on more marginal lands is so challenging the post model approach aims to first exclude the land resources that are to be used for food and feed production and for the biomass for 1G biofuel generation for which fixed policy targets exist. The land resources that are then 'left over' can then be expected to be available in potential for the production of biomass in response to other demands for biomass not covered by the model such as for bioeconomy applications, bioelectricity and heat generation. How this approach was exactly applied is explained in D2.3 'Outlook of biomass value chains' (Chapter 2) and results are presented in Chapter 6.

All approaches whether model, post-model assessments, extrapolations and expert judgement methodologies, have the same limitations regarding data input. Crucial for making good assessments is the reliable identification of all land categories relevant for the analysis. In relation to agricultural land resources it is clear that lands that in most statistical sources that is an underrepresentation of what can be regarded agricultural land, certainly in relation to recently abandoned lands or common lands that are semi-abandoned but may be good candidates for dedicated perennial cropping activities. As challenging to cover in such analysis are lands that are urban or recreational or semi-natural and that have no productive use or management (any) more. In the next an overview is therefore given of possible data sources that can be used for identification of interesting land resources for dedicated cropping.

3.2.3 Main data sources for land resource analysis for dedicated cropping

For identifying current land use and cropping patterns there are several statistical and spatial data sources available at EU wide level and at national level. An overview of main relevant statistical sources is provided in Table 3.2.

Table 3.2 Overview of main EU and international data sources on land use

Name of data source	Type of data collection	Spatial coverage	Spatial resolution	Temporal coverage	Temporal resolution
FADN	Stratified sample among farms	EU-28	FADN regions	1999 - 2003 (only EU-15) and 2004 - 2010 (EU-27)	Annual
FSS	Sample every 2/3 years and full census every 10 years	EU-28 + Norway, Switzerland, Croatia	FSS regions (Nuts 2/3)	For EU-27 from 2003-2007, 2010 census expected to be available in 2013. For EU-15 data go back to 1990	2/3 yearly
Eurostat annual crop statistics	National / regional statistics based on surveys	EU-28	National and for some items regional (NUTS1/2)	Starting from 1974 for some MS up to most recent year 2011	Annual
FAOSTAT	National statistics	Global	National	1961 - 2009	Annual
LPIS	Farmers survey	EU28 (only eligible area which likely excludes large parts of agricultural areas that are semi-abandoned.	Parcel size	1992 - 2012	Annual
LUCAS	(point) field sampling	samples in EU-27 countries	Selection of points ($\pm 25\%$) of 2 km grid	Some earlier pilot years, 2009, 2012	Every 3 year
UNFCCC	Country specific, combination of statistics and Remote Sensing	Annex 1 countries, incl. EU member states, except Malta and Cyprus	National	1990-2010	Annual

Name of data source	Type of data collection	Spatial coverage	Spatial resolution	Temporal coverage	Temporal resolution
OECD	National statistics	OECD countries	National	1990-2004	Annual
GlobCover	Satellite derived, but little details on crops as most categories refer to land cover classes.	global	300 m grid cell	2009	Once
GLC2000	Satellite derived, but little details on crops as most categories refer to land cover classes.	global	1 km grid cell	2000	Once
Corine Land Cover (CLC)1990, 2000, 2006, 2012	Satellite derived, but little details on crops as most categories refer to land cover classes.	EU-28 (except Sweden, Finland) + Montenegro, Serbia, Turkey	100 m grid cell	1990-2012	Every 6 years, enables to identify some land abandonment

The best EU wide data source that provides land use information at regional level (Nuts 2 and 3) is the Farm Structure Survey (FSS). The relevant data FSS provides in an EU wide harmonised way is on:

- Number of agricultural holdings and average size
- Land use and area (crops)
- Livestock (heads, LU per type)
- Organic farming

The frequency of data collection for FSS is every 2 years. This implies that the Member States are obliged to deliver the standard data every 2 years which can be based on a sample of farms but every 10 years a full scope survey is carried out in the form of an agricultural census. The most recent census took place in 2010 in all EU Member States. The data are currently under validation process and the first validated results are published in the database (see Agricultural census 2010 - provisional results). The Utilized Agricultural Area (UAA) is also covered in other agricultural statistics, namely the **annual crop statistics**. Both FSS and the crop statistics are fed by the National statistical bodies in charge of agricultural (land use) data collection which implies that all data available in FSS are also available from national statistical sources often at higher spatial and temporal resolution.

Other rich data source at national and regional level is the land parcel information system (LPIS) which is the spatial register within the Integrated Administration and Control System (IACS). The IACS ensures that payments of the EU Common Agricultural Policy (CAP) are made correctly. LPIS identifies and quantifies agriculture land for the purpose of targeting CAP payments so it provides for every land parcel the exact land use every year. The IACS/LPIS is operationalized by the paying agencies of each member state. The data is gathered each year through beneficiaries application forms that are filled out by each farmer receiving CAP payments. The advantage of these data is that the detail is high, all crops are covered, but that access to the data (at least at parcel level) is difficult. Another limitation is

that not all agricultural land is included s there are countries that do not register land that is not subject to CAP payments. Especially the category of agricultural lands that are (recently) abandoned are under-represented in this data source, while it is especially this type of land that is of interest for the allocation of dedicated perennial crops.

3.2.4 Sustainability risk to be incorporated in the sustainable potential assessment

Sustainability for non-food biomass use, particularly for bioenergy and even more specifically for cropped based biomass resources is an important issue in the policy and scientific debate for several years now. It is not surprising that there are many (global) studies that show that the shift from conventional energy production, with a negligible land demand, to low-carbon energy sources, including bioenergy, is a major driver of land use change and related GHG emissions in the future (Laborde, 2011; Searchinger et al., 2008; Al-Riffai *et al.*, 2010; E4tech, 2010; Edwards et al., 2010).

This is further exacerbated through the ambitions to shift towards a green circular economy in which more biobased products will take the place of fossil based products. The additional demand for biomass is therefore expected to increase even further although it is difficult to estimate the size of the total biomass needs for the biomaterials and biochemical sectors within 10 to 20 years.

Most critical issues in relation to the environmental sustainability of cropped biomass are (EEA, 2013 & ETC-SIA, 2013):

- 1) land use change effects and related direct and indirect GHG emissions
- 2) land use change effects and related biodiversity effects
- 3) effects on water quality
- 4) water quantity
- 5) soil quality effects (soil organic carbon, soil erosion, nutrients)

Basically all these effects are determined by the combination of type of land and soil chosen, the type of crop used and the type of management applied. The effects on biodiversity are determined both by direct uses of land and indirectly by the effects of the cropping activity on the overall environmental quality (soil, water, air).

How does increased demand for biomass lead to direct and indirect land use change?

The cultivation of crops requires land. If an additional demand for crops occurs, for example for the production of biofuels or biochemicals, this may lead to direct (dLUC) and indirect land use changes (iLUC). Direct land use changes occur when:

- 1) For the production of this additional crop demand currently productive land (e.g. agricultural land, already used for crop production for food, feed, fuel or fibre, including forest production) is used.
- 2) The crop is grown on newly converted formally unproductive land (e.g. land without any agricultural or forestry production, such as natural land).

In the first option, the original crop (or other productive land use) would have to be produced elsewhere. This is the starting point for the indirect effects (see Figure 3.2).

Figure 3.2: Direct and indirect land use effects (source: EEA, 2013 made by Uwe Fritsche, IINAS)

an overview of effects of potential land use and land management shifts resulting from biomass cropping on biodiversity is included in the Annex I to the Biomass Policies Deliverable 2.6 *‘Guidelines and indicators for the evaluation of sustainable resource efficient biomass value chains’*. In this same report a summary of the main principles determining the biodiversity effects are described in Section 4.2 and will not be repeated here. Basically, the text and table in the Annex 1 of Deliverable 2.6 show that demand for biomass is more likely to have an adverse effect on biodiversity if it leads to a further intensification of land use. However, biomass production sometimes also creates opportunities to extensify and/or diversify land use or introduce minimal management of abandoned habitats where removal of biomass creates opportunities for increasing habitat and species diversity. The effects on biodiversity depends very much on what is taken as the reference.

In addition effects also depend on the size of the changes caused by the shift to dedicated biomass crops and the type and presence of rare species their habitats and eventually on an ecosystem’s capacity to provide services. All changes in land use/land cover and land management change that cause the following effects are negative for biodiversity: i) lower species population sizes and composition, ii) invasion of disturbance-adapted species which dominate over rarer and threatened species and iii) overall habitat quality losses through e.g. lower humidity in the soil or lower air moisture, increased pesticide and nitrogen use, and loss of living biomass (e.g. in the case of disruption of (tropical) forests).

Effects of biomass crops also depend strongly on the type of crop chosen per situation. Rotational arable crops have higher soil quality requirements and therefore grow on good agricultural lands. Perennial woody and perennial crops can cope with poorer soil quality situations and still produce relatively high biomass yields. In addition, most perennial woody and lignocellulosic crops have a higher GHG efficiency than rotational arable crops since they have lower input requirements and the energy yield per hectare is higher because the full crop is harvested. However, arable crops like sugar beet are also performing very well in terms of energy yield per hectare because of extremely high sugar yields per hectare, but for other rotational arable crops (e.g. cereals, rape, sunflower) this is not the case and therefore underperform as compared to perennials. Because most woody and lignocellulosic crops have lower soil quality requirements they can well be grown on lower productive land on which they do not compete with rotational arable crops. Acceptable yields can still be reached and displacement effects (i.e. iLUC) are limited. This therefore makes perennials more suitable to be grown on more marginal and abandoned lands.

The introduction of perennials biomass crops, particularly in intensive arable lands, may also have positive effects if it leads to a decline in the use of inputs (water, pesticides use, nutrient inputs), increases the landscape structural diversity (provided the changes are not to large scale and the reference biota are not typical open space landscapes supporting birds of prey populations that depend on open landscapes). This may be positive for biodiversity and overall environmental quality, but it also causes displacement of food production.

Table 3.3 Environmental pressures and their link to biodiversity (source: EEA, 2007)

Environmental pressure	Link to farmland biodiversity
Erosion	Causes a loss of organic soil substances and leads to a loss of habitats. Furthermore, water filtering and buffering functions are reduced with potentially negative effects on biodiversity. Resulting

	nutrient losses cause eutrophication of surface water affecting wildlife flora and fauna.
Soil compaction	Soil structure and other affected soil parameters (air and water household) may lower abundance/diversity of soil biodiversity and wildlife flora.
Nutrient leaching to groundwater and surface water	Cause eutrophication of surface water and soils affecting wildlife flora and fauna (e.g. shift in species) and may also have direct toxic effects on flora and fauna
Pesticide pollution of soils and water	Toxic substances affect flora and fauna directly.
Water abstraction	Water abstraction may reduce the ground water level and cause changes in flora and fauna.
Indirect land use change	if biomass crops are exchanged for food and feed crops it implies that these crops may need to be cropped somewhere else and this may lead to loss of valuable habitats elsewhere.

Since the effects on biodiversity of biomass cropping are challenging to assess it is best to start from the precautionary principle and ensure that potential adverse effects are avoided. Guideline provided on environmental and related biodiversity risks are provided in the Table 3.3 which was already presented in the Biomass Policies Deliverable 2.6 but is repeated here.

From the guidelines provided in Table 3.3 a further SWOT analysis for biodiversity impacts per type of crop is presented in Annex 5 illustrating further that effects are determined by a combination of choice of land type, choice of crop and choice of management. The SWOT analyses provided in the Annex can be used for implementing the sustainable biomass potential for dedicated crops.

3.2.5 Main competing uses for dedicated crops

As became clear from the former crops use land on which food and feed production may take place. The most important crops used for the generation of 1G biofuels in Europe, e.g. sugar beet, cereals, rape and sunflower, and co-substrate crops (e.g. forage maize and forage grass) for the generation of biogas, are also used for food and feed. It is clear that because of this there is a direct competition for land between the production of crops used for food and crops used for non-food products. If perennial crops for biomass use the land that is also suitable for food crop production the same competition occurs. However, under current market demand and price levels it is very unlikely that higher economic margins can be reached with perennials crops on good agricultural lands as compared to those of rotational arable crops. Competition between perennials biomass crops and food and feed production is therefore considerably more limited then when it concerns 1G biofuel crops for which biofuel consumption targets were set.

3.3 Manure

Manure production in Europe is concentrated in the livestock production areas where large livestock populations are held in stables during the whole year or part of the year. Only when the livestock is kept inside manure can be collected.

In table 3.4 an overview is given of the different factors for which data need to be collected and the steps to take to estimate the technical potential for solid and liquid manure. Making a distinction between both types of manure is recommended since conversion processes can be different.

Table 3.4 Estimation steps and suggestions for data sources to calculate the technical manure potential

Step	Description/details	Suggestions for data sources
1) Identification of animal numbers (heads/livestock Unit (LU)) per type	Number of animals per type are well registered in agricultural statistics	FSS data provide animal heads and livestock unit data at very detailed spatial and animal type level. Data are updated every 2 years at least. All national agricultural data sources provide data on livestock numbers per type. For categories. For conversions from livestock units to heads see Annex 6 for information on data sources see Annex 7
2) Identification of number of days/year spent inside	An estimate in % terms needs to be made on the average time per year spent in stables. This needs to be identified for at least the major groups of livestock (e.g. dairy cattle, beef cattle, poultry, pigs, sheep and goats). Best is to estimate the number of housing days.	Information about the housing systems and number of housing days/grazing days outside can mostly be derived from FADN and SAPM (see Table 3.5 underneath and Annex 7). Data on number of housing days per type of cattle are also available from the GAINS database at national level. For details on GAINS database see Annex 7.
3) Calculate total manure production per animal per year by multiplying number of animals per type with either amount of manure produced or Nitrogen excretion factors and then conversion to tons manure (see Table 3.5)	The total manure production per type of animal can be calculated by using the average manure production levels from the BEE project (see Table 3.5) or by first calculating to nitrogen (N) excretion and then convert to ton manure.	For average manure production from BEE project see Table 3.5. For N-excretion levels for dry and liquid manure per type of animal per country and for the conversions to ton manure per type of animal see GAINS database as explained in Annex 7. N-excretion factors can be derived from GAINS database for which subscription is needed. Alternatively it is also possible to estimate the total manure production consulting local livestock specialists.
4) Classify total manure production per animal	Manure can be liquid and solid depending on the housing system in which it is produced and further	For % solid and liquid manure production estimates have been

Step	Description/details	Suggestions for data sources
type to solid and liquid manure	managed. % liquid and solid manure can be derived from expert based rough estimates on type of housing and manure treatment systems such as presented in BIOBOOST report or from other statistical sources. In the Miterra approach these data are derived from the GAINS database	made in the GAINS database. See Annex 7. FADN and SAPM data sources also provide information on types of housing and manure management systems. Alternatively experts can be consulted and publications.

Two approaches for calculation of the technical manure potential are explained below. The first has been applied in the BIOBOOST project (Pudelko, et al., 2013) and builds on the BEE project estimates for average manure production per livestock type and is referred to in that study as the theoretical manure production.

The second is based on the Miterra approach largely using GAINS database input data calculating the manure potential on the basis of the nitrogen (N) excretion factors specifically estimated per animal type per country based on average diets and types of housing and manure management systems. This second approach is more precise as it does not work with EU average manure production levels but takes account of national livestock specific Nitrogen excretion factors and distribution over solid and liquid manure management systems and from there uses conversion factors to calculate to tonnes liquid and dry manure.

The **first approach** was presented in the BIOBOOST report (Pudelko, et al., 2013) proposing the following calculation steps:

- 1) $TCP_Manure = (M_cattle + M_pig + M_poultry)$
- 2) $M_cattle = \sum NHead_{si} * LUs_i * MpHi * AHDi * Avi * UFi / 1000$
- 3) $M_pig = \sum NHead_{si} * LUs_i * MpHi * AHDi * Avi * UFi / 1000$
- 4) $M_poultry = \sum NHead_{si} * LUs_i * MpHi * AHDi * Avi * UFi / 1000$

where:

TCP_Manure = Theoretical potential of manure production (tonnes / year)

M_cattle = Theoretical potential of cattle manure production (tonnes / year)

M_pig = Theoretical potential of pig manure production,

M_poultry = Theoretical potential of poultry manure production,

NHead_{si} = Number of heads for i type of livestock,

LUs_i = Number of livestock units per head for i type of livestock,

MpHi = Amount of manure per livestock unit for i type of livestock, in kg per day,

AHDi = Animal housing number of days per year,

i = Type of livestock,

Avi = Availability factor: ratio of manure that can technically be collected from the stables, due to losses during storage is assumed at Avi = 0.75,

UFi = Use factor (percentage of manure that has no important alternative uses), is assumed UFi = 0.97.

Table 3.5 Initial values from BEE (Böttcher et al., 2010) used in BIOBOOST to calculate theoretical manure production with according to formulas presented in former.

Type of livestock (i)	L _{usi} Conversion head to LU (see Annex 6)	Mp _{Hi} Amount of manure per livestock unit for i type of livestock, in kg per day	AHD _i Animal housing number of days per year
Dairy cows	1	59.2	150
Bovine animals under 1 year old	0.4	6.4	150
Bovine animals 1 year or over but under 2 years, male	0.7	29.6	150
Bovine animals 1 year or over but under 2 years, female	0.7	29.6	150
Bovine animals 2 year old and over, male	1	32.1	150
Bovine animals 2 year old and over, heifers	0.8	32.1	150
Other cows	0.8	31.5	150
Pigs	0.3	5.5	365
Poultry	0.02	0.13	365

Sources: BEE (Böttcher et al., 2010), Eurostat

In BIOBOOST the calculation results in a total manure potential. However guidelines on the rough distribution in solid and liquid manure potential are given based on literature based average estimates. For details see (Bioboost report from Pudielko, et al., 2013 Table 8, page 65).

The **second approach** is based on the MITERRA model calculations and is more precise as it uses more detailed national specific factors on nitrogen (N) excretion for liquid and solid manure systems per animal type and housing days per livestock type. The key input data on this are available from the GAINS database (see Annex 7). How the specific GAINS data can be accessed is explained in Annex 7, but it requires registration and therefore the specific factors could not be presented in this report given intellectual property right arrangements. However, N-excretion rates can also be derived from national and regional experts or literature data (e.g. Velthof et al., 2015), which is recommended when manure estimates need to be made for specific smaller territories.

The Miterra approach can be presented in similar formulas as presented in the first approach:

- 1) $TP_l_Manure = (M_l_cattle + M_l_pig)$
- 2) $TP_s_Manure = (M_s_cattle + M_s_pig + M_s_poultry + M_s_sheep_goat)$
- 3) $M_l_cattle = \sum N_{Heads_i} * Ne_{Xi} * N_Ti \% AHD_i \% liqM$
- 4) $M_s_cattle = \sum N_{Heads_i} * Ne_{Xi} * N_Ti \% AHD_i \% solM$
- 5) $M_l_pig = \sum N_{Heads_i} * Ne_{Xi} * N_Ti \% AHD_i \% liqM$
- 6) $M_s_pig = \sum N_{Heads_i} * Ne_{Xi} * N_Ti \% AHD_i \% solM$
- 7) $M_s_poultry = \sum N_{Heads_i} * Ne_{Xi} * N_Ti \% AHD_i \% solM$
- 8) $M_s_sheep_goat = \sum N_{Heads_i} * Ne_{Xi} * N_Ti \% AHD_i \% solM$

where:

TP_l_Manure = Technical potential of liquid manure production (tonnes / year)

TP_s_Manure = Technical potential of solid manure production (tonnes / year)

M_cattle = Theoretical potential of cattle manure production (tonnes / year)

M_pig = Theoretical potential of pig manure production,

M_poultry = Theoretical potential of poultry manure production,

NHeds_i = Number of heads for *i* type of livestock,

NeXi=Nitrogen (N) excretion factor for *i* type of livestock head

N_Ti = Amount of manure in ton per kg N for *i* type of livestock*

%AHD_i = % housing time=Animal housing number of days per year/365

%liqM = % liquid manure production for type *i* type of livestock

%solM=% solid manure production for type *i* type of livestock

i = Type of livestock

***Conversion rates from kg N to Ton (*N_Ti*)**

* Pigs slurry: 0.125 ton manure per kg N

* Cattle slurry: 0.20 ton manure per kg N

* For poultry and sheep and goat only solid manure is accounted for.

* Poultry manure: 0.04 ton manure per kg N (N content is 25 kg N/ton)

* For sheep and goat manure: 0.1 ton manure per kg N (N content is 10 kg N/ton),

Based on data from the Netherlands from the MITERRA-NL model (Lesschen et al., 2011. And Hilst, et al., 2012)

Both approaches result in a total technical manure potential. In the second approach this is also divided in a solid and a liquid manure potential.

3.3.1 Main competing uses for manure

The main competing use for manure is the use for fertilisation of soils in agriculture. Opinions about which part of manure needs to be reserved for fertilisation of the soil and which part can go to energy (biogas mostly) or to other uses range widely. Overall liquid manure will be mainly used for biogas production, and digestate can be applied to the land, where all nutrients remain in the digestate. The other option is incineration, which is mainly the case for solid manure, but in this case all nitrogen and carbon is lost and only P and K can be recovered from the ashes and used as fertilizer

In the Biomass Futures study and also the BIOBOOST it was assumed that manure becomes a potential for alternative uses when it exceeds the 170 Kg N/ha as prescribed in the Nitrates Directive for Nitrogen Vulnerable zones. However in the Biomass Futures it was also acknowledged that the average manure application is far below this 170 kg N and was therefore set at 100 kg N on average.

In BIOBOOST the 85 Kg N/ha was taken as a threshold for all regions in the EU and only the manure available above this threshold was assumed to be included in the technical available potential (after subtraction of the competing uses).

There is also a wide group of experts that are of the opinion that the whole technical manure potential can be assumed to be available at least for biogas production since a dual application is possible by

first putting the manure into a biogas installation and then use the remaining digestate as a fertiliser for on farm use and/or locally.

For the assessment of the manure potential in this Biomass Policies study as presented in Deliverable 2.3 (*Outlook of biomass value chains*) a different line of reasoning was followed acknowledging that putting manure into a biogas installation does not 'solve' the problem of farmers to get rid of their surplus manure in order to comply with the Nitrate Directive. The aspect of scale was taken as trigger to evaluate manure as a potential for alternative use outside the fertilisation function it has. Scale is taken because logistically and economically it would not be feasible, and generally not be necessary from a regulatory framework, to put small and spatially dispersed manure potential into a digester or some alternative manure refinery chain. The choice of the scale above which manure becomes a serious potential was estimated to be at farms with 200 or more livestock units. In most countries this is usually a threshold above which most farmers in most EU countries start to be categorized as medium to large farmers. In addition to this 200 LU+ rule for the final potential calculation additional rules on competing uses are applied distinguishing between solid and liquid manure production as follows:

- 1) For liquid manure, all manure can go into digestion (100% available).
- 2) Solid poultry manure: 80% of the manure produced in stables on farms with >200 LU is included in the potential, the remaining 20% is expected to stay on the farm and used as fertiliser.
- 3) Solid cattle manure: 20% of the manure produced in stables on farms with >200 LU is included in the potential. The other 80% is expected to be used directly as fertiliser on land
- 4) Solid sheep and goat manure: 20% of the manure produced in stables on farms with >200 LU is included in the potential. The other 80% is expected to be used directly as fertiliser on land

For regional and national specific manure potential assessments it is recommended to specify the rules above in relation to competing uses and mobilisation assumptions with experts in the field to come to more realistic estimates of the manure availability for new uses above the conventional uses.

3.4 Primary agricultural residues

3.4.1 Straw and stubble potentials from crops

Straw is generally seen as an agro-residue with large potential, low ILUC risk and mobilisation options. It is therefore not surprising that many studies have already investigated the technical potential for straw. From a sustainability perspective there is however concern about what sustainable removal rates for straw can be particularly in relation to maintaining the soil organic carbon content of the soil.

In the following we will first present the methodology for estimating the technical straw potential. This is then followed by a discussion of sustainability risk and how to integrate these in sustainable straw potential assessments. Finally attention is paid to the competing uses of straw and guideline are presented as to which competing uses there are and how they can best be estimated.

Most straw potential studies build on the methodology for estimating the straw potential available for bioenergy production which was developed by the JRC already since 2006 (JRC and CENER, 2006 and

Scarlat et al., 2010). In this work the methodology for estimating a sustainable straw potential was developed by building on an EU wide inventory of straw yield and straw removal practices. The methodology was developed for a wide range of crops delivering straw including all cereals, rice, and maize, sunflower and oil seed rape. The JRC study provides guidelines to estimate the above ground residues using a crop specific residue to yield factor in the following formula:

The calculation of the residue-to-yield factor (see Table 3.6) is applied to the main product yield (grains) to estimate the above ground biomass production per crop in the following formula:

$$\text{RESIDUE_YIELD}_i = \text{AREA}_i * \text{YIELD}_i * \text{RESIDUE_2_YIELD}_i * \text{DM_CONTENT}_i.$$

Where:

- RESIDUE_YIELD_i = above ground biomass of crop i
- AREA_i = Crop area of crop i
- YIELD_i = Yield level of the main product (grains/seeds) of crop i
- RESIDUE_2_YIELD_i = Residue-to- yield factors for crop i .
See Table 3.6 for residue-to-yield factors identified in different studies:
- DM_CONTENT_i = Dry matter content of crop i
DM content reported by Scarlat et al. (2010) are as follows:
 - All cereals: 85%
 - Grain maize: 70%
 - Rice: 75%
 - Sunflower: 60%
 - Oil seed Rape: 60%

However the formula provided by Scarlat et al. (2010) applies to the whole above ground biomass. The straw part is however smaller, as stubbles remain on the field (see Figure 3.3). .. The straw : stubble ratio can be highly variable, depending on crop type, cultivar and harvest management. Based on Poulson et al. (2011) and Panoutsou and Labalette (2007) a straw stubble ratio of 55 : 45% was used (see Table 3.3).

This implies that the final technical straw potential for all cereals requires the application of the above presented formula times 0.55 to come to a straw potential. As no detailed data is currently available, it is recommended to apply this factor to all straw crops.

So the final straw yield is calculated as:

$$\text{Straw yield} = \text{RESIDUE_YIELD}_i * 0.5545$$

Figure 3.3 Straw part of cereal plant

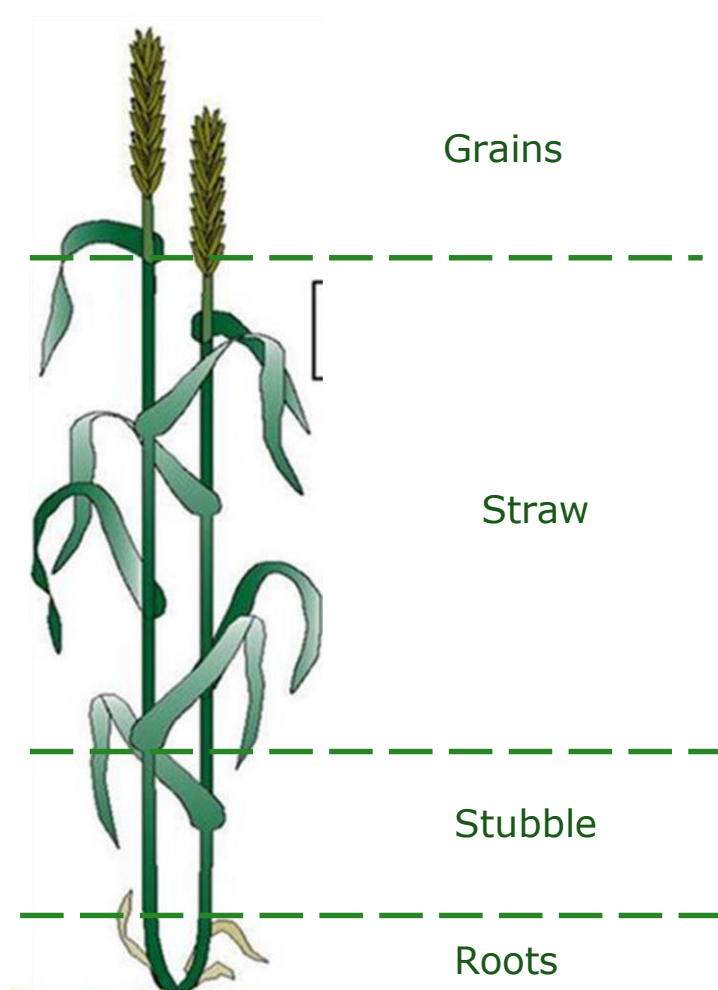


Table 3.6 Residue-to-yield factors used in different studies. ('Yield' refers to yield of main crop which is the grain).

Crop	Straw to grain yield ratio (on a dry mass basis)	
	Scarlat, et .all, 2010*	BIOBOOST (Pudelko, et al., 2013)*
Wheat and barley	$-0.3629 - \text{LN}(\text{yield}) + 1.6057$	$\text{Yield} * (0.769 - 0.129 * \text{ATAN}((\text{Yield} - 6.7) / 1.5))$
Grain maize	$-0.1807 - \text{LN}(\text{yield}) + 1.3373$	$-0.181 * \text{LN}(\text{Yield}) + 1.337$
Rice	$-1.2256 - \text{LN}(\text{yield}) + 3.845$	$-1.226 * \text{LN}(\text{Yield}) + 3.845$
Rape seed	$-0.452 * \text{LN}(\text{Yield}) + 2.0475$	$-0.452 * \text{LN}(\text{Yield}) + 2.0475$
Sunflower	$-1.1097 * \text{LN}(\text{Yield}) + 3.2189$	$-1.1097 * \text{LN}(\text{Yield}) + 3.2189$
Rye	$-0.3007 - \text{LN}(\text{yield}) + 1.5142$	0.9
Oats	$-0.1874 - \text{LN}(\text{yield}) + 1.3002$	0.9
Barley	$-0.2751 - \text{LN}(\text{yield}) + 1.3796$	0.9
other cereals: triticale, mixes of cereals, etc.	-	0.9

*In both Scarlat et al.(2010) and Pudelko et al. (2013) this refers to above ground residues

LN(yield): refers to the natural logarithm of the yield level

ATAN(Yield-6.7): refers to the arctangent, or inverse tangent, of a number (=yield level-6.7).

In the BIOBOOST project straw technical potentials were also assessed (Pudelko, et al., 2013). For the estimation of the straw production per hectare they have chosen to use ratios obtained from different sources. Their grain-to-straw ratios for wheat and barley were based on Edwards (2005) and ratios

for maize, rice, rapeseed and sunflower came from Scarlat et al. (2010). For the other cereals the ratio of 0.9 was applied (see Table 3.6).

In the study by Ecofys (Spöttle, 2013) and assessment of the straw potential in a selection of EU countries was also done using the residue-to-yield factors and the correlations identified by Scarlat et al. (2010) between the grain yield and the straw yield. These correlations were re-used to plot straw to grain yield ratio data against data on national specific crop yield levels, and then determine the curve of best fit. The results provide national specific grain-to-straw ratios (see Table 3.7).

Table 3.7 Straw-to-crop yield ratios as determined by the correlations from Scarlat et al. (2010) elaborated in ECOFYS study (Spöttle, et. al. 2013).

	Wheat	Barley	Oat	Rye
Denmark	0.89	0.93	1.01	1.03
France	0.90	0.87	1.03	1.05
Germany	0.88	0.89	1.02	1.03
Hungary	1.10	1.04	1.14	1.28
Italy	1.15	1.03	1.14	1.21
Netherlands	0.83	0.88	0.99	1.07
Poland	1.11	1.06	1.12	1.24
Romania	1.25	1.14	1.21	1.28
Spain	1.22	1.10	1.17	1.34
UK	0.86	0.90	0.97	0.97

Source: (Spöttle et. al. , 2013, p.27)

In the Ecofys study a further validation was also done of the resulting straw yield based on the grain-to-straw ratios by consulting national experts. Results of this validation suggest that the Scarlat ratios are a bit over-estimating the straw potential particularly for Poland, Denmark, Hungary and Romania where the Scarlat et al. (2010) ratio is especially optimistic for wheat. For other countries covered (Netherlands, Germany, Spain, UK, Italy) the ratio estimates are well in line.

Table 3.8 Overview of data sources providing information on area and yields to be used as input for calculation of straw potentials

Name of data source	Spatial coverage	Spatial resolution	Description/relevance
FSS	EU-28 + Norway, Switzerland, Croatia	Regional (Nuts2/3)	Data on areas under cultivation per crop (See also Annex 7)
Eurostat annual crop statistics	EU-28	National and for some items regional (NUTS1/2)	Crop statistics are collected on areas under cultivation (expressed in 1 000 hectares), the quantity harvested (expressed in 1 000 tonnes) and the yield (expressed in 100kg/ha). (See also Annex 7)
IACS/LPIS	EU28	Parcel size	Land use per parcel to be aggregated to any regional levels. Disclosure rules make access to these data difficult in some countries.

Data on area and yields of the main straw delivering crops can easily be derived from national and EU wide agricultural statistical sources (see Table 3.8, Annex 1 and Annex 7). Average yield data are available at national level but obtaining them for more detailed regional levels will require some more additional efforts. As for the yield information it is recommended to use more yearly averages in order

to neutralise yearly weather effects. For further details on trend analysis on crop yields see BIOBOOST report (Pudelko, et al., 2013, p38 'Time trend analysis').

Competing uses for straw

The main competing uses for straw are the maintenance of soil organic carbon and use of straw in animal production for bedding and feeding and in horticultural activities such as for example mushroom, flower bulbs and strawberry production.

The aspect of the soil conservation function of leaving behind straw in the field is addressed under the sustainability aspects in next sub-section.

Straw is a valuable residue with many uses and therefore it is also an additional source of income to the farmer. This is particularly the case in regions where there is a large concentration of livestock and/or other straw using horticultural activities. At the same time there are also countries where straw demand for non-agricultural uses, such as for electricity, heat and advanced fuels (cellulosic ethanol) is already common. Examples of the latter are some regions in Denmark, Italy and Spain. Here we will only concentrate on providing guidelines for estimating the competing use levels from conventional straw uses in the food and feed production thus in livestock and mushroom production.

Every region in Europe has specific straw use levels in livestock management and horticulture. Such straw use levels can be estimated by consulting local farming experts (farm advisors) and farmers. If this is not possible it is best to use average estimates published in other studies.

It is clear that there are different types of straw making them more suitable for one activity than the other. Straw most suitable for bedding should be dry and clean and absorbent. As to the latter it is clear that straw from oats and barley has a higher absorbent ability than wheat straw. Although wheat straw is most used in livestock because it is the most wide-spread cereal it is also less suitable to be used as feed as compared to other straw types as it is the least palatable. The particular characteristics of types of straw and their suitability for use in livestock production are well explained in the ECOFYS report (Spöttle, et. al. 2013).

In the Scarlat et al. (2010) paper estimates for animal straw use were as follows:

- * Equidae (Horses&mules): 1.5 kg straw/day/head
- * Cattle: 1.5 kg straw/day/head for 25% of the population
- * Sheep & goats: 0.1 kg straw/day/head
- * Pigs: 0.5 kg straw/day/head for 12.5% of the pig population)

In addition to straw use for livestock the mushroom production also consumes a lot of straw. This was also quantified in the study of Scarlat et al., (2010) indicating an EU-27 total straw consumption of 1600 Kton/year in the mushroom production. From Eurostat (FSS, 2010 census data) we know that there are 6380 mushroom production holdings in the EU this equals an average straw consumption per holding of 250.8 ton straw/year. It should be realised at the same time that once the straw is used in the mushroom production the remaining substrate can also be seen as a residue again, although the

remaining quantity and quality will be different. In some countries it can be re-used for soil fertilisation and converted to compost, but some countries require disposal as waste.

A further inventory of competing uses was also done in the ECOFYS study (Spöttle, et. al. 2013) consulting national experts in a selection of countries shows that in most countries straw use in animal production accounts for at least 85% of the current straw uses. It also shows that in Poland the straw use in animal production is estimated to be at a significantly higher level than average straw factors assumed in Scarlat et al. (2010). This illustrates the national variation which can only be taken into account when national experts are consulted.

Sustainable removal rates for straw

Straw is a residue and the main product, the grain, is driving the production of it. Most farmers have a focus in this main product and carefully consider the need to leave part of the straw behind to maintain the long term fertility of the soil. Incorporation of straw after harvest increases organic matter in the soil and adds nutrients, which will then lower the need for applying manure and or mineral fertilisers. The application of fertilisers also affects the GHG balance.

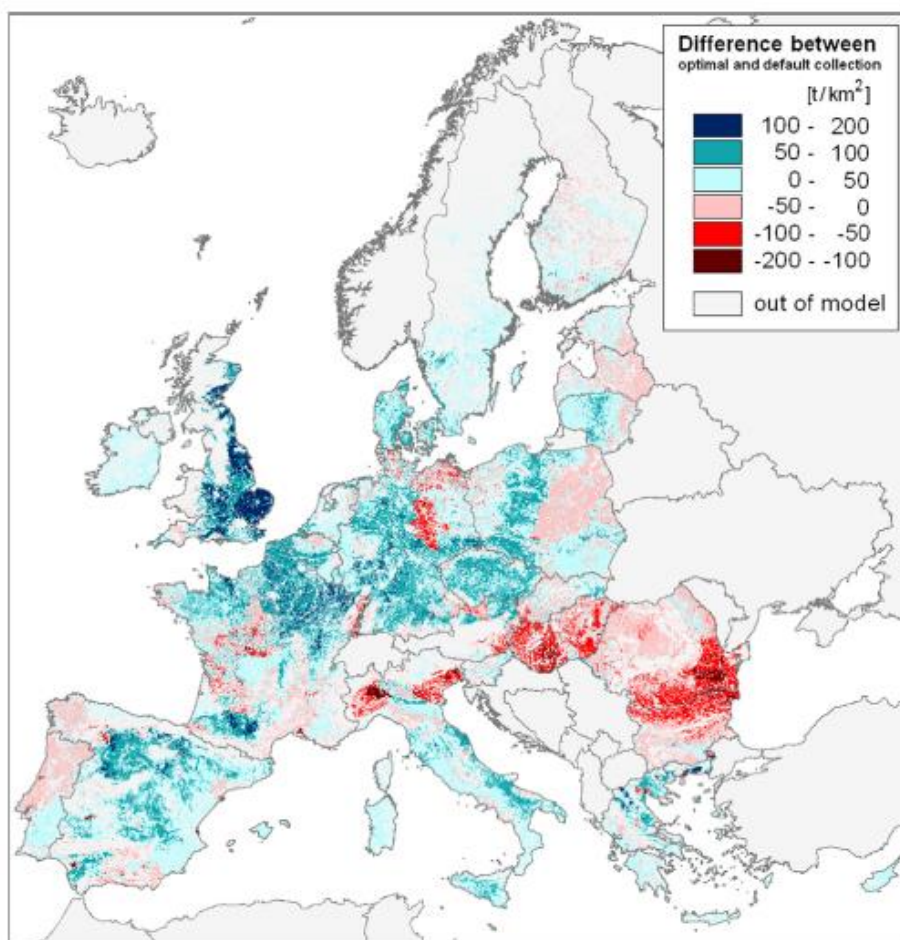
Especially the maintenance of soil organic matter is a relevant function of straw. Also the nutrient balance should be maintained, but nutrients are often replenished by mineral fertilizer, while the input of soil organic matter is often only coming from crop residues. The amount of straw to be kept in the field is complicated to estimate as it depends strongly on the soil and climate characteristics and the long term management practices.

Several modelling studies have assessed long term effect of straw removal on soil organic carbon (SOC) in the soil. Typical examples are the Century model (Parton, 1996) and the CESAR model. Vleeshouwers and Verhagen (2002) applied the CESAR model at European scale. They developed a concise model (CESAR: Carbon Emission and Sequestration by Agricultural land use) which calculates carbon input to the soil from plant residues and carbon output from the soil by decomposition of the accumulated organic matter in the soil.

A study by the JRC (Montforti et al., 2015) assessed SOC changes under different residue collection rates detailed in 3 scenarios ranges from 0 removal, to 50% removal to 100% removal. The 50% removal was assumed to be the default. The SOC development was simulated by the CENTURY model for the period 2013-2050 for the whole EU territory limiting to arable land. It showed that the removal rates for straw at which SOC is maintained vary strongly per location as they are the result of a complex interplay of soil characteristics (especially current SOC levels), climate zones, land cover and the agricultural production itself. The results show that full straw collection will lead to a decline in SOC in almost every location with a few exceptions. At the same time it was confirmed that in areas with higher agricultural yields, larger amounts of straw are produced, thus leading to higher C input into soils which also implies that removal of part of the straw will not decline the carbon stock in the soil. Overall results show that 50% default removal rates are sometimes enough to maintain SOC, sometimes more straw can be removed and sometimes less. Relatively high removal rates of straw, above the 50% default rate, are more often seen in the UK

and Denmark while lower removal rates, under the default value of 50% are more often seen towards the east and south of Europe in e.g. Estonia, Romania, Hungary and Italy and Portugal (See Figure 3.4).

Figure 3.4 Result map from the Montforti et al. (2015) study showing in red the places where 50% and higher straw removal rates lead to a decline in SOC and the blue areas allow for a 50% higher straw removal rate without decline the SOC.



Source: Montforti et al, 2015, Page 525 (fig. 6)

Overall sustainable removal rates as estimated by Scarlat et al. (See Table 3.9) are of course an average and can be conservative for the blue areas in the Montforti map (Figure 3.4) but can also be an over estimation in specific regions towards particularly the east and south of Europe.

In the ECOFYS study (Spöttle, et. al. 2013) a further inventory was done among national experts on the sustainable removal rates for cereal straw and the results are presented in Table 3.10 for selected EU countries.

Table 3.9 Sustainable removal rates considered by Scarlat et al. (2010)

Crop	Estimated sustainable removal rates % at field level
Wheat	40
Rye	40
Barley	40
Oats	40
Grain Maize	50
Rice	50
Rape seed	50
Sunflower	50

Table 3.10 Sustainable removal rates identified by ECOFYS (Spöttle, et. al. 2013)

Country	Sustainable removal rate
Denmark	40%
France	50%
Germany	34%
Hungary	33%
Italy*	40%
Netherlands*	40%
Poland*	40%
Romania	40%
Spain*	40%
UK	40%

*Followed Scarlat et al. (2010) no expert consulted

Experts in France expect the sustainable removal rates to be higher than 40%, which coincides with the map of Montforti et al. (2015) (see Figure 3.4), where the northern part of France, the main wheat production area, has a more positive SOC balance. The more conservative removal levels for Hungary and Germany also seem to be matching well with the Montforti map (Figure 3.4) where there are many red patches visible in these 2 countries indicating sustainable straw removal levels to be far below the 50% default.

In the S2BIOM project a further assessment is done using the Miterra model (Lesschen et al., 2011) of the removable straw levels in Europe while conserving the Soil Organic Carbon levels. It is based on “RothC-26.3”, model for the turnover of carbon in non-waterlogged soils (Coleman & Jenkins, 1999). It uses a monthly time step to calculate total organic carbon (t ha⁻¹), microbial biomass carbon (t ha⁻¹) and $\Delta^{14}\text{C}$ (from which the radiocarbon age of the soil can be calculated) on a years to centuries timescale. It needs few inputs and those it needs are easily obtainable. A key data source used as input is the LUCAS data on SOC stock (0-20 cm). These S2BIOM results are also used in Biomass Policies for specifying the B1 and B2 potentials which take account of more sophisticated sustainability requirements.

3.4.2 Pruning and cutting potentials from permanent crops

Permanent crops deliver pruning residues and biomass from tree and stump extractions when the plantation is at the end of its lifetime. In Europe the most important permanent crops delivering woody residues are:

- 1) Fruit trees (apple, pear, cherries, apricots, peach etc.)
- 2) Vineyards
- 3) Olives
- 4) Citrus
- 5) Berries
- 6) Nuts and other plantations

Pruning of all these permanent crops plantations is part of normal practice to enhance and maintain the production of the main fruit. The focus for estimating the biomass potential from permanent crops will be on the pruning material as this is delivering the largest and most stable amount of biomass from a permanent crop plantation.

Estimating the amount of pruning residues delivered by the different permanent crops is rather challenging however, given the wide variation in type of trees, shrub forms used, varieties and traditional practices. For these crops there is less understanding of the relation between yield levels of the main crop, 'fruit', and the residue potential. There have been several publications providing residue-to-yield ratios for the different permanent crops, especially covering the Mediterranean region, but the variation is very large (see Table 3.11).

Table 3.11 Overview of residue-to-yield factors found in different studies

	Greece: M. Mardikis, et al. (2004)	Del Blasi et al. (1996)	Portugal: Diaz and Azevedo (2004).	Serbia: Mladen et al. (2004)
Apples & pears	1.20-2.51	0.1-0.2	0.26-0.28	0.18-0.20
Cherries and other soft fruit	1.2		0.47	0.55-0.79
Nuts and other plantations	0.28	1.9	2.51	2.56
Citrus plantations	1.55-2.90	0.1	0.15-0.17	-
Olives	0.98	0.5-2.6	0.47	-
Vineyards	1.2	0.2-0.8	0.39	2.42

Sources: The figures are calculated averages found in the following studies:

[The state of biomass energy in Serbia; BIBLID: 0354-9836, 8 \(2004\), 2, 5-19; Mladen Ilic, Borislav Grubor and Milos Tesic. http://www.doiserbia.nb.rs/ft.aspx?id=0354-983604020051](http://www.doiserbia.nb.rs/ft.aspx?id=0354-983604020051)

A study on the production of agricultural residues in Italy; Biomass and Bioenergy Vol 12 No 5 pp 321-331 (1997); C.Di Blasi, V. Tanzi and M. Lanzetta.

M. Mardikis, A. Nikolaou, N. Djouras and C. Panoutsou (2004). Agricultural biomass in Greece. Current and Future Trends

Diaz and Azevedo (2004). Evaluation of biomass residuals in mainland Portugal. J. Dias, J.L.T. Azevedo In: Carvalho (Eds.), New and renewable energy technologies for sustainable development, Swets & Zeitlinger, Lisse (2004), pp. 215–228

Estimating the residue yield per hectare is very challenging for permanent crops and depends very strongly on local practices. On the other hand local practices of handling the residues may be changed to mobilise the residues for alternative uses and sources of income. The EuroPruning project was therefore started in 2014 to exactly fill the gap in data and knowledge on the availability of pruning residues in Europe and develop and implement pruning based logistical chains. The best and most recent EU wide source of information on availability of pruning residues and current removal practices was produced as part of this project (CIRCE et al., 2015).

The CIRCE (2015) report explains why there is such a large variation in residue-to-yield factors in permanent crops as there is an enormous diversity in crop form and in tree density of the plantation. In Italy for example there are already 40 different vineyard cultivation systems delivering very different pruning harvests. Although the vineyard type variation is the largest the CIRCE report also shows large variations in crop forms for other permanent crops varying between and within EU countries. A summary overview of the systems, type of pruning, the pruning period and the average pruning yield as presented in the CIRCE (2015) report is copied in this report (Table 3.12).

In the CIRCE report the factors determining the specific pruning yield levels were identified and cover climate and weather, crop (type, species, variety, age etc.), soil type, management (e.g. irrigation, intensity, density etc.) and human factors (preferred management, tradition). An attempt to identify correlations between all these factors and pruning yields per crop type did not result into patterns at statistically reliable correlation levels, for specific crops and specific factors.

Given the enormous variation identified in pruning yields, and the very diverse factors determining these yield levels it is recommended when analysing pruning residues from permanent crops to collect pruning yield levels at regional and local level for the territory the potentials need to be calculated for. If the area to be covered is large covering more European countries it is best to start from the information provided in the CIRCE report.

The identification of the most reliable pruning yield factors is the first step in the potential assessment. Next is then the calculation of the total potentials for which the following formula can be applied:

$$\text{RESIDUE_YIELD}_i = \text{AREA}_i * \text{RES_YIELD}_i * \text{DM_CONTENT}_i.$$

Where:

- RESIDUE_YIELD_i = total pruning yield of crop i in Ton/Year in dry mass
- AREA_i = Crop area of crop i
- RES_YIELD_i = Pruning yield Ton/Ha/Year in fresh mass of crop i
- DM_CONTENT_i = Dry matter content of prunings of crop i

All residue yields from all crops can then be added up to come to a total pruning yield per country.

The area of permanent crops per region can be derived easily from EU, national and regional statistical sources. For an overview of useful data sources we refer to the same data sources as discussed in the former for straw delivering crops (Table 3.8). At least these data sources provide good area figures for most permanent crop types like for olives, vineyards, citrus. However in statistics like the Eurostat-FSS database some fruit categories are mixed (see Table 3.13).

The residue yield level (RES_Yieldi) can best be derived from local experts as specified in the former or alternatively the average yield levels in the Table 3.12 can be used.

The dry mass content of prunings differs per type of crop and region. But as an average moisture content factor of 40% (=0.6 DM_Content) can be used for most permanent crops. The moisture content of olives can be assumed to be lower at 30% (= 0.7 DM-Content).

Table 3.12 Permanent crop pruning practices and average pruning yield (Ton/Ha/Y_{fm})

Crops	Country	Growing system (descriptive)	Pruning		Row width (m)	Pruning period												Pruning production (t/ha/y) _{fm}
			Type	Freq.		J	F	M	A	M	J	J	A	S	O	N	D	
Olive	Spain	Typical traditional (↓)	Manual	1 or 2	7-12													1-4
		Intensive (↑)	Combined	1	4													n.d.
	Italy	Typical traditional (↓)	Manual	1	7													1.6 – 2.1
Citrus	Spain	Old pattern (↓↓)	Manual	1														n.d.
	Spain	Intensive, bush	Combined	1	2-3													3.7-9.3
	Italy	Intensive, bush	Combined	1	5													0.7 – 1.9
Almond	Spain	Intensive	Combined	1	4													≈1
		Rainfed	Manual	1 or 2	7													0.4-1
		Irrigated (high vigour) (↓)	Manual	1 or 2	6-7													≈1
		Irrigated (low vigour) (↑)	Combined	1	5-6													n.d.
Hazelnut	Italy	Rainfed	Manual	1	5													1.5-3
	France	Traditional	Manual	1	8													2.3
Chestnut	France	Traditional	Manual	1	8													1.2
Walnut	France	Traditional	Manual	1	10													1.9-3.2
	France	Intensive (↑)	Combined	1	8													—
	Ukraine	Traditional	Manual	1 or 2	10													n.d.
	Ukraine	Intensified	Manual	1 or 2	5													3
	Slovakia	Traditional	Manual	1	10													n.d.
Stone fruits (peach, apricot, nectarine and plum)	Spain	Semi intensive	Manual or combined	1	5-6													2-3
		Semi extensive	Manual	1	6-7													2-3
	Italy	Non intensive	Manual / Combined	1	4-6													2.6-3
		Intensive (↑)	Combined	1	4													2.6-3
	France	Non intensive	manual	1	4-5													2-3
		Intensive	Combined	1	3													n.d.
	Slovakia	Non intensive (vase)	Manual	1	5-6													n.d.
		Intensive	Manual	1	3													n.d.
	Ukraine	Traditional plum	Manual	1	5-6													nd
Cherries	Spain	Intensive plum	Manual	1	4-5													4.4
		Non-intensive	Manual or combined	1	5-6													2-3
		Intensive	Manual	1	4-5													2-3
	Italy	Non-intensive	Manual / Combined	1	6													2.6-3
		Intensive (↑)	Combined	1	5													2.6-3
	Poland	Traditional	Manual	1	5-6													3-6
		Intensified	Manual	1	4-5													2-5
	Ukraine	Traditional	Manual	1	5-6													< 10
		Intensified	Manual	1	4-5													< 10
Sour cherries	Poland	Traditional (↓)	Manual	1	5													3.6
		Intensified (↑)	Manual	1	4													3-5
		Superintensive	Combined	1	4													n.d.
	Ukraine	Traditional	Manual	1	5-6													n.d.
		Intensified	Manual	1	4-5													4.4
Vineyard	Italy	Vase	Manual	1	4													1.8-2.9
		Espalier	Combined	1	2-6													1.8-2.9
	Spain	Vase (rainfed)	manual	1	3-4													1-2

Source: CIRCE (2015). D3.1 Mapping and analysis of the pruning biomass potential in Europe. EuroPruning project (KBBE.2012.1.2.-01).

Table 3.12 Permanent crop pruning practices and average pruning yield (Ton/Ha/Y_{fm})
(Continued)

Crops	Country	Growing system (descriptive)	Pruning		Row width	Pruning period	Pruning production	
		Espalier (vase/espalier)	Combined	1	2-5		2-4	
	France	Intensive grape for vine	Combined	1	2-3		1.5-3	
		Very intensive grape for wine	Combined	1	1-1.5		4	
		Grape for table	Combined	1	2-3		n.d.	
	Slovakia	Espalier	Manual	1	1-1.5		n.d.	
	Ukraine	Traditional	Manual	1	3		2-4	
		Intensive	Manual	1	2-3		2-4	
	Seed fruit	Italy	Non intensive	Manual / Combined	1	4-6		1.4-2.6
		Italy	Intensive (↑)	Combined	1	4		1.4-2.6
		Spain	Non intensive	Manual	1	4-6		2-4
Spain		Intensive	Combined	1	4		2-4	
France		Non intensive	Manual	1	4-6		2-3	
		Intensive	Combined	1	3-4		2-3	
Poland		Traditional (↓)	Manual	1	4-5		<6	
		Intensified (↑)	Getting mechanised	1	4		1.5-4.5	
Germany		Traditional (↓)	Manual	1	4-5		n.d.	
		New intensified (↑)	Getting mechanised	1	3-4		n.d.	
Netherlands		Intensive	Mainly manual	1	3-4		4.5	
Slovenia		Natural	Manual	2 to 5	Disperse		n.d.	
		Vase or spindle, intensive	Manual	1	4-5		2	
Slovakia		Intensive vase	Manual	1	4.5		n.d.	
		Intensive spindle	Manual	1	3.5		n.d.	
		Intensive espalier	Manual	1	3		n.d.	
Ukraine		Traditional	Manual	2	5		n.d.	
		Intensified	Manual	1	4		<7.5	
Combined: mechanised and manual combined; n.d.: not determined in the contacts done for preparing the country templates; (t/ha/y) _{fm} : tons per hectare and year expressed in fresh matter.								

Source: CIRCE (2015). D3.1 Mapping and analysis of the pruning biomass potential in Europe. EuroPruning project (KBBE.2012.1.2.-01).

Table 3.13 FSS permanent crop categories included in FSS and surfaces (ha) in 2010

Country	Code	Fruit species of temperate climate zones	Fruit species of subtropical climate zones	Berry species	Nuts plantations	Citrus plantations	Olive plantations - table olives	Olive plantations - oil production	Vineyards - quality wine	Vineyards - other wines	Vineyards - table grapes	Vineyards - raisins	Other permanent crops	Permanent crops
Belgique/België	BE	16360	0	320		0	0	0		0	0	0	50	21530
Bulgarija	BG	33620	0	2400	9480	0	0	0	23320	26160	2850	0	470	99650
Ceská republika	CZ	19320	0	1180	0	0	0	0	12530	1640	190	0	0	36950
Danmark	DK	2040	0	3990	10	0	0	0	0	0	0	0	20130	27720
Deutschland	DE	57480	0	7040	760	0	0	0	96830		180	0	15480	198760
Eesti	EE	1210	0	1360	0	0	0	0	0	0	0	0	0	3120
Éire/Ireland	IE	630	0	250	0	0	0	0	0	0	0	0	0	970
Elláda	EL	72420	4960	0	31560	42770	84870	621090	11490	39990	12580	22290	4750	950270
España	ES	194840	37110	3060	514540	287570	174420	1979300	525080	307500	18240	1800	31900	4086240
France	FR	123640	19730	3810	34410	4120			674360	105110	6170	0	14560	1018330
Hrvatska	HR	19950	370	710	6670	1900	200	16900				0	820	78300
Italia	IT	208690	28590	10730	176290	128920	13630	1109700	320860	304840	37300	0	12920	2380770
Kypros / Kibris	CY	3100	400	0	3470	3760	200	11440	560	6310	740	20	1290	31340
Latvija	LV	6430	0	1830	0	0	0	0	0	0	0	0	0	8510
Lietuva	LT	13180	0	6940	150	0	0	0	0	0	0	0	930	21550
Luxembourg	LU	130	0			0	0	0	1270		0	0	20	1500
Magyarország	HU	70420	0	6750	6590	0	0	0	36020	21680	2280	0	4520	151720
Malta	MT	370	0	0	0	110	70	70	430	100	80	0	0	1250
Nederland	NL	17710	0	1530	110	0	0	0	0	160	0	0	0	36960
Österreich	AT	13850	0	960	0	0	0	0	46620	0	0	0	1980	65200
Polska	PL	237570	0	89950	31420	0	0	0	0	340	0	0	5710	389670
Portugal	PT	39920	3050	210	115150	16930	4090	331750	144560	30940	2330	0	600	690730
România	RO	139200	0	720	1950	0	0	0	47620	108890	4850	0	4820	311430
Slovenija	SI	8450	0	40	690	0	0	890	15820	530	0	0	0	26800

Country	Code	Fruit species of temperate climate zones	Fruit species of subtropical climate zones	Berry species	Nuts plantations	Citrus plantations	Olive plantations - table olives	Olive plantations - oil production	Vineyards - quality wine	Vineyards - other wines	Vineyards - table grapes	Vineyards - raisins	Other permanent crops	Permanent crops
Slovensko	SK	6540	0	1330	300	0	0	0	10730	160	150	0	0	19640
Suomi/Finland	FI	760	0	3310	0	0	0	0	0	0	0	0	0	4580
Sverige	SE	1910	0	580	0	0	0	0			0	0		2940
United Kingdom	UK	23910	0	4740		0	0	0		1230	0	0	1810	36200
Ísland	IS	0	0	0	0	0	0	0	0	0	0	0	0	60
Norge	NO	2180	0	640	0	0	0	0	0	0	0	0	0	3050
Schweiz	CH	7360	0	460	0	0	0	0	13100	0	0	0	730	22630
Crna Gora	ME	950	30	10	10	230	0	300	2210	130	200	0	0	4650

Eurostat: FSS, 2010 data

Competing uses and sustainability

Like for most field residues they are an important source of nutrients and carbon and can therefore not fully be removed. On the other hand there is also a risk involved when leaving pruning residues in the field as these can also be a source of infections enhancing diseases in crops. If it happens there may be a need to first apply a pesticide treatment before the pruning takes place. Another option is to burn the pruning residues, but this practice is no longer permitted in all regions of Europe or subject to strict regulations. However, the way pruning residues are handled is very much dependent again on the typical practices per crop and region and the regulations in place.

On the other hand the advantages of the existing practice of leaving residues in the field may not always be the most environmentally sustainable solutions. Removal of part of the residues may still be possible without endangering the nutrient and carbon levels in the soil. However, knowledge on the levels of residue removal at which the carbon levels are maintained is limited. Overall it is however clear that leaving part of the (shredded) pruning residues will enhance the maintenance of soil organic carbon levels. What these levels should be is difficult to determine given the wide diversity in permanent crop types, soil and climate circumstances. The best is therefore to take local practices into account aimed at amending the organic levels in the soils.

The best inventory of what these practices are was done in the EuroPruning project and are described in the D 3.1 report of this project (CIRCE, 2015). The report shows that of the countries covered (not all EU countries were covered) in Spain, Italy and Ukraine the most common practice is the burning in open fires of pruning residues in the field. In France, Greece, Slovenia, Netherlands, Germany, Slovakia and Poland the most common practice is the shredding of the residues and leaving and/or incorporation into the soil. In some of these countries the use of a smaller part of the prunings, especially the thicker branches, as fuelwood is also occurring, although certainly not as a dominant practice.

3.5 Secondary residues from agricultural product processing

There are several secondary residues produced in the (industrial) processing of agricultural products.

In the following an overview is given of such products and guideline on how to assess their potential. In the last column specifications are also given on the conventional competing uses known for these residues.

Table 3.14 Overview of selection of most common secondary agricultural residues in Europe

Type	Definition and how to assess potential?	Calculation factors	Competing/ alternative uses
Olive pits	Olive pits are a by-product from the olive oil industry. Calculation can be done according to the total area (hectares) of oil olives and the average per hectare yield of olive pits or the residue/main product ratio. The latter requires data on area+average per hectare yield.	$\text{Area} * \text{per hectare olive pit yield}$ Suggestions for ratios: *Italy (Del Blasi, 1997): 0.3 ton d.m./ha/year of olive pitts or $\text{Area} * \text{per hectare yield of olives} * \text{residue to-main product ratio}$ *Portugal (Diaz & Azevedo, 2004): 0.07 d.m. residue/main product ratio *Greece (Nickolaou et al., 2002): 0.21 wet mass residue/main product ratio (wet assuming 30% moisture)	Mostly to energy, no alternative uses
Cotton gin residues	These are residues from the cotton ginning factories. The process of cotton ginning produces a by-product composed of bur and stem fragments, immature cottonseed, lint, leaf fragments, and dirt. So-called "cotton gin waste" or trash).	$\text{Area} * \text{per hectare yield of cotton} * \text{residue to-main product ratio}$ *Greece (Nickolaou et al., 2002): 0.1 wet mass residue/main product ratio (wet assuming 13% moisture)	Animal feed, compost
Cereal bran	These are residues from the flour mills. Calculation can be done according to the total area (hectares) of cereals used for flouwer production and the average per hectare yield of the	$\text{Area} * \text{per hectare yield of cereal} * \text{residue to-main product ratio}$ *Portugal (Diaz & Azevedo, 2004): for rey 0.3 wet mass residue/main product ratio (wet assuming 12.5% moisture). For	Animal feed

Type	Definition and how to assess potential?	Calculation factors	Competing/ alternative uses
	main product and then apply a residue/main product ratio.	wheat flower the ratio is 0.19 (13 % moisture) and for maize flower the reatio is 0.2 (18% moisture)	
Rice husk	These are residues from the rice mills. Calculation can be done according to the total area (hectares) of rice and the average per hectare yield of the main product and then apply a residue/main product ratio.	<i>Area * per hectare yield of rice * residue to-main product ratio</i> *Greece (Nickolaou et al., 2002): 0.16 wet mass residue/main product ratio (wet assuming 10% moisture)	Animal feed
Soy bean, sunflower and rape seed oil residues	These are residues from the vegetal oil industries. Calculation can be done according to the total area (hectares) of rice and the average per hectare yield of the main product and then apply a residue/main product ratio.	<i>Area * per hectare yield of oil seeds * residue to-main product ratio</i> *Portugal (Diaz & Azevedo, 2004): for sunflower 0.6 wet mass residue/main product ratio (wet assuming 10% moisture). For rape the ratio is (% moisture) and for soybean the ratio is 0.8 (13% moisture)	Animal feed
Nut peelings (walnut, almond, hazelnut)	These are secondary residues from the peeling plant for nuts. Calculation can be done according to the total area (hectares) of nut trees and the average per hectare yield of the main product and then apply a residue/main product ratio.	<i>Area * per hectare yield of nuts * residue to-main product ratio</i> *Greece (Nickolaou et al., 2002): 0.95-1.5 wet mass residue/main product ratio (wet assuming 5%-8% moisture)	Mostly to energy, compost
Beer dregs	Residues from the beer factories of which the main is the brewer's spent grain (85% of residues). Others are hot trub, residual yeasts & diatomaceous earth slurry	For every 100 kg of grain input 125 kg of wet spent grain (bagasse) is produced (80% moisture). Or for every 10 liters of beer 14-20 kg of wet spent grain is produced (see Dos Santos-mathias et al., 2014).	Animal feed, other chemical uses
Pressed grapes dregs	These are secondary residues from the vine industry. Calculation can be done according to the total area (hectares) of vineyards and the average per hectare yield of the main product and then apply a residue/main product ratio.	<i>Area * per hectare yield of grapes * residue to-main product ratio</i> *Portugal (Diaz & Azevedo, 2004): 0.19 wet mass residue/main product ratio (wet assuming 80% moisture)	Compost
Fruit juice dregs (oranges and other citrus)	The secondary residues from the juice industry. Calculation can be done according to the total area (hectares) of citrus (going to fruit	<i>Area * per hectare yield of citrus fruits * residue to-main product ratio</i>	

Type	Definition and how to assess potential?	Calculation factors	Competing/ alternative uses
	juice production!) and the average per hectare yield of the main product and then apply a residue/main product ratio.	*Portugal (Diaz & Azevedo, 2004): 0.56 wet mass residue/main product ratio (wet assuming 80% moisture)	
Sugar beet industry residues (pulp & molasses)	Residues from the sugar mill. Calculation can be done according to the total area (hectares) of sugarbeet and the average per hectare yield of the main product and then apply a residue/main product ratio.	About 76% of the sugarbeet ends up as pulp in the sugar mill process.	Animal feed
Potatoe industry residues	Residues from the potatoe processing industry. Calculation can be done according to the total area (hectares) of potatoes converted to starch and feed the average per hectare yield of the main product and then apply a residue/main product ratio. Main residues concern potatoe peels and press fibre	About 15% of the processed potatoes (towards chips, crisps and starch) consists of peels. The extraction of starch from strach potatoes into potatoe flour delivers press fibre which is estimated to amount to 15% of the input (e.g. 150 kg/ton potatoe input). The press fibre consists for 83.5% of moisture (Elbersen et al., 2011).	Animal feed

4 Biomass from forestry

In this part approaches to estimating biomass potentials from forestry are discussed together with the main sustainability risks and the main conventional competing uses for forest biomass.

For the assessment of biomass potentials from forestry one needs basic statistical data which come from forest inventories. Before analysing these types of data and the methods to assess forestry potentials it is important to understand the basic forest production system and the different products that can be harvested from forestry.

At the highest level three different biomass feedstock groups are derived from forestry: stemwood, primary residues and secondary residues from forest industries. The primary forest exploitation is driven by the stemwood demand. Stemwood is the main product and can be defined as the part of tree stem from the felling cut to the tree top with the branches removed, including bark. It can be classified in:

1. High quality stemwood for materials (e.g. for furniture, building materials)
2. Pulpwood stemwood (demand for it is mostly for conventional uses in paper, cardboard and plywood industries)

With the production of the stemwood many residue products are also available which can be (partly) removed from the forests and which cover: wood available from (pre-commercial) thinnings and the primary residues associated with the harvested stemwood.

These primary forestry residues consist of the following categories:

- 1) Stem and crown biomass from early pre-commercial thinnings which consists of (thin) stems, branches, bark and needles and leafs. Pre-commercial thinnings cover selective cuttings of young trees that have no value for the wood processing industry. Their removal is part of normal forest management and enhances the growth of the remaining trees.
- 2) Logging residues from thinnings also including stem and crown biomass which consists of (thin) stems and branches, bark, needles and leafs.
- 3) Logging residues from final fellings which is mostly branches, bark, needles and leafs
- 4) Stump extraction from final fellings which is the tree part below the felling cut so including tree roots
- 5) Stump extraction from thinnings which is also the part of the tree below the felling cut of the thinning tree

As to the removal of forest biomass there are several sustainability restrictions which are usually managed through forest management plans coordinated by forest state and/or owner organisations.

The common rule for sustainable forest management is that the long-term annual fellings do not exceed the net annual increment.

For the assessment of forest potential the focus should be on the 'forest available for wood supply' (FAWS) which is defined by FAO (1999) as 'forest where any legal, economic or specific environmental restrictions do not have a significant impact on the supply of wood'. This definition therefore covers forests where harvest is taking place, but could also include forests with no harvest. In many regions in Europe forest harvesting does not reach the net annual increment since in a share part of the forests there is no harvesting taking place, even though there are no legal nor environmental restrictions to do so. In these parts of the forests there is still additional harvest possible of:

1. Additional harvestable stemwood: stemwood which could be harvested without harming future harvests.
2. Additional residues: the primary residues associated with the additional harvestable stemwood.

For estimating the potential from forests for bioenergy and bio-material generation the guidelines presented here will focus on identifying the availability of primary and secondary forest biomass. The conventional stemwood uses for higher quality products in existing conventional material production processes (e.g. pulp and paper, furniture and building materials) should be subtracted for as far as possible from this potential.

The approaches presented here will be largely following the BEE Methods handbook (Vis et al., 2010) where an extensive overview and explanation is given of the methodologies to assess forest biomass potentials. Therefore it is not intended here to re-write but rather to provide guidance on which approaches are there and where further details can be found for implementing them. References will be made in several places to the BEE handbook and other references.

As discussed already in Section 2.3 in the BEE project 4 types of potentials can be assessed: theoretical, technical, economic and implementation potential. For the description of the recommended approaches to assessing the forestry potentials we will mostly refer to the theoretical and technical potential in the BEE methodologies report. Attention is then also paid to the more advanced, spatially explicit technical-sustainable potential for current and future years applied in this project to assess the forestry potential as presented in D2.3 'Outlook of biomass value chains' and for which data are included in the central cost-supply database.

4.1 Methods for assessing the primary forest biomass potential

4.1.1 Stemwood

The most basic assessment of the theoretical stemwood potential requires data on the minimum annual increment and the wood removals. Calculation of the theoretical stemwood potential for additional uses in energy and bioeconomy uses is then presented underneath (BEE Methods handbook, Vis et al., 2010, p.31):

$$THP_SW_{x,y} = NAI_{x,y} \times (1 - Hl_{x,y}) - SWrem_{x,y} \times (1 + Bf)$$

Where:

THP_SW_{x,y} = Theoretical stemwood potential for additional uses (energy and bioeconomy uses) in country x in year y

NAI_{x,y} = net annual increment of stemwood in country x in year y

Hl_{x,y} = harvest losses in country x in year y

SWrem_{x,y} = stemwood removals in country x in year y

Bf = bark fraction (0-1), which needs to be subtracted in case the stemwood removal data are reported underbark

Input data for making this calculation are easily available from national, Eurostat and FAO statistics, but are generally more challenging to get at detailed regional resolution. The data sources for this data are presented and discussed in BEE Methods handbook (Vis et al., 2010, p.32). As for the harvest losses (HL) it is suggested to use a default value of 0.08 (=8%) for coniferous and of 0.10 for the broadleaved species.

To assess the technical-sustainable stemwood potential for energy and other biobased uses the theoretical potential needs to be further reduced for different technical and sustainable reduction criteria. These technical criteria refer to soil fertility, technical limitations on the accessibility of the forest for example for slope and distance to forest roads. Sustainability criteria are related to biodiversity (e.g. no or limited exploitation of forest biomass in protected areas), soil and water protection areas, risks for soil compaction.

All these additional reduction criteria are crucial to make a more realistic technical and sustainable potential estimate and these are best to be obtained through a spatially explicit methodology using overlays of the forest areas with the areas imposing the reduction factors in order to derive realistic reduction shares. The reason spatially explicit assessment approaches need to be followed is because these reduction factors are simply not available from statistical data sources. What is possible however that average overlay results are used provided

extrnally specifying the share of forest area covered by e.g. protected areas or the shre of forests located on steep slopes.

4.1.2 Primary forestry residues

To assess the theoretical biomass potential for logging residues that is related to this additional theoretical stemwood potential as discussed above the assessment becomes more complicated. The logging residue potential depends on the maximum allowable volume of final fellings and the species composition. It is the latter type of information which is more challenging to obtain, specifically in relation to the species composition of the stemwood harvest in time. One can therefore only assume a similar species composition for every harvest year unless more specific species composition data are available from the forest inventory.

The calculation for the theoretical logging residues potential (at maximum utilisation rate, so assuming all residues are available for bioenergy and bioeconomy uses), the BEE study (Vis et al., 2010, p 37-38) proposes the following formula:

$$THP_LR_{x,y} = \sum_{i=1}^n (IRWremi, x, y / (1-HL_{x,y}) * BEF_{i,x,y}) + \sum_{i=1}^n (THP_SWi, x, y / (1-HL_{x,y}) * BEF_{i,x,y})$$

Where:

i	= tree species/tree species group
THP_LR _{i,x,y}	= theoretical potential for logging residues at a maximum utilisation rate in country x in year y
IRWrem _{i,x,y}	= industrial roundwood removals for i-tree species in country x in year y
THP_SW _{i,x,y}	= theoretical stemwood potential for i-tree species for energy and wider bioeconomy uses in country x in year y
Hl _{x,y}	= harvest losses (ie share of stem tops and small trees; 0-1) in country x in year y
BEF _{i,x,y}	= crown biomass expansion factor for i-tree species in country x in year y (the factors usually range between 0.1-0.5 for mature stands and do not include the stemwood itself)

The share of different species in the total growing stock and the species specific crown biomass expansion factors (BEF) are often difficult to obtain. If no data are available IPCC default values will need to be used which are generally considerably less accurate.

The technical potential for forest residues is calculated simply by relating the BEF to the technical stemwood potential instead of to the theoretical one. So in formula by changing it to:

$$TCP_TLR_{x,y} = \sum_{i=1}^n (IRW_{remi,x,y} / (1-HL_{x,y}) * BEF_{i,x,y}) + \sum_{i=1}^n (TCP_SW_{i,x,y} / (1-HL_{x,y}) * BEF_{i,x,y})$$

Where:

THP_TLR_{i,x,y} = Technical potential for total logging residues in country x in year y
 TCP_SW_{i,x,y} = technical stemwood potential for energy and other biobased products use for i-tree species in country x in year y

This implies that the reduction factors for the calculation of the technical (and possibly sustainable) potential have been subtracted as discussed above. The challenge here is that for calculation of total technical stemwood potential only a distinction can be made in coniferous and broadleaved species for the calculation of residues account needs to be taken of species specific stemwood production levels since residue potential levels are strongly dependent on the species types.

4.1.3 Stump biomass potential

Stump technical potential is calculated in a similar way as for primary residues again based on what is suggested in the BEE methods handbook (Vis et al., 2010). It is a factor dependent on the tree species. Every tree has a maximum stump biomass expansion factor.

$$THP_S_{x,y} = NAI_{x,y} \times BEFS_{i,x,y}$$

Where:

THP_S_{x,y} = Theoretical potential of stumps for additional uses (energy and bioeconomy uses) in country x in year y
 NAI_{x,y} = net annual increment of stemwood in country x in year y
 BEFS_{i,x,y} = stump biomass expansion factor for i-tree species (factor ranges between 0.14-0.23 and does not include the stemwood

For the technical potential it is necessary to apply the different technical and sustainable reduction factors.

The formula for calculating the technical stump potential is then:

$$TCP_S_{x,y} = RS * THP_S_{x,y} * RFc1_{x,y} * RFc2_{x,y} * RFc3_{x,y} * ... * RFcn_{x,y} * ...$$

Where:

TCP_S_{x,y} = Technical potential of stumps for additional uses (energy and bioeconomy uses) in country x in year y
 RFc1,2,3,...,x,y = reduction factors for different constraining criteria 1, 2, .. in a country and a year.

For stumps it is likely however that especially the sustainable reduction factors are large as the risks for adverse effects on especially biodiversity are large (see Section 4.3, Table 4.2). In many countries stump extraction is not even allowed according to sustainable forest management practices. Only in Sweden, Finland and UK it is normal practice.

The key principles of assessing stemwood and primary residue potentials for non-conventional wood biomass use in energy and wider bioeconomy uses have been explained above by making a summary of the BEE Methods handbook (Vis et al., 2010, p.31). For further details on data sources and more advanced forest biomass assessment methods we refer to this handbook.

4.2 Studies providing key data on forest biomass resources

In this section we will first describe the approach of the biomass potential assessment implemented in this study to elaborate the Biomass Policies biomass potentials presented in D2.3 and the biomass cost-supply database generated in the project. Attention will then be given to other EU-wide forest biomass assessment studies in order to also provide the reader an overview of potential study results which can be used for further biomass supply inventories. After all making an assessment of forest biomass availability is complicated and getting access to and doing the right interpretation of data as input for such an assessment is quite specialised work.

4.2.1 Biomass Policies approach to assessing primary forestry potentials

There are two scenarios of biomass availability from the primary forest sector assessed using a spatially explicit modelling method. The resulting potentials can be defined as technical-sustainable potentials taking account of conventional competing uses in order to estimate the remaining potential of primary forest biomass for energy and wider bioeconomy uses.

The assessment of stemwood harvest and residue potentials is done for two demand situations:

- 1) Baseline scenario: this uses a conservative demand for stemwood and pulp wood (Including known fuelwood demand) based on the EFI-GTM calculations for the EFSOS-II reference scenario (UNECE-FAO, 2011). This claim serves as the basis for a conservative assessment of the future stemwood and pulpwood harvest and residue potential levels in this study's baseline scenario. In other words, in this situation we assume that the remaining biomass potential for energy and other bioeconomy

uses will consist of the stemwood that is currently already going to fuelwood and all residues associated to the harvesting of the main product i.e. the stemwood. It should be realised however that part of the stemwood used for conventional material uses ends up as a potential for bioenergy and other bioeconomy uses as secondary residues. These secondary residues are assessed separately as is discussed in the next sub-section 4.3.

- 2) Optimistic scenario: this scenario assumes a higher demand for stemwood above EFSOS-II demand levels. For this optimistic demand (assuming that the demand for biomass from the energy and additional bioeconomy uses will further increase the market demand) a further mobilisation takes place of forest harvest into the unmanaged parts of the forest up to the level of what can be sustainably removed in terms of both stemwood and residues.

To assess the harvest and residue potential in both scenario situations two steps are followed in the assessment:

- 1) In the EFISCEN model the harvest demand is matched with the volume available for harvest every year according to age class and species distribution. EFISCEN then simulates yearly harvest levels at national level. The key data sources to make this assessments the national forest inventory data providing as detailed information as possible on 'forest available for wood supply' (FAWS) specifying data on area (ha); growing stock volume (m³/ha overbark); (if available) net annual increment (m³/ha/yr overbark); if available gross annual increment (m³/ha/yr overbark) and annual mortality (m³/ha/yr overbark) at the highest spatial resolution possible.
- 2) The harvest and residue potential calculation results from step 1 are then downscaled in this step in EFISCEN proportional (area share specific using a spatially explicit method) by taking account of sustainability constraints for the maximum extractable residue potential. This takes account of detailed spatially explicit information on tree species, slope, soil type and conservation/protected areas.

The EFISCEN model used to make the assessments simulates the development of all separate forest resources in relation to species specific age and volume in response to and external demand for wood biomass taking account as much as possible of spatially explicit information on technical and environmental constraints.

Further details on the implementation of EFISCEN, the input data and further assumptions used and the resulting potentials can be found in D2.3 'Outlook of biomass value chains' in Chapter 3 (on the methodology and data inputs) and chapter 6 (on the results).

4.2.2 Main studies of biomass forest sector resources

A key study on current and future forestry resources for 2010-2030 is the EFSOS II (UNECE-FAO, 2011). Although the assessment of forest biomass potentials for energy and wider bioeconomy uses was just one of the objectives of the study it provides a very useful data source on how much biomass can be sustainably sourced from European forest given demand situations in five different scenario situations for both conventional material uses and new demands for energy and new biomaterials.

In addition to the UNECE-FAO study there have also been several other European studies making forest biomass potential estimates for additional demands from mostly the energy sector, taking account of several sustainability constraints. These are presented in Table 4.1 and are all conducted making use of the EFISCEN model. Data

Table 4.1 Overview of key studies on forest biomass resources in Europe

Study	Aim	Sustainability restrictions	Time
EFSOS II: UNECE and FAO 2011 The European Forest Sector Outlook Study II 2010-2030. United Nations, New York and Geneva, 2011 : <i>http://www.unece.org/efsos2.html</i>	Provides an assessment of forest resources available between 2010-2030 in 1 reference and 4 policy scenarios to understand how the use of forestry resources may affect climate change, protection of biodiversity, space for recreation and leisure, and energy and raw material needs	Different per scenario but account is taken of technical and environmental constraints such as maintaining carbon stocks, increasing the protected and recreational and leisure areas, longer and shorter rotation periods, stricter residue removal rates, no stump extraction allowed etc.	2010, 2020 and 2030
EUwood study on woody biomass resources in Europe. Mantau et al. (2010) and Verkerk et al. 2011.	To estimate the potential supply of woody biomass for all uses from the forests in the European Union (EU), while considering multiple environmental, technical and social constraints. Three scenarios were assessed: High, medium and low mobilisation scenario.	Soil productivity, soil and water protection, biodiversity protection, recovery rate, soil bearing capacity, ownership distribution.	2010, 2020, 2030
EEB-study of forest biomass resources. IINAS, EFI & JR (2014). Forest biomass for energy in the EU: current trends, carbon balance and sustainable potential for BirdLife Europe, EEB, and Transport & Environment.	The study aims to assess what the amount of forest biomass is that can be sustainably be supplied for energy use within the EU up to 2030.	Biodiversity constraints related to soil productivity constraints, soil and water protection, biodiversity protection, recovery rate, soil bearing capacity, and GHG emission reductions	2020, 2030

4.3 Sustainability risks associated to primary forest biomass resources use

Forests have important functions for the mitigation of climate change, the maintenance and supply of biodiversity, protection of soil and water resources and supply of a wide range of products and functions for people.

Forests have an enormous extend as 32% of the land area in Europe is covered by forests and therefore have several major functions. Unsustainable forest management will therefore have strong adverse effects on climate mitigation but also on the overall economy and well-being of the population in most European countries.

The main factors that determine how much biomass from forests can be harvested in an (environmentally, not social economically) sustainable way have already been mentioned in the former. These are typically factors that have been addressed in the modelling studies mentioned in the Table 4.1.

An overview of typical factors that need to be taken into account when removing biomass residues from forests are presented in Table 4.2 based on a couple of literature inventory studies. An overview is given of the risks and also measure to mitigate these.

Table 4.2 Main environmental and biodiversity risks that need consideration in forest biomass harvesting for energy and material uses (Following the literature inventories done by Giuntoli et al., 2015, Fritsche et al., 2014 and for biodiversity effects Pedrolí et al., 2011)

Field	Characterisation of risk	Measure to mitigate effect
Soil physical properties	Intensive removal of forest residues may cause soil displacement and soil erosion and if done with heavy machinery it may also cause soil compaction and other structural changes. This will have a negative effect on the tree growth, if compaction is severe. All physical soil disturbances have adverse effects on soil biodiversity (see underneath). If stumps are also removed the soil disturbing effects will be even much larger	Avoid stump removal and full removal of all residues. Especially on steep slopes (>35 degrees), stony and dry soils removal of residues, especially stumps should be avoided completely. Only harvest residues in winter when the soil is more moist and try to use low impact machinery, especially on soils with weak-bearing capabilities.
Soil organic carbon	Some studies have shown that whole tree harvesting including the residues may cause a decline in SOC, although large variations in effects were shown depending on species and soil circumstances. Stump removal effects at the long term are unknown but soil disruption	Limit the removal of residues especially in areas with high SOC levels and try to remove residues only in areas and for species which have not shown declines in SOC.

Field	Characterisation of risk	Measure to mitigate effect
	at depth of 1 m. may also favour soil mineralisation.	
Nutrient pool	Removal of nutrients from forest is especially shown to take place through the removal of residues from spruce and pine trees because of higher N concentration in residues, especially the needles. Other nutrients like calcium, potassium, sodium and phosphorus have also been shown to decline with residue removals. Residue removals have also shown some acidification effects in some cases.	Avoid residue removal on soils with low fertility and nutrient pools and on dry and rocky soils. Only remove the branches but try to leave as much as possible the needles, leaves and bark. Do not remove the roots as especially coarse roots can be responsible for significant inputs of nitrogen and potassium into the soil. Compensate acidification effect with liming.
Pests and diseases	Removal of stumps and roots has been shown to decline the spread of diseases, especially fungal pathogens	Only remove stumps in case of large disease pressure.
Biodiversity	In forest habitats biomass removal through logging and residues harvesting may create risk for biodiversity loss. In Pedrolí et al. (2011) it is explained that effects predominantly depend on the intensity of the forest harvesting and the wider environmental context. Intensive forest harvesting going together with high removal levels of residues may have negative impacts on biodiversity through: ○ Loss of dead wood, which is considered the most important factor adversely affecting biodiversity in managed forests. ○ High removal rates of stumps and logging residues which may have a negative impact on forest plant species diversity, soil fauna, as well as on saproxylic species but also bird species feeding on invertebrates living in dead wood and in the soil. ○ Increased fertilisation may have impacts on vegetation and may lead to leaching of nitrogen causing eutrophication of surface water and soils affecting wildlife flora and fauna (e.g. shift in species) and may also have direct toxic effects on flora and fauna.	Limit removal of residues, like is already happening in certain countries, especially in areas of high biodiversity. So formulation of no-go areas is recommended.

Some risks have been identified in several studies and point in the same direction e.g. residue removal for biodiversity is clearly negative while the effect on SOC

and/or nutrients is not always pointing in the same direction. There are also several mitigation measures that can be taken to limit or neutralise the adverse effect. There is also a large variation in effects depending strongly on types of soil and climatic circumstances, species of trees and presence of sensitive biodiversity.

Carbon debt

A typical additional environmental risk that has to be addressed through the whole biomass utilisation chain is that of what is often referred to as the 'Carbon debt' effect. This effect is only applicable to bioenergy systems where wood is combusted which entails an immediate release of CO₂. When wood is left in the forest it would only slowly decompose or continue growing and capturing C. Because of this there is concern that use of certain forest biomass for energy generation may lead to additional GHG emissions above the fossil comparison if within the payback time the combusted carbon from the forest is not recovered through GHG mitigation of the re-grown forest. The length of the pay-back time is therefore very influential, but generally is set at 20 to 30 years because of the short time GHG emissions need to be mitigated to prevent the additional critical temperature increase of 2 degrees by 2050.

Because of this the Carbon debt may occur especially in systems where re-growth of forests is slower, like in boreal and temperate forests. On the other hand, it should also be acknowledged that forest management can promote increases in net annual increment which means that increased forest biomass removal can still allow for reductions of forest C stocks over time in energy conversion systems (ETC-SIA, 2014; EEA, 2014; Routa 2011). To what extent depends however on the type of forest biomass used, the type of forest management and the harvest cycles and also the further use of the biomass in the total bioenergy delivery chain.

The Carbon debt risk is thus especially applicable to forest bioenergy systems, while it is of less relevance when biomass goes into biomaterials or chemicals where the carbon remains captured in the product.

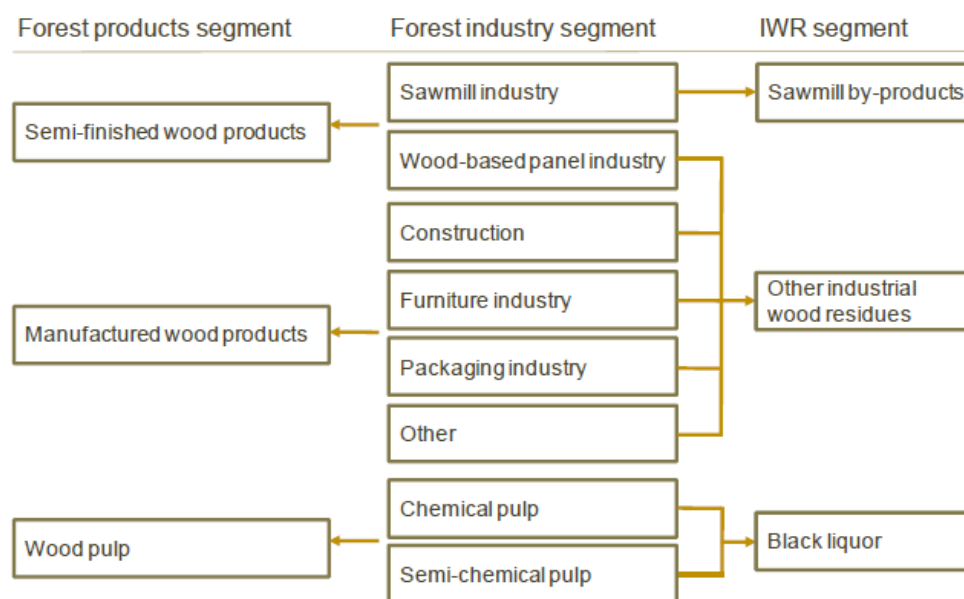
Further details on the Carbon debt issue can be read in EEA (2014) and in Fritzsche et al. (2014).

4.4 Secondary forestry biomass

As for the biomass potential from wood processing industry, the secondary forestry residues, there are 4 groups of biomass products (see Figure 4.1):

- 1) Sawmill by-products (excluding saw dust)
- 2) Saw dust from sawmills
- 3) Other forestry industry by-products
- 4) Black liquor

Figure 4.1 Diagram of forest industries producing secondary residues
(Source: Saal, U (2010) in EUwood Methodology report, 2010)



4.4.1 Sawmill by-products

The sawdust and the other residues originating from the sawmill industries are produced as a by-product during the processing of stemwood. The stemwood processing steps and resulting residues are well described in the Ecofys report (Spöttle et al, 2013, p 54-55) and in the EUwood methodology report by Saal, U (2010). It is as follows: When stemwood arrives at the sawmill, it is first debarked and the stemwood log ends are trimmed resulting in two types of residues, bark and slabs, which can be collected and the slabs can be further chipped. After this the stemwood logs are sawn, dried, planed and smoothed taking off the unwanted pieces. This all results in different types of residues:

- **Bark**
- **Sawdust** is generated when the stemwood logs are cut into planks. The amount of sawdust produced depends on the type of sawing machines used which can vary according to the thickness of the blades. Thicker

blades create more sawdust. If prices are high for sawdust, mills may decide to produce more sawdust until the prices drop again.

- **Slabs, edgings and trimmings** where slabs are the long rounded sides of the log that are sawn off and can be kept intact or further chipped. Edgings and trimmings are produced during edging of boards. Non-coniferous sawmills produce relatively more slabs than coniferous sawmills as the value of the residue wood is higher (than if it were chipped) and can be potentially used for other purposes.
- **Chips** are made out of the edgings and trimming residues of the planks that are generated during the sawmilling process.

Table 4.3 Size distribution and types of residues produced as % of total residue volumes in German sawmills (Source: Mantau and Hick (2008))

Situation for coniferous species

Sawmills size class	Max. annual capacity [m ³ log input]	Share of total cuttings [%]	SBP assortments		
			Dust [%]	Slabs [%]	Chips [%]
x-small sawmill	< 1,000	1.39	33.20	61.70	5.20
small sawmills I	1,000 - 2,500	3.97	34.27	57.23	8.51
small sawmills II	2,500 - 5,000	2.86	33.42	54.82	11.76
small sawmills III	5,000 - 10,000	7.52	33.85	28.84	37.31
medium size sawmills I	10,000 - 20,000	6.07	35.50	8.88	55.62
medium size sawmills II	20,000 - 50,000	7.56	38.73	1.82	59.46
large sawmills I	50,000 - 100,000	9.16	33.43	0.10	66.47
large sawmills II	100,000 - 500,000	34.38	35.20	0.40	64.40
x-large sawmills	> 500,000	27.09	31.40	1.00	67.60
Total		100.00	34.33	23.87	41.81

Situation for non-coniferous species

Sawmills size class	Max. annual capacity [m ³ log input]	Share of total cuttings [%]	SBP assortments		
			Dust [%]	Slabs [%]	Chips [%]
x-small sawmill	< 200	0.10	36.62	58.18	5.19
small sawmills I	200 - 500	1.64	36.81	57.67	5.60
small sawmills II	500 - 1000	1.15	35.40	48.61	15.98
small sawmills III	1000 - 2500	6.67	31.16	49.73	19.16
medium size sawmills I	2500 - 5000	7.38	30.47	51.80	17.80
medium size sawmills II	5000 - 10000	21.09	28.70	53.08	18.31
large sawmills I	10000 - 20000	29.98	39.86	39.86	20.30
large sawmills II	20000 - 50,000	15.70	27.38	36.03	36.59
x-large sawmills	> 50,000	16.29	24.30	36.00	39.70
Total		100.00	32.30	47.89	19.85

The recovery rate describes the ratio of roundwood input – and sawnwood output of a considered unit. This ratio is determined by the tree species, sawmill size and technology applied, in addition at country level this average ratio depends on the country's sawmill size structure. The ratio between sawnwood and by-products is therefore variable. Hence, comprehensive data for each country are necessary to estimate the sawmill by-products volumes. However the availability of data for all EU countries is limited, although some data are available on annual sawnwood production separated into coniferous and non-coniferous

sawnwood. Country specific data on recovery rates, sawmill sizes and sawmill size structures are partly available. In the whole of Europe a rough figure can be assumed to be 50/50 which means that 50% of the processed wood results in a main product and 50% into a by-product. As indicated this ratio can be very different as in Dutch sawmills it amounts to 53/47 for coniferous sawnwood and 51/49 for non-coniferous sawnwood and in Germany it is 60/40 for coniferous sawnwood and 65/35 for non-coniferous sawnwood.

Much more detailed data on the share of different types of residues per sawmill can be identified per country, but are not always published. For Germany Mantau and Hick (2008) made an extensive inventory see Table 4.3. Such inventories are scarce and not available for many countries.

Therefore in the EU wood study (Saal, U, 2010) an extensive assessment was done of the availability of sawmill by-products and since there is no better study published since then, it is logical to take this as the best example and data source. This is also the reason why the EUwood approach was also used in the EFOSOS II study and the approach was also extended to further non-EU countries there (See Annex 8).

In the following a summary is given of this EUwood approach. This approach can be up-dated and applied for the area of interest using more specific if available.

The first step in EUwood was an analysis of the size distribution of sawmills in individual countries. Based on this, the countries sawmill sector was categorized according to three possible structural types (See Table 4.5):

Type A are characterised by mostly large and very large (>500,000 m³) sawmills

Type B by large but not very large mills, there are no very large sawmills.

Type C is characterised by medium and small sawmills only. There are no extra-large mills; however, large mills have an important share of annual cutting

Table 4.5 Distribution of (selection of) countries according to sawmill size structure (Source: Saal, 2010 in EUwood Final report)

Coniferous sawmill size structure type			Non-coniferous sawmill size structure type		
A	B	C	A	B	C
Austria	Denmark	Bulgaria	Austria	Romania	Bulgaria
Czech Rep.	Finland	Greece	Germany	Estonia	Finland
Germany	Latvia	Ireland	Slovakia	Netherlands	Hungary

Source: EUwood

Secondly, the secondary residue volume was calculated. In EUwood an inventory was done of the relative recovery rates to be used as the starting point for the further distribution over types of residues. The recovery ranges used in EUwood were derived from different studies but the main source was from Fonseca

(2010) who identified recovery rates for each country. The recovery rate ranges were then grouped into three ranges to match to the Type A, B and C countries (Table 4.6).

Tale 4.6 Recovery rate per group of country classified according to size structure of sawmill industry (Source: Saal, 2010 in EUwood Final report)

Type	Coniferous	Non-coniferous
A	49-54%	40-50%
B	55-59%	51-55%
C	60-65%	56-66%

Based on the recovery rates the total secondary residue volume can be calculated. The statistical figures from FAOSTAT on the production data of coniferous and non-coniferous sawnwood were used as input³ for the EUwood (and EFSOS II) study. For up-dated calculations these FAOSTAT data can be downloaded as these are publicly available and regularly up-dated.

Calculation of the total volume of the sawmill by-products is calculated in EUwood in 2 steps:

$$\mathbf{TAC = SW_{produced} / RR_{assigned}}$$

Where:

TAC = total annual cutting volume going to the sawmill industry,

SW = sawnwood,

RR=recovery rate. This rate is countryspecific and depends on the size structure of the sawmill industry (see Table 4.6)

$$\mathbf{SBP = TAC / ((100\%-RR_{assigned}) - losses\%)}$$

Where:

SBP = Sawmill by-products – total volume

TAC = total annual cutting volume,

Losses% = This rate is an average share of 0.7% (coniferous) respectively 1.6% (non-coniferous) for losses. This is subtracted from the total cutting volume. Losses are considered as unrecovered volumes, which do not account for sawmill by-products or produced sawnwood (e.g. due to losses during transport).

³ See <http://www.factfish.com/statistic/sawnwood%2C%20non-coniferous%2C%20production%20volume>

Third the total sawmill by-product volume is further sub-divided in residues types according to the segments of residue products belonging to the sawmill country typology in A, B and C types as explained in the former (see Table 4.7).

Table 4.7 Segmentation in residue types per group of country classified according to size structure of sawmill industry (Source: Saal, 2010 in EUwood Final report)

Coniferous				Non-coniferous			
Type	Dust	Slabs	Chips	Type	Dust	Slabs	Chips
A	33.32	4.53	62.15	A	31.66	43.40	24.97
B	35.26	4.93	59.82	B	32.12	48.84	19.09
C	35.05	11.49	53.48	C	32.97	52.12	14.96

Source: EUwood

The results of the EUwood study for secondary sawmill residues were also used in this Biomass Policies study as is described in the Biomass Policies D2.3 'Outlook of biomass value chains'. The data were derived from EUwood study at national level and in thi study a further spatialisation (allocation) was done from national to Nuts 2 level.

4.4.2 Other forestry industry by-products

Other forestry industry by-products come from the processing of primary and further processed timber products, such as sawn wood, wood based panels, joinery products, etc., into for instance window frames, furniture, doors etc (see Figure 4.1). The by-products mainly consist of sawdust, shavings and off-cuts and their moisture content is often lower than that of sawmill by-products and amounts to 10-20% moisture. More than with the sawmill by-products, which are seen as a by-product, these biomass potentials are mostly considered as a waste stream. Their use is well organised though, much is already collected by waste-processing companies, and can often be collected for free or a small price. A larger part of these by-products then for the sawmills by-products is contaminated with paint, glue or other non woody materials and therefore only suitable to be used by waste processing companies. These waste companies also convert these contaminated residues into energy.

An estimation of the amount available of these residues was also done as part of the EUwood study (Saal, 2010) and further extended to all European countries as part of the EFSOSII study. For further details please consult the EUwood methodology and Final report (Mantau et al, 2010).

4.4.3 Black liquor

The fourth secondary forestry biomass type ‘black liquor’ is a by-product of the paper and pulp industry. It is mostly used by the industry itself as an important source of biomass to be converted into bio-electricity and heat. All of this potential can be considered to already being converted into bioenergy.

Approximately 40 to 50% of the input wood raw material is recovered as usable fibre in the chemical pulping processes (Smook, 1992 in Saal, 2010). The other “half” of the input wood along with an equal amount of spent caustic cooking chemicals, forms the black liquor.

Black liquor production data are published in FAOSTAT and up-dated regularly⁴. As part of the EUwood (Saal, 2010) and EFSOS II estimations of black liquor production levels were made and also econometric projection were implemented for calculating secondary forestry residues, including lack liquor) for 2020 and 2030.

4

<http://www.factfish.com/statistic/fibre%20pulp%2C%20recovered%2C%20production%20weight>

5 Biomass from waste

The waste potentials can best be assessed using Eurostat or national waste generation and waste treatment data as input. For Eurostat data can be downloaded directly from the Eurostat websites⁵. Since 2004 data on waste generation and treatment are collected per EU member state⁶. Because this data is collected according to fixed categories (European Waste Classification for statistical purposes) which are based on the waste sources, it is logical that the potentials assessed are also ordered accordingly. At the highest level a distinction is made between waste from households (HH) and waste from business activities (NACE classification). For a detailed classification of the Eurostat waste data see Table 4.1.

In order to calculate waste potentials the following steps are proposed:

- 1) First identify the total waste generation per category of waste (see Table 5.1)
- 2) Then identify the waste treatment categories
- 3) Calculate the waste treatment factors to identify which part is already going to alternative useful uses (e.g. compost, backfilling etc.) and which part of the waste is available for further conversion into energy or other future bioeconomy uses. So the part already going to energy is also perceived to be available as part of the potential.

The total waste generation reported by Eurostat in Table 5.1 (last column) is only the basis for assessing the biomass potential. The waste assessment can be done for the years for which data are available. A distinction is made between data used to determine the total waste generation and data to determine the current waste treatments. The latter figures determine the final potential.

⁵ <http://epp.eurostat.ec.europa.eu/portal/page/portal/environment/data/database>

⁶ Regulation on waste statistics (EC) No. 2150/2002, amended by Commission Regulation (EU) No. 849/2010, prescribe that data on the generation and treatment of waste is collected from the Member States.

Table 5.1 Waste categories selected from Eurostat for assessing the waste potentials

Household (HH)/ economic sectors (NACE)	Waste type	Definition	NACE code- waste statistics	Explanation	Kton DM for EU-28 in 2010 *
HH	Paper	See underneath NACE 'Paper cardboard'	EP_HH.W072	Paper	17,180
HH	Wood waste	These wastes are separately collected wood wastes from households.	EP_HH.W075	Wood waste	3,880
HH	Animal and mixed food	See underneath NACE 'animal and mixed food'	EP_HH.W091	Animal and mixed food	5,810
HH	Vegetal waste	See underneath NACE 'vegetal waste'	EP_HH.W092	Vegetal waste	20,320
HH	Municipal Solid Waste (MSW)	Household and similar wastes are mixed municipal waste, bulky waste, street-cleaning waste like packaging, kitchen waste, and household equipment except separately collected fractions. They originate mainly from households but can also be generated by all sectors in canteens and offices as consumption residues.	EP_HH.W101	Municipal Solid Waste (MSW)	138,260
HH	Common sludges	See underneath NACE 'common sludges'	EP_HH.W11	Common sludges	230,000
NACE	Paper and cardboard wastes	These wastes are paper and cardboard from sorting and separate sorting by businesses and households. This category includes fibre, filler and coating rejects from pulp, paper and cardboard production. These wastes are largely generated by three activities: separate collection, mechanical treatment of waste and pulp, and paper and cardboard production and processing. All paper and cardboard wastes are non-hazardous.	W072.TOTAL	Total paper	39,550
			W072.C17_C18	Paper from manufacture of paper and paper products; printing and reproduction of recorded media	7,870
			W072.TOT_excl_above	Paper from other economic sectors	31,680
NACE	Wood waste	These wastes are wooden packaging, sawdust, shavings, cuttings, waste bark, cork and wood from the production of pulp and paper; wood from the construction and demolition of buildings; and separately collected wood waste. They mainly originate from wood processing, the pulp and paper industry and the demolition of	W075.TOTAL	Total wood	55,300
			W075.C16	Wood from manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw	21,420

Household (HH)/ economic sectors (NACE)	Waste type	Definition	NACE code- waste statistics	Explanation	Kton DM for EU-28 in 2010 *
		buildings but can occur in all sectors in lower quantities due to wooden packaging. For some countries this category is corrected (e.g. PO, SK, ...) because this category overlaps with the forest potential category 'secondary forestry residues' particularly with the sub-category 'Other forestry industry by-products'. Wood wastes are hazardous when containing hazardous substances like mercury or tar-based wood preservatives, which makes it only suitable for incineration and not recycling.		and plaiting materials	
			W075.TOT_excl_above	Wood from other economic sectors	33,880
NACE	Animal and mixed food	Animal and mixed food wastes (09.1): item 31. These wastes are animal and mixed wastes from food preparation and products, including sludges from washing and cleaning; separately collected biodegradable kitchen and canteen waste, and edible oils and fats. They originate from food preparation and production (agriculture and manufacture of food and food products) and from separate collection. Animal and mixed waste of food preparation and products are non-hazardous.	W091.TOTAL	Total animal and mixed food	32,770
			W091.A	AnMixfood from Agriculture, forestry and fishing	11,580
			W091.C10-C12	AnMixfood from Manufacture of food products; beverages and tobacco products	12,780
			W091.E	AnMixfood from companies in water collection, treatment and supply; sewerage; remediation activities and other waste man. Serv.	810
			W091.G-U_X_G4677	AnMixfood from all services (except wholesale of waste and scrap)	6,510
			W091.TOTAL-4 above	AnMixFood other	1,090
NACE	Vegetal waste	Vegetal wastes (09.2): item 32. These wastes are vegetal wastes from food preparation and products, including sludges from washing and cleaning, materials unsuitable for consumption and green wastes.	W092.TOTAL	Total vegetal waste	33,130
			W092.A	Vegetal waste from agriculture, forestry and fishing	6,830

Household (HH)/ economic sectors (NACE)	Waste type	Definition	NACE code- waste statistics	Explanation	Kton DM for EU-28 in 2010 *
		They originate from food and beverage production, and from agriculture, horticulture and forestry. Vegetal wastes are non-hazardous.	W092.C10-C12	Vegetal waste from Manufacture of food products; beverages and tobacco products	15,500
			W092.E	Vegetal waste from companies in water collection, treatment and supply; sewerage; remediation activities and other waste management services	2,500
			W092.G-U_X_G4677	Vegetal waste from all services (except wholesale of waste and scrap)	6,360
NACE	Used fats & oils (UFO)	Used animal fats and vegetal oils.	NOT reported separately in Eurostat	This category is included in the Eurostat waste category 'Animal and mixed waste'.	
NACE	Municipal Solid Waste (MSW)	See MSW from HH above.	W101.TOTAL	Total MSW	47,970
NACE	Common sludges	These are waste water treatment sludges from municipal sewerage water and organic sludges from food preparation and processing. They mainly originate from households and industrial branches with organic waste water (mainly pulp and paper as well as food preparation and processing). They can also occur in waste water treatment plants or in the anaerobic treatment of waste. All common sludges are non-hazardous. Comparability can be problematic between countries using different statistical units as they will not assign the waste to the same economic sector.	W11.TOTAL	Total common sludges	18,930
			W11.C	Comsludges from all manufacture manufacturing companies	4,040
			W11.E	Comsludges from Water collection, treatment and supply; sewerage; remediation activities and other waste management services	12,680

To assess which part of the waste is already recovered for other useful uses and which part can really be seen as potential data on waste generation and waste treatment need to be combined. The waste treatment data are reported in Eurostat according to the following categories:

- 1) Waste going to recovery/treatment: NO POTENTIAL/Competing
- 2) Incineration with energy recovery: POTENTIAL (already going to energy)
- 3) Incineration without energy recovery: POTENTIAL (scenario specific)
- 4) Disposal on or into land (landfill): POTENTIAL (scenario specific)
- 5) Other disposal NO POTENTIAL/Competing

The treatment figures can be applied to the total waste generation figures as percentages and not as absolute figures as the absolute figures never add up to the total of the waste generation figures. The treatment data is specified at regional level (NUTS1) per type of waste category, while the waste generation data are only available at national level.

For the detailed analysis of the waste potentials we refer to the D2.3 report 'Outlook of biomass value chains' (Chapter 4) where a very detailed description is given of the full assessment of waste potentials taken both Eurostat and national data into account. In addition or certain types of waste streams such as for paper and cardboard, use fats and oils and municipal solid waste (MSW) additional data sources were consulted to make better interpretation of their current and future generation levels and recycling rates.

Future waste potentials

For extrapolations of waste potentials into the future it is best to calculate waste per head ratios by dividing total waste generation by number of inhabitants. Existing population development projections (e.g. such as from Eurostat, FAO and OECD) can then be used to extrapolate the waste generation data into the future. Assumptions need to be made however in relation to how waste treatment and recycling rates develop. A very useful study used for the calculation of current and future MSW potentials is the ARCADIS (2009), Assessment of the options to improve the management of bio-waste in the EU. Study for DG-ENV. Unfortunately no update of this study has been published until now.

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7 Annexes

Annex 1 Average yield levels for main sugar, starch and oil crops in the EU

Table 1 Yield levels (2010) based on 3-year average of sugar beet, cereals, sunflower, soya and rape (kg main product/ha)

Kg/ha	Barley	Durum wheat	Grain maize	Oats	Other cereals	Rape	Rye	Soya	Sugar beet	Sun flower	Soft wheat
Albania	2938		5117	2127	2483		2935	412	17517	2411	4193
Austria	4481	4220	9847	3581	4684	3148	3740	2773	67586	2649	5079
Belgium/ Luxembourg	8600		10689	5105	3277	3956	2926		72128		8868
Bosnia	2470		4597	2006	3135	2254	2803	2074		1032	2853
Bulgaria	3460	3251	5118	1834	3196	2291	1827	1182		2158	3074
Croatia	3402	4637	6881	2435	402	2064	2860	1089	50597	2415	4156
Cyprus	1605	2507		3975	1168						
Czech Rep.	3877		6777	2783	3564	2698	4032	1771	52397	2120	4966
Denmark	5459			4902	4508	3536	5081		59095		6858
Estonia	2842			1808	2461	1348	2264				3049
EU-27	4481	2979	7147	2705	4263	2893	3242	2853	62471	1828	5540
Finland	3331			2907	2246	1113	2732		37492	221	3567
France	6689	4519	9299	3684	6140	3396	5172	2770	79432	2409	6758
Germany	6465	5487	9407	4340	4627	3883	4763		63010	1901	7425
Greece	2705	2428	10933	2292	2833		2655	2418	59294	2368	3202
Hungary	3320	3479	5998	2149	2815	2004	2100	2208	54151	1884	3679
Ireland	7402			7341	5824	3231					8778
Italy	3516	3030	9227	2216	5990	2554	3201	3436	56779	2187	5400
Kosovo	1794		1888	2662	3655		2523			2315	4069
Latvia	2279			1583	2619	2145	2159				3364
Lithuania	2829		4123	1393	2933	1689	2051		46367		3799
Macedonia	2953		4440	2052	1826	2581	2586	1699	33814	1421	3027
Malta	4782				5398						5903
Moldova	3415		4039	1734			3288				3265
Netherlands	6226		10098	5692	2665	4292	4399		75621	3783	8944
Norway	3795			3977	3399	1632	5059				4522
Poland	3730		6264	2509	4208	2236	2672	2655	45196	1477	4725
Portugal	1606	1607	7076	1121	1406		986		42210	529	1437
Romania	2598	2245	4075	1789	2921	1759	2674	2356	38885	1244	2782
Serbia	2908		5081	1942	3419	2042	1857	3076	48588	2152	3051
Slovakia	2745	3565	5458	1591	2680	1936	1777	1713	53383	1810	3501
Slovenia	4450		9420	2843	6854	1771	3219	1449			5192
Spain	2875	1983	10227	2089	170	1749	1756	2132	81943	1242	3420
Sweden	4082		6384	3618	4622	2530	4780		51218		5575
Turkey	2925	2892	8269	2782	3489	334		3108	55021	2075	3502
UK	5849	3051		5529	4715	3544	6742		50943	3414	7808

Source: Capri-Coco database using Eurostat and national statistical data as input (Data are averages of 3 different reporting years).

Annex 2 Average yield levels for perennial crops on high and low yielding soils

NUTS2	Miscanthus (kg/ha)			Switchgrass (Kg/ha)			RCG (Kg/ha)			Willow (Kg/ha)			Poplar (Kg/ha)		
	average	High	Low	average	High	Low	average	High	Low	average	High	Low	average	High	Low
AT11	17277	17847	9503	16244	16779	8934	15529	16643	8541	11075	11440	6091	11314	11687	6223
AT12	15221	15221	8372	15105	15105	8308	14753	15242	8114	10446	10446	5745	6887	6887	3788
AT13	10095	10095	5553	14132	14132	7772	12333	12333	6783	10647	10647	5856	4390	4390	2415
AT21	10001	10001	5500	15261	15261	8394				11154	11154	6135	4969	4969	2733
AT22	13424	13424	7383	14437	14437	7940				10901	10901	5996	4753	4753	2614
AT31	11978	11978	6588	12456	12456	6851	13282	13282	7305	9646	9646	5305	5128	5128	2820
AT32	8768	8768	4822	14568	14568	8012	11385	11385	6262	11780	11780	6479	3181	3181	1749
AT33	6307	6307	3469	13938	13938	7666				9752	9752	5363	3921	3921	2157
AT34				14560	14560	8008	9551	9551	5253	10341	10341	5688	4228	4228	2326
BE10	13059	13059	7182	15374	15374	8456	14561	14561	8009	11992	11992	6595			
BE21	13183	13183	7251	12614	12614	6938	14618	14618	8040	9809	9809	5395			
BE22	13188	13188	7254	14220	14220	7821	14509	14509	7980	11878	11878	6533	5691	5691	3130
BE23	13028	13028	7166	15469	15469	8508	14530	14530	7992	10893	10893	5991			
BE24	13167	13167	7242	16967	16967	9332	14630	14630	8047	13142	13142	7228			
BE25	12898	12898	7094	15457	15457	8502	14836	14836	8160	11246	11246	6185			
BE31	13170	13170	7243	16284	16284	8956	14745	14745	8110	13060	13060	7183			
BE32	13329	13329	7331	16435	16435	9039	14782	14782	8130	13125	13125	7219			
BE33	12879	12879	7084	15165	15165	8340	14393	14393	7916	11997	11997	6598	9159	9159	5038
BE34	12740	12740	7007	15262	15262	8394	14184	14184	7801	11795	11795	6487	9370	9370	5153
BE35	13006	13006	7153	15866	15866	8727	14382	14382	7910	12973	12973	7135	10041	10041	5523
BG31	18045	20498	9925	15749	17890	8662	15674	17888	8621	10963	12453	6029	8246	9367	4535
BG32	18446	20919	10145	14404	16335	7922	15986	18196	8792	10210	11578	5615	8782	9959	4830
BG33	16690	22675	9180	11482	15600	6315	14041	19532	7722	9015	12247	4958	7050	9578	3878
BG34	15185	19071	8352	13199	16577	7259	13774	17103	7576	8516	10696	4684	6850	8603	3767
BG41	16092	21265	8851	12881	17022	7085	14272	18552	7850	8431	11141	4637	6742	8909	3708
BG42	15280	23286	8404	11769	17936	6473	13146	20125	7230	7527	11470	4140	5795	8832	3187

NUTS2	Miscanthus (kg/ha)			Switchgrass (Kg/ha)			RCG (Kg/ha)			Willow (Kg/ha)			Poplar (Kg/ha)		
	average	High	Low	average	High	Low	average	High	Low	average	High	Low	average	High	Low
CY00	10913	26042	6002	4111	9812	2878							4180	9926	2299
CZ01	13327	13327	7330	15797	15797	8689	13532	14235	7443	8825	8825	4853	8396	8396	4618
CZ02	13450	13450	7397	13097	13097	7203	13977	14177	7687	8659	8659	4763	7269	7269	3998
CZ03	12871	12871	7079	11763	11763	6470	13828	13828	7605	8670	8670	4769	5907	5907	3249
CZ04	12845	12845	7065	13664	13664	7515	13425	13816	7384	8744	8744	4809	6338	6338	3486
CZ05	13572	13572	7465	12248	12248	6736	14112	14112	7761	9067	9067	4987	6366	6366	3502
CZ06	15013	15013	8257	13795	13795	7587	14656	15027	8061	8951	8951	4923	6078	6078	3343
CZ07	14830	14830	8156	14114	14114	7763	14822	14850	8152	10416	10416	5729	8259	8259	4543
CZ08	13932	13932	7662	13290	13290	7309	14329	14329	7881	9928	9928	5461	8426	8426	4634
DE1	13752	13752	7563	15486	15486	8518	13547	14470	7451	10696	10696	5883	8397	8397	4618
DE2	11165	11165	6141	15466	15466	8507	13001	13001	7150	10893	10893	5991	5791	5791	3185
DE3	12458	12458	6852	15476	15476	8512	13274	13736	7300	10794	10794	5937	7094	7094	3902
DE4	14496	14496	7973	12443	12443	6843	13752	14781	7564	7572	7572	4165	5800	5800	3190
DE5	12978	12982	7138	13861	13865	7623	13495	14123	7422	9750	9753	5362	6399	6402	3520
DE6	12978	12982	7138	13861	13865	7623	13495	14123	7422	9750	9753	5362	6399	6402	3520
DE7	14053	14098	7729	14800	14847	8140	13213	14752	7267	11558	11594	6357	8290	8316	4559
DE8	12374	12374	6806	12490	12490	6870	12684	13474	6976	7498	7498	4124	5467	5467	3007
DE9	12627	12627	6945	13739	13739	7556	13675	13927	7521	9291	9291	5110	7276	7276	4002
DEA	13015	13015	7158	14760	14760	8118	14207	14207	7814	12085	12085	6647	0	0	0
DEB	13230	13230	7276	14071	14071	7739	13511	14167	7431	11218	11218	6170	8015	8015	4408
DEC	14276	14276	7852	14792	14792	8136	14123	14876	7768	11896	11896	6543	8868	8868	4877
DED	13416	13416	7379	14141	14141	7778	13954	14183	7675	9347	9347	5141	6676	6676	3672
DEE	13202	13202	7261	14042	14042	7723	13751	14937	7563	8535	8535	4694	6609	6609	3635
DEF	11108	11108	6109	12072	12072	6639	12943	12943	7118	7162	7162	3939	5423	5423	2983
DEG	12477	12477	6862	13697	13697	7533	12888	13766	7088	8908	8908	4899	7371	7371	4054
DK01	9390	9390	5164	10097	10097	5554	11770	11770	6474	7128	7128	3920	3871	3871	2129
DK02	9390	9390	5164	10097	10097	5554	11770	11770	6474	7128	7128	3920	3871	3871	2129

NUTS2	Miscanthus (kg/ha)			Switchgrass (Kg/ha)			RCG (Kg/ha)			Willow (Kg/ha)			Poplar (Kg/ha)		
	average	High	Low	average	High	Low	average	High	Low	average	High	Low	average	High	Low
DK03	9390	9390	5164	10097	10097	5554	11770	11770	6474	7128	7128	3920	3871	3871	2129
DK04	9390	9390	5164	10097	10097	5554	11770	11770	6474	7128	7128	3920	3871	3871	2129
DK05	9390	9390	5164	10097	10097	5554	11770	11770	6474	7128	7128	3920	3871	3871	2129
EE00				9931	9931	5462	10679	10989	5873	6991	6991	3845	6904	6904	3797
EL11	14279	25661	7854	8286	14890	4557									
EL12	13420	24782	7381	8598	15877	4729							4320	7977	2376
EL13	11171	22430	6144	10152	20383	5584							4933	9905	2713
EL14	11025	25648	6064	6452	15010	3549							3970	9236	2184
EL21	10830	24300	5956	7017	15745	3859							4934	11070	2713
EL22	11414	29840	6278	5661	14800	3113							5254	13737	2890
EL23	10287	27196	5658	4614	12197	2537							3677	9720	2022
EL24	9472	28452	5210	3895	11701	2142							3067	9214	1687
EL25	9396	29000	5168	3544	10939	1949							3333	10289	1833
EL30	9623	24000	5293	4208	10495	2314							3928	9796	2160
EL41	9309	29000	5120	3137	9774	1726							2909	9062	1600
EL42	10856	24000	5971	4230	9351	2326							4211	9310	2316
EL43	10785	24244	5932	4429	9957	2436							4635	10420	2549
ES11	12975	17597	7136	9400	12750	5170				9442	12807	5193	7361	9983	4048
ES12	11040	14777	6072	10498	14052	5774				9180	12287	5049	4516	6044	2484
ES13	12661	16830	6963	10389	13810	5714				9365	12449	5151	6325	8408	3479
ES21	13704	18517	7537	10203	13786	5612				9571	12932	5264	8518	11509	4685
ES22	13513	19046	7432	8531	12025	4692							7507	10581	4129
ES23	11616	19390	6389	6821	11386	3752							5462	9118	3004
ES24	12406	22164	6824	6020	10755	3311							4379	7823	2409
ES30	10238	24844	5631	3826	9284	2104							2764	6706	1520
ES41	10716	20103	5894	5726	10742	3149							3813	7152	2097
ES42	10861	26489	5974	4122	10052	2267							3008	7335	1654

NUTS2	Miscanthus (kg/ha)			Switchgrass (Kg/ha)			RCG (Kg/ha)			Willow (Kg/ha)			Poplar (Kg/ha)		
	average	High	Low	average	High	Low	average	High	Low	average	High	Low	average	High	Low
ES43	11196	28542	6158	3907	9960	2149							4020	10249	2211
ES51	13095	23184	7202	7699	13631	4234							4742	8396	2608
ES52	12400	28094	6820	5193	11766	2856							3938	8922	2166
ES53	14328	29000	7880	6168	12485	3393							5356	10840	2946
ES61	11696	29000	6433	4015	9955	2208							4229	10484	2326
ES62	11534	29000	6343	3346	8412	1840							3208	8066	1764
ES63	12124	22911	6668	6616	11553	3639							4947	8851	2721
ES64	12124	22911	6668	6616	11553	3639							4947	8851	2721
ES70	12124	22911	6668	6616	11553	3639							4947	8851	2721
FI19							8698	8698	4784	4269	4269	2348	2591	2591	1425
FI1B							9942	9942	5468	4547	4547	2501	3136	3136	1725
FI1C							9205	9205	5063	3550	3550	1952	2790	2790	1535
FI1D							6974	6974	3836				207	207	114
FI20							9762	10026	5369	893	893	491	1818	1818	1000
FR10	14928	15798	8210	15261	16151	8394	14363	16214	7899	12365	13086	6801	8531	9028	4692
FR21	14503	15404	7977	13966	14833	7681	14162	15883	7789	10921	11600	6007	6800	7222	3740
FR22	14333	14333	7883	14613	14613	8037	14710	15357	8091	11338	11338	6236	7718	7718	4245
FR23	13873	13873	7630	15482	15482	8515	14560	15438	8008	12828	12828	7055	8137	8137	4475
FR24	15226	17448	8374	13800	15815	7590	14615	17477	8038	10836	12418	5960	8479	9716	4663
FR25	13796	13796	7588	14929	14929	8211	15090	15791	8300	14341	14341	7887	8971	8971	4934
FR26	15552	17079	8553	14586	16018	8022	14911	17035	8201	11615	12756	6388	8602	9447	4731
FR30	13298	13298	7314	15930	15930	8762	14780	14856	8129	12278	12278	6753	6505	6505	3578
FR41	14525	14525	7989	14735	14735	8104	14535	15127	7994	11668	11668	6418	5598	5598	3079
FR42	14168	14168	7792	14412	14412	7927	14758	14758	8117	11397	11397	6268	4764	4764	2620
FR43	14434	14434	7939	15886	15886	8737	15028	15028	8265	12880	12880	7084	6047	6047	3326
FR51	15533	17463	8543	13334	14991	7334				12281	13807	6755	9058	10183	4982
FR52	14455	14455	7951	15791	15791	8685	15810	16393	8695	12984	12984	7141	11519	11519	6335

NUTS2	Miscanthus (kg/ha)			Switchgrass (Kg/ha)			RCG (Kg/ha)			Willow (Kg/ha)			Poplar (Kg/ha)		
	average	High	Low	average	High	Low	average	High	Low	average	High	Low	average	High	Low
FR53	14946	19609	8221	12730	16701	7002				10895	14294	5992	8646	11343	4755
FR61	16481	20176	9064	13642	16700	7503				11645	14256	6405	8382	10261	4610
FR62	14715	18408	8093	13344	16693	7339							9073	11349	4990
FR63	15668	17620	8618	15409	17328	8475	15479	17593	8514	12535	14096	6894	4146	4662	2280
FR71	13197	15089	7258	14253	16296	7839							7879	9008	4333
FR72	15164	16646	8340	13016	14288	7159	14952	16944	8224	10757	11808	5916	5982	6567	3290
FR81	12924	21508	7108	8584	14286	4721							5219	8685	2870
FR82	11049	19107	6077	8536	14761	4695							5096	8812	2803
FR83	11687	26222	6428	6638	14894	3651							5542	12434	3048
FR91	14293	16839	7861	13585	15524	7472	14840	15992	8162	11974	12814	6586	7304	8544	4017
FR92	14293	16839	7861	13585	15524	7472	14840	15992	8162	11974	12814	6586	7304	8544	4017
FR93	14293	16839	7861	13585	15524	7472	14840	15992	8162	11974	12814	6586	7304	8544	4017
FR94	14293	16839	7861	13585	15524	7472	14840	15992	8162	11974	12814	6586	7304	8544	4017
HR03	16623	21286	9143	13247	16893	7286	14482	18566	7965	9110	11598	5011	7244	9208	3984
HR04	16623	21286	9143	13247	16893	7286	14482	18566	7965	9110	11598	5011	7244	9208	3984
HU10	16366	20655	9002	14785	18660	8132	14363	18328	7900	9367	11821	5152	7669	9679	4218
HU21	16100	20423	8855	14814	18791	8147	14227	18236	7825	8389	10641	4614	8285	10509	4556
HU22	16971	19471	9334	16540	18977	9097	15141	17776	8327	10268	11780	5647	10246	11756	5636
HU23	15924	21023	8758	14623	19305	8043	14128	18770	7770	9076	11982	4992	8587	11337	4723
HU31	17498	18692	9624	17680	18886	9724	15371	16804	8454	11620	12412	6391	9577	10231	5268
HU32	17620	19690	9691	14257	15932	7841	15509	17523	8530	9300	10393	5115	6781	7578	3729
HU33	16923	21872	9308	12133	15681	6673	14717	19109	8094	8578	11086	4718	6348	8204	3491
IE01				11246	11246	6185	11410	11410	6275	9267	9267	5097	5893	5893	3241
IE02				10819	10819	5950	12226	12226	6724	9267	9267	5097	6015	6015	3308
ITC1	12219	15128	6721	12917	15991	7104							7794	9649	4287
ITC2	7629	7629	4196	12811	12811	7046							1943	1943	1069
ITC3	13839	22465	7612	8632	14013	4748							6020	9771	3311

NUTS2	Miscanthus (kg/ha)			Switchgrass (Kg/ha)			RCG (Kg/ha)			Willow (Kg/ha)			Poplar (Kg/ha)		
	average	High	Low	average	High	Low	average	High	Low	average	High	Low	average	High	Low
ITC4	13586	15671	7472	13339	15386	7337							5745	6626	3160
ITH1	9157	9157	5036	14465	14465	7956							3359	3359	1847
ITH3	15199	16266	8360	12338	13204	6786							5731	6133	3152
ITH4	15447	15447	8496	14657	14657	8061							4041	4041	2223
ITH5	16615	22534	9138	10484	14219	5766							5867	7958	3227
ITI1	15112	23730	8312	8709	13676	4790							6600	10364	3630
ITI2	14667	22699	8067	9321	14426	5127							6196	9589	3408
ITI3	15695	23825	8632	10289	15619	5659							5666	8601	3116
ITI4	14625	24695	8044	8795	14851	4837							6445	10883	3545
ITF1	14464	22642	7955	9288	14539	5108							5955	9322	3275
ITF2	14930	24539	8211	8147	13391	4481							5755	9459	3165
ITF3	14825	25728	8154	7671	13312	4219							5162	8959	2839
ITF4	16229	29000	8926	6216	11107	3419							5272	9420	2899
ITF5	15299	27222	8414	6525	11611	3589							4934	8780	2714
ITF6	15220	29612	8371	6414	12480	3528							5180	10078	2849
ITG1	15570	29000	8564	4640	8643	2552							4199	7820	2309
ITG2	13036	29000	7170	5619	12499	3090							4720	10499	2596
LT00				12987	12987	7143	12698	12698	6984	8806	8806	4843			
LU00	13059	13059	7182	15374	14589	8456	14561	14561	8009	11992	11992	6595	8565	8565	4711
LV00	0	0	0	11420	11420	7994	11934	11934	6564	8403	8403	4622	7219	7219	3970
ME00	16623	21286	9143	13247	16893	7286	14482	18566	7965	9110	11598	5011	7244	9208	3984
MT00	14168	21799	7793	9564	13545	5260	0	0	0	0	0	0	5329	8163	2931
NL11	11832	11832	6507	12440	12440	6842	13730	13730	7551	7258	7258	3992	5751	5751	3163
NL12	11583	11583	6371	11921	11921	6556	13605	13605	7483	8183	8183	4500	6769	6769	3723
NL13	11810	11810	6496	11019	11019	6061	13646	13646	7505	7397	7397	4068	6169	6169	3393
NL21	12723	12723	6998	11223	11223	6172	14263	14263	7845	8395	8395	4617	6926	6926	3809
NL22	13095	13095	7202	13553	13553	7454	14492	14492	7971	10560	10560	5808	5604	5604	3082

NUTS2	Miscanthus (kg/ha)			Switchgrass (Kg/ha)			RCG (Kg/ha)			Willow (Kg/ha)			Poplar (Kg/ha)		
	average	High	Low	average	High	Low	average	High	Low	average	High	Low	average	High	Low
NL23	12094	12094	6652	13117	13117	7214	13875	13875	7631	8174	8174	4496			
NL31	12797	12797	7038	14391	14391	7915	14377	14377	7907	11238	11238	6181			
NL32	11676	11676	6422	13315	13315	7323	13704	13704	7537	9060	9060	4983	6816	6816	3749
NL33	12473	12473	6860	13745	13745	7560	14276	14276	7852	9728	9728	5350			
NL34	12773	12773	7025	14244	14244	7834	14547	14547	8001	8369	8369	4603			
NL41	12931	12931	7112	12778	12778	7028	14456	14456	7951	9135	9135	5024	6257	6257	3442
NL42	13152	13152	7233	14700	14700	8085	14620	14620	8041	11324	11324	6228			
PL11	14494	14494	7972	14110	14110	7761	14376	14563	7907	8787	8787	4833	5823	5823	3203
PL12	14302	14302	7866	14735	14735	8104	14241	14375	7833	8213	8213	4517	5819	5819	3200
PL21	13596	13596	7478	12819	12819	7050	13943	13943	7669	9242	9242	5083	5267	5267	2897
PL22	13523	13523	7438	13937	13937	7666	14025	14025	7714	9830	9830	5407	5662	5662	3114
PL31	14942	14942	8218	15358	15358	8447	14752	14752	8113	9703	9703	5337	5722	5722	3147
PL32	14729	14729	8101	13456	13456	7401	14539	14539	7997	9749	9749	5362	7204	7204	3962
PL33	14378	14378	7908	15660	15660	8613	14462	14462	7954	10478	10478	5763	5950	5950	3273
PL34	13220	13220	7271	12639	12639	6952	13686	13686	7527	8365	8365	4601	5531	5531	3042
PL41	14469	14469	7958	14174	14174	7796	13962	14519	7679	7945	7945	4370	6161	6161	3388
PL42	12778	12778	7028	13068	13068	7187	13351	13649	7343	8744	8744	4809	6128	6128	3370
PL43	14386	14819	7912	13172	13568	7245	13418	14899	7380	8178	8424	4498	6563	6761	3610
PL51	13999	13999	7699	13352	13352	7344	14294	14294	7862	8883	8883	4886	4641	4641	2552
PL52	14405	14405	7923	13722	13722	7547	14593	14593	8026	9293	9293	5111	10102	10102	5556
PL61	13601	13601	7480	13022	13022	7162	13946	13989	7670	8241	8241	4532	5748	5748	3162
PL62	12508	12508	6880	13264	13264	7295	13028	13302	7166	8475	8475	4661	5486	5486	3017
PL63	11371	11371	6254	12718	12718	6995	12634	12634	6949	7972	7972	4385	6370	6370	3503
PT11	11468	20122	6307	8027	14086	4415				8351	14654	4593	5273	9252	2900
PT15	10684	29000	5876	7479	20300	4113							4056	11009	2231
PT16	11935	24163	6564	8354	16914	4595				7403	14989	4072	4581	9274	2519
PT17	14403	28725	7922	10082	20108	5545				7403	14989	4072	4581	9274	2519

NUTS2	Miscanthus (kg/ha)			Switchgrass (Kg/ha)			RCG (Kg/ha)			Willow (Kg/ha)			Poplar (Kg/ha)		
	average	High	Low	average	High	Low	average	High	Low	average	High	Low	average	High	Low
PT18	12074	29000	6641	8452	20300	4649							4155	9980	2285
PT20	12074	29000	6641	8452	20300	4649				7403	14989	4072	4581	9980	2519
PT30	12074	29000	6641	8452	20300	4649				7403	14989	4072	4581	9980	2519
RO11	17014	17775	9358	16862	17616	9274	15295	16355	8412	10907	11395	5999	7516	7852	4134
RO12	17671	22456	9719	11046	14037	6075	14994	19541	8247	9020	11463	4961	5282	6712	2905
RO21	18261	21047	10043	15194	17512	8357	15546	18294	8551	10276	11844	5652	6975	8039	3836
RO22	18341	20037	10088	15350	16770	8443	15990	17595	8794	11059	12082	6083	7981	8719	4390
RO31	18062	19423	9934	16232	17455	8928	16141	17436	8878	10800	11614	5940	7516	8083	4134
RO32	16153	16153	8884	17505	17505	9628	15289	15289	8409	12098	12098	6654	6269	6269	3448
RO41	15652	15652	8608	16180	16180	8899	14955	14955	8225	11661	11661	6413	5457	5457	3001
RO42	18664	21209	10265	20090	22829	11049	16055	18605	8830	11303	12845	6217	8544	9709	4699
SE11				9126	9126	5019	10317	10351	5674	8547	8547	4701			
SE12				9162	9162	5039	10541	10541	5797	7888	7888	4339			
SE21				11286	11286	6208	11313	11313	6222	8841	8841	4863			
SE22							9123	9123	5018	4785	4785	2632			
SE23							7140	7140	3927	602	602	331			
SE31							6323	6323	3478						
SE32				8633	8633	6208	10819	10819	5950	8277	8277	4552			
SE33				10053	10053	7037	10750	10750	5913	8089	8089	4449			
SI01	16820	17085	9251	11774	11959	6476				12889	12889	7089	5509	5596	3030
SI02	16820	17085	9251	11774	11959	6476				12889	12889	7089	5509	5596	3030
SK01	15617	18629	8589	10932	13040	6012	13934	17244	7664	9117	10876	5014	8885	10599	4887
SK02	15934	17612	8764	11154	12329	6135	14339	16500	7887	9768	10797	5372	8736	9656	4805
SK03	14573	14804	8015	10201	10363	5611	13931	14611	7662	10747	10917	5911	4535	4607	2494
SK04	15153	15153	8334	10607	10607	5834	14676	14676	8072	11332	11332	6233	5924	5924	3258
UKC1				4764	4764	2620	10697	10697	5883	6799	6799	3739	3471	3471	1909
UKC2				4764	4764	2620	10697	10697	5883	6799	6799	3739	3471	3471	1909

NUTS2	Miscanthus (kg/ha)			Switchgrass (Kg/ha)			RCG (Kg/ha)			Willow (Kg/ha)			Poplar (Kg/ha)		
	average	High	Low	average	High	Low	average	High	Low	average	High	Low	average	High	Low
UKD1	6806	6806	3743	4764	4764	2620	11441	11441	6293	6799	6799	3739	5241	5241	2882
UKD3	6806	6806	3743	4764	4764	2620	11441	11441	6293	6799	6799	3739	5241	5241	2882
UKD4	6806	6806	3743	4764	4764	2620	11441	11441	6293	6799	6799	3739	5241	5241	2882
UKD6	6806	6806	3743	4764	4764	2620	11441	11441	6293	6799	6799	3739	5241	5241	2882
UKD7	6806	6806	3743	4764	4764	2620	11441	11441	6293	6799	6799	3739	5241	5241	2882
UKE1	7696	7696	4233	5387	5387	2963	11968	11968	6582	7228	7228	3975	5013	5013	2757
UKE2	7696	7696	4233	5387	5387	2963	11968	11968	6582	7228	7228	3975	5013	5013	2757
UKE3	7696	7696	4233	5387	5387	2963	11968	11968	6582	7228	7228	3975	5013	5013	2757
UKE4	7696	7696	4233	5387	5387	2963	11968	11968	6582	7228	7228	3975	5013	5013	2757
UKF1	9950	9950	5473	6965	6965	3831	13355	13355	7345	8157	8157	4486	6538	6538	3596
UKF2	9950	9950	5473	6965	6965	3831	13355	13355	7345	8157	8157	4486	6538	6538	3596
UKF3	9950	9950	5473	6965	6965	3831	13355	13355	7345	8157	8157	4486	6538	6538	3596
UKG1	9269	9269	5098	6489	6489	3569	12877	12877	7082	10235	10235	5629	6600	6600	3630
UKG2	9269	9269	5098	6489	6489	3569	12877	12877	7082	10235	10235	5629	6600	6600	3630
UKG3	9269	9269	5098	6489	6489	3569	12877	12877	7082	10235	10235	5629	6600	6600	3630
UKH1	10989	10989	6044	7692	7692	4231	13802	14056	7591	9802	9802	5391	6931	6931	3812
UKH2	10989	10989	6044	7692	7692	4231	13802	14056	7591	9802	9802	5391	6931	6931	3812
UKH3	10989	10989	6044	7692	7692	4231	13802	14056	7591	9802	9802	5391	6931	6931	3812
UKI1	8636	8636	4750	6045	6045	3325	12510	12552	6880	8194	8194	4507	5915	5915	3253
UKI2	8636	8636	4750	6045	6045	3325	12510	12552	6880	8194	8194	4507	5915	5915	3253
UKJ1	11183	11183	6150	7828	7828	4305	13839	14157	7612	11394	11394	6266	9754	9754	5365
UKJ2	11183	11183	6150	7828	7828	4305	13839	14157	7612	11394	11394	6266	9754	9754	5365
UKJ3	11183	11183	6150	7828	7828	4305	13839	14157	7612	11394	11394	6266	9754	9754	5365
UKJ4	11183	11183	6150	7828	7828	4305	13839	14157	7612	11394	11394	6266	9754	9754	5365
UKK1	9799	9799	5390	6859	6859	3773	13745	13745	7560	11282	11282	6205	7411	7411	4076
UKK2	9799	9799	5390	6859	6859	3773	13745	13745	7560	11282	11282	6205	7411	7411	4076
UKK3	9799	9799	5390	6859	6859	3773	13745	13745	7560	11282	11282	6205	7411	7411	4076

NUTS2	Miscanthus (kg/ha)			Switchgrass (Kg/ha)			RCG (Kg/ha)			Willow (Kg/ha)			Poplar (Kg/ha)		
	average	High	Low	average	High	Low	average	High	Low	average	High	Low	average	High	Low
UKK4	9799	9799	5390	6859	6859	3773	13745	13745	7560	11282	11282	6205	7411	7411	4076
UKL1	7913	7913	4352	5539	5539	3047	12209	12209	6715	9241	9241	5083	5989	5989	3294
UKL2	7913	7913	4352	5539	5539	3047	12209	12209	6715	9241	9241	5083	5989	5989	3294
UKM2				10554	10554	5805	9637	9637	5300	8993	8993	4946	2713	2713	1492
UKM3				10554	10554	5805	9637	9637	5300	8993	8993	4946	2713	2713	1492
UKM5				10554	10554	5805	9637	9637	5300	8993	8993	4946	2713	2713	1492
UKM6				10554	10554	5805	9637	9637	5300	8993	8993	4946	2713	2713	1492
UKN0				10554	10554	5805	9637	9637	5300	8993	8993	4946	2713	2713	1492

Source: Biomass Futures (Elbersen & Staritski, 2012 and Elbersen et al., 2013)

Annex 3 Overview of suggested heating values for conversions of biomass (tons) to Joules

Biomass type	Unit	Mean LHVar same as Type	Moisture content(%)	Mean LHVar (GJ/ton)
barley	ton (as received)	Cereals	10.8	15.45
Durum wheat	ton (as received)	Cereals	10.8	15.45
Maize (grain)	ton (as received)	Maize	15.0	17.02
Oats	ton (as received)	Cereals	10.8	15.45
Other cereals	ton (as received)	Cereals	10.8	15.45
Rye	ton (as received)	Cereals	10.8	15.45
Soft wheat	ton (as received)	Cereals	10.8	15.45
Sugar beet	ton (as received)	Sugar Beet	0.0	16.60
Rape seed	ton (as received)	Rape	9.0	18.62
Sunflower seed	ton (as received)	Sunflower	9.0	18.43
Soya seed	ton (as received)	Soya	9.0	18.43
Energy maize	ton (as received)	Energy maize	10.8	15.76
Fodder grass cuttings	ton d.m.	Fodder grass cutting	0.0	17.22
Miscanthus	ton (as received)	Perennials: grassy crops	20.9	12.54
Switchgrass	ton (as received)	Perennials: grassy crops	20.9	12.54
Reed Canary grass (RCG)	ton (as received)	Perennials: grassy crops	20.9	12.54
Willow	ton (as received)	Perennials: woody crops	16.0	14.15
Poplar	ton (as received)	Perennials: woody crops	16.0	14.15
Poultry manure solid	ton (as received)	Dry Manure	26.4	9.44
Cattle manure solid	ton (as received)	Dry Manure	26.4	9.44
Pig manure solid	ton (as received)	Dry Manure	26.4	9.44
Sheep and goat manure solid	ton (as received)	Dry Manure	26.4	9.44
Cattle manure liquid	ton d.m.	Wet manure	0.0	16.70
Pig manure liquid	ton d.m.	Wet manure	0.0	16.70
Oil seed rape & Sunflower seed	ton d.m.	Straw	0.0	17.90
Grain maize	ton d.m.	Straw (stover)	0.0	17.90
Sugarbeet	ton d.m.	Sugarbeet field residues (leaves)	0.0	18.10
Rice	ton d.m.	Straw	0.0	17.90
all_cereals	ton d.m.	Straw	0.0	17.90
Apples and pears	ton d.m.	Prunings	0.0	19.80
Cherries and other soft fruit	ton d.m.	Prunings	0.0	19.80
Vineyards	ton d.m.	Prunings	0.0	19.80
Olives	ton d.m.	Prunings	0.0	19.80
Citrus	ton d.m.	Prunings	0.0	19.80
Olive Pits	ton d.m.	Olive Pits	7.0	18.78
HH Paper	ton d.m.	paper cardboard	0.0	18.02
HH Wood	ton d.m.	Post consumer wood	0.0	19.40

HH Animal an mixed food	ton d.m.	Animal Waste	0.0	15.90
HH Vegetal waste	ton d.m.	Verge Grass	0.0	18.10
HH Municipal Solid Waste (MSW)	ton d.m., only biogenic fraction	MSW	0.0	15.90
HH Common sludges	ton as received, only organic fraction (60%)	Sewage Sludge	20.6	8.71
NACE Paper	ton DM	paper cardboard	0.0	18.02
NACE Wood	ton DM	Post consumer wood	0.0	19.40
NACE Animal and mixed food	ton DM	Animal Waste	0.0	15.90
NACE Vegetal waste	ton DM	Verge Grass	0.0	18.10
Used fats and oils (UFO)	ton as received	Used fats/oils	0.0	38.10
NACE Municipal solid waste (MSW)	ton DM, only biogenic fraction	MSW	0.0	15.90
NACE Common sludges	ton as received, only organic fraction (60%)	Sewage Sludge	20.6	8.71
Road side verges	ton dm	Verge Grass	0.0	18.10
Round Wood fuel wood traditional use	ton dm	Roundwood/stemwood	0.0	18.25
Round Wood new purpose	ton dm	Roundwood/stemwood	0.0	18.25
Residues fuelwood traditional use	ton dm	Primary Forestry Residues	0.0	19.19
Residues new purpose	ton dm	Primary Forestry Residues	0.0	19.19
Sawmill by-products (excl. sawdust)	ton dm	Sawmill by-products (excl saw dust)	0.0	13.55
Sawdust	ton dm	Saw Dust	0.0	19.40
Other_industrial_residues	ton dm	Other industrial wood residues	0.0	19.40
Black_liquor	ton (as received)	Black Liquor	8.2	11.67
Landscape_care_wood	ton dm	Landscape care wood	0.0	19.40

Source: Phyllis database, Koppejan et al., 2009

Annex 4 Overview of models providing land availability and related biomass potentials from for food and non-food biomass

Common approaches to estimate direct and indirect land demand effects in third countries include computable general equilibrium (CGE) models and partial equilibrium (PE) models, but sometimes combinations of CGE and PE models are used. An overview of the most important models used in mostly global and EU wide assessment is given in table 1.

Partial equilibrium (PE) models are economic models that focus on a subset of economic sectors and do not link explicitly to other sectors of the economy. The limited scope allows a high flexibility in incorporating a high level of detail of competition for inputs such as labour, water, energy and fertiliser. Additionally, in the case of linear optimization models, the performance of solvers allows to incorporate a very large number of sectors and technologies at a detailed grid-cell level (for example up to 200,000 spatial units in GLOBIOM). The nature of PE models does not allow to consider links with other sectors. Several models try to circumvent this by combining models. A major disadvantage is that economy-wide competition is beyond the scope of most PE models. This can introduce some bias when sectors have a big role in an economy. For example, in developing countries, the link between agricultural income and the final consumer demand is generally missing because the supply and the demand side are not linked by the revenue cycling. Further, export and import of agricultural products and inputs are usually modelled in a relatively simple manner.

Table 1: Key models for land availability and cropped biomass potential assessment

Issue(s)	Description	Type of model	Region	Holder
Predicting land use changes	CLUE Scanner	Land change model, Partial equilibrium model	Regional	Alterra, IVM, VU Amsterdam
Trade policy scenarios	MIRAGE, including biofuel policies, poverty analyses.	computable general equilibrium model, recursive dynamic	multi-country	IFPRI, INRA
Macro-economic assessments	MAGNET, including bio-economy, renewable energy policies, agricultural and trade policies.	computable general equilibrium model, recursive dynamic	112 world regions	LEI-WUR
Food security	IMPACT, including, agricultural market developments, agricultural policies, technological developments.	Partial equilibrium model, recursive dynamic.	Global	IFPRI
Scenario outlooks for agricultural commodity balances	AGMEMOD, scenario outlooks for agricultural commodity balances (including bioethanol and biodiesel) and prices	Partial equilibrium model, recursive dynamic	EU countries, RU, UA, TR, CR,MK, RoW	AGMEMOD consortium (lead vTI and LEI-WUR)
Land allocation and deforestation projections	GLOBIOM, integrating the agricultural, bioenergy and forestry sectors, including biofuel policies, climate change policies.	PEE (Dynamic recursive)	28 world regions	IIASA
Market outlooks. Agricultural commodity balances	AGLINK-COSIMO, (including bioethanol and biodiesel) and prices	Partial equilibrium model, recursive dynamic	Global. Over 70 countries and regions worldwide	OECD, FAO

Issue(s)	Description	Type of model	Region	Holder
Agricultural commodity balances	CAPRI, (including bioethanol and biodiesel), prices and incomes, environmental indicators	Partial equilibrium model, static	Global. EU: NUTS2, plus 60 other countries and regions	University of Bonn, LEI, Lund uni., UPM, JRC-IPTS
Long-term world energy outlooks	POLES	Year-by-year recursive, Partial equilibrium model, rec. dyn.	world	JRC-IPTS
Agricultural commodity balances	ESIM, (including bioethanol and biodiesel) and prices	Partial equilibrium model, recursive dynamic	Global; individual EU MS, Turkey, USA, Rest-of-the-World-aggregate	University of Hohenheim and vTI
Agricultural supply and incomes	RAUMIS, including , environmental indicators	Supply model	Germany (Nuts3-level)	

Computable general equilibrium (CGE) models include an entire economic system (national or global) by accounting for interactions between all productive sectors, labour, flow of goods and capital between sectors (or countries), and government policies. Most global and regional CGE frameworks are not structured to model land-use alternatives and the associated emissions sources. CGE modelling efforts are hindered by a lack of data, especially data on vegetation cover linked to underlying economic activity. CGE models also tend to describe market responses more slowly than they actually occur.

A third family of methodologies consists of studies in which historical data on land use are used in combination with trend extrapolation and expert judgement to estimate land use change (LUC) and indirect land use change (ILUC) effects. These studies use a causal descriptive approach, in which cause and effect relationships are estimated using a combination of extrapolation of historical trends and expert and stakeholder opinion to define and quantify correlations. This approach is sometimes also referred to as the deterministic approach, because the key global calculation parameters are 'determined'. The models use fairly simple assumptions and calculate results in just a few steps. As a result, the causal descriptive approach is more transparent than the CGE and PE modelling approaches. The causal descriptive approach also allows inclusion of effects other than price driven changes, such as natural conditions and faster-than-expected increases in consumption. A disadvantage is that uncertainties arise from the use of expert judgement and trend extrapolation.

A last group of methodologies are the **integrated assessment models (IAMs)**. IAMs include models and tools from different disciplines (energy, economics, agriculture, biophysical processes, climate) to address complex environmental problems in an integrated way. IAMs have been developed and applied first in the context of global climate change assessment. Many global IAMs have since then also been used for evaluating land use impacts and the resulting environmental and social impacts. The strengths of IAMs are that different disciplines are integrated in a consistent modelling framework. In such a framework, trade-offs and synergies of policy strategies can be assessed, and feedbacks between different domains can be studied. Limitations are the complexity of the model and the limited level of detail.

Annex 5 SWOT analysis for environmental and biodiversity effects of dedicated crops

Feedstock type	SWOT	Secondary resource use	Land use productivity	(indirect) land use change	Direct biodiversity	Soil	Water quantity	Water quality
Agri crops: corn/maize	Strengths / Opportunities	-	crop with typical high mass yields/ha; can also be source of lignocellulose (crop residues)	-	Maize may provide shelter to fauna (e.g. birds), especially in monocultural landscapes mostly in autumn. It may increase landscape structural diversity.	Suitable and more common practice to produce it in no-till system	-	
	Weaknesses / Threats	Fresh material, can be used in the food/feed sector	-	Requires medium to high quality land and therefore more likely to compete with food and feed crops leading to (indirect) land use changes	Intensive annual (rotational) crop requires relative high inputs of N, pesticides and mechanisation (e.g. tillage) with possible adverse effects on soil biodiversity and water quality leading to pollution of habitats and eutrophication diminishing floristic diversity. If produced with irrigation in arid areas it leads to hydrological disturbances (depletion of water resources)	risks for soil erosion related to annual cropping (row crop, long period of uncovered soil) and compaction through tillage (late harvesting on wet soils) and tractor use for treatment with inputs.	Medium water requirement and high water efficiency. In dry-arid regions (Mediterranean, central EU) it will require irrigation because typical summer crop.	N-application rates are generally high but also good N-utilisation by crop. Especially in Central and southern Europe N-surpluses in maize are reported to be high. Leaching risk is high because of low soil coverage (row crop)
Agri crops: sugar beet	Strengths / Opportunities	-	very high sugar yield, especially in Western Europe. So high ethanol or biomaterial yield per hectare.	-	Some limited provision of nesting and shelter in autumn to some common faunistic species	-	-	
	Weaknesses / Threats	Fresh material, can be used in the food/feed sector	-	Requires high quality land and therefore competes with food and feed crops leading to (indirect) land use changes	Direct negative impacts on habitat quality through high pesticide and nitrogen applications.	risks for soil erosion relatively large as it is a root crop with limited soil cover, also after establishment. Heavy machinery use for both input spreading and particularly when harvested. Often late harvest on wet soils. Implies large compaction risk.	water consumption of agricultural crops - may need irrigation in dry regions/periods	Generally high N-application rates not completely compensated by high yields in combination with limited coverage (risk for erosion) also high risk for leaching. High pesticide use as poor competitive ability at young stage.

Feedstock type	SWOT	Secondary resource use	Land use productivity	(indirect) land use change	Direct biodiversity	Soil	Water quantity	Water quality
Agri crops: cereals	Strengths / Opportunities	-	use of straw can increase land use productivity (ton DM/ha)	-	Has a more open structure than most other rotational crops and therefore provides some nesting and shelter habitat, especially when spring crop. Also provides some more space for weeds which serve as food for fauna.	Compaction effect is limited as harvested in dry wheather.	Generally low water demand in barley, oats, rye, but higher in wheat	Overall adverse effect on water quality limited certainly in comparison to most other rotational and intensive horticultural crops.
	Weaknesses / Threats	Fresh material, can be used in the food/feed sector	relatively modest ethanol yield per hectare (much lower than sugar beet or cane)	Requires medium to high quality land and therefore more likely to compete with food and feed crops leading to (indirect) land use changes	Medium to low intensive annual (rotational) crop. Can in very intensive systems obtain higher inputs of N than needed for the yield.	covered soil, certainly in case of winter cereals, but spring cereals are more erodable.	water consumption of agricultural crops - may need irrigation in dry regions/periods	Low (rye, oats, triticale) to medium (bar-ley) N demands and medium N fixation, but also low removal of N at yield. So if intensively produced some risk for nitrogen leaching.
Herbaceous: grassy perennials (e.g. <i>Arundo donax</i> , switchgrass, <i>Miscanthus</i>)	Strengths / Opportunities	-	Higher land productivity when using marginal lands (compared to reference); in case of agricultural lands there generally is also a gain (but not necessarily) at least in terms of biomass production/ha as most perennials are high yielding.	Potential (indirect) land use change; limited in case of marginal lands, not suited for arable crops which require higher quality soils	No or low pesticide and nitrogen applications so (practically) no direct negative impacts on habitat quality; can provide winter shelter; birds nesting inside plants	Potential use of marginal lands, which can increase soil quality and soil carbon stock	Most herbaceous perennials are drought resistant (e.g. Switchgrass) and have a very efficient water use (C4-plant).	
	Weaknesses / Threats	Fresh material	-	If produced on medium to good quality soils competition with food and feed crops leading to indirect land use change	May also destroy sensitive habitats (e.g. steppic habitats, High Nature Value farmland, biodiversity rich grasslands) when introduced.	Damaging soil structure (e.g. harvesting, root removal after 20 years),	In arid circumstances because of deep roots ground water abstraction and depletion possible.	Some use of fertilisers / pesticides which can be leached to ground water and pollute habitats, but effect is very limited.

Feedstock type	SWOT	Secondary resource use	Land use productivity	(indirect) land use change	Direct biodiversity	Soil	Water quantity	Water quality
Herbaceous: solid agri residues (straw, corn stover)	Strengths / Opportunities	Residues which are difficult to use for material production	This results in a higher harvest of biomass (products and energy) per hectare of land	No land use change	-	-	indirect link to water use	
	Weaknesses / Threats	-	-	-	Biodiversity loss when harvesting too many crop residues. This may also have adverse effect on soil biodiversity.	Risk to loose soil organic carbon when overharvesting crop residues. Risk to loose nutrients when overharvesting	-	
Woody biomass crops (e.g. SRC-willow, poplar)	Strengths / Opportunities	-	Higher land productivity when using marginal lands (compared to reference); in case of agricultural lands there generally is also a gain (but not necessarily)	Potential (indirect) land use change; limited in case of marginal lands, not suited for arable crops which require higher quality soils	No or low pesticide and nitrogen applications so (practically) no direct negative impacts on habitat quality; can provide winter shelter; birds nesting inside plants	Potential use of marginal lands, which can increase soil quality and soil carbon stock	-	
	Weaknesses / Threats	Fresh material	-	If produced on medium to good quality soils competition with food and feed crops leading to indirect land use change	May also destroy sensitive habitats (e.g. steppic habitats, High Nature Value farmland, biodiversity rich grasslands) when introduced.	Damaging soil structure (e.g. harvesting, root removal after 20 years),	In arid circumstances because of deep roots ground water abstraction and depletion possible.	Some use of fertilisers / pesticides which can be leached to ground water and pollute habitats, but effect is very limited.

Anne 6 Livestock categories in FSS and conversion heads to LSU

The **livestock unit**, abbreviated as **LSU** (or sometimes as **LU**), is a reference unit which facilitates the aggregation of livestock from various species and age as per convention, via the use of specific coefficients established initially on the basis of the nutritional or feed requirement of each type of animal (see table below for an overview of the most commonly used coefficients).

The reference unit used for the calculation of livestock units (=1 LSU) is the grazing equivalent of one adult dairy cow producing 3 000 kg of milk annually, without additional concentrated foodstuffs.

Livestock group/type	Specification type of animal	LSU/animal
<u>Bovine animals</u>	Under 1 year old	0,400
	1 but less than 2 years old	0,700
	Male, 2 years old and over	1,000
	<u>Heifers</u> , 2 years old and over	0,800
	Dairy cows	1,000
	Other cows, 2 years old and over	0,800
<u>Sheep and goats</u>		0,100
<u>Equidae</u>		0,800
<u>Pigs</u>	Piglets having a live weight of under 20 kg	0,027
	Breeding sows weighing 50 kg and over	0,500
	Other pigs	0,300
<u>Poultry</u>	Broilers	0,007
	Laying hens	0,014
	Ostriches	0,350
	Other poultry	0,030
Rabbits, breeding females		0,020

Annex 7 Overview of data on agricultural parameters such as land use, yields, animal numbers, management and manure production levels

Farm Accountancy Data Network (FADN)

The Farm Accountancy Data Network (FADN) consists of an annual survey carried out by all the Member States of the European Union. FADN data are collected every year from a sample of the agricultural holdings in the European Union. Holdings are selected to take part in the survey on the basis of sampling plans established at the level of each region in the Union. The methodology applied aims to provide representative data along three dimensions: region, economic size and type of farming.

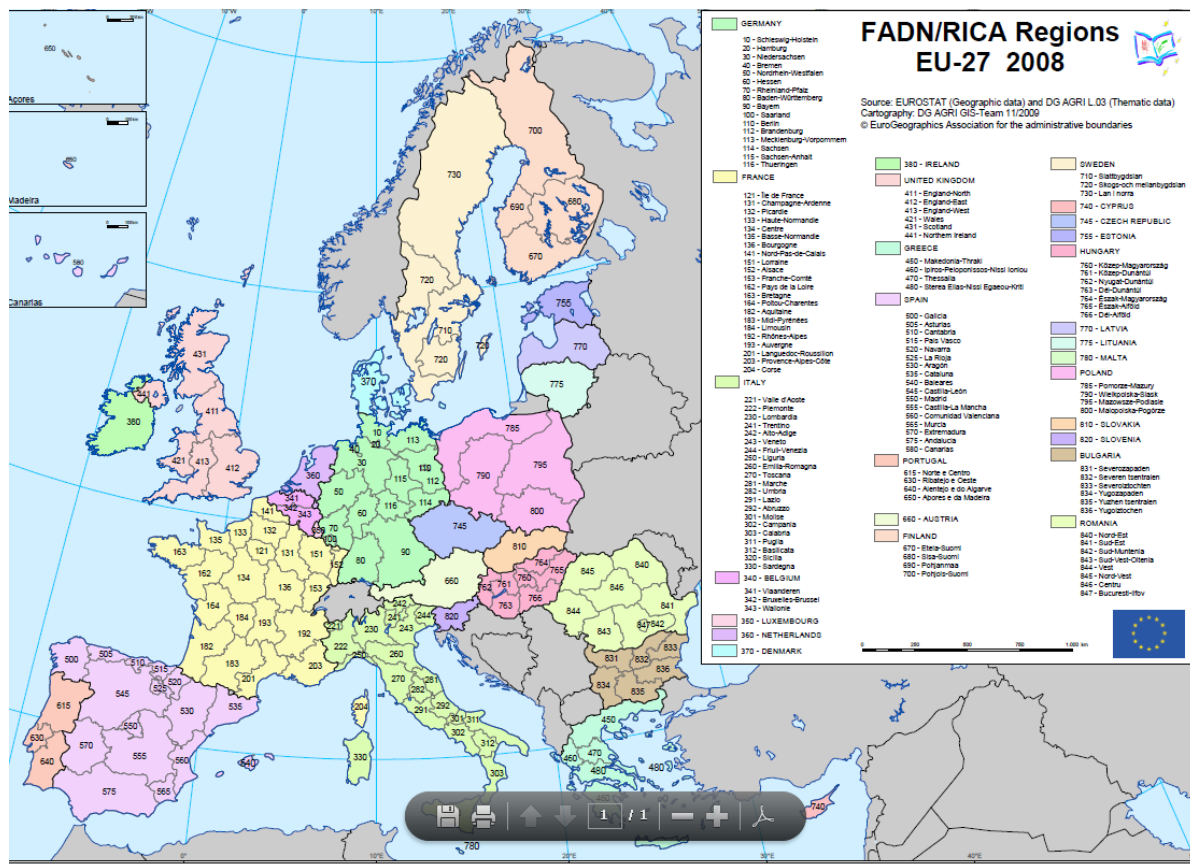
At this moment the FADN is the only source of microeconomic (farm level) data that is harmonised, i.e. the bookkeeping principles are the same in all countries. While the European Commission (DG-Agri) is the primary user of analyses based on FADN-data, aggregated data can be found in the Standard Results database (http://ec.europa.eu/agriculture/rca/diffusion_en.cfm). For assessment of manure potentials FADN is especially relevant in relation to manure management information providing information of stable types, type of manure management and management of livestock in terms of grazing days.

Currently, the annual FADN sample covers approximately 80.000 holdings. They represent a population of about 5.000.000 farms in the 25 Member States, which cover approximately 90% of the total utilized agricultural area (UAA) and account for about 90% of the total agricultural production of the Union. For the EU-27, that is including Bulgaria and Romania, the FADN represents about 6.400.000 farms. This implies that the representation of the Utilised Agricultural area and livestock numbers in FADN differs strongly per country because of the variation in economic size distribution of farms.

The stratification of the FADN sample is done using the information of the Farm Structure Survey (FSS) on distribution of the total EU farm population over size and (sectoral) type. The survey however does not cover all the agricultural holdings in the Union but only those which due to their size could be considered commercial. This implies that often part time farms and smaller extensive farms particularly occurring in Southern and CEEC are under-represented.

The FADN data are available at individual farm level per FADN region. However, the accessibility to the individual farm data are restricted to FADN Liaison Agencies and permission to use the data needs to be obtained from DG-Agri. Data are only available at the FADN region level (See Map 1). Publication of the data in reports requires a minimal representation of the figure by more than 15 farms.

Maps 1: FADN regions



Eurostat statistical data sources (FSS, crop survey and SAPM)

The main EU wide statistical source of information on agricultural land use is the **Farm Structural Survey (FSS) and the crop survey**.

FSS provides EU wide harmonised data on agricultural holdings in the EU on:

- Number of agricultural holdings
- Land use and area (crops)
- **Livestock**
- Main crops , area, yield, total production
- Farm Labour Force (including age, gender and relationship to the holder)
- Economic size of the holdings
- Type of activity
- Other gainful activity on the farm
- System of farming
- Machinery
- Organic farming

The frequency of data collection for FSS is every 2 years. This implies that the Member States are obliged to deliver the standard data every 2 years which can be based on a sample of farms but every 10 years a full scope survey is carried out in the form of an agricultural census. The most recent census took place in 2010 in all EU Member States.

The survey data can only be derived in aggregated format at different geographic levels (Member States, regions, and for basic surveys also district level). The data can also be arranged by size class, area status, legal status of the holding, objective zone and farm type.

In addition to the FSS there is also **Survey on agricultural production methods (SAPM)** which was carried out for the first time in 2010 to collect data at farm level on agri-environmental measures. European Union (EU) Member States could choose whether to carry out the SAPM as a sample survey or as an exhaustive survey. Data were collected on tillage methods, soil conservation, landscape features, animal grazing, animal housing, manure application, manure storage and treatment facilities and irrigation. With reference to irrigation, Member States were asked to provide estimation (possibly by means of models) of the volume of water used for irrigation on the agricultural holding.

The Member States collected information from individual agricultural holdings and, observing rules of confidentiality, data were transmitted to Eurostat. The results of the SAPM are linked at the level of individual agricultural holdings to the data obtained from the Farm structure survey (FSS) in 2010⁷.

The basic unit underlying the SAPM is the agricultural holding: a technical-economic unit, under single management, engaged in agricultural production. The SAPM covers all agricultural holdings with a utilised agricultural area (UAA) of at least one hectare (ha) and also those holdings with a UAA of less than 1 ha where their market production exceeds certain natural thresholds.

Crop statistics refer to annual data on area, production harvested and yield for cereals and for other main field crops (mainly dried pulses, root crops, fodder and industrial crops); humidity of the harvested crop (humidity content in %) and agricultural land use. For some products regional figures (NUTS 1 or 2) are available too. The data refer to areas under cultivation (expressed in 1 000 hectares), the quantity harvested (expressed in 1 000 tonnes) and the yield (expressed in 100kg/ha). The information concerns more than 100 crop products.

The earliest data are available from 1955 for cereals and from the early 1960's for fruits and vegetables. However most Member States have started to send in data in the 1970's and 1980's. The statistical system has progressively improved and enlarged. The current [Regulation \(EC\) No 543/2009](#) entered into force in January 2010. It simplified the data collection and reduced the number of crop sub-classes. At present Eurostat receives and publishes harmonised statistical data from 28 Member States broken down in:

- 17 categories and subcategories for cereals;
- 30 categories and subcategories for other main crops (mainly Dried pulses, Root crops and Industrial crops);
- 40 categories and subcategories for vegetables;
- 41 categories and subcategories for fruits;
- 18 categories and subcategories for UAA (Utilised Agricultural Area).
- For the full list of crops, please consult Annex 1 .

The main data sources are administrative records, surveys and expert estimates.

National Statistical Institutes or Ministries of Agriculture are responsible for the national data collection in accordance with EC Regulations. Eurostat is responsible for drawing the EU aggregations. For further information see: http://ec.europa.eu/eurostat/cache/metadata/en/apro_cpp_esms.htm#meta_update1418757870727

⁷ The legal basis for the SAPM is Regulation 1166/2008 of 19 November 2008 on farm structure surveys and the Survey on agricultural production methods, which repealed Council Regulation 571/88.

GAINS

Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS)-Model provides a consistent framework for the analysis of co-benefits reduction strategies from air pollution and greenhouse gas sources. To model these consistently a GAINS database was developed in which several key input factors are collected which have been assessed/measured in a consistent way in all countries of the world. The database was developed with expert input from a large number of experts all over the world.

The model considers emissions of:

- Carbon dioxide (CO₂)
- Methane (CH₄)
- Nitrogen oxides (NO_x)
- Nitrous oxide (N₂O)
- Particulate matter (TSP, PM₁₀, PM_{2.5} and PM₁)
- Sulfur dioxide (SO₂)
- Volatile organic compounds (VOC)

Certain versions of the **GAINS Model** also contain:

- Ammonia (NH₃)
- Carbon monoxide (CO)
- Fluorinated greenhouse gases (F-Gases)

For more details on the GAINS model and to obtain access to the GAINS database visit the link at:
<http://gains.iiasa.ac.at/gains/GOD/index.login?logout=1>

Annex 8 EFSOS II result for primary and secondary forest products in reference scenario 2010, 2020 and 2030

Summary supply 2010	Traditional firewood	Landscape care wood	Post-consumer wood	Sawmill and plywood residues	Other industrial residues	Black liquor	Domestic harvest	Bark	Harvest residues	Import of wood	Import of wood-based energy
Austria	2202	874	1004	5294	1992	3152	18163	2210	3892	2385	2357
Belgium	658	422	1856	793	750	1497	3114	336	14	3366	-4
Belarus	963	1689	481	1869	745	320	7834	3235	2007	-3097	-971
Bosnia and Herzegovina	1651	454	215	1009	154	67	2766	447	503	-866	-493
Bulgaria	2373	976	96	627	305	459	2928	460	1745	-376	-1735
Croatia	828	418	197	448	112	125	4527	682	686	-3641	-676
Czech Republic	1329	930	258	3481	851	1774	13831	1692	3122	-215	-2118
Denmark	698	526	1194	237	89	0	1225	161	485	-161	5868
Estonia	2948	303	69	1773	315	162	6886	967	834	-3429	-824
Finland	5287	1858	1118	13269	2469	16054	53712	5680	2266	10240	-2
France	26765	5488	5471	8949	2683	4224	29872	6030	8557	371	-8547
Germany	3787	3481	7568	15868	6857	4181	49444	6439	11437	6918	-4
Greece	893	1109	268	345	242	0	1666	307	361	333	3051
Hungary	2832	992	166	399	205	0	2787	741	1083	-1041	-111
Ireland	508	762	349	765	302	0	1862	387	226	978	-216
Italy	5551	2408	4440	1828	1997	359	2395	4899	631	7575	6287
Latvia	959	605	78	3114	601	0	11011	1166	2485	-5760	653
Lithuania	846	646	111	1422	301	0	5456	722	1395	-2166	-324
Netherlands	960	465	2334	199	41	30	873	100	123	238	2268
Norway	3207	2812	716	2189	351	2342	9482	2152	17	1111	-7
Poland	2055	3550	788	2968	2550	2092	32485	3343	6606	-7991	3613
Portugal	1099	1261	213	786	491	4687	6929	461	2030	2866	2462

Romania	3250	2159	536	3357	897	368	12327	2282	2708	-3376	3801
Serbia	1795	847	292	468	101	203	2646	448	405	-1085	3786
Slovakia	324	546	128	2088	462	1407	7523	800	2052	-293	-2042
Slovenia	1254	149	105	798	280	258	2635	532	323	-365	-313
Spain	5064	4634	2204	4783	1926	3973	14705	1343	4901	5037	-399
Sweden	3029	3536	951	16615	1850	21130	70569	8078	11539	-671	-11529
Switzerland	2911	331	755	1109	434	459	3444	1018	14	26	-4
Turkey	6656	8027	5238	5344	2010	336	13190	2279	4485	5894	-3515
United Kingdom	263	2679	4760	2140	1107	85	8082	1012	1714	1259	-35
Ukraine	5743	6126	1246	1623	723	29	6905	3142	2162	-1750	-2152
Small countries in Europe	5399	2375	415	294	212	0	1369	360	364	168	1857
EFSOS Total	104088	63437	45619	106250	34403	69772	412643	63910	81169	12479	-19

Summary supply 2020	Traditional firewood	Landscape care wood	Post-consumer wood	Sawmill and plywood residues	Other industrial residues	Black liquor	Domestic harvest	Bark	Harvest residues	Import of wood	Import of wood-based energy
Austria	2202	994	1120	4536	2098	3049	19168	2164	4037	488	4776
Belgium	658	480	2127	617	816	1707	3049	317	677	2922	-375
Belarus	963	1922	1114	1938	834	366	8895	3125	2432	-3670	-899
Bosnia and Herzegovina	1651	517	324	1007	172	78	2641	434	507	-730	-497
Bulgaria	2373	1111	144	683	344	529	3021	528	1770	-84	-1760
Croatia	828	476	293	383	127	150	4576	686	739	-3577	-681
Czech Republic	1329	1059	675	3838	935	2356	16027	1662	3993	-47	-2885
Denmark	698	599	1220	309	94	0	1138	147	548	-84	7196
Estonia	2948	345	159	1866	357	203	8436	945	998	-4488	-988

Finland	5287	2115	1214	11741	2753	17367	57666	5736	6303	5941	-392
France	26765	6247	6134	8048	2880	4125	30909	5781	8914	-152	-3081
Germany	3787	3963	8616	14951	7372	5511	54416	6549	16776	2123	-1855
Greece	893	1262	754	603	283	0	2221	326	436	-68	3370
Hungary	2832	1129	471	924	232	0	4338	743	1753	-891	-258
Ireland	508	867	538	980	335	0	2704	527	326	453	-316
Italy	5551	2740	6234	1388	2220	348	3094	4301	806	4466	8582
Latvia	959	688	223	3522	683	0	10477	1052	2540	-3853	1476
Lithuania	846	735	262	1679	336	0	5820	664	1528	-2000	-103
Netherlands	960	530	2372	206	43	34	789	93	136	332	3076
Norway	3207	3200	753	2240	385	2634	10261	2146	2238	525	-2228
Poland	2055	4041	3034	4813	2793	2651	37303	3285	7912	-3652	3043
Portugal	1099	1435	631	720	596	5326	6556	457	1920	2575	3291
Romania	3250	2457	1542	5427	1005	334	19573	2267	4745	-4026	3190
Serbia	1795	965	384	496	114	249	2853	432	449	-1239	4660
Slovakia	324	622	220	2229	518	1848	7176	771	1957	710	-1947
Slovenia	1254	170	139	1163	318	333	3693	492	506	-297	-381
Spain	5064	5275	3836	4588	2183	4247	15182	1425	5060	4102	368
Sweden	3029	4025	1021	16265	1904	22353	72509	8009	21933	-2062	-20265
Switzerland	2911	376	824	1042	461	555	3426	962	854	-84	-844
Turkey	6656	9137	6845	5916	2270	361	13676	2163	4673	7264	-2359
United Kingdom	263	3050	6810	2046	1164	95	8599	1008	1818	735	-540
Ukraine	5743	6974	1926	2003	836	37	8000	3066	2666	-925	-2656
Small countries in Europe	5399	2704	588	352	227	0	1582	347	463	165	2262
EFSOS Total	104088	72210	62548	108519	37689	76846	449773	62609	112412	872	-19

Summary supply 2030	Traditional firewood	Landscape care wood	Post-consumer wood	Sawmill and plywood residues	Other industrial residues	Black liquor	Domestic harvest	Bark	Harvest residues	Import of wood	Import of wood-based energy
Austria	2202	1115	1194	4152	2153	3282	21742	2075	4612	60	2918
Belgium	658	538	2295	587	851	1849	2902	327	674	3046	164
Belarus	963	2156	1466	2090	1002	458	15877	3059	4266	-2818	-9348
Bosnia and Herzegovina	1651	580	408	1019	201	100	2640	434	507	-117	-1228
Bulgaria	2373	1245	182	700	420	661	3132	540	1740	-14	-1730
Croatia	828	534	365	497	154	190	4451	666	719	-3213	-474
Czech Republic	1329	1187	918	3942	1060	2795	15334	1519	3872	-10	-2174
Denmark	698	671	1266	309	97	0	1387	167	586	-202	8206
Estonia	2948	387	209	1878	435	265	8628	896	1046	-4030	-1036
Finland	5287	2372	1332	11672	2812	18352	57080	5671	15566	4816	-5131
France	26765	7006	6491	9889	3013	4584	41882	6081	11844	-1151	-639
Germany	3787	4444	9225	14868	7662	7071	58209	6180	18162	2718	0
Greece	893	1415	904	678	310	0	2339	300	496	-131	4042
Hungary	2832	1266	633	1209	281	0	4196	729	1738	-185	467
Ireland	508	972	592	1076	346	0	3290	523	398	90	-414
Italy	5551	3073	7143	1491	2333	308	4486	3946	1218	3660	11484
Latvia	959	772	301	4384	831	0	13289	1275	3087	-3003	-895
Lithuania	846	825	356	1772	360	0	6521	725	1712	-2187	0
Netherlands	960	594	2493	221	44	37	894	101	154	251	3828
Norway	3207	3589	814	2417	402	2816	16168	2137	3550	34	-7412
Poland	2055	4532	4357	5219	3223	3034	36323	3247	7704	-778	4977
Portugal	1099	1609	764	700	641	5639	7444	481	2105	1688	4482

Romania	3250	2756	2097	5656	1201	425	19336	2247	4687	-1583	3471
Serbia	1795	1082	478	594	137	327	3166	440	510	-1344	5524
Slovakia	324	697	289	2415	606	2227	7294	775	1989	652	-1979
Slovenia	1254	191	178	1389	386	411	5493	436	807	-1166	-1265
Spain	5064	5916	4325	4316	2322	4607	14630	1388	5172	3772	1873
Sweden	3029	4514	1096	16330	1936	22594	79156	8574	22385	-6108	-16653
Switzerland	2911	422	858	1182	471	629	4235	941	1046	-393	-1036
Turkey	6656	10247	7733	6239	2439	378	13342	1974	4699	8826	84
United Kingdom	263	3421	7356	2071	1198	101	9085	1023	1925	-46	2
Ukraine	5743	7821	2556	2259	1052	45	7594	2901	2761	-147	-2751
Small countries in Europe	5399	3032	714	370	240	0	1624	317	505	283	2641
EFSOS Total	104088	80984	71386	113588	40620	83186	493168	62094	132242	1271	-1

